Analysis of Removal Alternatives for the Heavy Water Components Test Reactor at the Savannah River Site

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August 1996

*Department of Energy
Savannah River Site
Aiken, South Carolina*

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1.0 EXECUTIVE SUMMARY

This engineering study evaluates different alternatives for decontamination and decommissioning of the Heavy Water Components Test Reactor (HWCTR).

The HWCTR lies within a fenced two-acre property located in the northwest quadrant of the Savannah River Site, approximately 2.5 miles from the nearest major nuclear materials production facility and about three miles from the nearest site boundary. Cooled and moderated with pressurized heavy water, this uranium-fueled nuclear reactor was designed to test fuel assemblies for heavy water power reactors. It was operated for this purpose from March of 1962 until December of 1964.

The reactor is housed in a steel-domed containment building. The lower part of this building, made of reinforced concrete, extends approximately 61.5 feet below ground level. The 98-ton steel reactor vessel, two steam generators and related process equipment reside underground.

In 1965, all nuclear fuel was removed from the HWCTR site. Since that time, the containment building has remained in a condition that amounts to protective confinement, that is, effectively mothballed. In recent years, small auxiliary structures on the property have been demolished leaving only the containment building itself and a smaller connecting health physics building.

With the passage of the years, most of the radioactivity inside of the facility has decayed. Today, more than 99 percent of the residual radioactivity – estimated to be in the range of 3000 curies – is within the reactor vessel, effectively imbedded within the activated metal components. Some of the concrete radiation shielding which surrounds the reactor vessel is also radioactive, as is steel reinforcing bar and imbedded piping within the concrete shielding. Low level radioactive contamination pervades piping and process equipment inside of the reactor building. And traces of radioactive contamination spilled during the operating period are still detectable inside of the building in places such as crevices and drain pipes in the concrete floors.

Radioactive contaminants are predominately nickel-63 and cobalt-60. Also present are low levels of cesium-137 and other fission products along with uranium and transuranic radionuclides, such as plutonium-239. These materials came from failures of ten fuel assemblies which occurred during reactor operation. Also present, as in any older industrial facility, are small amounts of hazardous materials such as lead, mercury and asbestos.

The HWCTR facility is slowly deteriorating, gradually increasing the potential for exposure of site workers to its radioactive and hazardous materials. Because it is smaller and simpler in design than the weapons materials production reactors at the site, its decommissioning will serve as a effective prototype to begin the site reactor decommissioning program. Consequently, the Department of Energy (DOE) is moving forward with decommissioning of the facility. A broad range of possible alternative approaches has been considered. Four alternatives studied in detail include:

(1) *Dismantlement*, in which all radioactive and hazardous contaminants would be removed, the containment dome dismantled and the property restored to a condition similar to its original pre-construction state,

(2) *Partial dismantlement and interim safe storage*, where radioactive equipment except for the reactor vessel and steam generators would be removed, along with hazardous materials, and the building sealed with remote monitoring equipment in place to permit limited inspections at five-year intervals,

(3) *Conversion for beneficial reuse*, in which most radioactive equipment and hazardous materials would be removed and the containment building converted to another use such as a storage facility for radioactive materials, and

(4) *Entombment*, which involves removing hazardous materials, filling the below-ground structure with concrete, removing the containment dome and pouring a concrete cap on the "tomb".

Also considered was *safe storage*, where the decommissioning would be deferred while radioactive contaminants decay to safer levels. But this approach, which has, in effect, been followed for the past 30 years, did not warrant detailed evaluation.

The four other alternatives were evaluated, taking into account factors such as potential effects on the environment, risks, effectiveness, ease of implementation and cost. The preferred alternative was determined to be *dismantlement*. This approach is recommended because it ranks highest in the comparative analysis, would serve as the best prototype for the site reactor decommissioning program and would be most compatible with site property reuse plans for the future.

This removal alternative analysis for the HWCTR decommissioning was developed following guidelines contained in DOE's *Decommissioning Resource Manual*, reference 1.

2.0 INTRODUCTION

2.1 Purpose

This engineering study was developed to evaluate different options for decommissioning of the HWCTR at the Savannah River Site (SRS).

The decommissioning is being undertaken to reduce risks to workers and the public from the radioactive and hazardous contaminants associated with the HWCTR. The HWCTR project is one of many cleanup projects being undertaken as part of the environment restoration program at SRS. The experience gained will eventually be applied to the decommissioning

of facilities such as the site's five nuclear materials production reactors, which are substantially larger than the HWCTR and have a much larger radioactive material inventory.

This decision for decommissioning of the HWCTR is reflected in the *Savannah River Site Waste Management Final Environmental Impact Statement* of July 1995 which states that:

"The Heavy Water Components Test Reactor is the prototype for this program. [The decommissioning program for nuclear reactor facilities.] By starting with a small reactor, DOE can learn from experience and develop methods and procedures which will then be applied to the larger reactors."

The HWCTR project is also serving as a prototype for application of the Comprehensive Environmental Response, Compensation and Liability Act, known as CERCLA, to decommissioning activities at SRS. The CERCLA process is being followed on the project in accordance with a May 1995 agreement between the DOE and the U. S. Environmental Protection Agency. This agreement is embodied in the DOE's *Decommissioning Resource Manual*, reference 1.

2.2 Scope

This study considers a broad range of options for decommissioning of the HWCTR. It focuses on four which are representative and feasible. Each option is developed in sufficient detail to facilitate meaningful comparisons. Additional detailed planning will be necessary for the approach actually undertaken. Such planning will be incorporated into the HWCTR project Decommissioning Plan which is expected to be completed in Fiscal Year 97.

This study was prepared in accordance with the May 1995 agreement between the DOE and the U. S. Environmental Protection Agency. The agreement includes following the process of CERCLA in evaluation of decommissioning alternatives.

CERCLA, a federal statute also known as Superfund, provides the statutory authority for cleanup of hazardous substances that could endanger the public health, public welfare or the environment. Facilities such as the HWCTR contain nuclear materials which are included in the CERCLA definition of hazardous substances. In CERCLA parlance, the decommissioning of the HWCTR is being undertaken as a "non-time critical removal action." This study is, therefore, entitled an analysis of removal action alternatives and embodies the applicable provisions of the CERCLA process.

The evaluations in this document address the potential environmental impacts of different alternatives, the potential and actual risks, the implementation costs, the time to complete the major steps for each option, flexibility in future use of the property, ease of implementation and value as a demonstration project, as well other factors. Consequently, in accordance with reference 1, there will be no separate environmental assessment or

environmental impact statement for the HWCTR decommissioning, as would normally be the case under the National Environmental Policy Act.

2.3 Public Participation

The DOE and the Westinghouse Savannah River Company (WSRC) are soliciting comments from the public on this study. Comments should be addressed to one of the following persons:

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Each comment will be taken into account before the decision is made on the alternative selected for the decommissioning. This decision will be reflected in an "Action Memorandum" which will describe the reasons for the selection. This memorandum will also contain the DOE responses to public comments and explain how the comments affected the selection decision.

2.4 The Decontamination and Decommissioning Project Plan

In March of 1996, WSRC issued the *Heavy Water Components Test Reactor Decontamination and Decommissioning Project Plan*, reference 2. This document establishes initial cost, schedule and technical baselines for the project. It also describes the general approach to be taken to protect the safety and health of the workers and the public and to protect the environment, to the extent that such matters can be determined in the early stages of the project. The Project Plan will eventually evolve into the Decommissioning Plan, the principal planning document for the HWCTR decommissioning.

The HWCTR Decommissioning Project Plan recognizes that the actual end state of the facility will depend upon the outcome of this study. In turn, this study is consistent with the Project Plan and incorporates in later sections appropriate information from that document.

2.5 Organization of this Document

This study is organized, as recommended in reference 1, in the following manner:

- It begins with a discussion of *facility characterization*, which describes the HWCTR facility and the radioactive and hazardous contaminants associated with it,
- The objectives of the removal action are identified,
- The four different alternatives to be evaluated in detail are described,
- Each alternative is then evaluated in detail,
- A comparative analysis of the four alternatives is presented, and
- The recommended alternative is identified, along with the rationale for its selection.

Details such as equipment lists, schedules and references appear as appendices, along with a glossary of terms.

3.0 FACILITY CHARACTERIZATION

3.1 Site Description

The HWCTR facility is located on approximately two acres in the northwest quadrant of the SRS, on property known as U-Area. U-Area lies three miles from the nearest SRS property boundary and about two and one-half miles from any major nuclear materials production facilities on the site.

The federally-owned SRS reservation is located near Aiken, South Carolina. The DOE Savannah River Operations Office manages the SRS. The Westinghouse Savannah River Company operates the site under contract to DOE.

When considering different approaches to decommissioning a facility such as the HWCTR, factors taken into account include the nature of the surrounding property, how it is presently used and possible uses for it in future years.

The SRS occupies an area of approximately 310 square miles in western Southern Carolina in a mostly rural area of Aiken, Barnwell and Allendale counties, about 25 miles southeast of Augusta, Georgia. The Savannah River borders the site on the southwest side. Land bordering the SRS is chiefly forest and agricultural. The closest towns to the site are New Ellenton and Jackson, both in South Carolina. The closest residences stand about 200 feet from the site perimeter on the west, north and southeast sides.

The area near the HWCTR facility is mostly wooded, with an elevation of approximately 280 feet above sea level. No stream runs near the property. The water table at the site is some 30 feet below the lowest point in the reactor containment building.

Figure 1 shows the reactor containment building. The location of the HWCTR on the federally-owned site is shown in Figure 2. Figure 3 shows the HWCTR property. *Please note that Figures 2 and 3 and most other figures in this report are located in Appendix A.*

The SRS was built in the early 1950s to produce basic materials for nuclear weapons. Five large nuclear production reactors were built to produce these materials, as were various other supporting facilities for purposes such as fabricating reactor fuel, recovering the plutonium and tritium, and processing waste materials. The production reactors are no longer in service. Today, the mission of the SRS focuses on the environmental legacy of the Cold War, with processing for storage or disposal the radioactive and chemical wastes associated with operation of these reactors and their related facilities. Another prime mission is environmental restoration of the site, which includes projects such decommissioning of the HWCTR.

3.2 Facility Description and Brief History

3.2.1 Description of the HWCTR Facility.

The HWCTR was a pressurized heavy water test reactor used to test candidate fuel designs for heavy water power reactors. It was not a defense-related facility like the materials production reactors on the site. The nominal reactor power of 50 megawatts (thermal) was dissipated to the atmosphere through a muffler which lies approximately 110 yards east of the reactor building.

Figure 1 The HWCTR Facility

Details of the reactor containment building are shown in a series of illustrations and photographs in Figures 4 through 27 of Appendix A.

The containment building is 70 feet in diameter. The structure rises approximately 65 feet above the ground; the floor of the lowest level is approximately 52 feet below grade. The below-grade part was constructed of pre-stressed concrete. The hemispherical dome was fabricated from 0.75 inch thick carbon steel plate to a level of 30 feet above the ground. The upper part of the dome was made of 0.375 inch carbon steel. The dome shell contains approximately 170 tons of steel. The building was designed to withstand an internal pressure of 24 pounds per square inch and was pneumatically tested to five pounds per square inch.

The containment building houses the reactor and coolant systems, the refueling machine, the spent fuel basin and the reactor instrumentation. Arrangement of the reactor within the containment building is shown in Figure 4. The reactor core consisted of a central region of 12 test assemblies surrounded by a ring of 24 driver fuel assemblies, enriched in Uranium-235. Control rods, safety rods and instrument thimbles were interspersed throughout the core.

The reactor vessel has an overall height of 30 feet, a diameter of about eight feet and weighs approximately 98 tons. The vessel is made of carbon steel, three to five inches thick, clad internally with 0.25 inch stainless steel.

The reactor main cooling system operated at 1200 pounds per square inch (gage) and 250 degrees Centigrade. Two test loops, isolated from the primary cooling system, provided special test conditions. These loops contained four inch diameter stainless steel piping.

Components in the main circulating system include two steam generators, nine pumps, two gas recompressors, a filter, a deionizer and a large main storage tank. The steam generators are about 23 feet high and weigh about 19 tons. The two largest pumps in the primary system are approximately 13 feet tall. The primary loop piping is made of 10 inch diameter carbon steel, coated internally with an adherent magnetite film. This film, produced during initial operations, was considered effective in reducing corrosion buildup during plant operation.

Auxiliary fluid systems include those typically associated with water-cooled reactors, such as steam, a stainless steel purification system with filters and deionizers, and pressure relief systems. A 7165 gallon heavy water (D_2O) storage tank which fed various systems is located in the left purification room at the -52-foot level. A 15,000 gallon emergency deluge system water tank is located inside the top of the dome. This emergency water supply was never used.

Other equipment in the reactor building includes a small spent fuel basin, made of reinforced concrete lined with stainless steel. This basin, 9 feet by 13 feet wide, extends from the ground floor to the -27-foot level. It contains a 54 inch by 54 inch shipping cask pit that extends 16 feet below the basin floor.

A system of floor drains leads to a 350 gallon sump tank located in the monitor room at the -52-foot level.

A comprehensive list of HWCTR equipment appears in Appendix B.

