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ENVIRONMENTAL STATEMENT

**HTGR FUELS
REPROCESSING FACILITIES**

**National Reactor Testing Station
Idaho**

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JANUARY 1974

UNITED STATES ATOMIC ENERGY COMMISSION

DRAFT

MASTER

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Glossary

- APS - Atmospheric Protection System. An installation at the Idaho Chemical Processing Plant to filter all off-gases and process cell ventilation air through a deep bed roughing filter and a HEPA filter before discharge to the stack.
- BISO - Bi-isotropic. Two layers of pyrolytic carbon coating on HTGR fuel particles.
- Criticality - Formation of a critical mass i.e. the mass of nuclear fuel necessary for a chain reaction to take place.
- DF - Decontamination factor, ratio of radioactivity in the effluent to the radioactivity in the feed stream.
- Denitration - Converting uranyl nitrate solutions to a solid uranium trioxide.
- DOT - Department of Transportation
- "envelope" - An area within ICPP identified for processing HTGR fuels. (Shown in figure II-4)
- FSVR - Fort Saint Vrain Reactor
- GGA - Gulf General Atomic Corp., San Diego, California

HEPA - High Efficiency Particulate Air Filter

Headend - The process of converting a nuclear fuel into a solution from which uranium is recovered by solvent extraction.

HTGR - High Temperature Gas Cooled Reactor

ICPP - Idaho Chemical Processing Plant

KALC - Krypton absorbtion in liquid carbon dioxide-a process for removing Krypton from process off-gases.

NPH - Normal paraffin hydrocarbon, a diluent for the organic phase in the solvent extraction process

NRTS - National Reactor Testing Station

ORNL - Oak Ridge National Laboratory

ppm - Parts per million

RAF - Remote Analytical Facility, a facility at ICPP where highly radioactive samples are analyzed.

RCG - Radioactivity Concentration Guide which specifies safe radioactivity levels for the environment.

TBP - Tributyl phosphate, an organic solvent used in the extraction process.

TRISO - Tri-isotropic. Three layers (pyrolytic carbon, silicon carbide, pyrolytic carbon) of coatings on HTGR fuel particles.

TURF - Thorium Uranium Recycle Facility. An ORNL facility which will house the HTGR Fuel Refabrication Pilot Plant.

WCF - Waste Calcination Facility. A facility at the ICPP for converting liquid radioactive wastes to a granular solid.

WSA - Waste Storage Area. A facility at the NRTS for interim storage of solid wastes.

I. SUMMARY

This environmental impact statement was prepared in accordance with the National Environmental Policy Act of 1969 in support of the U.S. Atomic Energy Commission's proposal for legislative authorization and appropriation for a FY 1975 project. The estimated cost of the project is \$30 million. The purpose of this project is to (1) demonstrate the technology for reprocessing irradiated fuel from High Temperature Gas Cooled Reactors operating on the thorium fuel cycle; and (2) provide an interim reprocessing facility for HTGR fuels which may be accepted by AEC under its Chemical Processing Policy. This project will consist of a small addition to and modification of a portion of the existing Idaho Chemical Processing Plant (ICPP) to provide the capabilities for HTGR fuel reprocessing. The demonstration phase of the project will be coordinated with the HTGR Fuel Refabrication Pilot Plant that is planned for installation in the Thorium Uranium Recycle Facility (TURF) at the Oak Ridge National Laboratory (ORNL) at Oak Ridge, Tennessee. These projects complement each other in the development of HTGR fuel recycle technology.

The project will be located at the National Reactor Testing Station (NRTS). The NRTS is on a plain in southeastern Idaho that is covered primarily by sagebrush and grass. Antelope, coyotes, rabbits, and small rodents comprise the principal wildlife of the area. There are no permanent residents on the NRTS and the largest populated area in the region is Idaho Falls, 42 miles to the east.

The principal benefits from the proposed project will be the development of technical information essential to the design, construction, and operation

of large-scale commercial HTGR fuel processing plants and the verification of process and equipment design. It is expected that operating data from the plant will make possible a more accurate assessment of the environmental effects of large-scale thorium-uranium fuel processing programs and provide a basis for minimizing them. Additional benefits accruing from the processing of early commercial HTGR fuels include making available for recycle the fissile uranium-233 recovered in the processing operation and reducing the requirement for costly long term storage facilities.

Environmental costs associated with the project will be the temporary (but long-term) use of less than one acre of land within the NRTS boundaries, the release of low concentrations of some contaminants to the atmosphere and ground water, the permanent commitment of construction materials, the consumption of power, oxygen, and process chemicals, and an addition of a small amount of land dedicated to radioactive waste storage. The facility will be designed and operated to minimize the quantities of radioactive and nonradioactive discharges. Effluent cleanup systems will be designed to minimize the quantities of radioactive and nonradioactive discharges, and to meet the requirements of the Clean Air Act, as amended, and the Federal Water Pollution Act, as amended.

Alternatives to the proposed action include (1) temporarily storing the fuel until commercial reprocessing is available, (2) permanently storing the fuel, and (3) terminating the entire HTGR program. The proposed action is considered superior to the alternative courses of action.

Consideration of the available alternatives and their environmental impact and weighing anticipated benefits of the proposed action against its environmental and economic costs leads to the conclusion that the HTGR Fuel Reprocessing Project should be accomplished as proposed.

II. BACKGROUND

The U.S. Atomic Energy Commission (AEC) has in existence a research and development program to develop and demonstrate the technology needed to remotely process High Temperature Gas Reactor (HTGR) spent fuel elements. Key requirements of the program are to develop processes to recover the uranium isotopes contained within spent HTGR fuel, and to refabricate these uranium isotopes into recycle fuel elements for eventual reuse in commercial power reactors. This program is a combined effort between the AEC, General Atomic Corporation, Allied Chemical Corporation, and Oak Ridge National Laboratory to develop the basic technology needed to design and build a commercial HTGR fuel recycle plant for operation in the mid-1980's, at the time when large quantities of HTGR spent fuel will become available for recycle.

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

In the thorium fuel cycle (figure II-1) fresh fuel elements containing both thorium-232 and uranium-235 are used as the fuel source in a nuclear

HTGR THORIUM FUEL CYCLE

FIG. II-1

reactor to produce electrical power. In the reactor, thorium-232 is converted into uranium-233 by first absorbing a neutron, and then by radioactively decaying through a series of intermediate steps into uranium-233. In this reaction, where thorium is converted into uranium, the thorium is referred to as the fertile material and the end product uranium-233 as the fissile material.

At the present time the technology for reprocessing spent nuclear fuel from HTGRs has not been demonstrated in an integral facility. The HTGR fuel is significantly different from the light water reactor (LWR) fuel. The HTGR fuel is a graphite matrix fuel containing thorium, uranium-233 and uranium-235. Basically the HTGR fuel reprocessing consists of crushing and burning the fuel, separating the uranium-233 bearing particles from the uranium-235 particles, crushing the particles, burning the crushed particles, dissolving the uranium, separating the thorium and uranium by solvent extraction, and decontaminating the uranium by solvent extraction. LWR fuels are metallic clad and are reprocessed by shearing the fuel into small pieces, dissolving the uranium and decontaminating the uranium by solvent extraction. Thus, the technology developed for LWR fuel reprocessing is not applicable to HTGR fuel reprocessing.

The proposed project, including both the demonstration and interim processing phases is described in the following sections.

A. DETAILED DESCRIPTION

1. Project Scope and Status

A FY 1975 authorization has been requested for \$30 million to design, fabricate and install facilities at the ICPP for HTGR fuel reprocessing. At a later date (late 1970's) additional funds, which are presently undetermined but estimated to be less than three million dollars, will be requested to upgrade the facility to double the reprocessing rate for the interim production phase of the project.

Spent fuel elements from nuclear reactors are highly radioactive and cannot be handled directly by man. Therefore, remotely operated equipment located behind heavy shielding to protect personnel is required to reprocess spent nuclear fuel elements to recover the unused fissionable materials.

The demonstration phase of this project will reprocess the fuel from the Fort Saint Vrain Reactor (FSVR). Up to 2000 elements will be processed in the demonstration phase, which will begin in FY 1979 and be completed in FY 1980 or 1981, depending upon actual fuel discharges from the reactor. About 160 days of operation will be required during this time period using equipment with a processing capability of 12 fuel elements per day. Following the demonstration phase the plant will be modified and the capacity increased up to 24 HTGR fuel elements per day to permit interim processing of HTGR fuel during the time that commercial processing facilities are unavailable. This phase will be continued until all the HTGR fuel the AEC may accept

under its Chemical Processing Policy will have been processed. It is anticipated that up to 11,000 fuel elements from Delmarva Power Company, Philadelphia Electric Company and Southern California Edison may be available for reprocessing during this period (1981-1983).*

Spent fuel from the Peach Bottom Reactor is being safely stored at ICPP. This fuel will not be processed during the demonstration phase because the fuel is different than the Fort Saint Vrain Reactor (FSVR) fuel and the uranium-233 cannot be separated from the uranium-235. A new fuel storage facility is currently being constructed at ICPP to safely store fuel from the FSVR and the second core from Peach Bottom until the processing facilities are ready.

Experimental development necessary for design and installation of the process is continuing at an accelerated rate; however, the demonstration phase of the project will itself be an experimental effort, and process development will continue throughout its construction and operation.

The environmental impacts described in this document are based on the 24 fuel element per day processing rate.

2. Description of Fuel

Four types of fuel elements (FSVR, Initial Makeup (IM), Uranium-233 recycle (23 recycle), and Uranium-235 recycle (25 recycle)) (see table

*This Environmental Impact Statement is based on the assumption that 10,000 HTGR fuel elements will be processed in the interim processing facility. However, it is possible that some or all of the interim material will be stored for later processing in commercial facilities when available.

Figure II-2 Typical HTGR Fuel Element

Table II-1 HTGR Reference Fuel Particle Descriptions^a

Property	IM ^b Elements		23 Recycle Element		25 Recycle Element	
	Fissile Particle	Fertile Particle	Fissile Particle	Fertile Particle	Fissile Particle	Fertile Particle
Isotope	²³⁵ U	Th	²³³ U-Th	Th	²³⁵ U	Th
Kernel Composition	UC ₂	ThO ₂	(4.25 Th,U)O ₂	ThO ₂	UC ₂	ThO ₂
Kernel Diameter, μ m	200	500	400	500	200	500
Type Coating ^{c,d}	TRISO	BISO	BISO	BISO	TRISO	BISO
Coating Thickness, μ m						
Buffer Carbon	85	85	90	85	85	85
Inner Dense Carbon	25				25	
Silicon Carbide	25				25	
Outer Carbon	35	75	80	75	35	75
Total Particle Diameter, μ m	540	820	740	820	540	820

^aParticles will be bonded into fuel sticks for insertion into hexagonal graphite block fuel elements.

^bFor initial and makeup loadings.

^cTRISO designates three types of coatings of the kernel: buffer, silicon carbide, and dense pyrolytic carbon.

^dBISO designates two types of coatings of the kernel: buffer and dense pyrolytic carbon.

II-1) will be processed. The FSVR fuel element (shown in figure II-2) is a hexagonal block of graphite about 14 inches across the flats and 31 inches long and weighing about 234 pounds. The fuel elements contain coolant channels and fuel holes which are filled with rods composed of fuel particles (approximately 60 volume percent) dispersed in a graphite matrix. Two types of fuel particles are employed: fertile particles containing thorium carbide and fissile particles containing a mixture of uranium carbide and thorium carbide. These particles, called TRISO particles, are coated with consecutive layers of buffer pyrolytic carbon, isotropic pyrolytic carbon, and silicon carbide (SiC).

The other fuel elements are similar to the FSVR fuel elements with respect to geometry and dimensions. The primary difference is the different particle combinations that are used in the fuel elements as shown in table II-1. The IM element contains uranium-235 and thorium and will be used in initial and makeup fuel loadings of the HTGR; the 23 recycle element contains uranium-233 and thorium and will be used as the major HTGR recycle element; and the 25 recycle element contains recycled uranium-235 and thorium and will be used to recycle uranium-235 through the reactor.

3. Fuel Reprocessing*

Transport of spent fuel elements between the HTGR sites and the ICPP will be described in environmental impact statements prepared for the

*Prior to actual installation, the process now conceived may be altered slightly because of information gained in pilot-plant studies now in progress at ICPP, GGA, and ORNL. In no instance, however, will the environmental impact of the final process be more severe than stated herein.

individual reactor facilities. Transport of the spent fuel elements between the FSVR and the ICPP is described in the FSVR environmental statement.² This statement describes the safe transportation of FSVR fuel elements to the ICPP and documents the applicable federal regulations, such as DOT and AEC Regulatory, that will govern such shipments. At the ICPP, fuel will be transferred from the storage facility to the processing building (a distance of about 1/2 mile) in a fuel transfer cask designed to hold one storage canister of spent fuel. The cask will be monitored for radiation and external contamination (and decontaminated if necessary) before the transfer. The entire transfer will be made at a maximum speed limit of 20 miles-per-hour over existing paved roads in the restricted area within the ICPP security fence.

At the processing plant, the cask will be positioned outside the fuel handling cave and the fuel canister will be transferred into the cave using remote handling equipment. The fuel elements will be drawn from the canister one at a time. After any desired visual inspections are made through shielded viewing windows, the fuel elements will be separately fed into the headend process through a charging chute located in the floor of the cave.

The charging chute will guide the fuel elements into the first of three crushers located in a processing cell below the cave. The fuel elements will be rough-crushed in the first crusher, fed directly into a second crusher where the fuel element fragments will be reduced further, and

then fed directly into a third crusher where the fragments will be reduced to the desired final size. The crushed fuel element will then be collected in a hopper and weighed before being transferred to the primary burning process.

The four types of elements will be processed separately. From the weigh hopper, crushed fuel elements will be fed to a fluidized-bed primary burner where the bulk graphite and pyrolytic carbon coatings will be burned, exposing the SiC coat of the TRISO particles (fissile and FSVR fertile particles) and oxide kernels of the BISO particles (fertile and uranium-233 recycle fissile particles). Product from the burner will be fed to a classifier to separate particles containing uranium-235 from particles containing uranium-233. Fissile particles from 25 recycle fuels will be removed for disposal; fissile particles from the FSVR and IM elements can be processed for recycle to the reactor; particles containing uranium-233 (fertile and 23 recycle fissile particles) will be processed for recycle of the uranium-233 to the reactor. The particles will be crushed to penetrate the SiC coating for secondary burning (FSVR fertile, FSVR fissile and IM-fissile particles) or reduce the size of the kernel to expose uranium for dissolution (fertile particles and 23 recycle fissile particles).

Fines carried over from the primary burner will be removed from the burner off-gas by a cyclone separator and sintered-metal filter. These fines

will be recycled to the primary burner or combined with the crushed TRISO particles and fed batchwise into a fluidized-bed secondary burner where the remaining carbon will be burned and the uranium carbide converted to the oxide. The burned TRISO particles or crushed BISO particles will be transferred into a batch dissolver and contacted with HF-catalyzed nitric acid to dissolve the uranium and thorium.

After dissolution is complete, the leachate will be slurried into a separator where any undissolved solids will be separated and washed. The solids will then be dried and classified to separate any intact particles from broken silicon carbide hulls. The intact particles will be recycled or collected and stored for future processing or disposal and the broken silicon carbide hulls will be canned for disposal. The leachate and wash solution will be combined in tanks for accountability sampling.

From the accountability tanks, the solution will be piped to the solvent extraction system in building CPP-601. The solution will be steam stripped to remove excess acid and then adjusted to solvent extraction feed specifications. Uranium will be purified by two cycles of solvent extraction. The first cycle of solvent extraction will be accomplished in pulsed, sieve-plate columns utilizing 30 percent tributyl phosphate (TBP) (in a normal paraffin hydrocarbon (NPH) diluent) as the organic solvent. In this system, uranium and thorium will be extracted from the feed solution; most of the fission products will remain in the aqueous stream and will be sent to waste storage. The uranium and thorium will then be stripped back into an aqueous solution and concentrated by stripping or evaporation.

The resulting uranium-thorium solution will be fed into the second solvent extraction cycle (which utilizes either 30 percent or five percent TBP as the organic solvent) where the uranium will be selectively extracted from the aqueous feed. The thorium-fission product solution will be collected in waste tanks for sampling. After extraction, the uranium will be stripped back into an aqueous solution and concentrated by evaporation. The concentrated uranium solution will then be transferred to storage tanks and processed through a fluidized-bed denitrator to convert the uranyl nitrate solution to solid uranium trioxide (coated on particles of an inert material). Finally, the uranium trioxide product will be placed in containers and shipped offsite to the national uranium-233 storage repository at the ORNL. The shipping containers will comply with AEC Manual Chapter 0529 and Department of Transportation (DOT) regulations that place stringent controls on the containment and shipment of radioactive materials.

A more detailed description of the fuel reprocessing is presented in appendix A.

4. Gaseous, Liquid, and Solid Wastes

Waste streams from the fuel reprocessing will include (a) process off-gas streams, (b) cell ventilation gases, (c) undissolved solids from the process, (d) liquid wastes from the process, (e) process and cell decontamination solutions, (f) contaminated high-efficiency particulate air (HEPA) filters, and (g) other contaminated solid equipment and material. Expected releases and applicable guideline limits are given in tables D-VII; D-VIII and D-IX in Appendix D.

All process off-gas and cell ventilation exhaust streams will be filtered by at least two HEPA filters in series before exiting the uranium-233 containment envelope. These gas streams will then be routed through the Atmospheric Protection System (APS) before being discharged to the atmosphere. The APS will consist of a deep-bed fiberglass prefilter in series with a stage of parallel HEPA filters. All ICPP gaseous effluents will be processed through the APS before discharge to the stack. The APS will be a backup system to prevent significant amounts of particulate radioactivity from being discharged to the environment in the event of the rupture of a process filter. Process off-gas streams containing acid fumes or mists will be processed by scrubbers and demisters before being filtered by the aforementioned filtration systems.

An experimental system for removing krypton, iodine, and tritium will be tested at various times during the HTGR fuel reprocessing. All gaseous effluents from this system will be filtered by the APS before being discharged to the atmosphere.

Solid wastes from the headend process will be monitored to ensure negligible fissile content before being sealed in canisters for retrievable storage at the NRTS Waste Storage Area (WSA). Radioactive liquid wastes will be collected in existing waste tanks and eventually converted to a solid in the ICPP Waste Calcining Facility (WCF). The resulting solid waste will be stored at the ICPP in existing underground vaults designed for this purpose. Miscellaneous solid wastes (including contaminated equipment that cannot be

repaired) will be packaged for disposal at the WSA according to ICPP standard procedures that have been established specifically to ensure against spread of activity offsite. Environmental impact statements have been prepared for the WCF^[3] and waste calcine storage vaults.^[4] An environmental impact statement addressing waste management for the entire NRTS is being prepared and will be issued in the near future.

5. Facilities

The HTGR fuels reprocessing system will utilize existing ICPP building facilities with the exception of the denitration and ventilation systems which will require a new building adjacent to CPP-640 (refer to figure II-3 for the overall ICPP site layout). With the exception of the off-gas cleanup system, the fuels processing will be conducted within an "envelope" established to minimize the possibility of spreading contamination associated with uranium-233 to other areas of ICPP. (Refer to figure II-4 for envelope boundaries.) Off-gas to be processed in the off-gas cleanup system, as well as other gaseous and liquid effluents, will be processed, as required, to ensure that all contamination associated with uranium-233 is contained within the envelope. Solid effluent will be packaged before it leaves the envelope for transport or disposal in accordance with procedures that will be established specifically to ensure against contamination of the environment. Personnel entering and leaving the envelope will be required to follow procedures that will be established to inhibit the spread of any contamination.

Figure II-3

NEW CONSTRUCTION

AREA INCLUDED IN
U-233 ENVELOPE

Figure II-4 Layout of HTGR Fuel Reprocessing Facility

As indicated in figure II-4, the headend system for the fuel processing will be installed in cells 1, 2, 3, and 4 in building CPP-640. A fuel handling cave will be above Cells 2 and 3 with openings into these cells. The solvent extraction system will be installed in cells A, B, C, and D in building CPP-601. The denitration system will be installed in a portion of a new building which will be built adjacent to CPP-640. The remainder of this new building will house a solid product storage vault and the process ventilation, filtration, and exhaust systems. The off-gas cleanup system will be installed in an existing cell in building CPP-604. Analysis of process samples will be conducted in the existing Remote Analytical Facility (RAF) in building CPP-627. Detailed descriptions of these facilities are provided in appendix A.

The incoming fuel will be stored at ICPP in the Dry Irradiated Fuel Storage Facility, CPP-603, presently under construction. The fuel will be stored in canisters, each containing up to four fuel elements. The safety aspects of the storage of the fuel are covered in a safety analysis report ^[1] for the Irradiated Fuels Storage Facility located at ICPP.

6. Project Decommissioning

Because of uncertainties concerning future processing assignments for combustible fuels, a specific schedule has not been established for decommissioning the processing facilities; however, the facilities will be designed for ease of decommissioning. For example, the headend process will be designed for remote maintenance. Therefore, much of the

equipment can be dismantled and decontaminated remotely thus making decommissioning more readily accomplished. The solvent extraction, denitration, and off-gas cleanup portions of the overall process will not be decommissioned following completion of the HTGR fuel reprocessing. These facilities will be of a generalized design and may be modified for other future fuel reprocessing activities.

B. ANTICIPATED BENEFITS

1. Project Need and Schedule

The primary purpose for implementing the HTGR fuel reprocessing project is to provide information essential to the timely development of HTGR fuel recycle technology. Fuel from the FSVR will be processed during the first phase of the project to demonstrate the technology required for the design, construction, and safe operation of commercial processing facilities for irradiated HTGR fuel.

Current estimates indicate that a minimum of seven years is required to design, construct, license, and start up a commercial fuel recycle plant. Some facility and conceptual system design can begin one to two years prior to the time data from the demonstration described herein are available, but the data are required for detailed design effort. According to the proposed schedules, data will become available in FY 1980; hence, the earliest possible startup for a commercial facility would be 1985. The demonstration should begin as proposed to provide design data at the earliest possible date.

In addition to the FSVR, large commercial HTGRs are presently scheduled for startup during the early 1980's by Delmarva Power Company, Philadelphia Electric Company and Southern California Edison Company. Up to 11,000 HTGR fuel elements could be available for processing in FY's 1981 through 1983.

These fuels would be reprocessed during the interim processing phase of the project to eliminate the need for building additional storage facilities for this fuel.

2. Project Benefits

The benefits of the HTGR fuel reprocessing project include:

- a. Demonstrated application of the fuel reprocessing technology which can lead to early availability of commercial reprocessing facilities. Data will be provided for design and licensing of the commercial facilities.
- b. Reduction of fuel storage requirements.
- c. Provision of fissile materials for recycle at the earliest possible date.
- d. Reduced effect on the environment because reprocessing to recover fissionable material has less effect on the environment than obtaining an equivalent amount of material from ore resources.