3.2.2 *Brief History of the Facility*

The HWCTR was operated from March 1962 to December 1964 to test fuel elements and other reactor components of potential use in heavy water moderated and cooled power reactors. The total power history of the HWCTR was 13,882 megawatt-days. During operation, 36 different fuel assemblies were tested. Ten of these experienced cladding failures as operational capabilities of the different designs were being established.

The fuel assembly failures released fission products, uranium and transuranic radionuclides into the main cooling system and the isolated liquid loop. Even though the boiling loop was never used to test fuel assemblies, it, too, became contaminated with radioactivity as a result of a leak which developed in the "bayonet" fixture designed to isolate a test element in this system from the rest of the reactor vessel.

During the entire operating period the steam generators leaked heavy water into the steam system, which caused that system to become radioactively contaminated. The total heavy water loss from the plant during operation amounted to approximately 22,000 pounds, approximately one-third of which entered the steam system through the steam generators.

Spills of radioactive heavy water occurred frequently in most areas of the reactor building during the operating period. Residual contamination from such spills is described in section 3.7 below.

In December of 1964, operations were terminated and the facility was placed in a standby condition, as a result of the decision by the U. S. Atomic Energy Commission to redirect research and development work on heavy water power reactors to reactors cooled with organic materials. For about one year, site personnel maintained the facility in a standby status, then retired the reactor in place.

3.3 Summary of Existing Conditions

Although it is slowly deteriorating, the HWCTR facility is presently in relatively good condition. The reactor building is structurally sound and weather tight. The interior is reasonably clean and orderly, although the 0-level main floor is being used for equipment storage. Rusting is evident on carbon steel piping and components where insulation has been removed. The paint is still tightly adherent except in the stairwells and on equipment such as the refueling machine platform where it is flaking. (The refueling machine is a heavy, lead-shielded container also known as the transfer coffin.) Present conditions can be seen in photographs of Figures 9 through 18. A complete photographic record of the facility

was produced in connection with preparation of the 1996 *Facility Screening Characterization Report*, reference 3.

Accessible radiation levels are low. Radioactive and hazardous contaminants associated with the facility are described in section 3.7.

3.4 Transition/Deactivation Process and End Condition Achieved

Conditions in the HWCTR facility at the end of its operating period were well documented as described in reference 3. After the final reactor shutdown in December of 1964, all of the fuel assemblies and the two neutron sources were removed from the reactor and transported to the Receiving Basin for Off-site Fuel located in H-Area at the SRS. All other reactor components including control and safety rods, long term corrosion coupons, and a rod containing gamma ion chambers were left in the core, as were all housings and guide tubes.

After the heavy water was drained from the reactor systems, both the high and low pressure systems were vacuum dried and filled with nitrogen to minimize corrosion. The secondary coolant system was drained and left at ambient conditions. The shell sides of the steam generators and purge coolers were filled with nitrogen. A positive pressure on the reactor vessel and primary side systems was maintained from nitrogen filled cylinders until this operation was abandoned in November 1971.

Very few changes have been made in the HWCTR systems since shutdown. Some equipment has been removed, such as the boiling loop surge tank and heat exchanger. General area radiation levels have decayed to low values (less than one millirem per hour) with only a few isolated hot spots remaining. The physical location and status of the HWCTR systems are essentially the same as after the final shutdown, except for penetrations required to completely drain the residual fluid from system components, and, of course, lower radiation levels due to radioactive decay.

3.5 Surveillance and Maintenance Program

Since the retirement of the HWCTR, the facility has undergone periodic surveillance. Access has been controlled by the locked security fence surrounding the HWCTR site. Little maintenance has been required since the reactor retirement and draining of the systems were completed.

In 1975, HWCTR was placed in condition approximating safe storage or protective confinement. Radiation levels from cobalt-60, the principal radionuclide of concern, have decayed by a factor of approximately 16 since that time, significantly reducing the radiological hazards associated with the facility.

The outside of the containment dome was painted in 1991.

3.6 Previous Removal Actions and Cleanup

3.6.1 The 1976 Decommissioning Plan

Approximately 20 years ago, the U. S. Energy Research and Development Administration made preparations to decommission the HWCTR. To support planning for the decommissioning, a characterization study was accomplished in 1975 to determine the location and amounts of radiological contaminants in the facility. The results of this study are described in section 3.7. The study showed that radiation and radioactive contamination levels are low and that most of the radioactivity is contained within the reactor vessel.

A decommissioning plan, reference 4, also was prepared. Although this plan was not carried out due to lack of funding, certain aspects of the plan remain relevant in today's circumstances.

The 1976 decommissioning plan included an analysis of different alternatives for the decommissioning. They were *dismantlement*, *entombment* and *protective confinement*. These alternatives were defined as follows:

- *Dismantlement.* All radioactivity was to be removed to permit release to the general public. In addition, the dome would also be removed along with steel and concrete structures down to 16 feet below grade, the cavity below this level backfilled with earth and capped with a concrete pad at the -16-foot level and the remaining cavity backfilled with earth to grade level to clear the site for future construction.
- *Entombment.* All radioactive equipment above grade would be placed below grade. The reactor vessel and its head would be sealed, the dome removed and the entire below-ground structure filled with compacted earth or concrete. A reinforced concrete pad would also be poured on top of this and a waterproof barrier installed. The objectives of this approach were (1) to provide long-term security (100 years or longer) for the radioactivity to reduce risks to the public and (2) to minimize surveillance and maintenance of the facility.
- *Protective Confinement.* This approach would involve sealing and locking the building, painting the dome, installing moisture detectors to detect water leaking into the structure and establishing ground water monitoring wells around the building. (This approach is similar to safe storage.)

For each of these alternatives several different options were considered. Estimated costs and worker radiation exposure appeared in the 1976 decommissioning plan as follows:

Table 1 1976 Decommissioning Plan Alternatives

Alternative	Estimated cost	Radiation exposure	Aesthetic
Dismantlement, removal of structure to -16' level	\$5.4 million	20 person-rem	Best
Dismantlement, removing no underground structure	4.4 million	20 person-rem	Best
Entombment	1.7 million	5 person-rem	Good
Protective confinement	0.19 million	<1 person-rem	Least attractive

The cost estimates were in 1975 dollars. The aesthetic judgment concerned the appearance of the decommissioned site, with more weight being given to absence of man-made structures.

Risks associated with these different approaches were also evaluated. These focused on the potential for exposure of members of the public to radiation from the reactor vessel. Two pathways were considered: direct radiation and ingestion of water contaminated with radioactivity. Risks were shown to be low for each alternative. Potential direct radiation exposures were to be controlled by physical security arrangements. The highest potential exposure to the public from contaminated ground water in any scenario was estimated to be one one-thousandth of the federal guideline radioactivity concentration or lower.

The authors of the 1976 decommissioning plan concluded that "all three alternatives are feasible and involve a very low risk of near-term public exposure".

3.6.2 Since 1976

Although the 1976 plan was never carried out, the facility condition for the past twenty years has approximated the protective confinement approach. Additional work on the HWCTR decommissioning project began several years ago. In Fiscal Year 94, four auxiliary buildings on the HWCTR site were demolished and disposed of as clean waste. In early Fiscal Year 95 detailed radiological contamination surveys of the reactor building were performed. The results of these are reflected in the next section.

In 1995, asbestos thermal insulation was removed from the piping and components located inside the reactor containment. At the beginning of Fiscal Year 96, in addition to the reactor containment building, only two other small buildings remained on the property. One, the control building, was demolished in Fiscal Year 96. The other building is the health physics building, which is connected to the reactor building by a short passageway. Also still in place are the ventilation stack (Building 791-U) and the steam muffler, which lies outside of the security fence, 110 yards east of the reactor containment building.

3.7 Source, Nature and Extent of Contamination

3.7.1 Summary.

Radioactivity from operation and maintenance of the reactor and its associated systems remains inside of the containment building. The total amount of radioactivity has been estimated to be in the range of 3000 curies in 1996. More than 99 percent of this amount is contained within the reactor vessel in the form of neutron-activated metals. The radionuclides present are chiefly nickel-63 and cobalt-60.

Low levels of radioactive contamination are present inside of the reactor vessel and in various plant systems and equipment. Cobalt-60 from neutron-activated corrosion and wear products predominates. Also present are traces of tritium from heavy water, along with low levels of fission products, uranium and transuranic radionuclides from the fuel assembly failures. Traces of these radioactive materials also exist in cracks and crevices on the outside of equipment and in building floors, and inside of the spent fuel basin.

Table 2 Significant Radioactive Contaminants

Radioisotope	Half-life	Radiation	Source
Cobalt-60 (Co-60)	5.27 yr	Beta-gamma	Activation of steel
Nickel-63 (Ni-63)	100 yr	Beta	Activation of steel
Strontium-90 (Sr-90)	28.6 yr	Beta	Fuel failures
Cesium-137 (Cs-137)	30 yr	Beta-gamma	Fuel failures
Plutonium-239 (Pu-239)	24,110 yr	Alpha	Fuel failures
Plutonium-241 (Pu-241)	14.4 yr	Alpha	Fuel failures
Americium-241 (Am-241)	433 yr	Alpha	Fuel failures

The HWCTR reactor building also contains small amounts of hazardous contaminants common to older industrial structures. These include lead, mercury and traces of asbestos. Polychlorinated biphenyls (PCBs) are expected to be present also.

More detail on the radioactive and hazardous contaminants appears in paragraphs 3.7.3 through 3.7.11 below.

3.7.2 Basis for Estimates of Contamination

The following information formed the basis for conclusions about the contaminants in the facility:

- The radiological characterization study performed in 1975, the results of which are reflected in the 1976 decommissioning plan, reference 4. Characterization data included radiation and contamination levels on accessible surfaces, contamination levels inside of the spent fuel basin and several piping systems and radiation levels inside of the lower part of the reactor vessel. Tables 3 and 4

show radiological data from the 1975 study extrapolated to 1996 to account for radioactive decay.

- Detailed radioactive contamination surveys performed in 1994 when most of the reactor building was downgraded to radiological buffer area status. Approximately 1300 smear surveys for removable radioactivity were taken in 1994.
- Radiological scan surveys performed by WSRC in early 1996 on the 0-level floor and inside of the steam muffler.
- An in-depth study of facility drawings and historical records associated with the operational period. These records, which are summarized in the *Facility Screening Characterization Report*, reference 3, included radiological survey forms, log books, technical reports and reports documenting conditions after the final shutdown of the reactor.
- Visual inspections of the facility by U S ENERGY personnel in early 1996.

3.7.3 Induced Radioactivity

More than 99 percent of the radioactivity in the HWCTR facility is associated with induced radioactivity in the vessel and its internal structure, chiefly the thermal shields.

Induced radioactivity is also present in the concrete biological shield surrounding the reactor vessel. The highest levels are present in the region around the point of peak axial neutron flux, which was about four feet from the vessel bottom. The levels diminish with radial distance from the reactor vessel and with changes in elevation from the point of peak axial flux.

Table 3 Reactor Component Approximate Induced Activity, in Curies, in 1996

Component	Fe-55	Co-60	Ni-63	Total
Thermal shield	50	550	2100	2700
Monitor pin plate	1.9	20	78	100
Reactor vessel	1.8	15	9	26
Control, safety rods	0.5	5	16	22
Totals	54.2	590	2203	2848

3.7.4 Radiation Levels

Radiation levels in the HWCTR containment building are low. Most accessible areas have levels under one millirem per hour. The highest accessible level measured in recent years is 110 millirem per hour on a sample line in the right cyclone room at the -52 foot level.

The highest radiation levels in the facility exist within the reactor vessel. Levels of several hundred rem per hour are expected at the point of highest activation, which is on the inner wall of the thermal shield approximately four feet from the bottom of the vessel. Radiation levels from control and safety rods in the vessel are also expected to fall within this range.

No areas with radiation levels above natural background are known to exist on the HWCTR property outside of the reactor building. But detectable radioactive contamination is present inside of the steam muffler.

3.7.5 Radioactive Contamination

Radioactive contamination levels inside of the HWCTR facility are low. No detectable removable radioactive contamination is present in most accessible areas. One exception is the 0-level, where approximately one-half of the floor is posted as a radioactive contamination area.

Inside of the posted area are the reactor vessel head and the spent fuel basin. Within the spent fuel basin are low levels of radioactivity which include traces of fission products, uranium and transuranics.

Radioactive contamination is present in cracks and crevices in the concrete floors throughout the reactor building. Floor drains and the building sump also contain low levels of radioactive contamination, as does the imbedded piping that connects the floor drains to the sump tank.

Low levels of radioactive contamination are also present inside of the reactor vessel and various fluid and gas systems connected to the reactor. The following systems are known to be radioactively contaminated:

- Boiling-cooled isolated loop
- Coolant sampling
- Floor drains and building sump
- Liquid-cooled isolated loop
- Main circulating (main coolant)
- Purification
- Reactor gas pressure relief
- Reactor gas purge
- Seal supply
- Spent fuel basin purification
- Steam
- Water relief

Table 4 Cooling System Approximate Activity in Total Millicuries, 1996

System	Co-60	Transuranics	Fission Products
Main Process Water System	32	0.2	<0.1
Liquid loop	3	0.2	<0.1
Boiling loop	20	0.4	<0.1

Traces of radioactive contamination are expected to be present in the underground waste water storage tank located on the HWCTR property and in the underground piping which connects this tank to the reactor building system. Low levels of radioactivity are also present in the steam muffler and the underground steam line which leads to it, as previously noted.