- e. Conservation of national resources (uranium bearing ores).
- f. Realize the potential to produce 17 billion KWh of electricity through the expenditure of 6 million KWh of electricity for each year the plant will be operated at full throughput.

A significant advance in HTGR fuel reprocessing technology will result from the development, testing, and subsequent operation of the demonstration process. The data obtained are needed for and will be used in the design and operation of commercial reprocessing facilities for HTGR fuels. The demonstration will provide the basis for evaluating the potential environmental effects of commercial facilities and will be valuable in designing to minimize these effects.

Approximately 725 kilograms of fissionable material (uranium-233 and uranium-235) worth about \$8 million will be recovered by reprocessing FSVR fuels. During interim HTGR fuel reprocessing up to 2500 kilograms of fissionable material (uranium-233 and uranium-235) worth approximately \$25 million will be recovered annually. Recovering this material by reprocessing rather than obtaining an equivalent amount of material from ore resources will be more economical, will conserve natural resources, and will be less damaging to the environment. In addition, each year of interim processing can potentially make available fissionable material that can be used to produce 17 billion KWh of electricity

for an expenditure of 6 million KWh of electricity for reprocessing.

Utilizing the HTGR fuel reprocessing facilities for interim processing will avoid the long-term commitment of land and the use of construction materials to provide additional fuel storage facilities. Another benefit that will be derived from an interim processing facility is the additional operating experience. This experience will be of significant value to the startup and initial operation of a commercial processing facility for irradiated HTGR fuel.

C. CHARACTERIZATION OF EXISTING ENVIRONMENT

The NRTS was established in 1949 by the U.S. Atomic Energy Commission for building, testing, and operating various types of nuclear reactors, allied plants, and equipment. It is centered on a former Naval Proving Grounds which served the Navy's Pocatello (Idaho) Ordnance Depot. The NRTS is located along the western edge of the Upper Snake River, Lemhi and Beaverhead-Centennial Mountain Ranges. The NRTS comprises an 894 square mile area with an average elevation of 5,000 feet above sea level. The Idaho Chemical Processing Plant (ICPP) is located in the south-central portion of the NRTS, in Butte County, Idaho, about 42 air miles west of Idaho Falls. Figure II-5 shows the relative location of the ICPP--an enclosed area of approximately 100 acres--with respect to other facilities on the NRTS. Figure II-6 shows a typical view of the landscape adjacent to ICPP.

The NRTS is a limited access government reservation. It is limited for reasons of health, safety, and national security. There are no permanent residents on the site. The surrounding areas are sparsely

Fig. II-5. Detailed Map of NRTS

Figure II-6 Landscape Adjacent to ICPP

populated, with the largest populated areas (all small) located at Mud Lake and Terreton (3 miles east of nearest NRTS boundary), Arco (7 miles west of nearest NRTS boundary), Howe (2 miles north of nearest NRTS boundary), and Atomic City (2 miles east of nearest NRTS boundary). The respective distances of these towns from the ICPP are 29, 19, 15 and 12 miles. A detailed description of the NRTS is presented in appendix B.

1. Topography and Climatology

The climate at the NRTS is arid to the point of assuming desert-like characteristics. The topographic features which affect the NRTS weather patterns are the northeast-southwest orientation of the plain and the mountain ranges to the north and west. The NRTS is relatively level with an average elevation of approximately 5,000 feet above sea level. It is bounded to the north and west by mountain ranges with elevations as high as 6,000 feet above the plain. The predominant surface winds are southwesterly and northeasterly. Nearly all air masses entering the plain are forced to cross mountain barriers; thus, the air masses usually release moisture over the mountains and enter the plain dry, giving the region its desert-like characteristics (annual precipitation of 8.5 inches). The climate is cool, with the average maximum daily temperature ranging from 27 degrees F during winter months to 87 degrees F in summer. The average annual surface wind speed at the Central Facilities Area, about three miles south of the ICPP, is 7.5 miles per hour. Severe thunderstorms with wind gusts over 50 miles per hour and

hail of 1/2 inch or greater diameter occur at a frequency of less than once per year. Since 1949, no confirmed tornadoes have occurred within the present boundaries of the NRTS. One tornado occurred 5 1/2 miles east of the east boundary in June 1967 and another occurred 1 mile east of the east NRTS boundary in July 1972, but neither caused any damage. Three confirmed funnel clouds over the NRTS and three unconfirmed reports of funnel clouds have been recorded during the 24-year period.[5, 6]

2. Hydrology

The Snake River Plain consists of composite layers of interbedded volcanic rock and sedimentary material. The NRTS water table lies between 200 and 900 feet below ground level with the level at the ICPP about 450 feet below the ground surface. The direction of subsurface water flow is from the north and east toward the main part of the Snake River Plain to the south. The NRTS water supply is obtained from 24 production wells at a combined rate of about 2 billion gallons per year. Of this, the two ICPP production wells withdraw about 400 million gallons per year. The HTGR fuel reprocessing will increase the ICPP water usage by about 20 percent. Approximately 93 percent of the water used at the NRTS is returned to the Snake River Plain aquifer through deep wells and shallow pit or surface ponds. At ICPP, about 90 percent of the water withdrawn from the aquifer is returned via a deep (598 foot) injection well which discharges the water 140 feet below the top of the regional water table.

The NRTS lies in a basin which has no surface outlet for its streams. The largest source of water at the NRTS, the Big Lost River which is dry (on the NRTS) during much of the year, flows in a northeasterly direction and sinks into the desert floor at the northern end of the NRTS. Two smaller streams (Birch Creek and the Little Lost River) flow onto the northern portion of the NRTS and also sink into the desert. The only other surface water on the NRTS results from snow melt during the spring. Localized flooding and surface flow of water occasionally occur during periods of rain or snow when air temperatures are above freezing and the ground is deeply frozen. Drainage has been provided to carry water away from NRTS installations under such conditions.

3. Seismology

Until 1970, the region including the NRTS was classified as Seismic Risk Zone 2 by the Pacific Coast Uniform Building Code.^[7] The new Uniform Building Code (UBC)^[8] of the International Conference of Building Officials, issued in 1970, reclassified the NRTS into Zone 3. This imposes more stringent design criteria on new AEC facilities. All new facilities will be designed to meet the design criteria for the maximum credible earthquake for Seismic Risk Zone 3. A number of seismic instrument stations were installed in FY 1973 to monitor the fractional transmission of seismic energy from surrounding earthquake hypocenters to the NRTS. The Hebgen Lake earthquake (7.1 magnitude on the Richter Scale) occurred in 1968 at the extreme northeast corner of the Snake River plain. This is the greatest magnitude earthquake that has occurred in the eastern portion of the Snake River Plain during the period of recorded regional history (100 years).

4. Ecosystem

The ecosystem of the NRTS is typical for a semi-desert region (see figure II-6). The ICPP area is also typical of the NRTS, except that large mammals are excluded from the area by a chain-link fence. The types of vegetation are limited, with the most prominent ground cover being a mixture of sagebrush, lanceleaf rabbitbrush, and a variety of grasses. This vegetation covers practically all of the NRTS.

The vegetation supports a variety of desert rodents. Chipmunks and ground squirrels inhabit the shrub areas. The mixed grasslands are inhabited mainly by mice. The herb drylands are preferred by kangaroo rats; the white-footed mouse and the jack rabbit are found in all NRTS areas. The only large mammals seen commonly on the NRTS are the coyote, bobcat, and the pronghorn antelope (the latter is migratory, wintering south and summering north of the NRTS). Some migratory birds (doves, larks, and hawks) inhabit the NRTS during the summer. Other migrants, such as eagles (golden and very rarely the bald, which is an endangered species) and water fowl pass through the NRTS in the spring and fall.

Aquatic life is not significant at the NRTS. The only major surface water flows are the Big Lost River (which is dry much of the year), Birch Creek, and the Little Lost River.

Of special ecological interest are the flats (playas) that are subjected periodically to flooding by the Big Lost River. These flats support a

distinctive vegetation mixture composed almost solely of dense bluestem wheatgrass, and a small perennial herb, *iva axillaris*. These flats provide the most unique biota on the site. Sage grouse and pheasant are the only resident game birds; however, hunting is not permitted on the NRTS.

5. Land Use

The use of the land at the NRTS has varied over the years. In the late 19th century, the NRTS was crossed by two stage lines, and cattle were trailed eastward from Oregon to market. Two areas within the present NRTS boundaries were involved in unsuccessful irrigation projects about 1910. Numerous attempts to operate small dry farms were made, but all failed because of insufficient precipitation. During World War II, 270 square miles of the present site were used by the Navy for a gunnery range and another section was used by the Army Air Corps for aerial gunnery practice. Crested wheatgrass was planted in some areas to prevent erosion and to increase the usefulness of the land. At the present time, the NRTS land is used solely for development and testing of nuclear reactors, fuel reprocessing, and associated facilities. Some sheep grazing is allowed by special permit in the NRTS boundaries. The area is designated as a national game preserve not because of an extraordinary game population or to protect any particular species, but primarily because firearms are prohibited on the NRTS.

6. Historical Lands

Archeological surveys of the NRTS started during 1967 and are continuing. Location and survey sites and the preservation of antiquities are continuing. Artifacts recovered from the NRTS thus far indicate a long period of occupation by man ranging from the time of the mammoth hunters. These valuable sites are protected from relic hunters by law^[9, 10] and by limited access to the NRTS; this protection will be continued. Although no trace of early man has been found at the ICPP, standard NRTS operating procedures provide that suitable precautions be taken if items of archeological interest are unearthed. The Experimental Breeder Reactor No. 1 (EBR-I), located in the southwest part of the NRTS is listed in the 1971 National Register of Historic Places prepared by the National Park Service.

7. Environmental Monitoring

Monitoring of the environment is conducted by the NRTS contractors, the AEC's Health Services Laboratory (HSL), and the United States Geological Survey (USGS) in cooperation with National Oceanic and Atmospheric Administration (NOAA). The monitoring programs have been in effect since the inception of the National Reactor Testing Station and have been updated and improved as new instruments and techniques become available. The program includes monitoring within the ICPP facilities, monitoring within the NRTS boundaries, and monitoring of the off-site areas surrounding the NRTS.

Routine monitoring programs include determining the integrated direct radiation exposures, composition of waste effluents (both air and water),

water quality, noxious gas release, bioassay, airborne contaminants, soil radioactivity levels, analyses of selected locally produced foodstuffs, and radionuclide uptake by animals. Special monitoring programs are conducted on a non-routine, as-needed basis.

Background radiation levels at the NRTS are generally in the range of 12 to 15 microrem per hour. Some areas adjacent to the individual plant sites have a background radiation level of 30 to 90 microrem per hour.

III. ENVIRONMENTAL IMPACT

The reprocessing of HTGR fuels during normal operation and most accidents will have a minimal effect on the environment. However, some highly improbable accidents could adversely impact the environment. Reprocessing HTGR fuels at ICPP is expected to have an imperceptible effect on background radiation levels in Southern Idaho.

The estimated emissions and other environmental impacts of reprocessing the HTGR fuels are described in the following sections. The detailed information supporting the estimates is provided in appendix D.

The demonstration phase is aimed at providing data that will be used in the eventual design of a commercial facility, and a primary interest is in minimizing the impact on the surrounding environment.

A. PROBABLE ENVIRONMENTAL EFFECTS

1. Gaseous Discharges

The maximum gaseous release to the atmosphere from the HTGR fuels reprocessing will occur during the calcination of the HTGR wastes through the ICPP WCF and will consist of about 2.2 million standard cubic feet per day (scfd). The composition of the gas leaving the calciner will be 2.6 percent carbon monoxide, 6.5 percent carbon dioxide, 70 percent nitrogen, 20 percent oxygen, 0.1 percent nitrous oxides, and 6.7 percent unburned hydrogen and hydrocarbons. This off-gas will also contain minute quantities of particulates and radioactive materials that are well below the guidelines set by applicable federal regulations. These releases

from waste calcination are included in the maximum release values given in table III-1. An environmental impact statement for a new waste calcination facility at ICPP has been prepared.^[3]

The process and ventilation off-gases from the HTGR fuel processing will be passed through a roughing filter and a series of two HEPA filters. The off-gases will then be combined with other ICPP off-gases and processed through the APS. This total ICPP off-gas (160 million scfd) will then be discharged from the ICPP stack. The stack gas will be continuously monitored to detect changes in activity and to determine total activity releases over time.

Carbon Monoxide (CO) will be released at a maximum rate of 73,000 scfd with an environmental impact equivalent to that produced by about 300 automobiles operating at the 1975 emission standards. At the NRTS boundary the CO level from the operation of the proposed facility will be .0035 percent of the national ambient air quality standards.^[9]

Carbon Dioxide (CO₂), Oxygen (O₂), and Nitrogen (N₂) are natural constituents of the atmosphere. The maximum daily release rates of these gases are:

CO₂ - 390 thousand standard cubic feet (scf)

O₂ - 680 thousand scf

N₂ - 2.6 million scf

These releases will not have a significant effect on the natural concentration levels.

Calcination by-products will be produced during the conversion of the acid waste solution to a dry solid (calcination process). In the calcination process, oxides of nitrogen are produced and after being filtered are released from the 250-foot-high stack at the ICPP. The concentration of nitrogen oxides (expressed as NO_2) at the NRTS boundary is estimated to be .045 percent of the national ambient air quality standards.^[9] The calculated maximum short-term (1 hour) ground level concentration of nitrogen dioxide will be 410 g/m^3 , and will occur within the NRTS boundary. Oxides of sulfur will be generated when the wastes are calcined. As shown in Table III-1, the concentration of SO_x at the NRTS boundary will be 0.013 percent of the applicable federal regulations.^[9]

Dust (finely divided particulates) will be trapped by the HEPA filter systems that are required to remove radioactive materials. Thus, less than 540 mg/day of total particulates will be released. Approximately 85 percent of these particulates will be carbon; the remainder will be primarily oxides of uranium and thorium. The total dust concentration at the NRTS boundary is estimated to be less than 28 one-millionth percent of the national ambient air quality standard.^[9]

Carbon-14 (C-14), a radioactive isotope of carbon, will be released from the combustion process as carbon monoxide and carbon dioxide. The concentration of carbon-14 at the nearest NRTS boundary as a result of the fuels reprocessing is estimated to be 0.001 percent of the established Radioactivity Concentration Guide (RCG) value for an uncontrolled area.^[11] Thus no short- or long-term effect on the

environment is expected from carbon-14.

Krypton-85 and tritium are the principal radioactive gases released. A maximum of 2.8 million Curies (Ci) of krypton-85 and 110 thousand Curies (Ci) of tritium will be released annually assuming maximum burnup of all fuel reprocessed and that all of the krypton and tritium contained in each fuel element is released. The experimental equipment may initially have a low on-stream efficiency; therefore, release calculations were made assuming that the krypton and tritium removal equipment was not operating. Assuming no removal, the concentration of krypton-85 and tritium at the NRTS boundary will be less than 2.3 percent and 0.1 percent of the RCG values, respectively. When the krypton and tritium removal equipment is in operation, the concentrations will be much lower (possibly by a factor of 100 to 1000).

Iodine released annually will be a maximum of 5.5 Ci of iodine-129 and 8.7 Ci of iodine-131 assuming maximum burnup (6 years) and minimum cooling (180 days) of all fuel reprocessed. Assuming no iodine removal, the concentration of iodine-129 and iodine-131 at the NRTS boundary would be less than 0.05 percent and 0.01 percent of the RCG values, respectively. When the iodine removal system is operating efficiently the concentrations will be reduced, possibly by a factor of 100 to 1000.

The maximum estimated concentrations of gases, radioisotopes, and particulates released to the atmosphere during normal operation are summarized and compared with applicable guidelines in table III-1.

2. Discharges of Liquids

All process wastes will be sampled and processed through existing treatment facilities. All liquids from HTGR fuel reprocessing that are discharged to the biosphere will meet the applicable federal regulations.^[13] Approximately 34 thousand gal/day of water will be pumped from the Snake River Plain aquifer for chemical solution makeup. Eventually this liquid will be discharged to the atmosphere in the form of water vapor from the ICPP stack.

TABLE III-1

MAXIMUM ESTIMATED AIRBORNE RELEASES
FROM THE HTGR REPROCESSING DEMONSTRATION

Constituent	NRTS boundary Concentration ^{(a)(b)}	Applicable Federal Regulation ^(b)	Ratio of Boundary Conc. to Fed. Regulation
Carbon monoxide	$8.9 \times 10^{-4} \mu\text{g}/\text{m}^3$	$10 \mu\text{g}/\text{m}^3$ [9]	8.9×10^{-5}
Sulfur oxides	$7.7 \times 10^{-3} \mu\text{g}/\text{m}^3$	$60 \mu\text{g}/\text{m}^3$ [9]	1.3×10^{-4}
Nitrogen dioxide	$4.5 \times 10^{-2} \mu\text{g}/\text{m}^3$	$100 \mu\text{g}/\text{m}^3$ [9]	4.5×10^{-4}
Particulates	$4.2 \times 10^{-7} \mu\text{g}/\text{m}^3$	$75 \mu\text{g}/\text{m}^3$ [9]	5.6×10^{-9}
Carbon-14	$1 \times 10^{-11} \mu\text{Ci}/\text{mL}$	$1 \times 10^{-7} \mu\text{Ci}/\text{mL}$ [10, 13]	1×10^{-4}
Krypton-85	$7 \times 10^{-9} \mu\text{Ci}/\text{mL}$ (c)	$3 \times 10^{-7} \mu\text{Ci}/\text{mL}$ [10, 13]	2.3×10^{-2}
Tritium	$2 \times 10^{-10} \mu\text{Ci}/\text{mL}$ (c)	$2 \times 10^{-7} \mu\text{Ci}/\text{mL}$ [10, 13]	1×10^{-3}
Iodine-129	$9 \times 10^{-15} \mu\text{Ci}/\text{mL}$ (c)	$2 \times 10^{-11} \mu\text{Ci}/\text{mL}$ [10, 13]	4.5×10^{-4}
Iodine-131	$1 \times 10^{-14} \mu\text{Ci}/\text{mL}$ (c)	$1 \times 10^{-10} \mu\text{Ci}/\text{mL}$ [10, 13]	1×10^{-4}

(a) Assumes a mean annual dilution factor of 1.8×10^{-6} . The above values show that atmospheric releases due to the HTGR fuel processing will not have a significant impact upon the environment.

(b) Average annual concentrations.

(c) Assumes off-gas cleanup system is not operational.

In addition, up to 300 thousand gal/day of cooling water required for this process will be pumped from the aquifer and discharged through the service waste system to the 600-foot deep injection well. The temperature of the discharged water will be less than 5°C above the ambient temperature of the ground water and will not constitute a significant recharge of the aquifer (no significant change in water table). The service waste will be continuously monitored for activity. A diversion system downstream of the monitor will make it possible to divert any wastes containing significant activity to a holding tank and prevent the release of radioactive waste solutions to the environment. Therefore, no significant environmental effects from this discharge are anticipated.

Some aqueous chemical wastes will be discharged to the aquifer with the cooling water. Low-level radioactive wastes are concentrated and the chemical vapors and water condensed and discharged to the aquifer. These chemical vapors will be nitric acid and will amount to less than 25,000 gallons per year of 15 M nitric acid. Other aqueous chemical wastes will not be volatile and will be concentrated in an evaporator and transferred to the high-level waste tanks. All the high-level waste will be calcined so the non-volatile aqueous chemical wastes will be stored with the calcined solids. Organic wastes from solvent extraction will be decontaminated and then burned. The combustion gases will be filtered thru HEPA filters before being discharged to the atmosphere.

3. Solid Waste Disposal

Solid wastes from the HTGR headend process will consist of broken silicon

carbide hulls and unprocessed fines. Presently it is planned that the silicon carbide hulls (up to 80 kilograms/day) will be decontaminated and canned for retrievable storage at the NRTS WSA. Ultimately, they may be shipped to a Federal Repository. Some fissile particles may be placed in storage canisters and stored in the HTGR fuel storage facility until the decision is made to either process or dispose of the particles; any unprocessed particles ultimately may be shipped to a federal repository. Fines collected from the process will be sampled and either processed or canned for storage, depending upon composition. The exact composition of these fines is not known at this time, but they are expected to constitute a transuranic alpha waste consisting of graphite fines, broken fissile particles, and broken fertile particles. If not processed, the fines will be canned and stored in the fuel storage facility until they can be shipped to a federal repository.

The thorium-containing solution from the solvent extraction process will be stored with the radioactive waste solution and later calcined to a solid waste rather than recovered for use in fuel refabrication. The thorium from the HTGR will have a radioactivity associated with it that requires about 15 years to decay to a level where it can be handled directly by man. Therefore, a segregated storage for 15 years would be needed to utilize the thorium from HTGR reprocessing at ICPP. It is uneconomical to provide these thorium handling facilities in a small HTGR reprocessing plant such as that at the ICPP. The maximum total volume of calcined waste produced annually from the process is

expected to be 690 cubic feet. The calcined material will be stored in existing stainless steel vessels which are located in underground reinforced concrete vaults inside the present ICPP boundary. This type of storage has an anticipated lifetime of several hundred years and, if desired, the stored solids may be removed and shipped to a Federal Repository. An environmental impact statement for the calcined waste storage facilities has been issued.[3, 4]

Other solid radioactive waste generated during operation of the process will consist of small quantities of radioactively contaminated valves, piping, and other materials incident to operation of a chemical process. Items will be decontaminated as possible in ICPP decontamination facilities; the cleaning solutions will be treated in existing ICPP facilities. The solids will then be placed in retrievable storage at the WSA. No significant short- or long-term environmental effects are foreseen from this incidental quantity of solid waste.

4. Direct Radiation

The transfer and processing facilities provide adequate shielding of the radioactive materials at all times.

5. Summary of Radioactive Releases

The radioactive releases and associated exposures resulting from all other NRTS activities will be published in an environmental impact statement covering waste management activities at the NRTS. The releases

from the HTGR fuel processing will add to the existing releases at the NRTS. The sum of these releases will be below the applicable guidelines.^[10] (See section III.A.1, 2., and 3.)

6. Land Use and Construction

An additional structure (about 3200 square feet) will be built to accommodate the denitration process, process off-gas filtering systems, and cell ventilation filters. Land use (less than one acre) will consist of the space required for the additional structure and will be within the existing ICPP boundary fence.

7. Transportation

The environmental impact of the transportation of FSVR fuel to ICPP has been documented in the FSVR environmental statement.^[2] Transport of the spent fuel elements from the HTGR sites to ICPP will be described in environmental impact statements prepared for the reactor facilities.

Transfer of fuel from storage to processing cells will be made over existing paved roads within the ICPP boundary fence. Fuel and solid waste transfers are closely controlled to prevent accidents which might threaten the integrity of the cask.