Radioactive contamination in soil on the HWCTR property is expected to be minimal. This conclusion is based primarily on the results of three soil samples taken near the outlet of the steam muffler in April of 1996. These samples, which were taken by the WSRC Environmental Restoration organization, showed no detectable radioactivity above natural background in an area with a relatively high potential for contamination, given the presence of radioactive contamination in the muffler itself. There is some possibility of soil contamination on the HWCTR property from sources such as possible leakage of the underground tank. But no records showing soil contamination have been uncovered except for the January 1966 final radiological survey, which showed one small contaminated area, which was subsequently decontaminated, at the outfall of the ventilation stack condensate drain line.

3.7.6 Lead

Lead used for radiation shielding is present in the reactor building in numerous locations. Lead-shielded casks also remain in the building, along with the refueling machine which contains lead shielding. Lead may be present in paint on metal surfaces and in brass and bronze parts of piping systems. Some of the lead may be radioactively contaminated, which could produce a mixed waste.

3.7.7 Mercury

Small amounts of mercury are expected to be present in electrical equipment such as fluorescent lights.

3.7.8 Asbestos

Asbestos piping insulation was removed from the reactor building in 1995. But some asbestos insulation remains in place on two piping lines and asbestos debris is still present in

several locations. Asbestos also may be present in electrical cable insulation, gasket materials and wall penetration boots.

3.7.9 PCBs

PCBs are expected to be present at low levels in materials such as paint, electrical equipment and oils.

3.7.10 Waste Oils and Hydraulic Fluids

Oils which must be treated as regulated waste are present in the building in a number of locations. Some may contain hazardous constituents as defined by the Resource Conservation and Recovery Act and the Toxic Substances Control Act.

3.7.11 Additional Detailed Characterization

In paragraph 3.7.2, the basis for conclusions about radioactive and hazardous contaminants in the HWCTR facility was laid out. In mid-1996, additional characterization work was being performed by U S ENERGY Corporation to provide a more-detailed knowledge of the contaminants in the facility, its ventilation exhaust stack and the steam muffler. This work was undertaken to support detailed planning for the decommissioning. The results are not expected to significantly influence the analyses of decommissioning alternatives presented in this document.

3.8 Facility Safety Analysis Documentation in Effect

The present safety basis documentation for the HWCTR is the *Interim Safety Basis of the Heavy Water Components Test Reactor (HWCTR) Reactor Building (770-U, 735-U)*. This document, combined with the HWCTR Health and Safety Plan currently in effect, satisfies the applicable requirements of DOE Order 5480.4, *Environmental Protection, Safety, and Health Protection Standards*.

Note that information on risk and safety issues associated with the four decommissioning alternatives appears in section 5.4.

4.0 IDENTIFICATION OF REMOVAL ACTION OBJECTIVES

4.1 Objectives of Decommissioning

The following primary objectives have been established for the HWCTR decommissioning:

- Minimizing the risks to workers and to the public,
- Providing flexibility in future uses of the property,

- Minimizing the capital costs of the decommissioning work,
- Minimizing required maintenance and surveillance of the facility in future years,
- Recycling materials in the facility to the extent practicable,
- Providing valuable information for follow-on decommissioning projects at the SRS, and
- Minimizing radioactive waste stream volumes where economically justifiable.

4.2 General End Condition Criteria

- Increased physical security of radioactive equipment and building materials,
- Reduced or eliminated risk of radionuclide migration from the HWCTR property, and
- Improvement in the ability to release most or all the HCTWR site for unrestricted future use.

4.3 Related Remedial Actions Involving Soil or Water in the Vicinity

There are no present plans for any remediation of soil or water in the general vicinity of the HWCTR property.

4.4 Potential Future Uses of the Property

One goal of the HWCTR decommissioning project, as noted in Section 4.1, is to provide flexibility in future uses of the property. Considering the present vision for the future of the Savannah River Site will help place this goal into context.

The January 1996 *Savannah River Site Future Use Project Report* provides this vision. It expresses recommendations by various stakeholders on their preferences for future use of the federally-owned property. The report resulted from the efforts of a DOE-WSRC team that solicited ideas from interested organizations and individuals, holding a series of six public meetings in the region. The SRS Citizens Advisory Board participated, as did numerous other diverse organizations, including environmental advocacy groups.

The Future Use Report notes that while no general consensus was reached, several common themes emerged from the project. The project team embraced these themes as recommendations. Recommendations which could be relevant to the HWCTR project include:

- SRS boundaries should remain unchanged, and the land should remain under the ownership of the federal government, consistent with the site's 1972 designation as the first National Environmental Research Park.
- All SRS land should be available for multiple use, except for residential use, (e.g., industry, ecological research, natural resource management, research and technology demonstration, recreation and public education) whenever appropriate and non-conflicting.
- Residential uses of SRS land should be prohibited.
- Some of the land should continue to be available for nuclear and non-nuclear industrial uses, and commercial industrialization should be pursued.
- Future use planning should consider the full range of worker, public and environmental risks, benefits and costs associated with remediation.

Also relevant to the HWCTR project are site maps in the Future Use Report which show recommended uses of different parts of the property. The U-Area, where the HWCTR is located, and the B-Area, which encompasses U-Area, are designated for administrative facilities, a position endorsed by the Citizens Advisory Board.

The report states that the "recommendations will be considered by the DOE as it weighs ongoing and future mission needs, technical capabilities, legal requirements and funding throughout future planning and decision-making activities."

As time passes and conditions at the site and in the surrounding area change in the coming years, different ideas may prevail. But in the meantime, the *Future Use Project Report* offers the best available predictions of SRS land use that pertain to the HWCTR decommissioning project.

An important factor taken into account in the Future Use Project Team's recommendations is the proximity of U-Area and B-Area to other facilities on the site. Information on this subject appears in the site's *Land-Use Baseline Report* of June 1995.

This report shows that:

- B-Area, which encompasses the HWCTR property, is a primary administrative area,
- The HWCTR lies about 2.5 miles from the nearest nuclear industrial facility, F-Area with its high-level waste storage tanks and chemical processing facility, and
- The HWCTR lies outside of the radiological risk zone associated with the central nuclear facilities. This zone is defined by safety analyses which consider possible but extremely unlikely accidents which could release radioactivity. Outside of the zone the

- maximum amount of radiation exposure a person could receive in the event of an accident would fall below guidelines used by the DOE and the Nuclear Regulatory Commission for such accident scenarios.

The *Land Use Baseline Report* was available in draft form to those participating in the future use study, and is consistent with the *Future Use Project Report*.

5.0 REMOVAL ALTERNATIVES

5.1 Potential Alternatives

Five different alternatives were considered for the HWCTR decommissioning. Included were those utilized in past nuclear reactor decommissioning projects and those methods presently considered to be industry standards. Of the five, four were found to warrant detailed study. These alternatives are shown in Figure 28 below, illustrated in Figure 29 of Appendix A and explained in the following paragraphs.

5.1.1 Safe Storage.

The DOE *Decommissioning Handbook* and the American Nuclear Society's *American National Standard for Decommissioning of Research Reactors*, identify this alternative as SAFSTOR. This term means to defer decommissioning for a prolonged period of storage during which the facility is maintained so that the risk to public health and safety is acceptable. While in this condition, radioactive contaminants decay, reducing the radiological hazards associated with the facility. Under the American Nuclear Society's standard, SAFSTOR entails the following actions:

- A characterization study for radioactive materials,
- Removal of all fuel assemblies,
- Removal of all radioactive fluids and wastes,
- Removal or stabilization of radioactive contamination,
- Operation of appropriate support systems such as ventilation and fire prevention systems,
- Isolating and providing access control to remaining radioactive areas, and
- Instituting routine maintenance and surveillance measures.

The HWCTR facility has remained essentially in this state since the 1975 characterization study was performed. Radiation levels have decayed during that time, substantially reducing the hazards associated with dismantlement and other decommissioning methods. Little is to

be gained by continuing this condition, nor would it meet the objectives set for the decommissioning project. And experience in the nuclear industry has shown that proceeding without delay with decommissioning will often save costs in the long run, given the uncertainty associated with changing regulations and rising waste disposal costs. Therefore, the safe storage method does not warrant detailed analysis.

Figure 28. Alternatives considered

5.1.2 Alternatives Studied in Detail.

The four removal alternatives analyzed in detail are described in the following paragraphs. Major tasks associated with each alternative are identified, recognizing that variations within each alternative can produce a viable end condition. For example, in the partial dismantlement and interim safe storage process, all equipment with the exception of the

reactor vessel and steam generators would be removed. If this alternative were to be selected, a viable variation could be considered that limited the removal of other equipment. As another example, the entombment process requires the removal of recyclable metals. This could prove to be too costly and therefore, a variation might be chosen that would delete this task without affecting the overall end result of this alternative. Such options for the alternatives are discussed where they may have substantial merit.

Figure 29 of Appendix A provides a simple illustration of each of these alternatives.

5.1.3 Dismantlement

The Doe *Decommissioning Handbook* and the American Nuclear Society's *American National Standard for Decommissioning of Research Reactors*, call this approach DECON and note that it consists of removal of fuel assemblies, radioactive fluids, waste and other materials having activities above accepted unrestricted release levels, consistent with the principles of ALARA (maintaining personnel radiation exposure As Low As Reasonably Achievable). A good example of this approach is the decommissioning of the Shippingport Atomic Power Station in Pennsylvania, a summary of which appears on the next page.

This alternative merits evaluation in detail. Removing underground structures to five feet below grade level will be the primary case studied. This depth will permit removal of the entire ground floor (the 0-level), which has radioactivity in cracks and floor drain lines.

The dismantlement process would include the following major tasks:

- Modify the containment dome to facilitate removal of large components, e.g., the refueling machine, reactor vessel and steam generators
- Remove all process piping, pumps and motors, cable trays, duct work, and installed components, including the reactor vessel and steam generators.
- Remove all hazardous waste and mixed waste.
- Recycle equipment and materials as practicable.
- Remove activated and contaminated concrete.
- Remove building to below grade.
- Remove the ventilation exhaust stack.
- Remove steam muffler and associated underground steam line.
- Remove underground waste water tank and associated piping.
- Dispose of all waste.
- Backfill with earth and grade the site.
- Perform final radiological survey
- Release for unrestricted use.

The Shippingport Decommissioning Project

The decommissioning of the Shippingport Atomic Power Station serves as a good example of the *dismantlement* alternative, although this facility was much larger than the HWCTR facility.

The world's first large-scale nuclear power plant, the Shippingport station was located in Beaver County, Pennsylvania. It was built by the Atomic Energy Commission to demonstrate for commercial use the pressurized water reactor technology of the U. S. Navy's nuclear-powered submarines. The plant operated from 1957 until 1984. Its decommissioning, which was completed in December of 1989, was the first complete decontamination and decommissioning of a power-producing reactor in the nation.

Some facts about the Shippingport decommissioning project:

- Structures demolished: All to three feet below grade,
- Actual total cost of project: \$91.3 million,
- Cost of removing piping and equipment: \$8.5 million,
- Cost of removal and shipment of reactor pressure vessel: \$7.4 million,
- Cost of removal of structures and chambers: \$6.2 million,
- Cost of solid waste disposal: \$2.0 million,
- Cost of waste burial at DOE Hanford, Washington Site: \$2.2 million,
- Volume of low-level radioactive waste: 214,000 cubic feet,
- Duration of physical work: 40 months,
- Personnel radiation exposure: 152 person-rem.

Technology transfer was a prime objective of the project. Hundreds of reports, presentations, technical papers and videotapes were made available to widely disseminate the lessons learned. These documents, which are listed in the *Final Project Report of the Shippingport Station Decommissioning Project*, are available from DOE's Remedial Action Program Information Center in Oak Ridge, Tennessee.

Figure 30. The Shippingport Decommissioning. These before and after views of the 7.5 acre property illustrate what is meant by the "greenfields" complete dismantlement type of nuclear reactor facility decommissioning.

Three options associated with this alternative are discussed later in this document and included in the costs estimates. These are (1) removing the concrete structure down to the -5-foot-level, the primary approach, (2) removing the concrete structure down to the -16-foot level and (3) removing all of the concrete structure.

5.1.4 Partial Dismantlement and Interim Safe Storage

This approach entails removal of all radioactive equipment except for the reactor vessel and steam generators. It is a variation of the decommissioning approach being used for the 105-C plutonium production reactor at DOE's Hanford Site in the state of Washington. The Hanford 105-C reactor approach is summarized on the following page. In the case of the HWCTR, all radioactivity would be removed except for that in the reactor vessel, the reactor vessel biological shield and the steam generators, which would be sealed and left in place. The imbedded piping in the biological shield and in the floor drain system would remain in place. The containment dome would remain standing. The site would be left in a condition where the vessel and steam generators could be removed at some later time.

Such an approach could prove advantageous should funding for complete dismantlement not be forthcoming.