Transfer of uranium product off-site must satisfy stringent USAEC and DOT^[12, 13] regulations for container integrity and detectable surface radioactivity.

No adverse environmental impact is anticipated from the transportation of fuel or uranium product. Additional details of the fuel and product transportation are presented in appendix C.

8. Noise

Since the actual fuel reprocessing will be accomplished inside heavily shielded concrete cells, noise levels in personnel access areas and in the surrounding area will be low. Measurements indicate that typical noise levels in the areas accessible to personnel during processing are approximately 75 db (over the entire frequency range). The HTGR fuel reprocessing should not change these levels.

B. EXTRAORDINARY ADVERSE ENVIRONMENTAL EFFECTS

Potential accidents associated with the proposed fuel processing range from trivial events with moderate probability to significant accidents with very low probabilities. Accident probabilities are reduced by constraints built into the facility. The facility will also be designed to minimize the effects of any accident which might be initiated by natural phenomena of upper limit magnitudes, such as earthquakes, tornadoes, and floods. Administrative controls, such as detailed written procedures, well-trained operators, and close supervision will govern the process and minimize the potential for, as well as the effects of, abnormal operation.

If, despite all precautions, an accident should occur, it would probably be one of the following types: criticality, contamination, vehicle accident,

fire, or explosion. A summary of postulated accidents (in order of decreasing severity) follows:

1. Criticality

A criticality in the proposed facility is highly unlikely because (a) in some equipment a critical mass cannot be accumulated because of equipment geometry, (b) mass limits are placed on other equipment, (c) a soluble neutron absorber will be employed wherever a critical mass in solutions could occur, and (d) fixed neutron absorbers will be built into equipment where soluble absorbers cannot be used. Also, two independent failures will be necessary before a criticality could occur. If a criticality should occur, it would occur in a heavily shielded area. Resultant exposures would be within federal radiation standards as shown in tables D-VIII and D-IX in appendix D.

2. Filter Failure

To minimize contamination of facilities and the environment, double containment is provided where appropriate. Ventilation air flows from the operating areas into the radioactive areas and is filtered through two HEPA filters in series before being released to the building ventilation system. The gas is then passed through the APS prior to stack release. Exhaust gases from the process vessels are passed through two HEPA filters and the APS before discharge. Liquid contaminants and solid wastes will be routed to existing waste treatment systems. Minor contamination may occur, but the facility and equipment design, as well as administrative controls (strict adherence to Standard Operating Procedures), will make any contamination

of the environment that can lead to exposures exceeding the RCG values extremely unlikely.

3. Vehicle Accidents

The effects on the environment of an accident while transporting fuel or wastes on-site are expected to be almost negligible. Present detailed procedures governing the transport of fuels from the storage facility to the processing plant limit transport speeds to a maximum of 20 mph. The speed restriction, coupled with the fact that the transfer road is within the ICPP boundary fence (where the public is excluded), significantly reduces the possibility of any severe accident occurring. Even in the event of an accident, there is an extremely low probability of any release of radioactivity from the cask. Any measurable effects that might occur would be limited to the immediate area of the cask. The probability of death or injury due solely to radiation effects is extremely low.

Transport of uranium product off-site (see appendix C) is done only after satisfying stringent USAEC and DOT^[12, 13] regulations governing container integrity, radiation limitations, and surface contamination. These restrictions make it highly improbable that an accident would cause the release of the uranium product over a widespread area. Statistics on the shipment of hazardous materials^[14] indicate an accident frequency of about 1.7 accidents per million vehicle miles. Assuming a maximum of 6 shipments annually are made over a distance of 2300 miles each, the accident rate would be 0.024

accidents per year. Furthermore, of all accidents involving radioactive materials, only 2.5 percent^[14] have resulted in aerial dispersal or radioactive material entering a watercourse. Thus, there would be 2 percent chance of an accident occurring and a 0.05 percent chance of dispersed radioactive material release each year of processing. Therefore, it is not likely that shipping the uranium product will have a significant effect on the environment.

4. Fire and Explosions

A fire could conceivably occur in the headend or solvent extraction cells. Special fire protection will be provided in the headend and solvent extraction cells, and additional existing fire fighting equipment is available nearby. Gases resulting from a fire within any of the processing cells will be filtered before release to the stack. Explosions within the facility are of low probability, but the APS is designed to withstand the shock over-pressure from a credible explosion. Thus, the off-gas released to the atmosphere as a result of fire or explosion would not significantly affect the surrounding environment.

IV. UNAVOIDABLE ADVERSE ENVIRONMENTAL EFFECTS

The unavoidable adverse environmental effects resulting from processing the HTGR fuels can be attributed entirely to the gaseous, liquid, and solid wastes released from the plant; however, as shown in section III and appendix D, there are no significant environmental effects (long- or short-term) resulting from reprocessing the fuel.

The maximum annual emissions of radioactive materials from the process will be less than 3 million curies, essentially all of which will be in the form of krypton-85 (2.8 million curies) and tritium (110 thousand curies). Approximately 11 tons of oxides of nitrogen, 220 tons of carbon monoxide, and 3900 tons of carbon dioxide will be emitted annually during headend processing, product denitration, and calcination of the liquid wastes from the extraction cycles. These concentrations of both radionuclide and chemical discharges at the NRTS boundary will be well below the existing federal standards as detailed in appendix D. Operating within these standards will ensure that the fuel reprocessing will not have any significant short- or long-term effect on the environment.

Less than one acre of land will be committed to the HTGR fuel reprocessing. This land will be needed for the construction of one building and for solid waste storage. This land is inside the ICPP security fence and therefore has no value other than for nuclear fuel reprocessing uses.

V. ALTERNATIVES

Reasonable alternatives to processing the irradiated fuel in an HTGR fuel reprocessing facility are (1) interim storage of the fuel until a commercial facility is available, and (2) permanent storage of the fuel. Since reprocessing the HTGR fuel is the recommended course of action, alternative locations and processes for the facility must be examined in addition to the above options. These possibilities are discussed in the following paragraphs. The only other alternative is to stop operation of all present and future HTGR's, thus preventing the expending of the fuel which would lead to irradiated fuel processing. In light of the national energy requirements, this is not a viable alternative and no further discussion of this subject will be made.

A. ALTERNATIVE METHODS

The only HTGR in operation is the 40-MWe Peach Bottom nuclear power plant which has been in operation for over six years. The 330-MWe FSVR nuclear generating station is scheduled for startup during 1974. A number of larger (770 and 1160 MWe) HTGR's are scheduled for commercial operation during 1980 and beyond. These large commercial reactors will begin discharging fuel within a year after startup and each will discharge 700 to 1000 fuel elements annually. Currently, there are no facilities capable of processing or storing these amounts of irradiated HTGR fuels.

1. Interim Storage

An alternative to processing the irradiated fuel is to defer processing for a number of years with interim fuel storage until a commercial facility is available. The dry storage facility being constructed at ICPP was designed

for interim storage of the Peach Bottom I Core 2 and FSVR fuels, and has sufficient capacity (636 storage canisters that will contain 12 Peach Bottom or 4 FSVR fuel elements each) for storing Core 2 from Peach Bottom I and 1-1/3 cores from FSVR. Building additional storage facilities instead of reprocessing the HTGR fuel would require an expenditure of up to \$7 million per year until commercial reprocessing facilities are available.

Interim storage would also require more handling of fuel and the holding of significant inventories of fission products and fissile material at the storage area. It is more economical to recycle fissionable materials than to obtain the same material from ore resources. Also, there is much less environmental impact by reprocessing fuels to recover fissionable material than by obtaining an equivalent amount of fissionable material from processing ores. Thus, the environmental assessment, the economic evaluation, and the technological aspects all strongly favor reprocessing compared to the alternate of interim storage.

2. Permanent Storage

Another alternative to processing irradiated fuel is permanent disposal in a suitable federal repository without processing. This alternative would result in economic penalty from the lost value of the recoverable fissile materials, and the disposal cost for irradiated fuel elements. This cost would be much higher than the cost for disposal of high-level radioactive waste because of the potential criticality problems and the need to provide safe geometry for the storage of the fuel elements. This requires a large storage area with close control of the storage geometry, moderator, reflector, and separation from other fissile materials. Also, special precautions would have to be

taken to protect the environment since the fuel elements are susceptible to high-temperature oxidation and reaction with water. The effectiveness of permanent storage would be a function of isolation, and to evaluate the effectiveness of this isolation, such things as the long-term integrity of the fuel and its container, the availability and utility of disposal facilities, and the probability of a geological catastrophe must be considered. Other disadvantages of permanent storage compared to processing would be the lack of separation of long-lived alpha from shorter-lived gamma wastes, more voluminous storage of fission products, and lack of conservation of natural resources (fissile materials). It is more economical to recycle fissionable materials than to obtain the same material from ore resources. Also, there is much less environmental impact by reprocessing fuels to recover fissionable material than by obtaining an equivalent amount of fissionable material from processing ores. Considering these risks and disadvantages together with the loss of technical benefits for use in the ultimate design of commercial plants, permanent storage is not recommended.

B. ALTERNATIVE LOCATIONS

Fuel reprocessing could be conducted at any of the following locations:

- a. Any of three different AEC-owned facilities, i.e., Hanford, Savannah River, and ICPP.
- b. Any of three commercial irradiated fuel processing facilities in this country and others abroad.

- c. AEC-owned or privately-owned locations at which new receiving, processing, and waste management facilities could be built.

All of these facilities or locations would require new equipment to process the irradiated HTGR fuel.

Storage facilities for the FSVR fuel are being built at ICPP. If the demonstration were conducted at another site, the fuel would have to be transferred from ICPP with duplicate storage required at the chosen site. Transportation costs and the potential for transportation accidents would be increased. The ICPP has been and will be engaged in research and development of processes used for irradiated graphite fuel and other similar processes. The ICPP also will have gained expertise in processing of irradiated graphite fuels through the Rover Fuels Processing Facility.^[15] In addition, the ICPP (as do certain of the other sites) has advanced waste handling capabilities and is located in an isolated area, so that in the unlikely event of an accident the danger to the general public and the surrounding environment is minimized. The research and development, the operating experience in processing of irradiated graphite fuels, and the fuel storage area of ICPP give it an advantage over alternative sites.

C. ALTERNATIVE PROCESSES

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 non-volatile 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 alternate 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 carbides 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 the uranium.

The uranyl nitrate product from the solvent extraction system could be shipped to the national uranium-233 repository at Oak Ridge National Laboratory instead of converting the uranium to a solid for shipment. This alternative (shipping liquid) would be economically superior because the denitration process at the ICPP could be eliminated. The relative safety of shipping solids compared to shipping liquids has not been resolved on a national basis; however, it is current AEC policy to ship uranium materials as a solid rather than as liquids. Therefore, at the present time the reference process includes conversion of the uranyl nitrate to a solid for shipping.

An alternative to the product denitration process (releases of nitrogen oxides and low-level wastes) is microsphere preparation by a sol-gel process with its potential for release of low-level-radioactive and chemical wastes. This alternative is being investigated and the choice will be made based on economic and environmental assessments.

Various processes could be used for the off-gas cleanup system; no processing will be necessary to keep the off-gas well within the RCG value for an uncontrolled area.^[10] Alternative processes to the proposed KALC (krypton absorption in liquid carbon dioxide) 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 alternate processes. Alternate processes

for iodine removal could be the KALC process, the zeolite bed process (see section E.3 of appendix A), 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 process and zeolite bed process, and to compare these processes with the iodex process. The iodex process is currently the reference process for iodine removal because the technical feasibility of the alternate processes has not yet been demonstrated.

An alternate 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, reprocessing the fuel using the reference process is the recommended course of action.

VI. RELATIONSHIPS BETWEEN SHORT-TERM USES AND LONG-RANGE PRODUCTIVITY

HTGR fuel reprocessing at ICPP will have no significant cumulative effects on the environment. This assessment includes normal and abnormal events.

The land area required for the project is already within the NRTS and ICPP boundaries. The HTGR fuel processing facilities could be removed when they are no longer useful, but removal of these facilities would not release the land for uses other than those connected with the U.S. nuclear energy program. Other uses would require removal of virtually all existing AEC facilities at the NRTS.

The existing agricultural and recreational value of the land is negligible. Productive agricultural use would require clearing and development of irrigation at high cost. Millions of acres of similar, undeveloped land exist adjacent to the NRTS and in other parts of the state.

The present use of the land at the NRTS is probably its most productive use. The technology developed in activities at the NRTS is of national importance in terms of the wise use of resources and the continued availability of an adequate supply of energy at an acceptable cost.

The fuel processing will be a relatively short-term activity, but will have long-term effects through the application of technical data and experience obtained for the development of commercial irradiated HTGR fuel processing facilities, the elimination of the need to provide long-term storage for the fuel reprocessed, and the return of valuable fuel to the nuclear economy.

VII. STATE, LOCAL, OR REGIONAL CONFLICTS

The HTGR fuel reprocessing does not conflict with any known state, regional, or local plans or programs nor are there any known plans with any potential for conflict.

VIII. IRRETRIEVABLE AND IRREVERSIBLE COMMITMENTS OF RESOURCES

A. CONSTRUCTION MATERIALS

The estimated quantities of materials that will be used in the construction of process equipment, facility modifications, and other miscellaneous items needed for the demonstration and the additional quantities that would be required to convert to an interim facility for reprocessing irradiated HTGR fuel are as follows:

Stainless steel	120 tons
Concrete	2500 tons
Glass	30 tons
Carbon steel	110 tons
Copper	3 tons
Lead	70 tons
Hastelloy X	10 tons
Aluminum	11 tons
Nichrome	1000 pounds
Miscellaneous	1000 pounds

B. OXYGEN

Pure oxygen will be used to burn the graphite in the fuel elements. Most of this oxygen will be combined with carbon in the burning process to form carbon dioxide that will be released to the atmosphere. It is estimated that up to 66 million scf/yr of oxygen will be consumed.

C. PROCESS CHEMICALS

The estimated maximum quantities of process chemicals that will be used annually for HTGR fuel processing are:

Kerosene	88 thousand gal/yr.
Nitric acid (13.0 <u>M</u> HNO_3)	1.7 million gal/yr.
Hydrofluoric acid (48 wt. % HF)	33 gal/yr.
Aluminum nitrate ($\text{Al}(\text{NO}_3)_3 \cdot 9\text{H}_2\text{O}$)	940 thousand lb/yr.
Cadmium nitrate ($\text{Cd}(\text{NO}_3)_2$)	13 thousand lb/yr.
Sodium bisulfite	2.5 thousand lb/yr.
Sodium carbonate	59 thousand lb/yr.

D. ENERGY

It is estimated that about 5.4 million KWh/year of electrical energy will be used. This will be less than 4 percent of the electrical energy used annually at the NRTS.

IX. COST BENEFIT ANALYSIS

A comparison of the environmental, sociological, and economic costs with the potential sociological, economic, and technical benefits shows the proposed HTGR fuel reprocessing is desirable when compared to the available alternatives and should be implemented. The unavoidable adverse environmental effects (section IV) resulting from the proposed processing are considered to be minimal. As discussed in section V, none of the alternatives posed guarantees less adverse environmental effects and more overall benefits. The major anticipated benefits of the demonstration (section II.B) will be improved fuel reprocessing technology, availability of fissile material for recycle at the earliest possible date, and reduced fuel storage requirements, all of which contribute to reducing the environmental effects associated with future commercial HTGR fuel reprocessing facilities. Thus, the benefits will outweigh the environmental costs. The results of the overall analysis for the demonstration are presented in table IX-I.

A. ENVIRONMENT

When compared, the overall and long-term environmental benefits will exceed significantly the short-term environmental costs. The benefits will include the elimination (or at least reduction) of land commitments and resource utilization necessary for fuel storage facilities, a significant potential for reducing the environmental effects of commercial processing facilities for irradiated HTGR fuel and the conservation of natural resources in the form of uranium ore or other materials needed for the production of electricity. The environmental costs will consist of (a) the release of low concentrations of contaminants to the atmosphere and ground water,

TABLE IX-1
COST-BENEFIT SUMMARY FOR DEMONSTRATION

<u>Benefit</u>	<u>Cost</u>
<p><u>Environment</u></p> <p>Reduction of land commitments and resource utilization necessary for fuel storage.</p> <p>Conservation of natural resources, e.g., uranium ore.</p> <p>Reduction of environmental impact by recycling fissionable material rather than mining new fissionable material.</p> <p>Potential reduction of future environmental impacts of a commercial recycle plant.</p> <p><u>Economic</u></p> <p>Recovery of fissile and fertile material.</p> <p>Eliminate the necessity of building additional storage facilities (at about \$1000/fuel element) for future HTGR fuel discharges.</p> <p>Indirect technical - lower cost and lower risk (environmental, technical, and economic) commercial recycle plant.</p> <p><u>Technical</u></p> <p>Provide data for design and eventual operation of a commercial plant, lower cost, more efficient use of materials and energy, minimize effect of commercial plant on environment.</p> <p>Provide data in a timely manner to allow operation of a commercial plant at the earliest possible date.</p> <p><u>Sociological</u></p> <p>Electrical power produced from uranium resources recovered by the processing and made available for recycle to the reactors. The potential to produce electrical power amounting to about 3000 times the electrical power consumed to reprocess the material.</p>	<p><u>Environment</u></p> <p>Release of small amounts of radioactive carbon, krypton, iodine, and tritium (below applicable Federal Regulations).</p> <p>Release of carbon dioxide, carbon monoxide, oxygen, and stable xenon isotopes (which will not adversely affect the environment).</p> <p>Permanent commitment of construction materials.</p> <p>Consumption of power, oxygen, and process chemicals.</p> <p>Land use for process building and for temporary waste storage.</p> <p>Effluents of chemicals, heat, and sewage.</p> <p><u>Economic</u></p> <p>Capital expenditures of \$30 million for the demonstration phase.</p> <p>Modest (presently undetermined) additional capital expenditures for plant improvement and capacity increase for interim processing.</p> <p>Total incremental operating cost.</p>

(b) permanent commitment of construction materials, (c) consumption of power, oxygen, and process chemicals, and (d) an insignificant addition of land volume dedicated to temporary waste storage.

B. ECONOMIC

The cost of the HTGR fuel reprocessing facilities will be \$30 million to install the equipment for the demonstration phase and an additional modest capital expenditure (undetermined at the present time) for plant improvement and capacity enlargement to a rate of 24 fuel elements per day for the interim processing phase. Additional incremental operating costs at the ICPP will be less than 4 million dollars per year.

Direct economic benefits to be derived from processing HTGR fuels include:

1. Eliminate construction of additional spent fuel storage facilities. This represents a savings of up to \$7 million for each year of fuel processing.
2. Recovery of uranium (uranium-233 and uranium-235) worth up to \$25 million for each year of fuel processing.
3. Reduce the economic risk for commercial HTGR reprocessing facilities which could result in lower electrical power costs from early HTGRs.

C. TECHNICAL

Technological benefit is the primary objective of the proposed fuel processing. As stated throughout this document, the processing will provide the data to be used for the design, construction, and operation of commercial facilities. The processing will not only provide a workable process for HTGR fuels but will provide processes and design data for minimizing the effect of commercial reprocessing facilities on the environment. The technical information will also provide for a more economical design of commercial reprocessing facilities.

D. SOCIOLOGICAL

Sociological benefits derived from processing HTGR fuels will be the generation of electrical power from the uranium resources recovered and made available for recycle to the reactors.

E. ALTERNATIVES

Basically there are only two reasonable approaches -- storage or processing of the irradiated HTGR fuel. As discussed in section V, the various storage options might offer short-term environmental benefits over the proposed processing; however, long-term considerations (beyond the life of the facilities) favor reprocessing. Storage would prevent obtaining reprocessing information needed to minimize any potentially adverse impacts of commercial plants on the environment. Reprocessing is also desirable to recover and eventually recycle the fissionable material contained in the spent fuel, thus alleviating the necessity of mining

and enriching an equivalent amount of material or using non-renewable resources, such as fossil fuel.

Process options also exist; however, except as noted in section V, it is likely that these options would only result in complicating the process or increasing the overall environmental impact of the demonstration. Although it would be possible to perform the processing at a number of sites, the ICPP is the logical selection. The ICPP would require the least amount of modification, has operating experience with parts of the proposed process, has advanced waste handling capabilities, has demonstrated capability in safely reprocessing nuclear fuels, and will be the site where the HTGR fuel will be stored.

When all practical alternatives are considered, the HTGR fuel processing, as proposed, is more desirable than the alternatives.

F. CONCLUSION

In assessing and balancing the anticipated benefits against the environmental and economic costs, and after considering the available alternatives and their environmental effects, it is concluded that the proposed HTGR fuels reprocessing project should be accomplished.

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APPENDIX A

DESCRIPTION OF PROPOSED HTGR FUELS REPROCESSING PROJECT

The following sections contain a detailed description of the process and associated equipment and waste stream concentrations. Existing process equipment and new equipment that will be used for the process are also described.

A. FACILITIES

With the exception of the off-gas cleanup, the HTGR (high-temperature gas-cooled reactor) fuel reprocessing will be conducted within shielded cells located in an "envelope" established to minimize the possibility of cross-contaminating the other areas of the Idaho Chemical Processing Plant (ICPP) with uranium-233. The envelope is shown in figure A-1. Gaseous and liquid effluents will be processed as required to ensure that all contamination associated with uranium-233 is contained within the envelope. Solid effluent will be packaged before it leaves the envelope for transport or disposal in accordance with procedures established specifically to ensure against contamination of the environment. Personnel entering or leaving the envelope will be required to follow procedures that will be established to inhibit the spread of any contamination.

All new facilities and equipment will be designed to meet the requirements of the maximum credible earthquake for Seismic Risk Zone 3. The maximum credible earthquake for the ICPP would be of a magnitude 7.75 on the Richter scale with resultant bedrock acceleration of 0.33 g.

Fig. A-1. Layout of HTGR Fuel Reprocessing Facility

The new facilities will also be designed to withstand the following tornadic conditions:

1. Rotational wind velocity: 150 mph
2. Translational velocity: 25 mph
3. Peak differential pressure from atmospheric (12.3 psia): 0.75 psia
4. Pressure transient of 0.75 psia decrease in 3 sec followed by increase to atmospheric in 3 sec
5. Maximum wind loading shall create stresses in structural materials not to exceed 40% of yield strength.
6. Penetration of missiles from the above tornadic conditions.

The above tornadic conditions were selected as the design basis tornado by an unpublished study at the NRTS. This study concluded that tornadic conditions in southeastern Idaho are much less severe than in the midwestern United States.

The existing cells in building CPP-601, CPP-604, and CPP-640 that are to be used meet the above criteria; however, the process makeup areas in those buildings do not. These areas are not critical to the containment of radiological contamination.