The partial dismantlement and interim safe storage process includes the following major tasks:

- Modify carbon steel dome to facilitate removal of large components, e.g., the refueling machine
- Remove all process piping, pumps and motors, cable trays, duct work, and installed components with the exception of the reactor and two steam generators.
- Seal weld caps on vessel nozzles (outside of the biological shield) and on steam generator nozzles.
- Remove all hazardous materials and mixed waste.
- Recycle equipment as practicable.
- Remove the ventilation exhaust stack.
- Remove steam muffler and associated underground steam line.
- Remove underground waste water tank and associated piping.
- Dispose of all waste.
- Restore the carbon steel portion of the containment structure as necessary.
- Weld closed all containment building openings.
- Install remote monitoring equipment and establish periodic monitoring requirements, e.g., every five years.

The Interim Safe Storage of the 105-C Production Reactor at Hanford

Even though the Hanford 105-C reactor is much larger and different in design from the HWCTR, a variation of its "cocooning" concept merits consideration.

The 105-C reactor is one of nine large weapons materials production reactors located at the DOE's Hanford Site in the state of Washington. The reactor operated from 1952 to 1969. Shortly after the final shutdown, the used nuclear fuel was removed. Only minimal surveillance and maintenance has been accomplished since that time.

The reactor core consists of a block of graphite weighing 9,000 tons. It is surrounded by a reinforced concrete shield wall, three to four feet thick. The reactor building is a light industrial structure, 346 feet long, 150 feet wide and 120 feet high. Several areas of the building are in advanced stages of deterioration.

The DOE has determined that the reactor will be "cocooned" for safe storage until ultimate disposal. This process will entail sealing the reactor block in plastic. Openings in the shield wall will be sealed also. A new stainless steel roof will be installed over the shield wall. Radioactive equipment will be removed from the remainder of the building and the spaces decontaminated. This part of the structure will be razed, leaving only the cocooned reactor. Provisions will be made for remote monitoring and inspections at five year intervals. After a period of 50 to 75 years, the reactor block will be removed and buried in the site's radioactive waste disposal facility.

The 105-C interim safe storage program has been designated a large-scale demonstration project by the DOE's Morgantown Energy Technology Center.

5.1.5 Partial Dismantlement and Beneficial Reuse

This approach would follow the partial dismantlement and interim safe storage alternative, except that (1) reactor vessel and steam generators would be removed and (2) the structure would be set up for a purpose such as storage of radioactive material or equipment. The decommissioning of the Experimental Boiling Water Reactor (EBWR) at Argonne National Laboratory near Chicago, Illinois is a good example of such an approach. The containment building for that reactor, which bears similarities to the HWCTR building, was turned into a storage facility for transuranic wastes. A summary of the EBWR project appears on the next page.

The Decommissioning of the Experimental Boiling Water Reactor (EBWR)

This project is an example of a nuclear reactor building much like the HWCTR containment building being converted to a storage facility for transuranic waste materials.

Located at Argonne National Laboratory near Chicago, Illinois, EBWR was the first boiling water type nuclear power plant to produce electricity. It produced up to 100 megawatts of heat during operation. After ten years of operation, it was shutdown in 1967.

Decommissioning work began in 1986 and was completed in 1996. Radioactive equipment was removed. The reactor vessel was cut into pieces for disposal. Radioactive concrete biological shielding surrounding the reactor vessel was taken out. Because of the planned use as a storage facility for radioactive materials, the facility was not released for unrestricted use; low levels of radioactivity were allowed to remain inside imbedded piping in the biological shield, inside sealed floor drains and in parts of the building bridge crane.

Some figures associated with this project:

- *Total cost* - \$19,586,000 (include three characterization studies, engineering, etc.)
- *Total worker radiation exposure* - 20.87 person-rem (18.1 person-rem for reactor vessel complex removal)
- *Low-level radioactive waste generated* - 14,841 cubic feet (The cost of transportation and disposal of approximately two-thirds of this amount was \$50 per cubic foot, the remainder cost \$90 per cubic foot.)
- *Mixed waste* (both radioactive and hazardous) - 564 cubic feet

Note that the \$19,586,000 cost applies to the decontamination and decommissioning work only. Setting up the facility for storing transuranic wastes will cost approximately \$2,629,000.

Figure 31. The EBWR Containment Building

At the present time, no specific purpose for reuse of the HWCTR building has been identified. Hence, the analysis of this alternative assumes a generic waste storage scenario, with only infrequent access by personnel.

The beneficial reuse process would include the following major tasks:

- Develop and obtain necessary approvals for a waste storage plan.
- Modify carbon steel dome to facilitate removal of large components, e.g., refueling machine, reactor vessel and steam generators.
- Identify internal building waste storage areas desired.
- Remove the refueling machine.
- Cut piping from the reactor vessel and steam generators. Seal openings to the pressure vessels by welding steel plugs in openings.
- Remove the reactor vessel and steam generators.
- Remove activated concrete in the biological shield.
- Remove any interfering process piping, pumps and motors, cable trays, duct work, and installed components.
- Remove all hazardous waste and mixed waste.
- Recycle equipment as practicable.
- Remove the ventilation exhaust stack.
- Remove steam muffler and associated underground steam line.
- Remove underground waste water tank and associated piping.
- Dispose of all waste.
- Modify deck structure as necessary to support waste storage requirements.
- Restore the carbon steel portion of the containment structure.
- Upgrade building to meet current codes and requirements for intended use.

5.1.6 Entombment

The DOE *Decommissioning Handbook* and the American Nuclear Society's *American National Standard for Decommissioning of Research Reactors* describes the in-place entombment approach, which they call ENTOMB, as sealing all of the remaining highly radioactive or contaminated components (e.g., reactor structural components) within a structure integral with the biological shield. First, all fuel assemblies would be removed, along with all radioactive fluids and waste and selected components. (Fuel, radioactive fluids and waste have already been removed from the HWCTR.) Concrete would typically be poured into the below-ground building cavity to produce a monolithic structure. The radioactivity would remain entombed until it decayed to harmless levels. This time period would depend on the type and amount of radioactive contaminants. It would typically be longer than a century.

One nuclear reactor which was entombed in the early 1970s is located at Wright-Patterson Air Force Base in Dayton, Ohio. Information on this project appears on page 28.

The entombment process for the HWCTR would include the following major tasks:

- Modify carbon steel dome to facilitate removal of large components, e.g., the refueling machine.
- Remove all site equipment, above the zero reference point, that is located external to the biological shield, including the refueling machine.
- Remove all hazardous waste and mixed waste.
- Store the removed radioactive and contaminated equipment, if practicable, inside the containment building below the 0-level, as long as it is not mixed waste.
- Identify and remove, if practicable, all recyclable metals.
- Cut piping from reactor vessel and steam generators.
- Seal reactor vessel, and steam generator openings with welded steel plugs.
- Dispose of all waste.
- Secure the remaining radioactive components within a structure that will meet the criteria of prevention of access to the facility and maintaining structural integrity over an extended period of time, i.e., fill existing voids in containment building with concrete to a level of plus three feet.
- Remove the steel dome portion of the containment building.
- Remove the ventilation exhaust stack.
- Remove steam muffler and associated underground steam line.
- Remove underground waste water tank and associated piping.
- Cover the entire concrete surface with a waterproof barrier and seal with a waterproof membrane similar to that planned for the SRS low-level waste burial grounds.

The existing walls of the underground reinforced concrete structure are 18 inches thick; the bottom floor - referred to as the "base mat" - is five or more feet thick. Filling the cavity with concrete will produce a large monolithic concrete structure of high durability.

Consideration was given to filling the reactor vessel, steam generators and large piping with concrete grout to immobilize the radioactivity within this equipment. It was determined that use of this technique was unnecessary because of the high integrity of the equipment, especially the reactor vessel which contains most of the radioactivity, and the fact that the radioactivity inside of the equipment would be contained well within the monolithic structure.

After 100 years, the approximate amounts of radioactivity inside of this entombment, using the estimates of Table 3 and table 4 adjusted to account for radioactive decay, would be:

Table 5. HWCTR Radioactivity in Curies After 100 Years

Iron-55	Cobalt-60	Nickel-63	Plutonium-239, and other transuranics	Fission products
-	0.001	1000	< 0.001	< 0.0001

The Entombment of the Air Force Nuclear Engineering Center (AFNEC) Reactor

The AFNEC was a small 10 megawatt water-cooled reactor. Located at the Air Force Institute of Technology at Wright-Patterson Air Force Base in Dayton, Ohio, it was built to conduct studies related to nuclear propulsion of aircraft. It was operated from 1967 to 1970.

The reactor and its associated experimental facilities are enclosed in a steel-domed structure that looks much like the HWCTR containment building. The AFNEC containment shell stands 110 feet above grade and extends about 50 feet below the ground. The structure is 82 feet in diameter.

During 1970 and 1971, the reactor was entombed. First, non-structural radioactive components were removed. Radioactive cavities such as the reactor tank and test cells were filled with sand. Penetrations in the concrete biological shield were sealed by welding. Finally, additional concrete shielding was constructed to reduce radiation levels to less than 0.2 millirem per hour. The design lifetime of the entombment was 50 years.

In 1987, Oak Ridge National Laboratory performed a study for the Air Force of options to decommission the entombed reactor. The four options and their projected capital cost in 1987 dollars are:

- (1) A facility upgrade with continuing surveillance of the entombed structure (\$1 million),
- (2) Removing radioactive equipment from the tomb (\$26.4 million),
- (3) Removing radioactive equipment and removing the concrete monolith itself (\$27.9 million), and
- (4) Removing radioactive equipment, removing the monolith and razing the structure (\$42.2 million)

A decommissioning plan was eventually developed for the fourth option. But the plan was not carried out, chiefly because the Barnwell Low Level Radioactive Waste Disposal Site closed to waste generators outside the Southeast Compact, leaving no place to dispose of low level waste from the decommissioning work.

The Air Force finally decided to adopt option (1), and upgraded the entombed facility. In connection with this, all radioactive materials external to the structure were removed, including underground tanks.

The iron-55 radioactivity, with its 2.6 year half-life, would have decayed away. Virtually all of the cobalt-60 activity remaining would be inside of the reactor vessel, effectively imbedded in the metal components.

Virtually all of the nickel-63 activity also would reside inside of the reactor vessel, effectively imbedded in the metal. With its 100 year half-life, the nickel-63 would be still be present in amounts in the range of one curie even after 1000 years. But given the nature of its radioactive emissions - low-energy beta and no gamma - it is less hazardous than most other radioisotopes and can result in radiation exposure only if ingested or inhaled.

The transuranic radioisotopes referred to in Table 5 include plutonium-239, americium-241 and others. Owing to their long half-lives they would not decay significantly in a century. Pieces of HWCTR hardware, such a valve from the main cooling system, would still be radioactive in the year 2096. Fission products such as cesium-137 also would be present in amounts exceeding current limits.

Besides these radioisotopes, others are present in the HWCTR in smaller quantities, but they are less important than those just discussed.

In summary, given its present radioactive inventory, an entombed HWCTR would still contain low-levels of radioactivity above current limits even after a century. Of course, limits for acceptable levels of radioactivity may change over the years.

5.2 Radiological Release Criteria

The radiological release criteria for the HWCTR project have not yet been established. The criteria could involve an "unrestricted" or a "restricted" release, depending on the approach followed, or no release from radiological controls at all.

The dismantlement approach would entail an unrestricted release of the property. The property would then be available for any suitable use. The partial dismantlement and interim safe storage approach and the entombment approach would both entail restricted releases, with continuing institutional controls on the property. The partial dismantlement and beneficial reuse approach would entail continued institutional controls, the nature of which would depend on the actual use of the facility. The institutional controls would involve such things as radiological warning signs, controlled access and periodic radiological surveys and inspections.

The criteria for restricted release would be established based on the particular decommissioning scenario. They would include specifications for permissible radiation levels on accessible surfaces of the facility.

The unrestricted release criteria have not yet been established either, but they would likely follow the new radiation cleanup standard being developed by the U. S. Environmental Protection Agency (EPA). This standard will apply when it is issued. It is expected to require that personnel radiation exposure from residual radioactivity associated with unrestricted use of a cleaned-up site be less than 15 millirem per year above the natural background radiation rate.

In the past, unrestricted release criteria for DOE decommissioning projects have been set on a case by case basis. The criteria for the Shippingport Atomic Power Station in Pennsylvania serve as a good example since this was a DOE project which involved unrestricted release of the property following removal of radioactive material, with some below-ground parts of the structure remaining in place. These criteria included the following elements:

- A basic limit of "...100 millirem per year total committed effective dose equivalent to the maximum exposed individual of the general public under the worse case scenario..."
- Use of the surface radioactivity limits of the Nuclear Regulatory Commission's Regulatory Guide 1.86 long a nuclear industry standard,
- An average concentration of cobalt-60, the limiting radionuclide, of less than 6 picocuries per gram in the top three meters of soil, and
- An average exposure rate of less than 0.05 millirem per hour one meter from the wall of a buried underground structure which could conceivably be occupied in the future.

With the new EPA standard, the unrestricted limits for the HWCTR project with the dismantlement scenario would be expected to entail limits below those accepted for the Shippingport decommissioning.