1. Headend Processing Cells

The headend system for the process will be installed in existing, heavily shielded cells in ICPP building CPP-640. This building adjoins the main process building, CPP 601, and contains 5 cells (as shown in figure A-2),

Figure A-2 Building CPP-640

each provided with exterior shielding walls 4-1/2 feet thick. Cells 1, 2, 3, 4, and a fuel handling cave directly over cells 2 and 3 will be used; cell 5 is committed to an unrelated project.

The fuel handling cave will have interior dimensions approximately 10 x 26 x 10 feet high and will be lined with stainless steel to facilitate cleanup and decontamination. The cave will be equipped with three shielded viewing windows, an electromechanical manipulator, three sets of master slave manipulators, and additional fuel handling equipment. The cave will be accessible through a hatch in the ceiling, an entry door in the wall or through floor penetrations leading to cells 2 and 3.

Cells 1 and 2 are nearly identical. Both are 10 x 16 x 19-1/2 feet high and will be lined with stainless steel to facilitate decontamination. Cell 1 is equipped with two shielded viewing windows and one set of master slave manipulators. A 5-ton bridge crane and an electromechanical manipulator will be added to enhance handling capabilities for remote maintenance of equipment. Cell 2 is already equipped with three shielded viewing windows, two sets of master slave manipulators, a 3-ton bridge crane, and an electromechanical manipulator. A common passageway intersects the end of each cell and is equipped with a 15-ton capacity transfer dolly. A sliding radiation shielding door separates the two cells. The passageway is accessible from outside both cells 1 and 2 through sliding radiation-shielding doors.

Cells 3 and 4 are identical, each is 11-1/2 x 17 x 30 feet high and will be lined with stainless steel. An existing 3-1/2 feet thick removable wall now located between the cells will be removed in an earlier fuel processing campaign to provide a single large cell that is 26-1/2 x 17 x 30 feet high. Two shielded viewing windows will be installed, one in cell 3 and the other in cell 4. Two sets of master slave manipulators, a 5-ton bridge crane, and an electromechanical manipulator will be added to provide the necessary remote handling capabilities. A passageway will be installed between cells 1 and 3.

2. Solvent Extraction Processing Cells

The processing cells to be used for the HTGR solvent extraction are located adjacent to other shielded cells within the main processing building at ICPP, building CPP-601 (Cells A, B, C, and D). The first cycle solvent extraction will be located in cell D which is 19 x 20 x 27-1/2 feet high. This cell is constructed of normal density concrete with a 5-foot thick ceiling. The east and west walls, which face the access corridor and the sampling corridor, respectively, are 5 feet thick; the north and south walls, which are common with adjacent processing cells, are 4 feet thick.

The second cycle solvent extraction will be located in cell C which is 19 x 20 x 27-1/2 feet high. This cell is also constructed of normal density concrete. The east and west walls, which face the sampling corridor and access corridor, respectively, are 5 feet thick; the north and south walls are common with adjacent processing cells and are 4 feet thick. The cells will be lined with stainless steel to facilitate decontamination.

Cells A and B, 19 x 15 x 16-1/2 feet high and 19 x 15 x 17-1/2 feet high, respectively, will be used for waste handling, uranium salvage, etc. These cells are also constructed of normal density concrete. The east and west walls, which face the sample corridor and access corridor respectively, are 5 feet thick. The north wall is common with cell C and is 4 feet thick. The south wall is common with the access corridor and is 5 feet thick. Cell A, located directly over cell B, has a 5 feet thick ceiling. A 4 feet thick floor with removable hatch separates the two cells.

3. Denitration and Process Ventilation Facility

The product denitration system will be located in a new building which will be adjacent to the existing building CPP-640. This new building will house the ventilation, filtration, and exhaust systems and the solid product storage vault. This new building will be constructed of reinforced concrete with overall dimensions of 74-1/2 x 43 x 37 feet high. The building will be divided into two separate cells with a common emergency door. The cell containing the denitration system and storage vault will be 40 x 40 x 36 feet high (the storage vault will be 14 x 8 x 10 feet high). It will be equipped with denitration system equipment, two personnel entry doors, an 8 x 10 feet freight door, and a 3-ton bridge crane. The ventilation cell will be 30 x 40 x 36 feet high and will have one access door. It will contain the filtration, scrubbing, demisting, and drying equipment required for the wet-vessel off-gas system (process off-gases from aqueous process systems and storage tanks). It will also contain the filtration equipment required for the dry-vessel off-gas system (cell ventilation, cooling air, pneumatic transport gas, etc). All process gases and air, with the exception of those directed to

the off-gas cleanup system, will be processed through this cell prior to release to other exhaust gas cleanup systems.

4. Off-Gas Cleanup Facility

The off-gas cleanup system will be located in the existing middle cell on the west side of building CPP-604. The cell is constructed of ordinary concrete with inside dimensions of 20 x 24 x 35 feet high. The east, west, and south walls, and the ceiling are 2 feet thick. The north wall is 4 feet thick. The lower 6 feet of the cell is lined with stainless steel.

5. Analytical Facilities

The required process sample analyses will be conducted in the existing Remote Analytical Facility (RAF) in building CPP-627. Portions of two other existing rooms in this building will also be utilized. Some upgrading of the facility will be required to perform this function, such as providing containment cells, improved hoods and remote handling equipment, improved ventilation, decontamination and repair facilities, etc. The analysis area will be included in the "envelope" established for the project.

B. HEADEND PROCESS

Schematic diagrams for the headend processes for the demonstration phase and the interim processing phase are shown in figures A-3 and A-4, respectively. Some of the headend processing steps differ for the two phases because of differences in the fuel particles used in the fuel elements to be processed.

Fig. A-3. Schematic Flow Diagram of Headend Process

Fig. A-4. Schematic Diagram of Interim Headend Process

1. Fuel Transfer

The fuel elements will be stored in the dry Irradiated Fuel Storage Facility, CPP-603, that is being constructed at ICPP. The fuel will be stored in canisters, each containing up to four fuel elements. The fuel elements will be transferred from the storage facility to building CPP-640 (a distance of 1/2 mile) in a fuel transfer cask designed to hold one storage canister of spent fuel. The cask will be monitored for radiation and external contamination before and after fuel transfers. The transfer will be made over existing paved roads within the ICPP boundary fence. Existing cask transport vehicles (straddle carriers) will be utilized for fuel movement between the two buildings.

2. Fuel Handling, Observation, and Charging

At the processing plant, the building crane will be used to position the cask on alignment tracks outside the fuel handling cave. The cask will be aligned and coupled with the fuel transfer penetration in the cave wall, and the cask and penetration doors will be opened. The canister will be transferred to the cave, and the fuel elements will be drawn from the canister, one at a time, with remote fuel handling equipment. They will be stored in a 12-element storage rack. The required observations, identifications, and inspections will then be performed. An electromechanical manipulator, three sets of master slave manipulators, and a fuel extraction device will be available in the cave for fuel element manipulation and equipment adjustment. Following

the necessary observations and inspections, the individual fuel elements will be placed in a charging chute and fed to the primary crusher.

3. Fuel Crushing

The carging chute will direct the fuel elements to the crushing equipment in cell 2 directly below the fuel handling cave. Three stages of crushing will be used to achieve the desired fuel element reduction.

The fuel elements will be rough crushed in the initial stage to fragments having a 6-in. ring size. The fuel element fragments will be transferred to the secondary crusher and further reduced to fragments of a 2-in. ring size. The resulting fragments will then be gravity fed to the tertiary crusher and reduced to the desired 3/16 in. size. The crushed fuel elements will then be fed to a weigh hopper for material balance measurements. An inert atmosphere will be maintained in the three crushing units to prevent the pyrophoric reaction of carbide fuel particles. All fines that become airborne during crushing will be confined to the process, purged from the crushing units, filtered from the purge stream, and deposited in the weigh hopper. The crushing components will be designed and arranged in the cell to facilitate decontamination, remote adjustment, remote maintenance, and to allow provision for shielding of components which may be vulnerable to high radiation.

From the weigh hopper, the crushed fuel will be transported to a collection-transfer hopper. If pneumatic transport is used, transport gas will be filtered as it leaves the collection-transfer hopper to remove entrained fines and then will be discharged to the dry-vessel off-gas system.

The crushed fuel in the collection-transfer hopper will be transferred by gravity to the primary burner feed hopper. All three hoppers described above--the weigh hopper, the collection-transfer hopper, and the primary burner feed hopper--will be sized and designed to prevent a nuclear criticality. Vibrators will be attached to each of the hoppers to facilitate fuel product removal and transport.

4. Crushed Fuel Burning

Crushed fuel will be continuously fed from the feed hopper by a variable speed auger arrangement into a fluidized-bed primary burner. The feed rate will be determined by burner off-gas concentration. Burner temperature will be about 900°C. Internal pressures in the burner will be between 15 and 24 psia.

Heat generated by the burner will be removed by forcing air through a clamshell jacket surrounding the bed portion of the burner. Primary burner off-gases may be cooled by an in-vessel cooling system in the top section of the burner to prevent exceeding the temperature limitations of the filters. The cell ventilation system will remove the heat transferred to the cell environment. The fluidizing gas fed to the burner will be oxygen, inert gas, or any mixture of the two at a total flow of approximately 43 scfm per burner. The crushed fuel feed rate will be setpoint controlled. Burner bed temperature will be controlled by fluidizing gas composition (regulation of oxygen flow). The flow of gas to the burner will be

sufficient to maintain fluidization. In the burner, most of the graphite (approximately 80 percent) will react with the oxygen and leave the burner as a gas. This gas will consist primarily of carbon dioxide (approximately 90 percent); carbon monoxide will constitute less than 10 percent and the remainder will be oxygen.

The primary burner off-gas, with entrained fines, will be cooled and passed through a cyclone separator and sintered-metal filter for fines removal. This gas will then be discharged to the off-gas cleanup system. The accumulated fines will be recycled to the primary burner or transferred to the secondary burner. The burning process will expose the silicon carbide (SiC) coated fissile and fertile particles of the Ft. St. Vrain Reactor (FSVR) fuel, and the SiC coated fissile particles and oxide kernels of the fertile particles and uranium-233 recycle fissile particles of the HTGR fuels processed during the interim phase.

Primary burner ash will be removed from the bottom of the burner and transferred to an air classifier for particle separation. Vibrators will be used, as necessary, to facilitate material transfer.

5. Particle Separation

Particle separation will be accomplished in air classifiers. During the demonstration phase, the burner ash will be separated into three categories: fines, fissile particles, and fertile particles. The fines (about 22 kilograms/day) will be collected in a hopper and held for eventual

processing or shipment to a federal repository. The fissile particles (about 254 kilograms/day) will be collected and placed in storage containers for eventual processing. The fertile particles (about 212 kilograms/day), which may require additional classification (separating the larger particles from the small particles to permit optimum particle crushing), will be collected in hoppers for additional processing. Particle separation will be achieved by forcing a regulated stream of gas (air or inert up through the stream of particles. Individual particles will either become entrained in the gas or will settle in the gas stream, depending upon their weight and cross-sectional area, thereby allowing the desired separation to be accomplished. Vibrators will be attached to hopper discharge lines, as necessary, to facilitate material transport.

During the interim processing phase of the project, the burner ash will be separated into three and possibly four categories: fines, fissile particles, fertile particles and uranium-233 recycle particles. The fines will be collected in hoppers and held for eventual processing or shipment to a federal repository. Fissile particles from 25 recycle fuels* will be removed for disposal while fissile particles from IM elements* will be collected in hoppers for eventual processing. The uranium-233 fertile and 23 recycle fissile particles*, which could require additional classification, will be collected in hoppers for additional processing. Particle separation will be achieved by forcing a regulated stream of gas (air or inert) up through a stream of particles. Individual particles will

*See Table II-1 for definition.

either become entrained in the gas or will settle in the gas stream, depending upon their weight and cross-sectional area, thereby allowing the desired separation to be accomplished. Vibrators will be attached to hopper discharge lines, as necessary, to facilitate material transport.

6. Particle Crushing

The fertile particles of the FSVR fuel are TRISO coated and will be the first particles processed for the demonstration phase. These fertile particles will be fed by gravity from the collection hoppers to double-roll particle crushers at a rate of about 212 kg/day. The crushers will break the silicon carbide outer coating and expose the inner layers of buffer carbon and the uranium and thorium carbide kernels for burning in the fluidized-bed secondary burner. The process flow path through the crusher will be enclosed to prevent the release of dust generated during particle crushing. Volatile and gaseous fission products may be released when the SiC hulls are broken; therefore, the crushers will be purged with inert gas and maintained at a slight vacuum below cell pressure. The crusher purge gas will be directed to a sintered-metal filter equipped with a pulsed-blowback system, to confine the dust to the process. Following filtration, the purge gas will be recycled or directed to the off-gas cleanup system. The crushed fertile particles will be transferred to the secondary burner feed hopper. The fissile particles of the FSVR fuel are TRISO coated and will be eventually processed using the same particle crushing procedure as for the fertile particles.

The only particles which will require crushing in the interim processing phase will be the TRISO coated fissile particles because the fertile and recycle particles are BISO coated. The fertile and recycle uranium-233 particles may be crushed to give a more rapid dissolution rate. The TRISO fissile particles will be crushed in the same manner as the FSVR particles as described previously.

7. Crushed Particle Burning

The crushed fertile particles from the FSVR fuel elements along with any fines from the primary burner, if not recycled, will be gravity fed on a batch basis to the fluidized-bed secondary burner. The fluidizing gas, oxygen, carbon dioxide, or any desired mixture of the two, will be started and the burner resistance heaters turned on to maintain an operating temperature of approximately 900°C. Internal pressures in the burner will be from 14 psia at the top of the bed to 20 psia at the bottom. After the burner has reached operating temperature, the off-gas will be continuously monitored. When the off-gas indicates insufficient carbon in the bed to support combustion, the burner will be shut down. During secondary burning, all remaining carbon will be consumed and the uranium and thorium carbides will be converted to their respective oxides. The broken particle hulls will serve as the inert bed material. Off gases will be withdrawn from the burner through sintered-metal filters to ensure that essentially all of the graphite remains in the burner until consumed and to minimize the release of particulate contamination. These filters will be located in the top of the burner vessel and will be equipped with a pulsed-blowback system. Graphite dust and particulate contaminant collected on the

filters will be returned to the fluidized bed by cyclic pulses of the filter blowback system. Off-gas cooling may be achieved by an in-vessel cooler located in the upper section of the burner. The resulting burner off-gas will be directed to the off-gas cleanup system prior to being processed through the Atmospheric Protection System (APS)*. The cell ventilation system will remove the heat transferred to the cell environment. The fissile particles from the FSVR and IM fuel elements will be similarly processed.

8. Dissolution

Secondary burner ash will be gravity fed, on a batch basis, to the dissolver (leacher). The burner ash will consist of broken silicon carbide hulls, thorium and uranium oxides, fission product oxides, and possibly some intact particles. The ash will be leached in a solution containing 13.0 M nitric acid, 0.04 M hydrofluoric acid, 0.05 M aluminum nitrate, and neutron absorbing material, such as cadmium, boron, etc., if necessary, at 120°C. The thorium, uranium, and fission product oxides will be leached from the broken particles. The dissolver will have a conical bottom and will be equipped with an air sparger at the bottom of the cone. The sparger will be

*The APS will be a filtration system consisting of deep-bed and HEPA filters. All ICPP process off-gases and cell ventilation gases are processed through the APS before discharge to the stack. The APS is essentially a backup system to prevent significant radioactive particulate release to the environment in the event of a process filter rupture.

operated during leaching operations and while draining the dissolver to keep insolubles mixed in the solution. This will ensure that the leaching acid contacts the particles adequately during dissolution and will also minimize plugging of lines while draining the dissolver. The leachate, consisting of a slurry of hydrofluoric acid, nitric acid, aluminum nitrate, thorium, uranium, fission products, particle hulls, intact particles, and neutron absorber (if required), will be transferred by steam-jet eductors to a centrifuge for solids-liquid separation.

Off-gases from the dissolver will be passed through a reflux condenser, discharged into the wet-vessel off-gas, and finally processed through the APS.

9. Solids-Liquid Separation

In the centrifuge, the broken silicon carbide hulls and intact particles will be separated from the leachate, washed with nitric acid, and then washed with water to remove any residual leachate. The solids will be sampled or scanned to determine the uranium content. If the uranium content meets disposal allowances, the solids will be dried and the broken silicon carbide hulls separated and canned for disposal; otherwise, the solids will be slurried with an acid solution and recycled through the centrifuge. Any intact particles will be recycled to the particle crusher after being separated from the broken silicon carbide hulls by air classification.

The leachate and wash solutions will be combined in collection tanks and sampled to determine uranium, thorium, and solids content. From these tanks, the leachate will be transferred through process piping to the solvent extraction system.

C. SOLVENT EXTRACTION

The solvent extraction processing system will consist of four main operations: feed preparation, first cycle extraction, second cycle extraction, and uranium salvage. The system will be installed in existing cells in building CPP-601.

1. Feed Preparation

After each accountability tank in the headend system has been filled and sampled, its contents will be transferred to the collection-feed tank for the steam stripper. In the stripper, the solution will be heated to about 135°C and steam stripped to remove additional acid. The nitric acid will be carried overhead with the steam and will be condensed and collected in a tank. After being sampled, the acid will be sent to the appropriate waste system as determined by activity content or recycled for uranium recovery. The bottoms from the stripper (containing the uranium, thorium, and fission products) will be collected in a tank, sampled, and any chemical additions made to adjust the solution to solvent extraction flow-sheet specifications. The adjusted solution will then be transferred into the feed tank for the first solvent extraction cycle.

2. First Cycle Extraction

The first extraction cycle will utilize an organic solvent consisting of 30 percent tributyl phosphate (TBP) in a normal paraffin hydrocarbon (NPH) diluent. A schematic diagram of feed preparation and first cycle extraction is shown in figure A-5. In the extraction-scrub column, uranium and thorium will be extracted into the solvent and scrubbed with nitric acid to remove fission products. The scrub solutions and the remainder of the aqueous feed will be withdrawn from the bottom of the column, sampled, and transferred to existing high-level waste storage tanks for future calcination if the uranium concentration meets existing specification. If the uranium content is above limits, the solution must be recycled through the extraction-scrub column.

The solvent, containing thorium and uranium, will be withdrawn from the top of the column and transferred to the stripping column where the thorium and uranium will be stripped from the solvent using dilute nitric acid. The resulting aqueous solution will be withdrawn from the bottom of the stripping column and transferred to the solvent scrub column. The used organic solvent will be processed through a cleanup system to remove radiolytic decomposition products and reused.

In the solvent scrub column, the aqueous uranium-thorium solution will be contacted with kerosene to remove any TBP carried over from the stripping column. The solution will be withdrawn from the bottom of the column and concentrated by evaporation to about 1.5 M thorium. The concentrated

Fig. A-5. Schematic Flow Diagram of Feed Preparation and First Cycle Extraction

solution will then be collected and transferred to the second extraction cycle. The kerosene will be monitored for uranium content prior to being burned as fuel in the WCF.

3. Second Cycle Extraction

Two alternative systems are presently being considered for use as the second extraction cycle: a system using 30 percent TBP in NPH as the organic solvent, or a system using five percent TBP in NPH as the organic solvent. Schematic diagrams of these systems are shown in figures A-6 and A-7, respectively. Equipment requirements for the two systems are similar.

In the system using 30 percent TBP, the uranium-thorium solution will be fed into an extraction-scrub column identical to that used in the first extraction cycle. The thorium and uranium will be extracted into the solvent and transferred to the partitioning column. The scrub solutions and remainder of the feed solution will be collected, sampled, and transferred to existing waste storage tanks if the uranium content is sufficiently low.

In the partitioning column, the thorium will be selectively stripped from solvent with dilute nitric acid. The thorium solution will be contacted with fresh solvent to re-extract any uranium that may have been stripped with the thorium. The thorium solution will then be withdrawn from the bottom of the column and sampled for uranium content. If the

Fig. A-6. Schematic Flow Diagram of Second Cycle Extraction-Acid Thorex

Fig. A-7. Schematic Flow Diagram of Second Cycle Extraction-Modified Acid Thorex

uranium content is sufficiently low, the thorium solution will be concentrated by evaporation and transferred to existing waste storage tanks for future calcination.

The uranium-containing solvent will be withdrawn from the top of the partitioning column and transferred into the stripping column. The uranium will be stripped from the solvent into dilute nitric acid, withdrawn from the bottom of the column, and transferred to the solvent scrub column. The used solvent will be withdrawn from the top of the column, processed through a cleanup system to remove radiolytic decomposition products, and reused.

In the solvent scrub column, the uranium solution will be contacted with kerosene to remove any TBP carried over from the stripping column. The solution will be withdrawn from the bottom of the column and concentrated by evaporation to about 350 grams uranium/liter. The concentrated solution will then be transferred to collection tanks for the denitration system. The kerosene will be monitored for uranium content prior to being burned as fuel in the WCF.

In the system utilizing five percent TBP, the uranium will be (1) selectively extracted from the feed solution in the extraction column, (2) scrubbed to remove remaining thorium and fission products in the scrubbing column, (3) stripped into dilute nitric acid in the stripping column, (4) scrubbed to remove residual TBP in the solvent scrub column,

and then (5) concentrated by evaporation and transferred to collection tanks for the denitration system. This system will require that the thorium/fission product scrub solution be recycled to the extraction column to re-extract any uranium scrubbed out. Waste, solvent, and solvent scrub streams will be processed identically to those in the alternate 30 percent TBP system.

4. Uranium Salvage

Waste solutions from the extraction cycles, any other process equipment wastes, or solutions from floor drains in cells where uranium-233 will be processed or handled that contain significant amounts of uranium-233 will be transferred into holding tanks in the uranium salvage system. After being sampled to establish concentration requirements and chemical adjustment requirements, the solutions will be adjusted, processed through a salvage evaporator, and collected in recycle tanks. Condensate from the evaporator will be sampled and transferred to existing low-level waste-processing equipment if the uranium content is sufficiently low (otherwise, the condensate will be recycled through the salvage evaporator). The salvaged solution will then be recycled to the first or second extraction cycle (based on composition) for uranium recovery.

D. DENITRATION SYSTEM

The product denitration system will include two liquid product holdup tanks, a feed pump, the denitration vessel, sintered-metal filters, a condenser, a demister, an off-gas vacuum pump, several filters, a water separator, a condensate tank with pump, a product collection vessel, an

off-gas blower, a glove box around the denitration and collection vessels, a glove box for product packaging and loadout, and a product storage vault. A schematic diagram of the process is shown in figure A-8.

The denitration process is based on the thermal decomposition of uranyl nitrate solution to uranium trioxide. The denitration process will be operated on a continuous basis.

The uranyl nitrate solution will be contained in the two liquid product holdup tanks, which contain less than 210 liters each of 350 gram uranium/liter. The uranium nitrate solution at ambient temperature flows from the product holdup tanks to the centrifugal feed pump. The pump discharge will be fed at a rate of 3 liters/hour to an external-mix-type nozzle on the denitration vessel. A recirculation line will be provided from the pump discharge to the product holdup tanks to maintain a large liquid flow for cooling the pump. A water flush line and an air purge line will be installed on the feed line to clean the nozzle of feed solution at the end of the run and to clear the nozzle in case it becomes clogged. Ambient air will be supplied at a flow rate of 130 scfh to the external mix nozzle to atomize the uranyl nitrate solution.

The atomized uranyl nitrate solution will be sprayed into a fluidized bed of inert particle (such as aluminum oxide, thorium oxide or zirconium oxide) and heated to a temperature between 300° and 400°C by an external electrical heater. The uranyl nitrate will be converted to uranium trioxide, which will

Fig. A-8. Schematic Flow Diagram of Denitration Process

coat the inert particles. The coated particles will overflow through the 1-in.-dia product overflow line, into the collection vessel. To minimize plugging, the product overflow line will be properly sized and provided with electrical heaters to maintain the line temperature at 250°C (to prevent moisture condensation) and a 10 scfh air purge supply to sweep condensible vapors out of the line. The product overflow line will also be equipped with pounding lugs, a vibrator, and a rod-out line from the glove box to aid in removal of the uranium trioxide product.

The initial starting bed in the denitration vessel will be an inert material (such as aluminum oxide, thorium oxide, or zirconium oxide) in a size range of -30 to +325 mesh. This starting bed and subsequent uranium trioxide bed will be fluidized by heated air which will pass through an air distributor plate at a flow rate of 300 scfh, a temperature of 300°C, and a pressure of 12.3 psia. The air flow rate to be used will be the minimum needed to provide adequate fluidization. The fluidizing air will be supplied to the lower plenum of the denitration vessel through a series of valves and a flow recorder controller that will be provided with an alarm for low fluidizing air flow. Other instrumentation will be provided as necessary. During operation the bed temperature will be controlled within $\pm 5^{\circ}\text{C}$ in the range of 300°C to 400°C; the pressure immediately above the bed will be controlled at 50-in water gage vacuum.

The system will operate under a vacuum. The off-gas will be discharged after several intermediate cleaning steps to the wet-vessel off-gas system and will eventually be processed through the APS. After leaving

the bed, the process off-gas -- consisting mainly of fluidizing air, water vapor, and oxides of nitrogen -- will flow through filters in the top of the denitrator to remove over 99.9% of the entrained uranium trioxide dust particles. The filters will operate at a temperature of 300°C, an inlet pressure of 10.3 psia, and an outlet pressure of 8 psia. Once the off-gas has been filtered; it will pass to the tube side of the condenser and be cooled to 70°C at which time part of the water vapor with nitrogen dioxide condenses and forms a nitric acid solution. The condenser will also remove uranium trioxide dust particles which have passed through the sintered-metal filters.

From the condenser, the remaining off-gas will pass through a demister to separate entrained liquid, and then through a preheater, where the temperature will be raised to 130°C before the gas enters a high-efficiency particulate air (HEPA) filter. The HEPA filter will collect any remaining traces of uranium trioxide dust in the off-gas and serve as a backup device should one of the sintered-metal filters fail. After filtration, the gases will be pumped by a vacuum pump through a water separator and into the wet-vessel off-gas system, in which the gas will again be filtered twice before being processed through the APS.

The condensate from the condenser, and any additional liquid removed in the demister, will flow by gravity to the condensate tank where it can be sampled to determine the uranium content. Periodically the condensate will be pumped to the salvage hold tanks. The condensate,

along with other salvage solutions, will be concentrated in an evaporator and recycled to the solvent extraction system, if necessary, for recovery of uranium.

When enough dry uranium trioxide product (9-11 kg including inert material) is available to fill a storage container, the uranium trioxide will be transferred to the product glove box. The product will drain by gravity through the 1-in. Schedule 40 drain line into the blender. The product drain line will be sized to prevent plugging. After blending, the product will be drained from the blender into small bottles (tared). A sample (60 g) will be removed from the product as it is being placed into the bottles. The bottles, 1 x 3 in., containing the uranium trioxide products, will be sealed with tared lids while in the glove box. The sealed bottles will also be sealed in tared plastic bags in the bag-out port and weighed on a calibrated balance outside the glove box. The bottles, containing 9-11 kg of uranium trioxide, will be sealed inside a tared and marked standard metal isotope shipping can 4-1/4 in. OD x 6-7/8 in. long with 0.10 in. walls. The void inside the can will be filled with tared, crumpled aluminum foil. The isotope shipping can will be weighed on a calibrated balance, placed in the inner container of the shipping container, and stored in the shipping container in the product vault. The shipping container will comply with AEC Manual Chapter 0529 and Department of Transportation (DOT) regulations that place stringent controls on the shipment of radioactive materials.

The amount of product stored prior to shipment will be dependent upon the amount of uranium trioxide in storage, total amount of fuel scheduled for reprocessing, and the time in storage. The following guidelines will be used:

1. Each shipment will contain no more than 60 shipping containers, such that the total transport index of the shipment (one on truck) is equal to or less than 50.
2. A shipment will be made after completion of each scheduled HTGR fuel reprocessing campaign.
3. A shipment will be made well before approaching the limits used for the shielding requirements, i.e., 3-mo-old uranium-233 and 400-ppm uranium-232.

Based on these guidelines, the shipping containers will be loaded on a truck for shipment to Oak Ridge National Laboratory (ORNL).

E. OFF-GAS CLEANUP SYSTEM

The off-gas cleanup system will remove particulate, volatile, and gaseous atmospheric contaminants from the effluent gas streams of the HTGR fuel reprocessing pilot plant. Schematic diagrams of the processes are shown in figures A-9 through A-11.

Particulate and volatile fission products -- zirconium, niobium, ruthenium, cerium, cesium, and selenium -- and any other particulate-condenser-type

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Fig. A-9. Schematic Flow Diagram of Tritium and Iodine Removal Process

Fig. A-10. Schematic Flow Diagram of Alternate Simplified Iodine and Tritium Removal Process

Fig. A-11. Schematic Flow Diagram of KALC Process

filter train before the gas stream leaves the uranium-233 envelope.

Equipment for removal of gaseous fission products -- tritium, iodine, and krypton -- will be in the middle cell on the west side of the Waste Disposal Building, CPP-604. Off-gas from the headend process in CPP-640 will flow through the new ventilation facility to CPP-604 through a small duct inside the main vent. Instrument displays and operator controls will be in the operating area in CPP-604.

The processes for removing gaseous fission products are still the subject of study. Candidate processes are outlined below:

1. Tritium Removal

To ensure the complete conversion of all tritium to tritiated water vapor, the off-gas will be oxidized in the presence of a copper oxide catalyst. See figure A-9. The gas will then be cooled and passed through a molecular sieve to remove all water vapor. If the relative humidity of the gas stream is too low, steam may be added ahead of the molecular sieve to improve the efficiency of the process. From the sieve the gas will be heated to begin the iodine removal process. The tritium will be recovered from the process by regenerating the molecular sieve. A pair of sieves will be arranged in parallel so that one can be regenerated while the other is in use. Heated air will be passed through the sieve being regenerated. This air will then be passed through a condenser. The tritium collected by the condenser may be fixed as a solid hydrate for

disposal, or it may be sold as isotopic tritium. The solid hydrate will be packaged and stored or disposed of in accordance with yet-to-be-developed procedures that will be established specifically to ensure protection of the environment.

2. Iodine Removal

The off-gas will be passed through a decomposition tower where fuming nitric acid will be used to break the complex iodines into elemental iodine. See figure A-9. The gas will then be heated and passed to an oxidation tower where the iodine will be scrubbed from the gas with nitric acid. The iodine-bearing acid will be processed through a still where the iodine will be distilled off and collected as a viscous liquid. This liquid can be stored or heated and evaporated to a dry powder. Storage or disposal will be in accordance with yet-to-be-developed procedures that will be established specifically to ensure protection of the environment.

The off-gas from the oxidation tower will pass through a demister and condenser to remove nitric acid and water vapor. Any liquid collected will be recirculated to the oxidation tower. After being cooled the gas will flow through molecular sieves to remove any residual water vapor. The gas stream from the sieve will pass to the KALC (krypton absorption in liquid carbon dioxide) process.

A pair of molecular sieves will be arranged in parallel so that one can be regenerated while the other is being used. A small stream of off-gas

from the sieve in use will be heated and passed through the one being regenerated to vaporize and absorb any collected liquid. This gas stream will then be passed through a condenser. Any liquid collected will then be recirculated to the cooler preceeding the molecular sieve.

3. Alternate Process

A possible alternate, less complex, system for removing both iodine and tritium is shown schematically in figure A-10. After oxidation, the off-gas would be passed through a lead-zeolite bed where the iodine in the off-gas would react with the lead zeolite to form lead iodide. A pair of lead zeolite beds would be arranged in parallel to permit changing one bed while the other is in use. A single silver-zeolite bed would serve as a backup for the lead zeolite. Tritium would be removed as described for the previous process.

Either process is expected to produce a DF greater than 100 for iodine and between 10 and 100 for tritium.

4. Rare Gas Removal

The KALC process (see figure A-11) will be used to remove krypton from the off-gas stream by selective absorption in liquid carbon dioxide. In this process, the off-gas, which consists mostly of carbon dioxide, will be compressed to 20 atm and cooled to liquify the carbon dioxide prior to passing into the rare gas absorption column. The krypton and xenon will be absorbed in the liquid carbon dioxide while the light gases such as

oxygen, nitrogen, and carbon monoxide will be essentially not absorbed thus separating the noble gases from the light gases in the absorption column. The liquid carbon dioxide with absorbed noble gases will then flow into the fractionation column which operates at a lower pressure and a higher temperature than the absorption column. In this column, some of the carbon dioxide and any light gases will be removed, thus increasing the concentration of the noble gases in the liquid carbon dioxide. The concentrated noble gases - liquid carbon dioxide stream will flow into the stripper column where the noble gases and some carbon dioxide will be volatilized from the remaining liquid carbon dioxide. The noble-gas-rich stream will flow through a pair of condensers and then a cold trap to further remove carbon dioxide from the noble gases. The noble gases krypton and xenon will be collected in compressed gas storage bottles. Because carbon dioxide will be the major constituent of the initial process off-gas, a considerable amount will be collected by the krypton removal system. The carbon dioxide in excess of the amount required to operate the KALC process will be passed through a still, vaporized, and processed through the APS.

A DF greater than 100 is expected for krypton. The concentration factor (CF) for krypton is expected to be greater than 1000.

The off-gas flow is expected to be about 120 scfm for the demonstration phase. The composition of the off-gas is expected to be approximately as follows:

1. Carbon dioxide - 105 scfm
2. Oxygen - 11 scfm
3. Carbon monoxide - 4 scfm
4. Nitrogen - Small amount

The following small quantities of gaseous fission products are expected to be processed by the off-gas cleanup system for the demonstration phase:

1. Tritium - 0.014 g/day
2. Iodine-129 - 67 g/day
3. Krypton-85 - 119 g/day

The noble gases collected will be either shipped off-site for experimental use or stored temporarily prior to final disposal. Storage or disposal will be in accordance with yet-to-be-developed procedures that will be established specifically to ensure protection of the environment.

All parts of the process equipment which serve as a containment boundary for the off-gas will be constructed of stainless steel, except for those parts of the system exposed to the corrosive effects of iodine. These parts include ducting between the denitration-ventilation building and CPP-604, the decomposition tower, demister, condenser, nitric acid still, and iodine removal apparatus. These items will be constructed of materials resistant to iodine corrosion. Other parts not of stainless steel include such items as valve stem packing and compressor seals.

The off-gas flow is expected to be 240 scfm for interim processing phase. The composition of the off-gas is expected to be approximately as follows:

1. Carbon dioxide - 210 scfm
2. Oxygen - 22 scfm
3. Carbon monoxide - 8 scfm
4. Nitrogen - Small amount

The following quantities of gaseous fission products are expected to be processed by the off-gas cleanup system for the interim processing phase:

1. Tritium - 0.028 g/day
2. Iodine-129 - 134 g/day
3. Krypton-85 - 238 g/day

F. UTILITIES

The utilities required will include electrical power, steam, compressed air, and water. These are available in the quantities needed from the existing ICPP facility with only minor modifications. The estimated annual quantities required for processing irradiated fuel are:

Electrical power	6 million KWh
Steam	11 million pounds
Compressed air	2.7 billion standard cubic feet
Water	80 million gallons

The refrigeration units in the off-gas cleanup system and the secondary burner in the headend process will consume a large share of the electrical power used. Water will be used in some processes and for heat removal. Compressed air will be used for instrumentation and controls and for sparging, air lifts, fluidizing, etc. Steam will be used for heating in some processes and for steam-jet eductors to transfer some solutions.

G. PROJECT DECOMMISSIONING

Because of uncertainties concerning future processing assignments for combustible fuels, a specific schedule has not been established for decommissioning the processing facilities; however, the facilities will be designed for ease of decommissioning. The solvent extraction, denitration, and off-gas cleanup portions of the overall process will not be decommissioned. These facilities will be of a generalized design and will be suitable to use for other fuel reprocessing activities.

APPENDIX A

REFERENCES

1. International Conference of Building Officials (1970), Uniform Building Code, 1970 Edition, Vol. I.

APPENDIX B

CHARACTERIZATION OF EXISTING ENVIRONMENT

The National Reactor Testing Station (NRTS) was established in 1949 by the U. S. Atomic Energy Commission for testing various types of nuclear reactors, allied plants, and equipment. It is centered on a former Naval Proving Grounds which served the Navy's Pocatello (Idaho) Ordnance Depot. The NRTS is located along the western edge of the Upper Snake River Plain in southeastern Idaho. Lying at the foot of the Lost River, Lemhi and Beaverhead-Centennial Mountain Ranges, the NRTS comprises an 894-sq mi area with an average elevation of approximately 5,000 ft above sea level. Three streams entering the Station from the west and northwest move out across alluvial fans into playas or sinks in the northwestern or northern portions of the Station. Principal surface materials at the NRTS are basalt, alluvium, lacustrine sediments, slope wash sediments and talus, silicic volcanic rocks, and sedimentary rocks. Plant life consists mainly of sagebrush and various grasses. The Idaho Chemical Processing Plant (ICPP) is located in the south-central portion of the NRTS, in Butte County, Idaho, about 42 air mi west of Idaho Falls. Figure B-1 shows the relative location of the ICPP -- an enclosed area of approximately 100 acres -- with respect to other facilities on the NRTS. Figure B-2 shows a typical view of the landscape adjacent to ICPP.

The NRTS is a government reservation with access limited for reasons of health, safety, and national security. There are no permanent residents on the site. The surrounding areas are sparsely populated, with the largest populated area near the ICPP being Idaho Falls (42 mi to the east). Other populated areas (all small) are located at Mud Lake and Terreton (29 mi

Fig. B-1. Detailed Map of NRTS

B-3

Fig. B-2. Landscape Adjacent to ICPP

northeast), Arco (19 mi west), Howe (15 mi north), and Atomic City (12 mi southeast).

1. Topography and Climatology

The topographic features which affect the NRTS weather patterns are the northeast-southwest orientation of the plain and the mountain ranges to the north and west. The NRTS is relatively level with an average elevation of approximately 5,000 ft above sea level. It is bounded to the north and west by mountain ranges with elevations as high as 6,000 ft above the plain.

The National Oceanographic and Atmospheric Administration (NOAA) has operated a meteorological observation program at the NRTS since 1949. In addition to recording day-to-day weather data and providing daily operational forecasts for the NRTS, the NOAA staff has maintained an intensive research and development program to improve the reliability prediction and measurement of meteorological parameters which influence safe conduct of operations on the NRTS. A number of meteorological stations are located throughout the NRTS to measure simultaneously the spatial variation of such meteorological parameters as temperature, wind speed and direction. Towers at several locations on the NRTS provide these data in the vertical to a height of 250 ft. Additional support to the NRTS-based NOAA staff is available through the National Weather Service.

During the 24 year period of record, the extremes of temperature have varied from a low of -43°F in January to a maximum of 103°F in July. During winter months, the average maximum temperature is approximately 27°F with an

average minimum of approximately 3°F. The summer data indicate an average maximum of 87°F, an average minimum of about 50°F. Strong surface-based temperature inversions typical of desert climates are pronounced at the NRTS. These occur nearly every night of the year and occasionally all day long during December and February. Typically, strong surface based temperature lapse rates are observed nearly every afternoon from early spring until late fall and on more than 50% of the mid-winter afternoons.

During the summer months, there is a very sharp diurnal reversal in wind direction. Winds blowing from the southwest (upslope) predominate during daylight hours, and northeasterly winds persist at night. The reversal normally occurs a few hours after sunrise and again shortly after sunset.

Storm tracks, which generally move across the NRTS from west to east often affect the normal diurnal wind pattern. Prior to passage of storm fronts, strong southerly winds persist, switching to westerly or occasionally northerly upon passage of the storm front.

The record of average wind speed shows a minimum of about 5 mph in December and a maximum of 9 mph in April and May. The highest maximum hourly average speed near the ground surface (20 ft level) was 51 mph from the west-southwest. Calm conditions prevail 11% of the time. See Figure B-3 for most frequent wind directions and velocities.

Fig. B-3. NRTS Annual Average Wind Roses

Since all air masses entering the Snake River Plain must first cross over a mountain barrier, and in so doing, precipitate a large percentage of their moisture, yearly rainfall is light. The average annual precipitation at the NRTS is 8.5 in. Precipitation amounts are at a maximum during May and June and reach a minimum in July. Snowfall ranges from a low of about 12 in. per year to a high of about 45 in. per year. The type of precipitation which occurs over the NRTS is generally dictated by the season; ie, showers in the summer, showers or periods of rain or snow in the spring and fall, and periods of snow in the winter.

The relative humidity at the NRTS is quite low with a monthly average minimum of 15% in August and a monthly average maximum of 89% in February and December. On a daily basis, a maximum is reached just before sunrise at a time of minimum temperature and the minimum late in the afternoon near the time of maximum temperature. Large variations in relative humidity occur as a result of summer thunderstorms and large-scale storms predominantly from late fall through spring.

On the average, two or three thunderstorm days occur during each of the months from June through August. The surface effects from thunderstorms over the Snake River Plain are usually much less severe than are experienced east of the Rocky Mountains or even in the mountains surrounding the plain. Strong wind gusts can occur in the immediate vicinity of thunderstorms and are usually quite localized and of short duration. The highest instantaneous speed recorded at 20 ft above the

ground was 78 mph from the west-southwest. Although small hail frequently occurs with thunderstorms, damage from this cause has not been experienced at the NRTS.

Three confirmed funnel clouds (vortex cloud which does not reach the ground), three unconfirmed funnel clouds, and two tornadoes (1 mi and 5-1/2 mi east of the eastern boundary of the NRTS, respectively) which caused no damage, have been documented in the 24 yr of observation at the NRTS. Meteorological and climatological data are summarized in References 1-9.

2. Geology

The geology of the desert plain on which the NRTS is located has been studied intermittently by the U.S. Geological Survey for the past 35 yr. The particular area occupied by the NRTS has been intensively studied since 1949 and is documented in References 6 and 7.

The plain extends in a 350-mi arc across the southern part of the State of Idaho. The NRTS occupies a physiographic basin within the confines of this plain. The elevation within the NRTS ranges from 4,800 to 5,500 ft above sea level. Mountain ranges on the north and west rise to elevations of 10,000 ft or higher.

Except for small areas along the mountain fronts and two volcanic cone-like buttes, the entire NRTS area is underlain by a succession of Pliocene, Pleistocene and geologically recent basaltic lava flows. These

form layers of hard rock of varying thickness from 10 to 100 ft. The physical characteristics and horizontal distribution of the flows vary. Unconsolidated material, cinders, and breccia are interbedded with the basalt. The beds are nearly horizontal with no structural deformation evident. These layers have been penetrated by drilling to a depth of 1,497 ft. On the basis of geophysical and geologic evidence gathered from surrounding areas, the depth of these layered deposits is inferred to range from less than 1,000 ft to more than 5,000 ft. It is inferred also that these rocks are underlain with geologically older silicic volcanic and sedimentary rocks, perhaps ranging from Cambrian to Tertiary ages. The most recent volcanic activity in the region occurred at the Craters of the Moon National Monument, approximately 25 mi southwest of the NRTS, about 1,500 to 2,000 yrs ago.

The southern and eastern perimeter of the basin is formed by elevated ridgelike structures. These features have intercepted the Big and Little Lost Rivers and Birch Creek diverting them into playa-like depressions on the NRTS where their waters are dissipated by seepage and evaporation.

A generalized soil profile to a depth of 100 ft beneath the ICPP is shown in Figure B-4. The surface soils and regolith along the streams are made up of alluvial sands and gravel of varying thickness. These grade into finer-textured sediments toward the terminal ends of the streams. The surface soils over the remainder of the NRTS are formed

Fig. B-4. ICPP Soil Profile

by eolian and loessal deposits of varying thickness. Sandy soils derived from windworked beach and bar deposits formed in old playa lakes or ponds are especially common in the northern part of the Station. In many places, basalt rock is not covered. Local playa areas contain deposits 10 to 15 ft in thickness. Alluvial fans occur along the mountain fronts.

That soil fraction with a particle diameter less than 2 mm has the capacity to absorb radioactive ions. This size fraction consists of quartz, calcite, feldspar, dolomite, montmorillonite and hydromica (illite). The cation-exchange capacity has been determined and formulae developed for estimating the amount of radioactive cesium and strontium which will be absorbed under given circumstances⁽⁸⁾. The capacity to retain or absorb cesium is considerably higher than for strontium.

3. Hydrology

The Snake River Plain is semi-arid and ground water is a resource of primary interest. This ground water is discharged at large springs in the valley of the Snake River about 125 mi southwest of the NRTS. Wells on the NRTS tap an aquifer system, and although the system yields copiously, pumpage from the wells is only a very small percentage of the water available. Withdrawals for irrigation are large in other parts of the plain but not in the vicinity of the NRTS. Detailed hydrologic data are contained in Reference 9.

The Big Lost River, Little Lost River, and Birch Creek enter the NRTS where their flows are dissipated by seepage and evaporation. The normal flow of these streams is diverted for irrigation upstream from the NRTS and enters the NRTS only intermittently. Flood stages occur in the spring from watershed snow melt. Protection from potential flooding of the Big Lost River has been provided by diversion works in the southwest corner of the NRTS. This control consists of a dam and a channel leading to an impounding area where the water seeps into the ground. The water normally flows in the main channel unless the gates at the dam are closed. The river flow varies considerably from year to year. During 1961, for instance, the channel was dry at the NRTS but in June of 1965, it had flow of approximately 2,200 cu ft/sec. The flow of the two other streams is relatively insignificant and offers little or no flood treat.