5.3 Specific End Condition

This section addresses how well each of the four alternatives satisfies the end condition criteria described in section 4.2 above.

5.3.1 *Dismantlement*

The facility would be brought to a condition where (1) the equipment and components are removed, (2) activated and contaminated concrete is removed, (3) the facility is decontaminated to acceptance levels for unrestricted release, (4) all structures have been demolished to below-grade level and (5) the site has been backfilled, graded and landscaped. This condition would be similar to the condition attained during the decommissioning of the Shippingport Atomic Power Station. It would readily satisfy the criteria of section 4.2.

Any of the three options associated with this alternative - removal of the concrete structure to the -5-foot level, to the -16-foot level or removal of all of the below-ground structure - would satisfy the criteria.

5.3.2 *Partial Dismantlement and Interim Safe Storage*

The facility would be brought to a condition where all radioactive equipment but the reactor, steam generators and biological shield would be removed from the building. The upper portion of the containment building would be restored and all openings welded shut in order for the facility to function as the top of the cocoon. Remote monitoring equipment to detect

excessive moisture and other potential problems would be installed. Plans would be in place for entry into the building at five year intervals for inspections.

This condition satisfies two of the three criteria of section 4.2. It increases the physical security of the radioactive equipment and building materials by effectively sealing the building. By removing all of the radioactive equipment except for the reactor vessel and steam generators, it improves the ability to eventually release the HWCTR site for unrestricted use. But it does not significantly reduce the risk of radionuclide migration from the property, because most radioactivity would remain inside the reactor vessel. The matter of radionuclide migration is discussed in section 5.4 below.

5.3.3 Partial Dismantlement and Beneficial Reuse

Equipment removed would include the reactor vessel, steam generators and other large components. The activated portion of the biological shield and contaminated concrete would be removed. Process piping items and other installed components interfering with designated storage areas would be removed. Given the planned use as a radioactive materials storage facility, the building would not be completely released from radiological controls. Imbedded radioactive piping, such as floor drains and that inside of the biological shield, would remain in place.

Upon completion of the equipment removal, the containment building would be restored to suitable condition for use as a storage area. Decks and other structural components would be reinforced as required to support the approved waste storage plan. This condition would be similar to the end condition of the EBWR at the Argonne National Laboratory.

This approach improves the physical security of radioactive equipment and building materials to some degree by relocating nearly all of the radioactivity to the SRS low-level waste disposal facilities. Consequently, there is also reduced risk of radionuclide migration from the HWCTR property. And the ability to release most or all of the property for unrestricted use also improves.

5.3.4 Entombment

The facility would be brought to a condition where all equipment above the 0-level reference point has been removed. The underground structure would be removed down to -5 feet or lower, depending on the option chosen. The containment building would be filled with concrete to a level of three feet above the 0-level reference point. The carbon steel portion of the containment building would then be removed. Landscaping to improve aesthetics could be executed if desired.

This approach meets the section 4.2 criteria as follows: The physical security of the radioactivity is increased by containing it within a buried concrete vault. The risk of radionuclide migration is diminished for the same reason. The ability to eventually release

most or all of the site for unrestricted future use is not improved. Even after 100 years of entombment, much of the equipment would remain radioactive by today's standards. And removing the equipment from the monolithic structure would be costly as the Air Force found during its study of one of its old nuclear reactors at Wright-Patterson Air Force Base.

5.4 Risks and Safety Issues

In this section, risks and safety issues associated with the HWCTR decommissioning alternatives are discussed, with the focus on workers and the public. Potential environmental impacts from the decommissioning work are addressed in the next section.

Radiological risks associated with external radiation exposure are addressed quantitatively. Other risks are addressed in a qualitative fashion. The results of previous studies such as those associated with the *SRS Waste Management Final Environmental Impact Statement* are utilized as applicable. This approach is consistent with the graded approach for applying the requirements of the Comprehensive Environmental Response, Compensation and Liability Act to nuclear decommissioning work expressed in reference 1.

5.4.1 Summary

Risks associated with the HWCTR decommissioning, regardless of the approach selected, would be low. No unusual safety issues would be involved. A detailed Health and Safety Plan will ensure that the safety of workers is protected.

The most significant radiological risks are associated with worker radiation exposure. This exposure would be relatively low for each alternative, compared with that on other nuclear reactor facility decommissioning projects.

Insofar as nonradiological risks associated with the decommissioning work are concerned, these are similar to those involved with modifying or dismantling a nonnuclear commercial or industrial building of similar size and age. There are no special workplace hazards. Controls commonly used in industry and on SRS to ensure occupational safety will ensure that the nonradiological risks associated with the HWCTR decommissioning are small.

5.4.2 The Nature of Radiological Risks

Everyone, from the moment of conception, is exposed to ionizing radiation naturally present in the environment. This ionizing radiation is known as background radiation. It comes from radioactive materials in the earth and within our bodies. It also appears as cosmic radiation from outer space. The amount of background radiation that one receives in the United States averages about 0.3 rem per year. This amount varies significantly from place to place.

Decommissioning a nuclear facility such as the HWCTR entails radiation exposure to workers above natural background levels. The public could also be exposed to radiation

levels above background, especially from shipments of radioactive metals to off-site recycling facilities.

Scientists agree that exposure of people to high levels of ionizing radiation can cause some forms of cancer. Risk factors have been developed that relate radiation exposure to the increased rate of fatal cancers, based on studies of groups of people accidentally or occupationally exposed to relatively high levels of radiation. The International Commission on Radiological Protection identifies risk factors for fatal cancers of 0.0005 per person-rem for the general population and 0.0004 per person-rem for workers. (Risk factors are lower for workers because most of them are adults.)

Many scientists believe that these risk factors are conservative because they entail extrapolating cancer rates associated with high radiation exposures to low exposure levels where there is no direct evidence that radiation exposure causes cancer.

The following examples illustrate how these factors are used in estimating cancer risk.

- If a group 10 people received an average individual dose of 0.3 person-rem per year exposure from natural background radiation over a 70-year lifetime, their collective risk of dying from cancer is increased by a factor of about 1 in 10 from this radiation exposure. (This value comes from multiplying ten persons by 0.3 person-rem by 70 years by the 0.0005 risk factor, which equals 0.105, or about 1/10th.)
- A group of 100 radiation workers who each receive occupational exposure of one person-rem over a ten-year career - a typical exposure in the nuclear industry - has an increased risk of fatal cancer from this exposure of one chance in 25 or 0.04. (From multiplying 100 by one by 0.0004.)

The use of accepted risk factors therefore provides an estimate of increased cancer risk from radiation exposure to workers and the general population. Note that risks in the range of 1×10^{-4} or 0.0001 are small compared to others that most people accept, such as dying in motor vehicle accidents (0.013) or drowning (0.0026).

Another way to help place the additional cancer risks into perspective is to consider statistics on cancer mortality in the United States. According to the U.S. Centers for Disease Control and Prevention 23.5 percent of human deaths in this country are caused by some form of cancer.

5.4.3 HWCTR Radiological Risks

Four factors combine to make the radiological risks low. First, only moderate amounts of radioactivity are present in the facility. Second, the vast majority of this radioactivity is in the form of activated steel, with the radioactivity effectively imbedded in the metal inside of the reactor vessel. Third, once the decommissioning is completed, the radioactivity will either be removed from the facility or sealed in place so that the probability of exposure to workers or to the public is not significant. Fourth, extensive controls will be used to handle

radioactive material and minimize radiation exposure to workers and the public during the course of the decommissioning work and in shipment of radioactive materials from the HWCTR site.

5.4.4 Pathways for Radiation Exposure

In the decommissioning of the HWCTR, several possible pathways exist for exposure of workers and members of the general public to radioactivity from the facility. The most significant are:

- *External exposure.* Workers will receive external exposure to gamma radiation during the course of the decommissioning work. Amounts would vary with the alternatives. Members of the public could be exposed to gamma radiation from radioactive metals transported to off-site recycling facilities. People on the property after the decommissioning could receive some radiation exposure from residual radioactivity at the site.
- *Ingestion of radioactive materials.* Workers could ingest radioactive particles during the course of the work, and receive internal radiation exposure as a result. After the facility is decommissioned, people on the property could possibly ingest materials containing trace amounts of residual radioactivity.
- *Inhalation of airborne radioactivity.* Workers could breathe airborne radioactive particles during decommissioning work.
- *Waterborne radioactivity.* If radioactivity from the facility were to get into surface water or ground water, radiation exposure to humans could eventually result.

5.4.5 Risks of External Exposure

Estimates of the worker radiation exposure associated with the four decommissioning alternatives appear in section 5.8.4. The estimates range from four person-rem for dismantlement and partial dismantlement and beneficial reuse, to one person-rem for entombment. Worker radiation exposure will be maintained as low as reasonable achievable using techniques summarized in reference 2.

Using the risk factors described in section 5.4.2, the estimated risk of an additional cancer death among all of the workers who receive this exposure would be 0.0016 (1.6×10^{-3}) for four person-rem and 0.0004 (4×10^{-4}) for one person-rem.

Note that the HWCTR exposure estimates are low for nuclear reactor facility decommissioning work. Worker radiation exposure for the larger-scale Shippingport decommissioning project was 152 person-rem. On the Experimental Boiling Water Reactor decommissioning project the worker exposure was 20.87 person-rem.

Radiation exposure to workers from transportation of radioactive waste to SRS disposal facilities is estimated to be much less than one person-rem. The risk of an additional cancer death among a group exposed to one person-rem would be 0.0004 (4×10^{-4}).

The most credible way that members of the public could receive external radiation exposure from the decommissioning would be exposure to radiation from packaged metal piping and components transported to off-site recycling facilities. This material would be shipped by truck in large steel containers. Department of Transportation regulations allow radiation levels up to 0.2 rem per hour on the outside of the package and at the outer point of the transport vehicle in such shipments. The actual radiation levels would be substantially lower than those permitted by the regulations; they are expected to fall below 0.001 rem per hour.

Risks associated with transportation of radioactive and hazardous waste from SRS were evaluated in detail in the *SRS Waste Management Final Environmental Impact Statement*. Projected shipments evaluated included those from nuclear decommissioning projects such as HWCTR. Accident impacts were taken into account as well as incident-free shipments. Conservative assumptions were used. The results showed that risks from transportation of the material were small, a conclusion validated by extensive experience.

In the dismantlement alternative, adherence with the radiation cleanup standard would ensure that people on the property after the decommissioning do not receive significant radiation exposure from residual radioactivity. Compliance with the cleanup standard would be independently verified so that there is good assurance that the criteria have been met. With the entombment alternative, significant radiation exposure to those on the property after the decommissioning would likewise be prevented by adherence to a cleanup standard which would ensure that accessible radiation levels are insignificant. With the other alternatives, physical security measures such as those presently in place as outlined in reference 2 would limit access to authorized personnel who would be monitored for radiation exposure.

5.4.6 Risks Associated With Ingestion of Radioactive Materials

Risks from ingestion of radioactive materials are negligible both to workers and the general public.

Workers risks are minimized by controls over radioactive materials handled during the decommissioning work. These controls are summarized in reference 2.

The most credible pathway for members of the general public to ingest radioactivity from the HWCTR would occur after the decommissioning, from residual radioactivity at the cleaned-up site. The radiation cleanup standard used to determine that the property is suitable for unrestricted release from radiological controls would ensure that possible radiation exposures from ingestion of materials on the property are negligible.

5.4.7 Risks From Inhaling Airborne Radioactivity

As with ingestion of radioactive material, risks to workers from this pathway would be avoided by the protective measures outlined in reference 2.

And, as with possible ingestion of radioactive materials, risks to those on the property after the decommissioning is completed would also be negligible because the cleanup standard used would take this pathway into account.

5.4.8 Risks From Waterborne Radioactivity

Risks from radioactivity associated with the HWCTR decommissioning contaminating nearby surface water or ground water under the property would be extremely small. This matter is addressed further in section 5.5.1.

5.4.9 Risks Associated With Nonradiological Pollutants

Nonradiological contaminants associated with the HWCTR facility were described in section 3.7. They include lead, mercury, asbestos and PCBs.

All four decommissioning alternatives call for removing such materials from the facility. Therefore, the risks associated with these materials apply to the decommissioning workers. Worker risks will be minimized by protective measures which will be detailed in the Health and Safety Plan. The nonradiological contaminants in the HWCTR facility are similar to those found in nonnuclear building of similar age and construction. Such contaminants are commonly encountered in building modification and demolition work. Appropriate protective measure for workers are well established.

The potential ecological impacts of nonradiological pollutants in the HWCTR facility are addressed in section 5.5.1.

5.5 Potential Impacts of Each Alternative

In accordance with reference 1, separate National Environmental Policy Act documents, such as an environmental assessment or an environmental impact statement, are not required for decommissioning performed under the Comprehensive Environmental Response, Compensation and Liability Act. In such a case, as the HWCTR project, the alternatives analysis is to address the ecological, socioeconomic, off-site and cumulative impacts of the alternatives being considered.

5.5.1 Ecological Impacts

The potential ecological impacts of the HWCTR decommissioning project fall into four areas: (1) water quality, (2) air quality, (3) soils and (4) terrestrial biota and endangered and threatened species.