Localized ponding and surface flow of water occur occasionally as a result of unusual situations involving extended periods of above-freezing temperatures, prolonged light rainfall, extensive areas of snow and deeply frozen ground. These situations sometimes are encountered during late winter or early spring. When these conditions prevail, nuisance flooding and soil erosion can occur in localized areas unless adequate drainage is provided.

The regional ground water table is 200 ft below the land surface in the northern part of the NRTS, 800 to 900 ft in the southern part, and 450 ft at the ICPP. The water flows through voids and fissures in and between the basalt flows. The water table has a gradient toward the southwest,

and the direction of flow is inferred to be in that general direction (Figure B-5). Recharge of the ground water reservoir is by underflow from adjacent mountainous areas, seepage along the river and creek channels and seepage from playa ponds.

The ground water in the vicinity of the ICPP normally contains about 200 ppm of dissolved solids, with calcium and magnesium carbonates being the predominant solutes. The water temperature within a zone 50 to 100 ft below the water table in the vicinity of the ICPP ranges between 50 and 54°F.

The NRTS water supply is obtained from the 24 production wells at a combined rate of approximately 2×10^9 gal/yr. Of this the two ICPP production wells withdraw approximately 4×10^8 gal/yr. The HTGR process will increase the ICPP usage by about 20 percent. Approximately 93% of the water used at the NRTS is recharged to the Snake River Plain aquifer through deep wells and shallow pit or surface ponds. About 90% of the total ICPP water is returned to the ground system via a deep (598 ft) injection well which injects the water 140 ft below the top of the regional water table.

4. Seismology

Prior to 1970, the NRTS was classified within Seismic Zone 2 of the Uniform Building Code of the International Conference of Building Officials^[10].

In 1970, the classification was changed to a higher risk Zone 3 (Figure B-6)^[11]. This action imposed more stringent design criteria on facilities

Fig. B-5. NRTS Subsurface Water Flows

Fig. B-6. Seismic Risk Map of United States

constructed after May 1970.

Twenty-one earthquakes equivalent to Modified Mercalli Intensity V or higher have been recorded in Idaho since 1894. The epicenters of these earthquakes have been 100 mi or more from the ICPP. No destructive quake has occurred on the eastern part of the plain (Figure B-7)^[12]. The most recent large earthquake took place in August 1959, which was accompanied by surface faulting near Hebgen Lake, Montana, about 120 mi northeast of the ICPP. This quake, which produced an intensity of V to VI in the region comprising the NRTS, caused no damage to facilities at the NRTS (Figure B-8)^[13].

Two faults in the foothills of the mountains north of Arco and Howe, a few miles from the NRTS boundary, are geologically recent and are evidenced by fault scarps. These faults indicate that individual displacement of more than 40 to 50 ft have occurred in relatively recent geologic time. Evidence suggests that the faults probably have incurred displacement during the last 30,000 yr., possibly during the last 10,000 yr. Movement even in the last 4,000 yr cannot be ruled out ^[14].

A number of seismic instrument stations were installed in FY 1973 to monitor the fractional transmission of seismic energy from surrounding earthquake hypocenters to the NRTS. In spite of its Zone 3 classifications, no important earthquakes have originated in the eastern portion of the Snake River Plain during the period of regional history (100 yr).

Fig. B-7. Seismic Characteristics of the Intermountain Region

ISOSEISMAL MAP
MONTANA EARTHQUAKE, NOVEMBER 23, 1947
MAG. 6.25

ISOSEISMAL MAP
EARTHQUAKE OF AUGUST 17, 1959, MAG. 7.1

Fig. B-8. Isoseismal Map of Two Regional Earthquakes

5. Ecosystem

The ecosystem of the NRTS is typical for a semi-desert region. The ICPP area is also typical of the NRTS, except that large mammals are excluded from the area by a chain-link fence. The types of vegetation are limited, with the most prominent ground cover being a mixture of sagebrush, lanceleaf rabbitbrush, and a variety of grasses. This vegetation covers practically all of the NRTS.

The vegetation supports a variety of desert rodents. Chipmunks and ground squirrels inhabit the shrub areas. The mixed grasslands are inhabited mainly by mice. The herb drylands are preferred by kangaroo rats; the white-footed mouse and the jack rabbit are found in all NRTS areas. The only large mammals seen commonly on the NRTS are the coyote, bobcat, and pronghorn antelope (the latter is migratory, wintering south and summering north of the NRTS). Some migratory birds (doves, larks, and hawks) inhabit the NRTS during the summer. Other migrants, such as eagles (golden and very rarely the bald, which is an endangered species) and waterfowl pass through the NRTS in the spring and fall.

Aquatic life is not significant at the NRTS. The only major surface water flows are the Big Lost River (which is dry much of the year), Birch Creek, and the Little Lost River.

Of special ecological interest are the flats (playas) that are subjected periodically to flooding by the Big Lost River. These flats support a distinctive vegetation mixture composed almost solely of dense bluestem

wheatgrass, and a small perennial herb, *iva axillaris*. These flats provide the most unique biota on the site. Sage grouse and pheasant are the only resident game birds; however, hunting is not permitted on the NRTS.

The Atomic Energy Commission conducts extensive bio-environmental monitoring studies on the NRTS and on adjoining public and private lands. It sponsors other studies by universities and research organizations. Research has been undertaken to determine long-term, test-related effects.

Laboratory and domestic plants and animals, native species, and natural biotic communities have been used in controlled experiments and studies under actual conditions to develop predictive capability and to evaluate the transfer of airborne radionuclides to plant and animal life. These studies have included investigations of the interception, biological accumulation, and retention of specific radionuclides, principally radioiodine, by plants and animals. Many of these experiments and studies have been completed. Studies on the air-to-surface transfer of radionuclides are still in progress. Several studies have been conducted since 1953 by the Environmental Branch of the AEC's Health Services Laboratory and others to determine the impact of NRTS activities on the environment.^[17-34]

6. Population

The nearest concentrated population to the ICPP is Atomic City, located approximately 12 mi to the southeast, with about 14 residents. The total population within a 20-mi radius of the ICPP is approximately 440; within a 30-mi radius, approximately 2,600; within a 40-mi radius, about 16,500; and within a 50-mi radius, about 63,000.

No one is allowed to reside on the NRTS. An average work force of 4,200 employees is present at the NRTS during the day shift, and about 750 employees are on-site during each of the other shifts. These are average numbers that vary with changes in operational requirements and construction work.

7. Land-Use

In the latter years of the 19th century, the NRTS was crossed by two stage lines, and cattle were trailed eastward from Oregon to market. Dry canals and associated structures still remain in two areas within the present site boundary which were involved in unsuccessful irrigation projects around 1910. Cultivation by dry farming has been undertaken at various times on about 10% of the NRTS's present land area; these attempts failed because of insufficient precipitation.

During World War II, 270 sq mi of the present NRTS were used by the U.S. Navy for a gunnery range and another section was used by the Army Air Corps for aerial gunnery practice. These military facilities, comprising 431,200 acres of land, were transferred to the AEC in 1950 and 1953. In 1958, 140,500 acres to the north and east were added to the existing area to make up the present NRTS.

At the present time, the NRTS land is used solely for development and testing of nuclear reactors and associated facilities. Some sheep grazing is allowed by special permit within the boundaries. The area is designated as a national game preserve, not because of an extra-ordinary game population or to protect

any particular species, but primarily because firearms are prohibited on the NRTS.

All access to the NRTS, except the public highways traversing the NRTS, is controlled by the AEC. Four major all-weather roads service the area. Air lanes over the NRTS are closed below 10,000 ft (mean sea level) in accordance with Federal Aviation Agency regulations. The Union Pacific Railroad crosses the southwest corner of the NRTS. A spur line services the NRTS facilities.

8. Historical Lands

Archeological surveys of the NRTS started during 1967 and are continuing. Location and survey of sites and the preservation of antiquities is continuing. Artifacts recovered from the NRTS thus far indicate a long period of occupation by man ranging from the time of the mammoth hunters. These valuable sites are protected from relic hunters by law and by limited access to the NRTS; this protection will continue. Although no trace of early man has been found at the ICPP, standard NRTS operating procedures provide that suitable precautions be taken if items of archeological interest are unearthed. The Experimental Breeder Reactor No. 1 (EBR-I), located in the southwest part of the NRTS is listed in the 1971 National Register of Historic Places prepared by the National Park Service.

9. Environmental Monitoring

Monitoring of the NRTS environment is carried out by the AEC's Health Services Laboratory (HSL) and the U.S. Geological Survey (USGS) in cooperation with the National Oceanographic and Atmospheric Administration (NOAA). Monitoring programs have been conducted since the time the Station was established and

have been improved as new instruments and techniques become available. HSL environmental monitoring results are reported twice a year. Reports on the USGS monitoring program are made periodically; a comprehensive report was published in 1972.^[15]

Ground water is sampled weekly by HSL at 24 production wells at the station, and analyses for radioactivity are performed. Twelve wells outside the NRTS boundaries are sampled twice per year and analyzed for radioactivity. The location of the wells sampled are shown in Figure B-9.

A continuous air sampling program is maintained at eight on-site and ten off-site locations as shown in Figure B-10. Samples are changed weekly and analyzed for radioactivity. The concentrations of suspended particulate material are also determined for these samples. Natural dustfall rates are measured routinely. A program for monitoring sulfur dioxide concentrations in air at locations on and near the NRTS is currently being developed. This program should verify the results of diffusion calculations which indicate that sulfur dioxide concentrations are well below standards established by the Environmental Protection Agency (EPA).^[16]

A limited number of samples of NRTS soil have been obtained and analyzed for radioactivity. A soil sampling survey of the entire NRTS and its environs is currently underway to determine the concentrations of fallout radionuclides in NRTS and nearby soils.

Fig. B-9. NRTS Production and Monitoring Wells

ACC-A-0028

Fig. B-10. NRTS Air Sampling Network

Direct radiation is measured at locations on and near the NRTS. All nearby population centers are included in the direct radiation monitoring grid.

Samples of foodstuffs produced near the NRTS which are known to be important in the transfer of radionuclides to man are collected routinely and analyzed for specific radionuclides (I-131, Cs-137, and Sr-90). Grade A and Grade B milk samples are obtained weekly and monthly, respectively, from locations indicated in Figure B-11. Wheat is sampled at harvest time each year; sampling locations also are shown in Figure B-11.

Sampling of animals (primarily jackrabbits but including antelope, mourning doves, fleas, and ticks) and plants (mainly sagebrush) has been conducted by the HSL on an intermittent basis to monitor for uptake of radionuclides.^[17-35] Significant levels of some nuclides, particularly I-131, have been found in both plant and animal samples collected following special on-site tests (conducted by HSL personnel) and following atmospheric weapons testing (both U.S. and abroad).^[25] Domestic livestock (mainly sheep and some cattle) are grazed on peripheral areas of the NRTS for short periods of time in the early spring. Their resident time on the station is limited, and the approved grazing lands are at least 3 miles from nuclear facilities. For these reasons an extensive sampling program for these animals has not been attempted. As antelope graze over the entire NRTS, they are considered a better bio-indicator of uptake of radionuclides. I-129 has been detected in antelope thyroids at a maximum

content of about 5% of the limiting concentration.^[35] Dose calculations for man^[36] show that dose to an adult male's thyroid maintained at the highest value observed in antelopes would be about 21 mrem/year. In addition, Cs-137 has been detected in antelope meat and liver, but in low concentration. Consumption of all the flesh and the liver from a single antelope containing the highest Cs-137 levels observed to date would result in a radiation dose of less than 2 mrem.

In addition to the HSL water sampling program mentioned above, ground water sampling and analysis are conducted by the USGS. These analyses provide a part of the information upon which periodic reports dealing with the Snake River Plain Aquifer are based. Water level measurements, Big Lost River discharge measurements, and other hydrologic and geologic data are obtained and reported by the USGS.

Fig. B-11. Radiological Monitoring of the NRTS Environs

APPENDIX B

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APPENDIX C
TRANSPORTATION OF HTGR FUEL

Irradiated fuel for processing will be stored at the ICPP Irradiated Dry Fuel Storage Facility. Because the HTGR fuel will be in an existing storage facility at the ICPP, the transfer of fuel from the reactor to the ICPP area will not be a part of this project and is not discussed in this document. The transportation of the spent fuel elements from the FSVR to ICPP is covered in the FSVR Environmental Impact Statement ^{1/}. Transport of the spent fuel elements from the HTGR sites to ICPP will be described in environmental impact statements prepared for the reactor facilities.

Fuel will be transferred from the dry fuel storage facility to the reprocessing area, four elements at a time, in a specially-designed 20-ton cask carried by either a straddle carrier or a low-boy truck. A maximum of 1650 trips will be required annually to transfer the fuel. The entire distance between the storage facility and the main plant (about 1/2 mile) will be within the ICPP perimeter.

The cask will have 6 in. of lead shielding to reduce radiation from the fuel to acceptable levels. Also, all transfers will be monitored by qualified personnel to assure that acceptable radiation exposures will be maintained. All casks will be decontaminated, if necessary, to appropriate levels before transfer. Fuel transfers have been made safely and routinely within the ICPP for many years; if an accident were to occur, qualified and adequately trained personnel will always

be available to minimize the consequences to others in the area. Because the entire transfer route will be within the ICPP boundaries, there will be no possibility of radiation exposure to the general public while transporting the fuel.

The maximum decay heat generated by each element will be approximately 1400 Btu/hr, or a total of approximately 6000 Btu/hr for the filled cask. This amount of heat will not be sufficient to increase the fuel element temperature to the oxidation point or to cause a major fission product release from overheating the fuel while the fuel will be in the cask. Also, the four fuel elements will be critically safe within the cask, so there will be no criticality problem during transfers. Calculations show several hundred elements will be required to form a critical mass under optimum conditions.

All transfers will take place on existing paved roads, already used for fuel shipments. No significant increase in traffic density will result from the transfers (a maximum of six per day).

The uranium trioxide product will be shipped by truck from ICPP to Oak Ridge National Laboratory (approximately 1900 miles) where it will be stored at the national uranium-233 repository or used for fuel refabrication. Prior to shipping, the uranium trioxide product will be packaged within shipping containers and in a method to comply with AECM-0529 ^{2/} and applicable safety regulations of the Department of Transportation ^{3,4/}. The number of units shipped will be determined using the following guidelines:

1. Each shipment will contain no more than 60 shipping containers such that the total transport index of the shipment (on one truck) is equal to or less than 50.
2. A shipment will be made well before approaching the limits used for the shielding requirements, i.e., 3-mo-old uranium-233 with 400-ppm uranium-232.

The loaded containers will be suitable for placement in any array; however, the truck will be loaded (from front to back) three containers wide and one layer high. The product shipping containers will be tied down to the van using approved wooden frames. Health Physics personnel will survey and label the shipping containers.

For truck transportation, a commercial truck firm well experienced in transporting hazardous materials will be contracted. The company will have special equipment and knowledgeable personnel who are experienced in the technical and administrative details of radioactive material shipments.

Since the uranium trioxide product will be shipped to Oak Ridge by the method and in compliance with the regulations mentioned, the shipment will have no detrimental impact upon the environment.

REFERENCES

APPENDIX C

1. Final Environmental Statement Related to Operation of Ft. St. Vrain Nuclear Generating Station of Public Services of Colorado, Document No. 50-267 (August 1972).
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3. Title 49, CFR Parts 170-189, and Title 14, CFR Part 103, "Hazardous Materials Regulations."
4. Title 46, CFR Part 146, "Transportation or Storage of Explosives or Other Dangerous Articles or Substances, and Combustible Liquids On-board Vessels."

APPENDIX D

DETERMINATION OF RADIOACTIVE AND CHEMICAL RELEASES TO THE ENVIRONMENT

Release of radioactivity and chemicals to the environment as a result of reprocessing irradiated HTGR fuels is discussed in this appendix. Releases are considered for normal fuel reprocessing first; releases occurring during postulated accidents are considered in the second part of the appendix. Calculational methods for determining these releases are also presented.

A. NORMAL OPERATION

A description of the process and equipment is presented in Appendix A. Basically, the process consists of crushing and burning the graphite fuel matrix, separating the fertile and fissile particles, crushing the silicon carbide particle coating, burning the inner carbon, leaching the burner product, separating the uranium from the thorium and fission products, and converting the uranium product to an oxide.

During this process, various effluents will be released to the environment under controlled conditions. Fission product solutions will be stored and eventually converted to a solid substance in a fluidized-bed calciner. The chemicals used, radioactive materials processed, and releases of materials to the environment are discussed in the following sections.

1. Inventories of Chemicals and Radioactive Materials

Various chemicals are required to reprocess the HTGR fuel. The fuel also contains fission and activation products formed during irradiation.

Chemicals and Utilities Required: The chemicals and utilities consumed during processing are listed in table D-I. The quantities are shown for maximum daily and maximum annual consumption. Although it is possible to operate all parts of the system simultaneously, the system will not always be operated that way; consequently, the total daily consumption of chemicals and utilities is not necessarily the cumulative sum of the daily quantities shown. Most likely, the waste-calcination system will be operated individually and separately from the other operations.

Fuel Reprocessed: The Ft. St. Vrain Reactor (FSVR) fuel to be reprocessed will have the following approximate composition per fuel element:

Graphite	104 Kg.
Uranium-233	237 g.
Uranium-235	142 g.
Thorium	10 Kg.
Silicon Carbide	5 Kg.
Fission Products &	
Other Materials	900 g.

The quantities of fission and activation products in the fuel depend on the fuel burnup and the elapsed time since the fuel was removed from the reactor. The amounts of radioactive nuclides expected to be

TABLE D-I

MAXIMUM UTILITIES AND CHEMICAL CONSUMPTION FOR HTGR FUEL PROCESSING PROJECT

	<u>Headend</u>		<u>Solvent Extraction</u>		<u>Denitration</u>		<u>Off-Gas Cleanup</u>		<u>Calcination</u>		<u>Annual^a Project</u>
	<u>Daily</u>	<u>Annual^a</u>	<u>Daily</u>	<u>Annual^a</u>	<u>Daily</u>	<u>Annual^a</u>	<u>Daily</u>	<u>Annual^a</u>	<u>Daily</u>	<u>Annual^a</u>	
Air, scf	9.6(6) ^b	2.6(9)	5.8(4)	5.2(6)	7.8(3)	7.0(5)	1.5(4)	4.1(6)	1.1(6)	5.5(7)	2.7(9)
O ₂ , scf	2.2(5)	6.1(7)							1.0(5)	5.0(6)	6.6(7)
CO ₂ , scf	5.8(4)	1.6(7)					1.5(2)	4.1(4)			1.6(7)
Steam, lb	2.4(3)	6.6(5)	5.4(4)	4.9(6)					1.0(5)	5.0(6)	1.1(7)
Cooling Water, gal	3.2(4)	8.8(6)	3.0(6)	2.7(8)	4.5(2)	4.1(4)			3.2(5)	1.6(7)	3.0(8)
Electricity, kWh	3.2(3)	8.8(5)	2.4(2)	2.1(4)	1.7(3)	1.5(5)	1.4(4)	3.9(6)	9.6(3)	4.8(5)	(5.4)(6)
Kerosene, gal			5.9(2)	5.3(4)					7.0(2)	3.5(4)	8.8(4)
HNO ₃ (13.0 M) gal	1.5(2)	4.1(4)	1.9(4)	1.7(6)			4.2	1.2(3)	1.5(2)	7.5(3)	1.7(6)
HF (48 wt%) gal	1.2(1)	33									33
NaHSO ₃ , lb	9.0	2.5(3)									2.5(3)
Al(NO ₃) ₃ ·9H ₂ O, lb	3.4(3)	9.4(5)									9.4(5)
Cd(NO ₃) ₂ , lb	4.8(1)	1.3(4)									1.3(4)
Na ₂ CO ₃ , lb			6.5(2)	5.9(4)							5.9(4)

^aMaximum annual rates, actual usage may be lower.^b9.6(6) is equivalent to 9.6×10^6 .

present in a FSVR fuel element are shown in tables D-II and D-III.

These figures are based on a uranium-thorium fuel cycle with an average burn-up of 10^5 MWd/metric ton of thorium and uranium. The fuel is assumed to have been irradiated for six years and cooled for 180 days before processing. The fission product inventory was calculated using the RSAC^[1] computer code. Assumptions used in the calculations are described in section C.1 of this appendix. The radioactive material inventories for HTGR fuel will be comparable to the FSVR fuel element inventories; therefore, these data were also used for environmental evaluations for the interim processing phase.

2. Gaseous Releases

Radioactivity in Gaseous Streams: Gases generated while reprocessing HTGR fuel are filtered through a series of two high-efficiency particulate-air (HEPA) filters before leaving the process cells, are passed through the backup filtration provided by the Atmospheric Protection System* (APS), and are discharged through a 250 foot stack. The process filters and backup provided by the APS limit the amount of particulate material discharged to the environment. The decontamination factors (DF's) assumed for filtration are discussed in section C.3. The bulk of the radioactivity released into the gaseous streams from reprocessing HTGR fuels will result from: (a) crushing and burning in the headend, (b) denitration of the

*The APS will consist of a deep-bed fiberglass prefilter in series with a stage of parallel HEPA filters. All ICPP gaseous effluents are processed through the APS before discharge to the stack. The APS is a backup system to prevent significant amounts of particulate radioactivity from being discharged to the environment in the event a process filter ruptures.

TABLE D-II
HEAVY ISOTOPE INVENTORY IN FSVR FUEL ELEMENT^[a]

<u>Nuclide</u>	<u>Fissile Particles (Ci/element)</u>	<u>Fertile Particles (Ci/element)</u>	<u>Total (Ci/element)</u>
Ra-223	1(-7) ^[b]	2(-7)	2(-7)
Ra-224	3(-3)	5(-3)	8(-3)
Ra-225	2(-10)	2(-10)	5(-10)
Ra-226	1(-6)	2(-6)	3(-6)
Ra-228	4(-3)	7(-3)	1(-2)
Ac-227	5(-5)	8(-8)	1(-4)
Ac-228	4(-3)	7(-3)	1(-2)
Th-227	5(-5)	8(-5)	1(04)
Th-228	1(-1)	2(-1)	3(-1)
Th-229	6(-7)	9(-7)	1(-6)
Th-230	3(-4)	4(-4)	7(-4)
Th-232	4(-4)	7(-2)	1(-1)
Pa-230	2(-8)	4(-8)	4(-8)
Pa-231	8(-4)	1(-3)	2(-3)
Pa-233	1(3)	2(3)	3(3)
Pa-234	4(-2)	7(-2)	1(-1)
U-230	1(-7)	2(-7)	3(-7)
U-232	8(-1)	1	2
U-233	8(-1)	1	2
U-234	1(-1)	2(-1)	3(-1)
U-235	2(-4)	--	2(-4)
U-236	7(-3)	--	7(-3)
U-237	1(-4)	--	1(-4)
U-238	1(-5)	--	1(-5)
Pu-236	8(-2)	--	8(-2)
Pu-238	1(2)	--	1(2)
Pu-239	9(-2)	--	9(-2)
Pu-241	5(1)	--	5(1)
Pu-242	2(-3)	--	2(-3)
Pu-244	2(-10)	--	2(-10)
Am-241	9(-2)	--	9(-2)
Am-242m	6(-3)	--	6(-3)

TABLE D-II (Cont'd)
HEAVY ISOTOPE INVENTORY IN FSVR FUEL ELEMENT^[a]

<u>Nuclide</u>	<u>Fissile Particles</u> (Ci/element)	<u>Fertile Particles</u> (Ci/element)	<u>Total</u> (Ci/element)
Am-242	6(-3)	--	6(-3)
Am-243	4(-2)	--	4(-2)
Cm-242	2(1)	--	2(1)
Cm-243	1(-2)	--	1(-2)
Cm-244	6	--	6
Cm-245	5(-5)	--	5(-5)

[a] Based on 6 yr irradiation and 180 days cooling time. Some elements will not have been irradiated that long at processing time.

[b] 1(-7) is equivalent to 1×10^{-7} .

TABLE D-III

RADIOACTIVE MATERIALS IN FSVR FUEL^(a)

<u>Nuclide</u>	<u>Activity per Average Fuel Element</u>		
	<u>Fissile</u> <u>Particles</u> (Ci/element)	<u>Fertile</u> <u>Particles</u> (Ci/element)	<u>Total</u> (Ci/element)
H-3	8	4	2(1) [c]
C-14	7(-2) [b]	6(-2)	1 [d]
Se-79	2(-2)	1(-2)	3(-2)
Kr-85	3(2)	2(2)	5(2)
Rb-87	7(-7)	4(-7)	1(-6)
Sr-89	8(2)	9(2)	2(3)
Sr-90	2(3)	1(3)	3(3)
Y-90	2(3)	1(3)	3(3)
Y-91	1(3)	1(3)	2(3)
Zr-93	8(-2)	4(-2)	1(-1)
Zr-95	2(3)	2(3)	3(3)
Nb-95	3(3)	3(3)	6(3)
Tc-99	3(-1)	1(-1)	4(-1)
Ru-103	2(2)	1(2)	3(2)
Rh-103m	2(2)	1(2)	3(2)
Ru-106	5(2)	3(2)	7(2)
Rh-106	5(2)	3(2)	7(2)
Pd-107	5(-4)	2(-4)	7(-4)
Sn-123m	1(1)	1(1)	2(1)
Sb-125	4(1)	3(1)	7(1)
Te-125m	1(1)	9	2(1)
Sn-126	2(-2)	1(-2)	3(-2)
Sb-126m	2(-2)	1(-2)	3(-2)
Sb-126	2(-2)	1(-2)	3(-2)
Te-127m	2(2)	3(2)	5(2)
Te-127	2(2)	3(2)	5(2)
Te-129m	4(1)	4(1)	8(1)
Te-129	4(1)	4(1)	8(1)
I-129	8(-4)	6(-4)	1(-3)
I-131	1(-3)	1(-3)	2(-3)
Cs-134	4(1)	2(1)	6(1)
Cs-135	4(-2)	1(-2)	5(-2)

TABLE D-III (contd)
 RADIOACTIVE MATERIALS IN FSVR FUEL^(a)

<u>Nuclide</u>	<u>Activity per Average Fuel Element</u>		
	<u>Fissile</u> <u>Particles</u> (Ci/element)	<u>Fertile</u> <u>Particles</u> (Ci/element)	<u>Total</u> (Ci/element)
Cs-137	2(3)	1(3)	3(3)
Ba-137m	2(3)	1(3)	3(3)
Ba-140	6(-1)	6(-1)	1
La-140	7(-1)	6(-1)	1
Ce-141	3(2)	3(2)	5(2)
Pr-143	1	1	3
Ce-144	7(3)	6(3)	1(4)
Pr-144	7(3)	6(3)	1(4)
Nd-147	5(-2)	4(-2)	9(-2)
Pm-147	4(3)	2(3)	6(3)
Sm-151	5(1)	2(1)	7(1)
Eu-154	3	1	4
Eu-155	4(1)	3	4(1)

[a] Based on 6 yr irradiation and 180 days cooling time. Some elements will have been irradiated for shorter periods of time.

[b] 7(-2) is equivalent to 7×10^{-2} .

[c] H-3 total includes 10^5 Ci present outside of the fissile and fertile particles.

[d] C-14 total includes 0.9 Ci present outside of the fissile and fertile particles.

uranium product, (c) burning the organic waste, and (d) calcining the aqueous waste. The remaining off-gas streams (such as vessel off-gas and cell ventilation) contribute virtually no radioactivity during normal processing.

The estimated concentrations of radioactive isotopes from headend processing of the fertile particles (a) at the stack, (b) at the points where the maximum ground concentrations occurs, and (c) at the nearest NRTS boundary point are shown in table D-IV and compared with applicable AEC concentration guides.^[2] Normal and short-term atmospheric diffusion is discussed in section C.4. During normal operation with high-burnup fuel, fission products which are released from the stack result in a cloud gamma exposure at the NRTS site boundary of less than 2×10^{-7} rem/day. This would result in a dose at the site boundary of less than 0.08 mrem/year. As this document is being prepared, the exposure resulting from all other NRTS activities is being established and will be reported in a forthcoming environmental impact statement for waste management activities at the NRTS. Applicable Federal guidelines^[2] will not be exceeded by the addition of releases from HTGR fuel reprocessing to the existing releases at the NRTS when the HTGR fuel is processed.

Fissile particles may also be processed. The estimated releases and concentrations from the processing of the fissile particles are shown in table D-V. These releases are based on an irradiation time of six years and a decay time of 180 days.

TABLE D-IV

CONCENTRATIONS OF RADIOACTIVITY IN
GASES FROM HTGR FUEL REPROCESSING^(a)
(Fertile Processing)

<u>Nuclide</u>	<u>Daily Activity Release (Ci/day)</u>	<u>Concentration at top of Stack (μCi/mL)</u>	<u>Maximum Short-Term Concentration at Ground Level Near ICPP (μCi/mL)</u>	<u>Maximum Concentration at Nearest NRTS Boundary (μCi/mL)</u>	<u>AEC^(b) Boundary Guidelines (μCi/mL)</u>
H-3	4(2) ^(c)	1(-4)	2(-6)	2(-10)	2(-7)
C-14	2(1)	7(-6)	1(-7)	1(-11)	1(-7)
Se-79	4(-14)	1(-20)	2(-22)	2(-26)	--
Kr-85	5(3)	2(-3)	3(-5)	3(-9)	3(-7)
Rb-87	1(-18)	3(-25)	5(-27)	6(-31)	2(-9)
Sr-89	2(-9)	6(-16)	1(-17)	1(-21)	3(-10)
Sr-90	2(-9)	7(-16)	1(-17)	1(-21)	3(-11)
Y-90	2(-9)	7(-16)	1(-17)	1(-21)	3(-9)
Y-91	2(-9)	7(-16)	1(-17)	1(-21)	1(-9)
Zr-93	9(-14)	3(-20)	4(-22)	5(-26)	4(-9)
Zr-95	4(-9)	1(-15)	2(-17)	2(-21)	1(-9)
Nb-95	7(-9)	2(-15)	4(-17)	4(-21)	3(-9)
Tc-99	3(-13)	9(-20)	1(-21)	2(-25)	2(-9)
Ru-103	3(-10)	8(-17)	1(-18)	2(-22)	3(-9)
Rh-103m	3(-10)	8(-17)	1(-18)	2(-22)	2(-6)
Ru-106	6(-10)	2(-16)	3(-18)	3(-22)	2(-10)
Rh-106	6(-10)	2(-16)	3(-18)	3(-22)	--
Pd-107	5(-16)	2(-22)	2(-24)	3(-28)	--
Sn-123m	3(-11)	8(-18)	1(-19)	1(-23)	--
Sb-125	7(-11)	2(-17)	3(-19)	4(-23)	9(-10)
Te-125m	2(-11)	7(-18)	1(-19)	1(-23)	4(-9)
Sn-126	3(-14)	9(-21)	2(-22)	2(-21)	--
Sb-126m	3(-14)	9(-21)	2(-22)	2(-26)	--
Sb-126	3(-14)	9(-21)	2(-22)	2(-26)	--
Te-127m	7(-10)	2(-16)	4(-18)	4(-22)	1(-9)
Te-127	7(-10)	2(-16)	4(-18)	4(-22)	3(-8)
Te-129m	1(-10)	3(-17)	5(-19)	5(-23)	1(-7)
Te-129	1(-10)	3(-17)	5(-19)	5(-23)	1(-7)

TABLE D-IV (cont'd)

CONCENTRATIONS OF RADIOACTIVITY IN
GASES FROM HTGR FUEL REPROCESSING^(a)
(Fertile Processing)

Nuclide	Daily Activity Release (Ci/day)	Concentration at top of Stack ($\mu\text{Ci}/\text{mL}$)	Maximum Short-Term Concentration at Ground Level Near ICPP ($\mu\text{Ci}/\text{mL}$)	Maximum Concentration at Nearest NRTS Boundary ($\mu\text{Ci}/\text{mL}$)	AEC ^(b) Boundary Guidelines ($\mu\text{Ci}/\text{mL}$)
I-129	3(-3)	2(-9)	4(-11)	4(-15)	2(-11)
I-131	1(-2)	4(-9)	7(-11)	3(-15)	1(-10)
Cs-134	6(-11)	2(-17)	3(-19)	3(-23)	4(-10)
Cs-135	4(-14)	1(-20)	2(-22)	2(-26)	3(-9)
Cs-137	2(-9)	7(-16)	1(-17)	1(-21)	5(-10)
Ba-137m	2(-9)	7(-16)	1(-17)	1(-21)	--
Ba-140	1(-12)	4(-19)	6(-21)	7(-25)	1(-9)
La-140	2(-12)	5(-19)	7(-21)	8(-25)	4(-9)
Ce-141	6(-10)	2(-16)	3(-18)	3(-22)	5(-9)
Pr-143	3(-12)	9(-19)	1(-20)	2(-24)	6(-9)
Ce-144	1(-8)	4(-15)	6(-17)	7(-21)	2(-10)
Pr-144	1(-8)	4(-15)	6(-17)	7(-21)	--
Nd-147	1(-15)	3(-20)	5(-22)	5(-26)	8(-9)
Pm-147	4(-9)	1(-15)	2(-17)	2(-21)	2(-9)
Sm-151	5(-11)	1(-17)	2(-19)	3(-23)	2(-9)
Eu-154	3(-12)	8(-19)	1(-20)	1(-24)	1(-10)
Eu-155	7(-12)	2(-18)	3(-20)	4(-24)	3(-9)
Ra-223	5(-19)	2(-25)	3(-27)	3(-31)	8(12)
Ra-224	1(-14)	3(-21)	6(-23)	6(-27)	2(-11)
Ra-225	8(-22)	2(-28)	4(-30)	4(-34)	--
Ra-226	4(-18)	1(-24)	2(-26)	2(-30)	2(-12)
Ra-228	2(-14)	5(-21)	8(-23)	9(-27)	1(-12)
Ac-227	2(-16)	6(-23)	9(-25)	1(-28)	8(-14)
Ac-228	2(-14)	5(-21)	8(-23)	9(-27)	6(-10)
Th-227	2(-16)	6(-23)	9(-25)	1(-28)	--
Th-228	5(-13)	2(-19)	2(-21)	3(-25)	2(-13)
Th-229	2(-18)	6(-25)	1(-26)	1(-30)	--
Th-230	1(-15)	3(-22)	5(-24)	6(-28)	8(-14)
Th-232	1(-15)	4(-22)	7(-24)	8(-28)	1(-12)
Th-234	2(-13)	5(-20)	8(-22)	9(-26)	1(-9)

TABLE D-IV (cont'd)

CONCENTRATION OF RADIOACTIVITY IN
GASES FROM HTGR FUEL REPROCESSING^(a)
(Fertile Processing)

<u>Nuclide</u>	<u>Daily Activity Release (Ci/day)</u>	<u>Concentration at top of Stack ($\mu\text{Ci}/\text{ml}$)</u>	<u>Maximum Short-Term Concentration at Ground Level Near ICPP ($\mu\text{Ci}/\text{ml}$)</u>	<u>Maximum Concentration at Nearest NRTS Boundary ($\mu\text{Ci}/\text{ml}$)</u>	<u>AEC^(b) Boundary Guidelines ($\mu\text{Ci}/\text{ml}$)</u>
Pa-230	1(-19)	3(-26)	5(-28)	5(-32)	3(-11)
Pa-231	3(-15)	9(-22)	1(-23)	2(-27)	4(-14)
Pa-233	4(-9)	1(-15)	2(-17)	2(-21)	6(-9)
Pa-234	2(-13)	5(-20)	3(-22)	9(-26)	--
U-230	4(-19)	1(-25)	2(-27)	2(-31)	4(-21)
U-232	3(-12)	9(-19)	1(-20)	2(-24)	9(-13)
U-233	3(-12)	1(-18)	2(-20)	2(-24)	4(-12)
U-234	4(-13)	1(-19)	2(-21)	2(-25)	4(-12)

(a) Based on 6 years irradiation and 180 days cooling time. Gaseous releases originate from simultaneous operation of the primary burner and the secondary burner.

(b) Reference 2.

(c) 4(2) is equivalent to 4×10^2 Ci/day.

TABLE D-V

CONCENTRATIONS OF RADIOACTIVITY IN
GASES FROM HTGR FUEL REPROCESSING [a]
(Fissile Particles)

Nuclide	Daily Activity Release (Ci/day)	Concentration at top of Stack ($\mu\text{Ci}/\text{mL}$)	Maximum Short-Term Concentration at Ground Level Near ICPP ($\mu\text{Ci}/\text{mL}$)	Maximum Concentration at Nearest NRTS Boundary ($\mu\text{Ci}/\text{mL}$)	AEC ^[b] Boundary Guidelines ($\mu\text{Ci}/\text{mL}$)
H-3	3(2) ^[c]	1(-4)	2(-6)	2(-10)	2(-7)
C-14	3	9(-7)	1(-8)	2(-12)	1(-7)
Se-79	7(-14)	2(-20)	3(-22)	4(-26)	--
Kr-85	1(4)	4(-3)	6(-5)	7(-9)	3(-7)
Rb-87	3(-18)	8(-25)	1(-26)	1(-30)	2(-9)
Sr-89	3(-9)	1(-15)	2(-17)	2(-21)	3(-10)
Sr-90	9(-9)	3(-15)	4(-17)	5(-21)	3(-11)
Y-90	9(-9)	3(-15)	4(-17)	5(-21)	3(-9)
Y-91	5(-9)	1(-15)	2(-17)	2(-21)	1(-9)
Zr-93	3(-13)	1(-19)	2(-21)	2(-21)	4(-9)
Zr-95	7(-9)	2(-15)	3(-17)	4(-21)	1(-9)
Nb-95	1(-8)	4(-15)	6(-17)	7(-21)	3(-9)
Tc-99	1(-12)	4(-19)	6(-21)	7(-25)	2(-9)
Ru-103	7(-10)	2(-16)	3(-18)	4(-22)	3(-9)
Rh-103m	7(-10)	2(-16)	3(-18)	4(-22)	2(-6)
Ru-106	2(-9)	6(-16)	9(-18)	1(-21)	2(-10)
Rh-106	2(-9)	6(-16)	9(-18)	1(-21)	--
Pd-107	2(-15)	6(-22)	1(-23)	1(-27)	--
Sn-123m	4(-11)	1(-17)	2(-19)	2(-23)	--
Sb-125	2(-10)	5(-17)	8(-19)	9(-23)	9(-10)
Te-125m	5(-11)	2(-17)	3(-19)	3(-23)	4(-9)
Sn-126	7(-14)	2(-20)	3(-22)	4(-26)	--
Sb-126m	7(-14)	2(-20)	3(-22)	4(-26)	--
Sb-126	7(-14)	2(-20)	3(-22)	4(-26)	--
Te-127m	8(-10)	2(-16)	4(-18)	4(-22)	1(-9)
Te-127	8(-10)	2(-16)	4(-18)	4(-22)	3(-8)
Te-129m	1(-10)	4(-17)	7(-19)	8(-23)	1(-9)
Te-129	1(-10)	4(-17)	7(-19)	8(-23)	1(-7)

TABLE D-V (cont'd)

CONCENTRATIONS OF RADIOACTIVITY IN
GASES FROM HTGR FUEL REPROCESSING^[a]
(Fissile Particles)

<u>Nuclide</u>	<u>Daily Activity Release (Ci/day)</u>	<u>Concentration at top of Stack ($\mu\text{Ci}/\text{mL}$)</u>	<u>Maximum Short-Term Concentration at Ground Level Near ICPP ($\mu\text{Ci}/\text{mL}$)</u>	<u>Maximum Concentration at Nearest NRTS Boundary ($\mu\text{Ci}/\text{mL}$)</u>	<u>AEC^[b] Boundary Guidelines ($\mu\text{Ci}/\text{mL}$)</u>
I-129	2(-2)	5(-9)	8(-11)	9(-15)	2(-11)
I-131	2(-2)	7(-9)	1(-10)	1(-14)	1(-10)
Cs-134	1(-10)	4(-17)	7(-19)	8(-23)	4(-10)
Cs-135	1(-13)	4(-20)	7(-22)	8(-26)	3(-9)
Cs-137	9(-9)	3(-15)	4(-17)	5(-21)	5(-10)
Ba-137m	9(-9)	3(-15)	4(-17)	5(-21)	--
Ba-140	3(-12)	7(-19)	1(-20)	1(-24)	1(-9)
La-140	3(-12)	9(-19)	1(-20)	2(-24)	4(-9)
Ce-141	1(-9)	3(-16)	5(-18)	6(-22)	5(-9)
Pr-143	5(-12)	2(-18)	3(-20)	3(-24)	5(-9)
Ce-144	3(-8)	9(-15)	1(-16)	2(-20)	2(-10)
Pr-144	3(-8)	9(-15)	1(-16)	2(-20)	--
Nd-147	2(-13)	6(-20)	1(-21)	1(-25)	8(-9)
Pm-147	2(-8)	5(-15)	8(-17)	9(-21)	2(-9)
Sm-151	2(-10)	6(-17)	1(-18)	1(-22)	2(-9)
Eu-154	1(-11)	4(-18)	6(-20)	7(-24)	1(-10)
Eu-155	2(-10)	4(-17)	7(-19)	8(-23)	3(-9)
Ra-223	6(-19)	2(-25)	3(-27)	3(-31)	8(-12)
Ra-224	1(-14)	3(-21)	6(-23)	6(-27)	2(-11)
Ra-225	8(-22)	2(-28)	4(-30)	4(-34)	--
Ra-226	4(-18)	1(-24)	2(-26)	2(-30)	2(-12)
Ra-228	2(-14)	5(-21)	8(-23)	9(-27)	1(-12)
Ac-227	2(-16)	6(-23)	9(-25)	1(-28)	8(-14)
Ac-228	2(-14)	5(-21)	8(-23)	9(-27)	6(-10)
Th-227	2(-16)	6(-23)	9(-25)	1(-28)	--
Th-228	5(-13)	2(-19)	2(-21)	3(-25)	2(-13)
Th-229	2(-18)	7(-25)	1(-26)	1(-30)	--
Th-230	1(-15)	3(-22)	5(-24)	6(-28)	8(-14)
Th-232	1(-15)	4(-22)	7(-24)	8(-28)	1(-12)
Th-234	2(-13)	5(-20)	8(-22)	9(-26)	1(-9)

TABLE D-V (cont'd)

CONCENTRATIONS OF RADIOACTIVITY IN
GASES FROM HTGR FUEL REPROCESSING [a]
(Fissile Particles)

<u>Nuclide</u>	<u>Daily Activity Release (Ci/day)</u>	<u>Concentration at top of Stack ($\mu\text{Ci}/\text{mL}$)</u>	<u>Maximum Short-Term Concentration at Ground Level Near ICPP ($\mu\text{Ci}/\text{mL}$)</u>	<u>Maximum Concentration at Nearest NRTS Boundary ($\mu\text{Ci}/\text{mL}$)</u>	<u>AEC [b] Boundary Guidelines ($\mu\text{Ci}/\text{mL}$)</u>
Pa-230	1(-19)	3(-26)	5(-28)	5(-32)	3(-11)
Pa-231	3(-15)	9(-22)	1(-23)	2(-27)	4(-14)
Pa-233	4(-9)	1(-15)	2(-17)	2(-21)	6(-9)
Pa-234	2(-13)	5(-20)	9(-22)	1(-25)	--
U-230	5(-19)	1(-25)	2(-27)	2(-31)	4(-12)
U-232	3(-12)	9(-19)	1(-20)	2(-24)	9(-13)
U-233	3(-12)	1(-18)	2(-20)	2(-24)	4(-12)
U-234	5(-13)	1(-19)	2(-21)	2(-25)	4(-12)
U-235	8(-16)	2(-22)	4(-24)	4(-28)	4(-12)
U-236	3(-14)	9(-21)	1(-22)	2(-26)	4(-12)
U-237	5(-16)	1(-22)	2(-24)	3(-28)	--
U-238	5(-17)	1(-23)	2(-25)	3(-29)	5(-12)
Np-237	4(-14)	1(-20)	2(-22)	2(-26)	1(-13)
Pu-236	3(-13)	9(-20)	1(-21)	2(-25)	--
Pu-238	5(-10)	1(-16)	2(-18)	3(-22)	7(-14)
Pu-239	4(-13)	1(-19)	2(-21)	2(-25)	6(-14)
Pu-240	3(-13)	1(-19)	2(-21)	2(-25)	6(-14)
Pu-241	2(-10)	6(-17)	9(-19)	1(-22)	3(-12)
Pu-242	9(-15)	3(-21)	4(-23)	5(-27)	6(-14)
Pu-244	8(-22)	3(-28)	4(-30)	5(-34)	6(-14)
Am-241	3(-13)	1(-19)	2(-21)	2(-25)	2(-13)
Am-242m	2(-14)	7(-21)	1(-22)	1(-26)	2(-13)
Am-242	2(-14)	7(-21)	1(-22)	1(-26)	1(-9)
Am-243	1(-13)	4(-20)	7(-22)	8(-26)	2(-13)
Cm-242	8(-11)	2(-17)	4(-19)	4(-23)	4(-12)
Cm-243	4(-14)	1(-20)	2(-22)	2(-26)	2(-13)
Cm-244	2(-11)	7(-18)	1(-20)	1(-23)	3(-13)
Cm-245	2(-16)	6(-23)	1(-24)	1(-28)	2(-13)

[a] Based on 6 years irradiation and 180 days decay.

[b] Reference 2.