5.5.1.1 *Water Quality*

The decommissioning work will involve remediation of hazardous pollutants and radioactivity and the possibility of releases of these materials to the surrounding waters and groundwater supplies.

Nonradiological pollutants. For nonradiological pollutants, there is equal risk involved with each of the decommissioning alternatives as each alternative involves removal of all regulated wastes, wastes which fall under the Resource Conservation and Recovery Act, wastes controlled by the Toxic Substances Control Act and other hazardous materials.

While the possibility of water pollution from contaminant migration during decommissioning work exists, a number of factors make this risk extremely small. The nearest stream, Upper Three Runs Creek, runs approximately a mile southeast of the property. Thus, the possibility of pollutants getting to and being transported by streams as a result of the decommissioning work is negligible.

The ground water table lies 90 to 100 feet below the surface of the HWCTR property, over 30 feet below the lowest point of the structure. The containment structure is essentially impervious to water. Since the structure would remain intact during hazardous pollutant remediation work, the possibility of contaminants from the work getting through the structure and into the ground water is extremely remote.

Another factor which minimizes the potential for releases of waterborne pollution involves the types and quantities of the contaminants - primarily solids with only small amounts of liquids - which will be remediated under strict controls. Simply put, the pollutants involved would not migrate during the type of work required for their removal.

To put the potential impacts associated with removal of nonradiological pollutants during decommissioning work into perspective, they are no greater than those involved with the remediation of a typical, commercial nonradiological facility of similar age and construction.

There is no risk of migration of nonradiological environmental pollutants from the HWCTR site following completion of decommissioning work because all of the decommissioning alternatives call for removal of regulated wastes, those covered under the Resource Conservation and Recovery Act, those covered under the Toxic Substances Control Act, and other hazardous materials. (Asbestos remediation is addressed in section 5.5.1.2.)

Radiological pollutants. The potential impacts associated with radiological contamination releases to the environment during the decommissioning work are also very small. Minute amounts of radioactivity may be released to the environment during the demolition work. The releases will be almost exclusively in the form of airborne radioactive particles and very low levels of radioactivity contained in concrete dusts. The radioactivity involved will not

migrate far from the source and will be deposited on ground surfaces in the vicinity of the HWCTR site. But given the controls which will be in use, these releases will be so small that they will not be measurable when compared to natural background radioactivity. Thus, the probability of measurable quantities of radioactivity getting to streams, rivers or ground water is negligible.

Following decommissioning work, the possibility of migration of radioactivity from the HWCTR site will vary from very small to zero, depending on the alternative chosen. For the dismantlement alternative, since all radioactivity will be removed from the site, there remains no further risk of migration. Even the entombment alternative, which leaves the greatest amount of radioactivity at the site, offers only a slight chance for radioactive material migration. This is because of the integrity of the entombment structure coupled with the fact that the water table is approximately 30 feet below the bottom of the structure. The potential of radionuclide migration for the two remaining alternatives falls between the dismantlement and entombment alternatives since each involves removal of more of the radioactive material than does the entombment alternative.

It is expected that the radioactive wastes from the decommissioning work will be disposed of on-site at the Solid Waste Disposal Facility and the E-Area Vaults. The HWCTR low-level radioactive waste will constitute only a small fraction of the waste in these facilities. The potential impacts of radionuclide migration from these facilities on water quality have been shown to be small (reference 3).

5.5.1.2 Air Quality

Very small and probably negligible quantities of air pollutants would be released by the decommissioning work. Given the amounts and types of releases, long term air quality would not be effected.

Nonradiological Air Pollutants. Most of the asbestos containing materials have already been remediated at the HWCTR site. However, some small quantities of asbestos-containing materials (e.g., insulation in electrical wires and gaskets) are expected to be removed during decommissioning work. As with other hazardous materials, this material will be removed prior to any large-scale structural demolition work. This sequence allows the structure to provide a secondary containment for the work, virtually eliminating the possibility of releases of asbestos to the environment. Therefore, the only hazards involved will be to those individuals carrying out the asbestos removal work. Given that this work will be performed by trained workers using appropriate controls, the potential for asbestos exposure to these people is low.

No volatile organic compounds are known to be present at the HWCTR site and it is planned that none would be introduced during or after the decommissioning work. Also, no chlorinated fluorocarbons are known to be present and it is expected that none will be released during or after the decommissioning work.

The only degradation in air quality which will be realized during the decommissioning process would come from dust-generating work, primarily concrete demolition and earth moving. While such dust-producing work is necessary to some extent with any of the alternatives, dismantlement involves the most demolition and thus will produce the most dust. Proven methods for dust suppression will be employed to reduce the amount of dust generated. Standard methods of dust control including the use of equipment such as dust masks will be used to minimize worker exposures. The dust produced during demolition work will be no greater than that typically produced by razing a small to moderate size commercial or industrial facility.

Radiological Air Pollutants. Very small quantities of airborne radioactive contaminants are expected to be released during the decommissioning work. This is primarily the result of trace levels of radioactivity adhering to concrete and being released with the dust produced by demolition work. Proven techniques will be used to contain the radioactivity. The quantities of radioactivity released would be so small and would be dissipated so quickly that they would be undetectable. No radioactivity releases approaching the airborne release limits of 40CFR61 *Protection of the Environment* are expected.

5.5.1.3 Soils

As previously noted, very small quantities of radionuclides could be released to soils in the vicinity of the HWCTR facility during demolition work. However, the radioactivity levels would be so small as to be undetectable, even with sensitive laboratory instrumentation. There is very little possibility of soil contamination from nonradiological pollutants as a result of the decommissioning work. This is because of the nature of the pollutants and the controls which will be employed for the remediation work.

As stated elsewhere in this document, soil surveys and any necessary remediation are beyond the scope of the decommissioning effort and are to be accomplished as part of a separate environmental restoration program.

5.5.1.4 Terrestrial Biota and Endangered and Threatened Species

No long-term ecological consequences are expected from the decommissioning work. There are no known endangered or threatened species on the HWCTR property. The plant habitat at the site consists almost exclusively of various wild grasses and weeds indigenous to the area. The only wooded area is the muffler site. Small trees, brush and native grasses are present in this area.

The decommissioning work will damage or destroy native grasses on the property along with some plants and small trees in the area near the muffler. However, given the plant life which currently exists at the site, the area can be expected to recover naturally within several years of the decommissioning. While the dismantlement alternative provides for the largest disturbance, this alternative includes site restoration, part of which includes replanting the affected areas after fill and grading.

Limited disturbance of animal life in the area is expected. In a very small number of cases, injury or death to animal inhabitants may occur. This includes small animals, rodents and amphibians. Bird life is not expected to be affected. However, since the site encompasses only two acres of the 310-square-mile federal reservation, long term damage to the animal populations in the vicinity is not expected and recovery from any damage would occur in a short while.

5.5.2 Socioeconomic Impacts

It is estimated that less than 50 people will be involved with the HWCTR decommissioning effort at any one time. Given the current average employment level at SRS of about 16,000, the socioeconomic impact of the work would be negligible. It is expected that part of the workforce involved in the decommissioning work would come from the local area.

No increased social or economic risks to minorities or low-income populations as a result of the decommissioning work are expected.

Regarding land use, as discussed previously, only the dismantlement alternative would make the property available for unrestricted uses. The other alternatives would require that the area remain under some type of radiological controls.

There are no known or suspected cultural resources which could be disturbed or destroyed by the decommissioning activities at the HWCTR site.

Depending upon the alternative chosen, decommissioning could improve the appearance of the site. The best alternative from the aesthetic standpoint would be dismantlement, which would restore the site to conditions similar to those which existed prior to construction. Entombment provides the next best condition, in that it eliminates the dome and limits the amount of above-grade material present after the decommissioning work is complete. The partial dismantlement and beneficial reuse alternatives provide little change from the current condition because the dome, which is the most prominent feature on the site, would remain in place. The partial dismantlement and interim safe storage approach would be similar.

5.5.3 Off-Site Impacts

5.5.3.1 Waste Materials

The HWCTR decommissioning effort will generate moderate quantities of waste materials. This includes both hazardous and non-hazardous waste. A significant portion of this waste will also be radioactive.

Of the four alternatives, dismantlement, because it involves removing all of the equipment and a portion of the structure below grade, will generate the most waste. Entombment, which entails removal of the dome, and the partial dismantlement and interim safe storage

and the beneficial reuse approaches, in which the dome remains intact, would generate smaller quantities of waste materials.

Nonradioactive, Non-Hazardous Waste. Nonradioactive, non-hazardous waste generated by the decommissioning work will consist chiefly of building rubble (concrete and reinforcing steel), some limited amounts of piping and equipment and structural steel. In either the dismantlement or entombment alternatives, the dome will be demolished and become nonradioactive waste. Nonradioactive steel and other metal waste materials would likely be sold as scrap and recycled. Material that can not be recycled, such as building rubble, will be disposed of in an onsite sanitary landfill.

Nonradioactive, Hazardous Waste. Decommissioning work would generate small quantities of nonradioactive, hazardous waste. Since each alternative calls for removal of all hazardous waste and materials, the amounts generated will be the same for each of the four removal alternatives. The waste streams include asbestos-containing materials, along with wastes associated with the Resource Recovery Conservation Act - primarily lead, brass, bronze, mercury-containing components and small amounts of waste oils. Also, wastes controlled by the Toxic Substances Control Act - lubricants, electrical components and small amounts of waste oils containing PCBs - will be generated. Most of these wastes would be temporarily stored in permitted storage facilities at SRS prior to shipment to permitted treatment, storage and disposal facilities. Given the nature and quantities of the hazardous waste materials which will be shipped to the off-site contractor, there would be negligible potential environmental impact.

Radioactive, Non-Hazardous Waste. Significant quantities of non-hazardous, radioactive waste will be generated during decommissioning work. The quantities of this waste vary with each alternative, with dismantlement providing the most. Since all of this waste will be disposed of on-site, no off-site effects would be expected.

Radioactive, Hazardous Waste. Radioactive hazardous waste, with similar hazardous constituents to those in nonradioactive hazardous waste discussed previously, will also be generated. The quantities in these waste streams are not dependent on the removal alternative because all of the alternatives require that these wastes be removed from the facility. A small amount of radioactive asbestos-containing material will have to be removed. Significant quantities of mixed waste (wastes which are both hazardous under the Resource Conservation and Recovery Act and radioactive) will be generated. Small quantities of radioactive wastes controlled by the Toxic Substances Control Act are also expected.

Some of these waste materials will be sent off site. Much of the mixed waste is expected to be shipped to off-site facilities which will have the treatment capability for the waste streams. Some of this waste may be amenable to recycling, for example the lead in the transfer coffin may be able to be extracted from the steel shell and recycled as scrap metal. Off-site shipments of hazardous, radioactive wastes are unlikely to have any environmental impact.

Job Control Waste. In addition to the equipment and waste materials removed from the facility during the decommissioning, there will be "job control waste". This waste will include things such as plastic sheets, cloths, protective clothing and small tools which are used during the course of the work. Most of this material will fall into the categories of radioactive, non-hazardous waste or nonradioactive, non-hazardous waste. Quantities will be small compared to other waste materials generated during the work.

5.5.4 Cumulative Impacts

The total potential environmental impacts which would be associated with the HWCTR decommissioning are small. Each alternative entails negligible potential impacts on water quality, air quality, soils, terrestrial biota and endangered or threatened species. The socioeconomic impacts of each alternative would also be minor. Off-site impacts would be minimal and limited to those associated with transportation of radioactive materials and wastes of types and quantities which are routinely shipped around the country.

Cumulative impacts result from the incremental impact of the HWCTR decommissioning when added to other past, present and foreseeable future actions at SRS. Considered in the context of such actions, the principal cumulative effects of the HWCTR decommissioning are positive ones - to eliminate or reduce a radiological hazard in a part of the site designated for administrative use in future years and to serve as a pilot program for decommissioning of other nuclear reactors at the site. The impacts associated with transportation and disposal of wastes from the decommissioning have already been taken into account in reference 3.

5.6 Effectiveness of Each Alternative

In sections 5.7 through 5.10, the effectiveness of each removal alternative is addressed. Effectiveness is considered in terms of:

- Environmental protection,
- The health and safety of workers and the public,
- The Applicable or Relevant and Appropriate Requirement, or ARARs, and
- The achievement of the removal objectives of section 4.1.

5.7 Environmental Protection

5.7.1 Policy

The HWCTR Decommissioning Project Plan, reference 2, summarizes the policy of DOE and WSRC regarding compliance with all environmental laws and regulations and all national environmental goals.

As noted previously, the HWCTR decommissioning will be carried out as a non-time critical removal action under the Comprehensive Environmental Response, Compensation and Liability Act. HWCTR will be the first decommissioning project at SRS carried out in this fashion. Section 5.9 identifies the Applicable or Relevant and Appropriate Requirements associated with environmental laws which will apply to the HWCTR project.

5.7.2 Implementation

Compliance with both federal and state regulations will be implemented through a series of programs and procedures specifically written to address the regulatory requirements. The principal document used to ensure that this policy is carried out will be the HWCTR Decommissioning Plan.

5.7.3 Dismantlement

Potential environmental impacts of the dismantlement approach include those associated with (1) the removal of radioactive equipment and structural materials and dismantlement of the structure, (2) the transportation of the radioactivity to waste disposal or recycling facilities and (3) the disposal of radioactive waste in the SRS disposal facilities. Once the dismantlement is completed, and final radiological surveys verify that the applicable cleanup standards have been met, there would be no significant environmental impact on the site property since it will have been effectively restored to its pre-construction state.

In section 5.5, the potential environmental impacts which could be associated with the decommissioning were considered in detail and found to be small.

5.7.4 Partial Dismantlement and Interim Safe Storage

Potential environmental impacts associated with this decommissioning alternative include (1) those connected with removal of radioactive equipment, (2) those from transporting radioactive materials, (3) those at the waste disposal facilities and (4) those from radioactive materials which remain inside of the reactor building.

The review described in section 5.5 of potential environmental impacts which could be associated with the decommissioning showed that the potential impacts of this alternative would be small.

5.7.5 Partial Dismantlement and Beneficial Reuse

Potential environmental impacts associated with this approach include (1) those related to equipment removal, (2) those from transportation of radioactive material, (3) those at the waste disposal facilities, (4) those from the radioactivity remaining in the facility and (5) those related to storage of the waste in the building.

The discussion in section 5.5 shows that the potential environmental impacts which could be associated with the decommissioning work would be small.

The potential environmental impact associated with storage of material in the facility would obviously depend on the type and amount of material. Since this study addresses a generic waste storage scenario, assumptions must be made to estimate the potential environmental impact of storing waste materials in the HWCTR containment building. If one makes the assumption that transuranic wastes would be stored in the building, similar to the EBWR plan, an estimate can be made of the potential environmental impact, drawing on the EBWR experience.

An evaluation of the potential environmental impacts of the EBWR transuranic waste storage plan was performed as part of an environmental assessment of proposed upgrading of waste storage facilities at Argonne National Laboratory. This study indicated that the proposed actions would not adversely affect the surrounding environment. It concluded that the environmental consequences of the related construction work would be localized to the building site and that the environmental impact of operations would be minimal.

5.7.6 Entombment

With the entombment approach, all of the radioactivity would be fixed in a concrete structure and the external dose rate would be essentially background. The tomb would be approximately 60 feet deep and 70 feet in diameter. Approximately three feet of the tomb would protrude above grade.

As indicated in section 5.5, the potential environmental impacts which could be associated with this alternative would be small.

5.8 Health and Safety of Workers and the Public

Measures to be taken to protect the health and safety of workers and the public during the HWCTR decommissioning are outlined in reference 2. In this section, these measures are summarized, then differences related to health and safety among the four alternatives are discussed.

5.8.1 Physical Security

Physical security for the HWCTR facility is provided at several levels. First, the general public is excluded because the facility is on the SRS government reservation, with armed guards providing access control to the site. Second, the HWCTR property is surrounded by a chain link fence with appropriate security measures such as locks, warning signs, and key control by the facility custodian. These arrangements prevent access except by authorized project personnel or by visitors escorted by authorized personnel. Third, the entrances to each of the buildings at the HWCTR are secured by door locks, which are under the control of the custodian. Fourth, access by authorized personnel is administratively controlled by WSRC Procedure RP 18.0201, *Inactive/Surplus Facilities Access Control*.

5.8.2 Occupational Safety and Health

Health and safety of site project personnel would be controlled by adherence to WSRC Manual 8Q, *Employee Safety Manual*. A Health and Safety Plan specifically for the HWCTR would be in effect. Also, 29 CFR 1926 *Occupational Safety and Health Administration Standards for Construction*, and 29 CFR 1910 *Occupational Safety and Health Administration Standards for General Industry* would apply. Where variances to these requirements are necessary, they will be pursued in accordance with DOE Order 5483.1A, *Occupational Safety and Health Program for DOE Contractor Employees at Government-Owned and Contractor-Operated Facilities*.

Occupational safety and health of decommissioning subcontractor personnel will also be controlled by adherence to the standards listed above.

Industrial hygiene and safety support will be provided by the decommissioning subcontractor. Safety oversight will be provided by the WSRC Occupational Safety and Hygiene Department.

5.8.3 Radiation Protection

All radiological work at HWCTR will be performed in accordance with the SRS radiological protection program, as specified in the WSRC 5Q Manual, *Radiological Control*. This program complies with the following requirements:

- 10CFR 835 - *Occupational Radiation Protection*,
- DOE/EH-0256T - *US DOE Radiological Control Manual*,
- DOE Order 5400.5 - *Radiation Protection of the Public and the Environment*, and
- DOE Order 5480.11 - *Radiation Protection for Occupational Workers*.

Elements of the SRS radiological control program include careful planning of the work, using only skilled and trained workers, briefing the workers, following detailed procedures and oversight by qualified radiological control personnel.

5.8.4 Minimizing Worker Radiation Exposure

The HWCTR project will have a formal program to ensure that radiation exposure associated with decommissioning operations is kept as low as reasonably achievable. Elements of this program will include establishing a Radiological Awareness Committee, conducting formal pre-job reviews and monitoring actual radiation exposure to identify trends and needed improvements.

Estimates of the approximate personnel radiation exposure associated with the different approaches are as follows:

- Dismantlement: 4 person-rem,
- Partial dismantlement and interim safe storage: 2 person-rem,
- Partial dismantlement and beneficial reuse: 4 person-rem, and
- Entombment: 1 person-rem.

These estimates are consistent with those of Table 1 which were made in 1976, when radioactive decay of cobalt-60, the chief source of external radiation exposure, is taken into account.

5.8.5 *Emergency Preparedness*

The WSRC 6Q Manual, *SRS Emergency Plan* describes the SRS emergency response program. The HWCTR Facility Custodian will be responsible for the implementation of this plan.

5.9 The Applicable or Relevant and Appropriate Requirements

These requirements referred to as ARARs, consist of those cleanup standards, standards of control, and other substantive requirements, criteria or limitations promulgated under federal environmental, state environmental or SRS siting laws that specifically address a hazardous substance, pollutant, contaminant, remedial action, location or other circumstance found at a CERCLA site.

The Applicable or Relevant and Appropriate Requirements for the HWCTR project include:

- The Comprehensive Environmental Response, Compensation and Liability Act (CERCLA)
- The Clean Air Act of 1970 (CAA),
- The Clean Water Act of 1977 (CWA),
- The Safe Drinking Water Act of 1974 (SDWA),
- The Resource Conservation and Recovery Act (RCRA),
- The Toxic Substances Control Act of 1976 (TSCA), and

- The Superfund Amendment and Reauthorization Act of 1986 (SARA).

Other federal regulations and DOE Orders which apply to the HWCTR project are listed in the DOE *Decommissioning Handbook*. In addition to federal regulations, the state of South Carolina has promulgated regulations that, in many cases, augment or exceed the requirements of the federal regulations. In such instances, the state regulations will govern the HWCTR project along with any required federal regulation. And, as noted previously, the U. S. Environmental Protection Agency's new radiation cleanup standard will apply to the HWCTR project when it goes into effect.

In accordance with DOE and WSRC policy, these regulations will be complied with, no matter which alternative is selected for the HWCTR decommissioning.

5.10 The Achievement of Removal Objectives

The HWCTR removal objectives are described in paragraph 4.1. Briefly, the seven objectives are: (1) minimizing risks, (2) providing flexibility for future uses of the property, (3) minimizing capital costs, (4) minimizing future surveillance and maintenance, (5) recycling materials as much as practicable, (6) providing information for the follow-on reactor decommissioning work at SRS, and (7) minimizing radioactive waste stream volumes where economically feasible.

5.10.1 Dismantlement

- (1) The dismantlement approach would entail low risks to both the workers and the public, as explained in section 5.4.
- (2) It would provide maximum flexibility for future uses of the property by releasing the site for unrestricted use.
- (3) The capital costs would be relatively high, as discussed in section 5.14.
- (4) Future surveillance and maintenance would be eliminated.
- (5) Recycling of materials would be maximized since all equipment would be removed from the facility and available for recycling.
- (6) This approach would provide extensive information for follow-on projects because it entails complete dismantlement, including removal of the reactor vessel. Procedures used and methods developed for the HWCTR could be adapted to the larger SRS production reactors in many cases.
- (7) This approach would generate more waste stream volume than the others.

5.10.2 Partial Dismantlement and Interim Safe Storage

- (1) This approach also would entail low risks to both the workers and the public, as explained in section 5.4.
- (2) It would provide less flexibility for future uses of the property than the dismantlement approach because the site would not be released for unrestricted use.
- (3) The capital costs would be less than for complete dismantlement, as discussed in section 5.14.
- (4) Future surveillance and maintenance would be minimal, with inspections inside of the facility at approximately five-year intervals.
- (5) Recycling of materials would be significant since most equipment would be removed from the facility and available for recycling.
- (6) This approach would provide extensive information for follow-on projects. Many of the procedures used and methods developed could be adapted to the larger SRS production reactors.
- (7) The waste stream volumes with this approach is lower than with dismantlement.

5.10.3 Partial Dismantlement and Beneficial Reuse

- (1) This approach also would entail low risks to both the workers and the public, as explained in section 5.4.
- (2) It would provide no flexibility for future uses of the property other than storage.
- (3) The capital costs would be substantial, as discussed in section 5.14.
- (4) Future surveillance and maintenance costs would be significant, since the facility would still be in use.
- (5) Recycling of materials would be significant as with the dismantlement approach, since all equipment would be removed from the facility and available for recycling.
- (6) This approach would provide extensive information for follow-on projects. Many of the procedures used and methods developed could be adapted to the larger SRS production reactors.
- (7) The volumes of waste streams with this approach would be lower than with dismantlement but higher than with the other alternatives.

5.10.4 Entombment

- (1) Like the others, this approach also would entail low risks to both the workers and the public, as explained in section 5.4.
- (2) It would provide some flexibility for future uses of the property, even though the entombment would require minimal controls.
- (3) The capital costs would be less than for the other approaches, as discussed in section 5.14.
- (4) Future surveillance and maintenance would be minimal.
- (5) Recycling of materials would be less significant as with the other approaches, since most of the equipment would not be available for recycling.
- (6) This approach would provide less information for follow-on projects than would the other alternatives, although some of the procedures used and methods developed could be adapted to the larger SRS production reactors.
- (7) The waste stream volumes would be low with this approach.

5.11 Ease of Implementation

5.11.1 Technical Feasibility

Experience has shown that all alternatives are technically feasible. Ample precedents exist, including the examples cited in section 5.1.

Detailed information on decontamination and decommissioning technologies appears in a number of sources, such as the DOE *Decommissioning Handbook*. The national and international literature on this subject is available through DOE's information clearinghouse - the Remedial Action Program Information Center in Oak Ridge, Tennessee.

The development of innovative technologies for nuclear decontamination and decommissioning work is sponsored by DOE through several initiatives, including its Morgantown Energy Technology Center in Morgantown, West Virginia, which is presently sponsoring two nuclear reactor decommissioning projects in the DOE weapons complex. These are the 105-C Reactor decommissioning at Hanford, Washington and the CP-5 Reactor decommissioning at the Argonne National Laboratory in Illinois. Experience gained from both of these projects will become available for the HWCTR project.

5.11.2 Equipment, Personnel, and Support Services Availability

Special equipment needed to decommission the HWCTR is available, regardless of the option chosen. Such equipment includes:

- A 125-ton minimum capacity mobile crane,
- Special lifting and handling equipment for components such as the reactor vessel and steam generators,
- Concrete removal equipment,
- Metal segmenting equipment to cut up structural steel, piping, tanks, etc.
- Surface decontamination equipment for purposes such as removing paint containing lead or PCBs.

There are a number of firms in the United States that are experienced in nuclear facility decontamination and decommissioning work.

Support services needed for the decommissioning work are readily available. These include:

- Analytical laboratory services,
- Radiological control technician services,
- Rigging and handling services,
- Radioactive piping cutting services,
- Radioactive concrete cutting services, and
- Radioactive facility demolition services.

5.11.3 Administrative Feasibility of Licenses and Easements

There are no known licenses that currently apply to SRS that would influence this alternatives study or its implementation during decommissioning of the HWCTR facility. Nor has any future licensing need which would impact the decommissioning been found.

Likewise, there are no known easements that currently apply at SRS which would influence this alternatives study or its implementation. And no future easement been found which would impact the decommissioning.

5.12 Nature and Amount of Waste Generated

5.12.1 Types of Wastes

Different types of waste materials that will be generated during the decommissioning work include:

- Low-level radioactive waste,
- Hazardous waste such as that containing lead, PCBs and asbestos,
- Mixed waste that is both hazardous and radioactive,
- Nonradioactive solid waste.

Although transuranic radionuclides such as plutonium-239 are present in the HWCTR in trace amounts, the concentrations are low enough to preclude having to classify any waste materials as transuranic waste.