[c] 3(2) is equivalent to 3×10^2 Ci/day.

The tritium, noble gases, and iodine released during reprocessing may be recovered and stored during portions of the fuel reprocessing; thus, the maximum release concentrations may be lower than shown in tables D-IV and D-V for these gases.

Activity released from the denitration of uranium product consists predominantly of uranium trioxide particulates. Concentrations of uranium-232, uranium-233, and uranium-234 at the NRTS site boundary are estimated to be 1×10^{-27} , and 2×10^{-28} $\mu\text{Ci/ml}$, respectively. The AEC guide values are 9×10^{-13} , 4×10^{-12} , and 4×10^{-12} $\mu\text{Ci/ml}^2$.

Activity releases from burning organic wastes (tributyl phosphate and hydrocarbons) from the HTGR process will be no worse than those occurring when other fuels are processed at ICPP.^[3] The alpha content of the organic waste is monitored and the maximum alpha activity must be less than the equivalent of 1.5 $\mu\text{g Pu/l}$ before burning is permitted. Stack concentrations will be no more than 10^{-13} $\mu\text{Ci/ml}$ alpha emitters, 8×10^{-11} $\mu\text{Ci/ml}$ for ruthenium-108/106, and 3×10^{-12} $\mu\text{Ci/ml}$ for strontium-90.

Decontamination factors obtained during calcination will be comparable to DF's obtained during previous operations.^[4] Ruthenium and strontium released, therefore, will be less than 0.1 $\mu\text{Ci/day}$ each.

Gaseous Chemical Release: Some chemicals will be released through the off-gas system during normal operation. These consist of combustion products and other gases generated from burning fuel elements and organic liquid wastes.

Still other materials (primarily oxides of nitrogen) will be released when denitrating the uranium product and calcining the aqueous waste. Estimated releases of these materials are summarized in table D-VI.

Stack concentrations of the nonradioactive chemical air contaminants are shown in table D-VII. Dilution of the stack gases in the atmosphere reduces the concentrations at ICPP ground level (occupational standard) and at the nearest NRTS boundary (ambient standard) by factors of 1.6×10^{-2} and 1.8×10^{-6} , respectively. The resulting concentrations are well within the standards.

3. Liquid Release

Liquid effluents released to the environment normally will consist of essentially pure water and some nitric acid and are similar in quantity and quality to those generated when reprocessing other types of fuel. Low level radioactive wastes are concentrated and the vapors condensed, verified to be below radioactive release limits and discharged to the aquifer. These condensed vapors are water and nitric acid and will amount to less than 25,000 gallons per year of 15 M nitric acid. All other aqueous chemical wastes will be calcined and stored with the radioactive solid waste.

High-level liquid wastes (raffinates from the extraction cycles) are converted to solids and thus are not released to the environment as a liquid. Any other liquids which may contain radioactivity are handled separately; the waste is evaporated to concentrate the fission products. The evaporator bottoms are combined with the high-level liquid wastes and eventually are calcined. The vapor from the evaporator is condensed and passed through an ion exchange

TABLE D-VI

GASEOUS CHEMICAL RELEASES FOR HTGR FUEL REPROCESSING

	Headend				Solvent Extraction				Organic Waste Disposal				Waste Calcination				Total Annual
	Vessel Off Gas		Burner Off Gas		Vessel Off Gas		Denitration		Purification		Solvent Burner		Vessel Off Gas		Process Off Gas		
	Daily	Annual	Daily	Annual	Daily	Annual	Daily	Annual	Daily	Annual	Daily	Annual	Daily	Annual	Daily	Annual	
H ₂ , scf	6.0(5) ^a	1.7(8)	--	--	2.3(4)	2.1(6)	6.8(3)	6.1(5)	3.5(4)	3.1(6)	1.7(5)	1.5(7)	2.2(5)	1.1(7)	1.5(6)	7.5(7)	2.8(8)
O ₂ , scf	1.6(5)	4.4(7)	9.6(3)	2.6(6)	6.0(3)	5.4(5)	1.8(3)	1.6(5)	9.2(3)	8.3(5)	4.1(3)	3.7(5)	6.1(4)	3.1(6)	4.3(5)	2.1(7)	7.3(7)
CO, scf	--	--	9.6(3)	2.6(6)	--	--	--	--	--	--	--	--	--	--	6.3(4)	3.1(6)	5.7(6)
CO ₂ , scf	--	--	1.9(5)	5.2(7)	--	--	--	--	--	--	4.1(4)	3.7(6)	--	--	1.6(5)	8.0(6)	6.4(7)
NO _x , scf	--	--	--	--	--	--	150	1.3(4)	--	--	--	--	--	--	3.2(3)	1.5(5)	1.7(5)
P ₂ O ₅ , lbs	--	--	--	--	--	--	--	--	--	--	1.7(2)	1.5(4)	--	--	--	--	1.5(4)
Unburned H ₂ and hydro- carbons, scf	--	--	--	--	--	--	--	--	--	--	--	--	--	--	1.8(4)	9.0(5)	9.0(5)

^a6.0(5) is equivalent to 6.0 x 10⁵.

CHEMICAL CONCENTRATIONS
DISCHARGING FROM THE STACK^[a]

TABLE D-VII

	<u>Headend Combustion</u>	<u>Product Denitration</u>	<u>Organic Waste Combustion</u> ^[b]	<u>Aqueous Waste Calcination</u> ^[c]	<u>Federal Standard Occupational</u> ^[d]	<u>Federal Standard Ambient</u> ^[e]
CO (mg/cu m)	80	--	--	500	55	10
CO ₂ (mg/cu m)	2400	--	600	2000	9000	--
NO (mg/cu m)	--	--	--	1.8	30	--
NO ₂ (mg/cu m)	--	--	--	11.06	9	0.1
H ₃ PO ₄ (mg/cu m)	--	--	17	--	1	--
SO _x (mg/cu m)	--	--	--	4.2 ^[f]	13	.06

[a] Based on total stack discharge of 1.1×10^5 scfm. Stack concentrations shown should be multiplied by factors of 1.6×10^{-2} and 1.8×10^{-6} for comparison with the occupational and ambient standards, respectively.

[b] Based on 1000 l of 30 volume percent TBP processed per day. Discharge of phosphorous most likely would be as P₂O₅ particles.

[c] Based on 1500 scfm off-gas rate and composition shown in Reference 6.

[d] Based on Occupational Safety and Health Standards, Reference 5.

[e] Based on National Primary Ambient Air Quality Standards, Reference 6.

[f] Assume all sulphur released to off-gas.

unit to remove small amounts of fission products which may carry overhead from the evaporator. The condensate (15 M nitric acid) is monitored, sampled, and released into the service waste system if the activity level is below established limits. The bulk of the liquid in the service waste system is cooling water and steam condensate, and no radioactivity or chemicals other than nitric acid are expected in this waste. This stream is monitored continuously for radioactivity and can be diverted into a holding tank and recycled to the process if radioactivity is detected. Organic liquid wastes are burned and released as gases. Thus, the only liquid effluent from reprocessing HTGR fuel will be that from the service waste system.

The thermal effects from discharging the service waste stream into natural water in the area also will be negligible. A maximum of 3×10^5 gallons per day of cooling water will be discharged at a temperature about 5°C higher than the ambient water temperature of the Snake River Plain aquifer.

5. Solid Wastes

Two types of radioactive solid waste will be generated as a result of the proposed process: (a) crushed particle hulls and miscellaneous trash which will be packaged and stored at the NRTS Waste Storage Area (WSA)^[7, 8], and (b) the solids generated in the Waste Calcining Facility (WCF) during calcination of the high-level liquid waste, which will be stored in stainless steel bins contained in underground reinforced concrete vaults.

The silicon carbide particle hulls will account for up to 15,000 kgs of solids annually which must be disposed of after leaching. The total activity associated with the hulls will consist only of minor amounts of

fission products not removed during the leaching process. Filters from off-gas cleanup systems also will be stored at the NRTS.

The high-level liquid wastes (6.6×10^5 liters annually) will be converted to solids in the WCF.^[4] These solids will be stored in air-cooled, stainless steel bins contained within concrete vaults. Up to 690 cubic feet of solids, containing essentially all the fission product activity, will be produced annually during calcination of the of the liquid wastes from the HTGR fuel processing. This waste, consisting of granular solids, is stored in facilities designed so that waste can be removed and transferred to a Federal repository in the future, if and when such practice is desirable.

Some of the fissile particles (with their corresponding fission products and heavy metals) may not be processed. If not, these particles would be stored temporarily at ICPP and considered a solid "waste." Temporary storage would be accomplished in the HTGR fuels storage facility and would not have any significant environmental impact. At some future time a decision will be made as to their disposition; namely, continued storage at ICPP (perhaps the calcine storage bins), permanent disposal in a federal repository, retrievable storage at NRTS, or completion of the reprocessing cycle to recover uranium. The impact of completing the reprocessing cycle is included in this statement; any other method of long-term disposal will require environmental evaluation.

B. ACCIDENT CONDITIONS

Various accidents, many of which are highly improbable, can be postulated which would result in larger releases of chemicals or radioactivity to the environment than those which occur during normal operation conditions. Some of those accidents are discussed in the following sections.

1. Gaseous Releases

Failure of Burner Off-Gas Filters: If the burner off-gas filters in the processing cell were to rupture, and if the daily processing rate remained unchanged, more particulates would be released through the stack. (Even in this case, the backup filtration provided by the APS would provide significant off-gas cleanup). For this case the iodine was assumed to be totally released from the fuel elements and 50 percent of the iodine was assumed to deposit in the system prior to reaching the stack.^[9] DF of 10^7 was assumed for the solids because of the APS filters.

The exposures at the NRTS boundary for this postulated accident are shown in table D-VIII. The exposures would be well within the AEC accident guide values which are listed in table D-IX.

Failure of Denitrator Off-Gas Filters: When denitrating the product from fertile particles, failure of the process off-gas filters could cause an accidental release of uranium isotopes. Assuming a simultaneous failure of the denitration and the dry vessel off-gas APS filters but no failure of the APS filters results in a DF of 10^7 .

TABLE D-VIII

EXPOSURE AT THE NRTS BOUNDARY DURING POSTULATED ACCIDENTS

<u>Postulated Accident</u>	<u>Whole Body, rem</u>	<u>Thyroid Inhalation, rem</u>	<u>Thyroid Injection, rem</u>	<u>Bone Inhalation, rem</u>
Burner Off-Gas Filter Failure	3(-6) ^(a)	5(-5)	2(-2)	3(-4)
Stored Radioactive Gases Release	1(-3)	2(-2)	7	-
Secondary Burner Failure	2(-6)	1(-5)	5(-3)	1(-4)
Fuel Handling Cave Fire	7(-5)	1(-5)	5(-3)	-
Criticality	3(-3)	4(-2)	6	1(-6)

(a) 3(-6) is equivalent to 3×10^{-6}

TABLE D-IX

AEC GUIDELINES FOR EMERGENCY SITUATIONS ⁽¹⁰⁾

<u>Exposure</u>	<u>Guideline, rem</u>
Whole Body	25
Thyroid Inhalation plus Ingestion	300
Bone Inhalation	150

The calculated concentrations at the nearest NRTS boundary for uranium-232, uranium-233, and uranium-234 are 2×10^{-17} , 2×10^{-17} , and 6×10^{-18} $\mu\text{Ci/ml}$, respectively. These concentrations are below the AEC guide values^[2] for normal operation, and releases from denitration of fissile particle product would be even lower. Total activity release would be minimized because the filters contain low pressure-differential alarms, and denitration would be stopped immediately upon off-gas filter failure.

Failure of Calcination Process Off-Gas Filters: The final filters in the WCF provide additional cleanup for strontium and ruthenium in the waste that is being calcined. Based on past experience, the strontium-90 and ruthenium-106 release rates would increase by factors of 630 and 850 respectively, if these filters were to fail.^[4] Consequently, the concentrations of these gases at the top of the stack would increase, but they still would be less than 7×10^{-6} $\mu\text{Ci/ml}$.

These releases result in concentrations at the NRTS boundary that are less than the RCG values for an uncontrolled area.^[2] Actually, even at these low concentrations, extended operations of the WCF with failed filters would not occur; the WCF would be shut down, and the filters would be replaced.

Accidental Release of Stored Radioactive Gases: Certain radioactive gases (tritium, krypton-85, and iodine) will be collected for demonstrational purposes and stored temporarily during reprocessing of the HTGR fuel. For this accident, the total fuel inventory of krypton-85 and tritium and 50 percent of the iodine is assumed to be released separately over a period of

one hour and during class F^[11] condition. The exposures for this postulated accident are shown in table D-VIII and would be much lower than the AEC guide values for accident conditions given in table D-IX.

Secondary Burner Failure: If the secondary burner failed during processing, it is conceivable that entire fission product inventory would be released into the cell. The maximum inventory in the burner would be expected to be equivalent to the fissile particle fission products in five fuel elements. Again, if such an accident occurred, a DF of 10^7 for the solid fission products would be expected through the APS. The cell filters, in this case, were assumed to have failed at the same time the burner failed.

Exposures for this postulated accident are shown in table D-VIII. The accident exposures would not exceed the applicable 10 CFR 100 guidelines^[10] for accidental releases given in table D-IX.

Fuel Handling Cave Fire: If a fire occurred in the charging cave with 12 elements present, certain gaseous fission products within the graphite matrix conceivably could be released. Most of the fission products, however, would not be released because they are confined within the fertile and fissile particles. Assuming a 20 percent release for the noble gases and a 10 percent release for the halogens (because of particle breakage) and release over a period of one hour during a class F condition, the exposures shown in table D-VIII would result. As noted by a comparison of the accident exposures in table D-VIII to the AEC guide values in table D-IX, the accidental exposures would not exceed the guidelines for emergency situations.

Criticality: An accidental criticality would produce additional fission products and also would release energy to scatter the other fission products already present in the irradiated fuel. If a criticality of 10^{19} fissions (prompt burst) and 7×10^{19} fissions (over a period of 20 minutes) occurred, total exposures shown in table D-IX would be expected. These exposures are based on fission products produced during the criticality as well as fission products from the fertile particles for four elements. They are based on 100 percent release of the noble gases, 50 percent of the halogens, and one percent of the solids from the solution--the same bases as those in reference 8 for maximum credible accidents with reactors. In this case, half of the iodine is assumed to remain in solution. A DF of 10^7 is assumed as the solids pass through the APS, and 50 percent of the released iodine is assumed to deposit prior to being discharged from the stack. The total release was calculated for a class F condition assuming a three minute transport time to the top of the stack. The exposures for this postulated accident would be well within established guidelines.

2. Liquid Releases

Certain chemical solutions required for fuel reprocessing are stored in tanks prior to use. If, for some reason, the tanks containing these solutions were to rupture, chemicals conceivably could be released to the service waste system and eventually to the environment. Chemicals to be used, and the approximate amounts to be stored, are listed in table D-X. Although spilled chemicals could be released to the environment during an accident, the first would be diluted by the large quantities of water (about 1 million 6gallons per day) normally discharging to the service waste system. Although certain components (e.g., nitrogen trioxide, total dissolved solids, etc.) temporarily might

TABLE D-X
CHEMICALS FOR HTGR PROJECT STORED IN PROCESS MAKEUP AREA

<u>Solution</u>	<u>Concentration, mol</u>	<u>Capacity, gal</u>
HNO ₃	13.0	350
HF	0.04	100
Al(NO ₃) ₃	0.05	500
HNO ₃	13.0	1500
HNO ₃	5.0	1200
TBP-NPH	--	300
Kerosene	--	500
Na ₂ CO ₃	0.5	50

exceed drinking water standards on a one-time-accident basis, no significant damage to the environment is expected.

C. CALCULATION METHODS

The following is a description of the assumptions and calculational techniques used to calculate the amount of radioactive material released to the environment during the HTGR fuel reprocessing.

1. Fuel Activity Inventory

Fuel Irradiation History: As described in section II of this report, two types of processing may be conducted: fissile particles and fertile particles. The particles to be processed will be from fuel elements containing up to approximately 3.4 mWd burnup over a period of six years. The particles are assumed to decay for a minimum of 180 days prior to being processed.

Fission Product Inventory: The fission product inventory for the two cases noted above was calculated using the RSAC computer code.^[1] A summary of the activities is presented in table D-III.

Activation Product Inventory: Fuel impurities of nitrogen (100 ppm) and lithium (0.5 ppm) were assumed in the calculation of the activation products of tritium and carbon-14 listed in table D-III.

2. Processing Rates

Calculations for processing are based on a processing rate of 24 fuel elements per day and 275 processing days per year. Based on these rates, the required times for various parts of the process are as follows:

Headend: full time

Solvent Extraction: full time

Denitration: The denitration equipment was assumed to operate concurrently with the solvent extraction equipment.

Organic Waste Disposal: Organic wastes are assumed to be burned at the rate of 1,000 l/day. Waste from the solvent scrub columns (kerosene) is collected and may be used as fuel for the WCF.

Calcination: At an assumed net calciner feed rate of 3,000 gallons per day, it will take approximately 165 days of calcining time per year to convert the radioactive aqueous wastes to solids.

3. Off-Gas Filtration

All off-gases from reprocessing HTGR fuels will be processed through a series of at least two HEPA filters before leaving the process area. The off-gases will then be combined with other ICPP off-gases and processed through the APS. The APS provides backup filtration to prevent significant releases in the event of process filter failure. Based on actual operating experience with the WCF at ICPP^[4] a decontamination factor of 10^7 for particulate contamination will be achieved through the first HEPA filter. This decontamination includes retention of contaminants by process components as well as the HEPA filter DF. Although the HTGR process will not be identical to the waste calcination process the processes are considered sufficiently similar to apply the same decontamination factors.

Ruthenium decontamination in the calciner (10^5 DF) is different than particulate fission product decontamination (10^7 DF) probably because the ruthenium forms a volatile (tetraoxide) species in the calciner. Ruthenium

behaves like a solid particulate in the HTGR combustion process.^[12] Therefore, a combined process and HEPA filter DF of 10^7 was assumed for ruthenium in the HTGR process.

Experimental studies^[13] at Los Alamos Scientific Laboratory have shown that a decontamination factor of 10^3 can be realized for each HEPA filter in a series of four HEPA filters. Therefore, after the first HEPA filtration each subsequent HEPA filtration of the HTGR process off-gas was credited with a DF of 10^3 .

4. Atmospheric Diffusion

Mean annual relative concentrations during all meteorological conditions for releases from the 76-meter ICPP stack have been evaluated over a ten year period.^[14] A mean annual relative axial concentration (X/N) of 3.8×10^{-8} sec/m³ has been assumed for the normal diffusion of material to the nearest site boundary located at a distance of approximately 1.3×10^4 meters. This results in a dilution factor of 1.8×10^{-6} from the top of the stack to the site boundary assuming a stack flow of 1.1×10^5 scfm.

A maximum short-term concentration near the ICPP occurs during a looping meteorological conditions defined by the diffusion equation.^[14]

$$\frac{x}{Q} = (x,0,0) = \frac{x^{2-n}}{\pi \bar{u} \sigma_y \sigma_z (x^2 + h^2)^{(2-n)/2}} \quad (1)$$

where: $\frac{x}{Q}$ = relative axial concentration (m^{-3})

$\bar{u}$ = wind velocity (m/sec)

σ_y, σ_z = respectively the standard deviations of the cloud in the horizontal and vertical directions.

x = downwind distance (m)

h = stack height (m)

n = dimensionless stability parameter

The looping condition is assumed to occur during a class A meteorological conditions^[14] with 2.2 m/sec wind velocity. Values used for σ_y and σ_z are those derived by Markee for the NRTS^[14] (the maximum concentration was calculated to occur at a distance of approximately 85 m from the base of the stack).

The relative axial concentration at the nearest site boundary for all accident cases was maximized by assuming fumigation meteorological conditions defined by the equation:^[14]

$$\frac{x}{Q} (x,0,0) = \frac{1}{(2\pi)^{1/2} \bar{u} \sigma_y h} \quad (2)$$

A 2 m/sec wind velocity was assumed, and the value of σ_y used is that derived by Markee for a class F meteorological condition.^[14]

In all cases, no credit has been taken for depletion of the effluent plume of radioactive material due to deposition on the ground.

D. RADIOLOGICAL EXPOSURE CALCULATION METHODS

This section describes the methods used to calculate radiation exposures.

1. Thyroid Inhalation Exposure Calculation

A thyroid inhalation exposure resulting from an accidental criticality may be calculated using the following equation:

$$\text{Exposure} = \sum_{j=131}^{135} F Q_j \left(\frac{X}{Q}\right) K_j D_j \quad (3)$$

where: F = fraction of total inventory released to the environment

Q_j = curies of the j^{th} iodine isotope in the fuel

$\frac{X}{Q}$ = axial concentration at the receptor location (sec/m^3)

K_j = inhalation exposure conversion factor for the j^{th} iodine isotope

D_j = depletion factor resulting from radioactive decay prior to reaching the receptor.

Each of the factors in the Equation (3) is evaluated and discussed separately.

Fraction of the Total Iodine Inventory Released to the Environment (F):

Iodine release assumptions for a criticality accident are the same as those used for accident analyses as specified in TID-14844^[11]. That is, 50% of the iodines in the fuel are released to the surrounding area, and 50% of the released iodines adsorb onto internal surfaces of the facility. Thus, 25% of the total iodine inventory is assumed to be released to the environment.

Curies of Iodine in the Fuel Undergoing Criticality (0): The iodine inventory is calculated using the RSAC computer code.^[1]

Axial Concentration at the Receptor Location ($\bar{Q}$): The equation used to describe the axial concentration are described in equations (1) and (2) of this appendix.

Inhalation of Exposure Conversion Factor (k): Iodine inhalation exposure conversion factors are based on those recommended for the "standard man" by the ICPP.^[15] A breathing rate of $3.47 \times 10^{-4} \text{ m}^3/\text{sec}$ has been assumed, and correction has been made for radioactive decay during uptake. The resultant exposure conversion factors are given in table D-XI.

Depletion by Radioactive Decay (D): Credit has been taken for radioactive decay during transport to the receptor. A transport distance of $1.3 \times 10^4 \text{ m}$ and a wind velocity of 2 m/sec yields a decay time of $6.5 \times 10^3 \text{ sec}$.

2. Cloud Gamma Exposure

Cloud gamma exposures are calculated using the RSAC computer code.^[1] RSAC calculates a numerical solution over a cloud of finite size whose dimensions are defined by the generalized Gaussian diffusion equation.

3. Thyroid Ingestion Exposure

Thyroid ingestion exposures are also calculated using the RSAC computer code.^[1]

TABLE D-XI

THYROID INHALATION EXPOSURE CONVERSION FACTORS

<u>Iodine Isotope</u>	<u>Exposure Conversion Factor (rem-m³/Ci-sec)</u>
131	496
132	4.07
133	99
134	0.83
135	19.2

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