5.12.2 The Form of the Waste Materials

The HWCTR project waste will include:

- *Various pieces of equipment such as the reactor vessel assembly, steam generators, pumps, tanks, heat exchangers, lead-shielded casks, etc.* Appendix B lists approximately 75 different items, along with their location, size, weight and other information. Nearly all of this equipment is expected to be radioactive. Decontamination to permit unrestricted release will likely not be cost effective. Note that much of this equipment can be recycled to recover usable metals as explained in section 5.13.
- *Radioactive concrete.* The inside of the biological shield is radioactive from neutron activation. Concrete on the floors is contaminated, especially in crevices.
- *Radioactive imbedded piping.* Piping that pierces the concrete biological shield is radioactive. It would be removed in the dismantlement alternative. Piping associated with floor drains is also radioactive. Some of this runs through the spent fuel basin shield wall. All radioactive imbedded piping would be removed with the dismantlement approach.
- *Radioactive ventilation equipment.* It is anticipated that all of the building ventilation ducting and other ventilation equipment will prove to be radioactive.

- *Radioactive structural steel.* Some structural steel in the facility is radioactive. Most of this material can be recycled. The dome itself contains approximately 170 tons of structural steel. With the dismantlement and entombment approaches, the dome would be taken apart.
- *Job-control waste.* These waste materials will be produced during the decommissioning work. They will include things such as rags, plastic radiological containments and small tools.

No contaminated soil is included in estimates related to the HWCTR decommissioning because soil remediation, should any become necessary, will be handled as a separate environmental restoration activity.

5.12.3 Waste Packaging

The radioactive and mixed waste will be packaged in accordance with the WSRC 1S Manual *Waste Acceptance Criteria*. It is expected that much of this material will be packaged in B-25 boxes, standard carbon steel containers which are six feet long, four feet wide and four feet high. Each B-25 box will hold up to 98 cubic feet of waste. The maximum allowable weight of 5000 pounds per box will be a limiting factor for some materials. For example, only 33 cubic feet of concrete weighing 150 pounds per cubic foot could be put into a single B-25 box. Figure 32 shows B-25 boxes.

Other large containers such as "sea-land containers" would be used as practicable to minimize segmenting of equipment and structural steel for recycling. These containers are typically 20 or 40 feet long. Such containers would be used to transport the material to the recycling facility, but they cannot be used for disposal of radioactive waste.

Medium-sized equipment such as heat exchangers, coolers and small tanks would be segmented as necessary and placed in containers for disposal or recycling. Large equipment such as the reactor vessel and steam generators, if removed under the dismantlement or partial dismantlement and beneficial reuse alternatives, are expected to be sealed by welding steel blanks over nozzle openings, so that they, in effect, serve as their own strong, tight containers.

5.12.4 Waste Disposal Sites

Present plans call for the low-level radioactive waste associated with the HWCTR project to go to SRS disposal facilities. All low-level waste except for large equipment would go into the E-Area Vaults. This facility is shown in Figure 33.

Large radioactive equipment would likely be sent to the SRS Solid Waste Disposal Facility for shallow land burial in engineered trenches, such as the one shown in Figure 32.

Mixed waste would be stored at SRS in an approved mixed waste storage facility pending disposition under the Federal Facility Compliance Act. It is expected that the HWCTR mixed waste will be processed under the *SRS Mixed Waste Approved Site Treatment Plan*. Hazardous waste would be disposed of by a hazardous waste contractor at a suitable treatment-storage-disposal facility.

These plans are consistent with those expressed in the *SRS Waste Management Final Environmental Impact Statement* of July 1995.

5.12.5 Waste Minimization Program

A variety of methods will be used to minimize waste associated with the HWCTR decommissioning, among them:

- Material taken into the facility which might become waste during the decommissioning work will be kept to a minimum,
- Waste materials will be segregated into different waste types as much as practicable as they are generated,
- Commercially available size reduction techniques such as supercompaction, metal melting and incineration will be used to reduce waste volume, and
- Metals such as stainless steel, carbon steel and lead will be recycled as much as practicable.

These methods are consistent with waste management practices described in reference 3.

5.12.6 Dismantlement

Approximate waste volumes for the dismantlement alternative would be in the range of:

- Low-level radioactive waste: 19,250 cubic feet. Radioactive concrete from the biological shield would make up approximately 3800 cubic feet of this amount. Approximately 540 cubic feet of contaminated concrete would be removed from floors in the facility
- Mixed waste (both hazardous and radioactive): 280 cubic feet,
- Non-radioactive solid waste: 24,800 cubic feet with the underground structure removed to minus five feet, 40,300 cubic feet with the structure removed to minus 16 feet and 72,400 cubic feet if all of the underground structure were removed.

These estimates are based on the following assumptions:

- Eighty percent of equipment and piping in the facility, by volume, is radioactive.
- Radioactive equipment includes the reactor vessel assembly, the steam generators, the entire steam system including the muffler, the underground tank, and most piping and equipment in fluid systems.
- An average depth of eight inches of concrete in the biological shield surrounding the core region is radioactive,
- Concrete floors are radioactive to an average depth of two inches,
- Estimates for concrete are based on disposal volume in B-25 boxes considering the 5000 pound per box weight limit, except for the lower axial biological shield,
- The 170-ton steel dome is not radioactive,
- An average of approximately seven cubic feet of incidental low level radioactive waste would be generated each day during removal of radioactive equipment (a type of waste commonly called job control waste), and

PCB waste and other hazardous wastes would also be generated.

These estimated waste volumes can be accommodated in the SRS disposal facilities planned for use. They are consistent with estimates for future site facility decontamination and decommissioning work contained in the *SRS Waste Management Final Environmental Impact Statement*. More detailed information on these estimates, and the ones which follow, will be available from WSRC.

5.12.7 Partial Dismantlement and Interim Safe Storage

This alternative would entail removing all of the equipment except the reactor vessel and the two steam generators. The dome would remain in place.

Approximate waste volumes for this alternative would be in the range of:

- Low-level radioactive waste: 5,400 cubic feet,
- Mixed waste: 280 cubic feet,
- Non-radioactive solid waste: 2,850 cubic feet.

These estimates are based on assumptions similar to those used in the dismantlement alternative estimate, taking into account differences between the two approaches. PCB waste and other hazardous wastes would also be generated.

These estimated waste volumes, less than for the dismantlement alternative, can be accommodated in the SRS disposal facilities planned for use on the HWCTR project.

5.12.8 Partial Dismantlement and Beneficial Reuse

This option would entail approximately 60 percent of the equipment removal associated with the complete dismantlement alternative. The dome would remain in place, along with embedded radioactive piping. Decontamination of areas such as concrete floors would be limited to that necessary to establish radioactive material storage area controls.

Approximate waste volumes for this alternative would be in the range of:

- Low-level radioactive waste: 11,600 cubic feet,
- Mixed waste: 280 cubic feet,
- Non-radioactive solid waste: 2,200 cubic feet.

These estimates are based on assumptions similar to those used in the dismantlement and partial dismantlement and interim safe storage waste estimates, taking into account difference between the approaches.

PCB waste and other hazardous wastes would also be generated.

These estimated waste volumes, less than for the dismantlement alternative, can be accommodated in the SRS disposal facilities planned for use on the HWCTR project.

5.12.9 Entombment

This alternative generates the least amount of waste to be removed and disposed of. Only the hazardous materials and mixed waste, and equipment above the 0-level floor would be removed, along with the containment dome.

Approximate waste volumes for this alternative would be in the range of:

- Low-level radioactive waste: 2,380 cubic feet,
- Mixed waste: 280 cubic feet,
- Non-radioactive solid waste: 8,800 cubic feet.

These estimates are based on assumptions similar to those used in the other waste estimates, taking into account differences between the approaches.

PCB waste and other hazardous wastes would also be generated.

5.13 Material Recycle/Reuse Opportunities

5.13.1 Reuse Opportunities

There are no significant opportunities for reuse of the HWCTR equipment, given its age and condition. Possible reuse of the building itself for another purpose is addressed in the partial dismantlement and beneficial reuse alternative.

5.13.2 Recycle Opportunities

Potential metal recycling opportunities include:

- Carbon steel and stainless steel piping,
- Structural steel including the containment dome,
- The steam generators,
- The refueling machine (transfer coffin),
- Heat exchangers and coolers,
- Lead-shield casks,
- Stainless steel deionizer and filter vessels,
- Some lead bricks and lead sheet,
- The 7165-gallon heavy water tank, the 15,000-gallon emergency deluge tank, the 8000-gallon underground waste water tank and smaller tanks,
- The steam muffler, and
- The ventilation exhaust stack.

This list is not all inclusive; other equipment could be recycled as well. Note that the radioactive equipment and material, which includes most items listed, would have to be recycled by a commercial vendor licensed for such work.

The most opportunities for recycling would be realized if the dismantlement alternative were chosen. The entombment alternative would offer the fewest opportunities for recycling.

Note that in mid-1996, disposal of radioactive recyclable metals at SRS as low level radioactive waste was less costly than recycling them.

5.14 Cost

5.14.1 Methodology For Cost Estimates

An activity-based cost approach was used. Each major task was divided into its individual cost components. Where appropriate, tasks were further divided into subtasks. Crew labor composition, equipment necessary and material costs were detailed on each task estimate worksheet.

Markups were applied to the estimates for overhead, profit, bonds and contingencies. Percentages for markups were: overhead 20 percent, profit 10 percent, bond three percent and contingency 20 percent. These figures were based on cost engineering judgment and experience.

The estimates, which are in 1996 dollars, are considered conceptual because work plans for the project are not yet developed.

5.14.2 Cost Estimates for Each Alternative

Table 6 on the next page shows the costs of the four different alternatives.

The dismantlement alternative costs are estimated to be:

- Option 1 - structure removal to minus five feet: \$15,821,949,
- Option 2 - structure removal to minus 16 feet: \$17,142,999,
- Option 3 - removal of entire underground structure: \$24,259,057.

The cost of the partial dismantlement and interim safe storage alternative is estimated to be:

- Option 1 - steam generators removed: \$8,956,149,
- Option 2 - steam generators remain in place: \$8,692,523.

The partial dismantlement and beneficial reuse alternative is estimated to cost \$14,424,291. This figure does not include the expenses associated with establishing the facility as a storage area. These costs would add an amount in the range of \$2.6 million, based on the cost of setting up the former EBWR containment building as a storage facility for transuranic waste.

Table 6 Cost of Different Alternatives

Task	Dismantle	PD&ISS*	Reuse	Entomb
Mobilization at site	\$95,746	\$95,746	\$95,746	\$95,746
Refurbish polar crane and place in service	122,428	122,428	122,428	N/A
Remove radioactive equipment	765,877	538,291	197,504	152,780
Remove all equipment above 0-level	72,315	N/A	N/A	72,315
Modify dome for large equipment removal	17,560	17,560	17,560	17,560
Remove steam generators	263,626	N/A	263,626	N/A
Seal steam generators by welding	87,876	87,876	87,876	87,876
Remove reactor vessel	507,808	N/A	507,808	N/A
Seal reactor vessel by cutting and welding	217,769	217,769	217,769	217,769
Remove lead-based paint	564,909	96,841	96,841	564,909
Remove PCBs	174,314	174,314	174,314	174,314
Remove other hazardous material	174,314	174,314	174,314	174,314
Decontaminate concrete	157,807	23,476	104,334	N/A
Remove activated concrete in bioshield	132,616	N/A	132,616	N/A
Remove structure to -5 feet	449,953	N/A	N/A	N/A
Remove structure to -16 feet	835,889	N/A	N/A	N/A
Remove structure to -52 feet	2,879,642	N/A	N/A	N/A
Remove underground tank	51,110	51,110	51,110	51,110
Remove muffler and underground steam line	212,562	212,562	212,562	212,562
Remove ventilation exhaust stack	230,103	230,103	230,103	230,103
Remove radioactive imbedded piping	335,451	N/A	335,451	N/A
Remove containment dome	688,837	N/A	N/A	688,837
Restore patch in containment dome	N/A	199,741	199,741	N/A
Seal all building openings	N/A	12,001	N/A	N/A
Establish remote monitoring equipment	N/A	256,320	N/A	N/A
Bring building up the latest codes for reuse	N/A	N/A	3,525,813	N/A
Modify building to support reuse	N/A	N/A	N/A	N/A
Waste disposal - option 1, -5 feet (baseline)	5,518,009	1,849,912	3,358,162	2,560,411
Waste disposal - option 2, -16 feet	6,453,123	N/A	N/A	N/A
Waste disposal - option 3, -52 feet	11,525,428	N/A	N/A	N/A
Backfill cavity with concrete	N/A	N/A	N/A	597,105
Backfill cavity with earth	121,829	N/A	N/A	121,829
Seal entombment with waterproof membrane	N/A	N/A	N/A	18,952
Final radiological survey	2,162,519	1,621,998	1,621,998	261,549
SRS engineering and planning support	2,066,355	2,066,355	2,066,355	2,066,355
Other costs	630,257	643,795	630,257	706,074
Total cost for each alternative**	\$15,821,949	\$8,692,523	\$14,424,291	\$8,950,641

*PD&ISS is Partial Dismantlement and Interim Safe Storage. **Note that the total costs are for the baseline cases

The cost of the entombment alternative is estimated to be:

- Option 1 - cavity filled with concrete: \$8,950,641,
- Option 2 - Cavity filled with earth: \$8,475,365.

5.14.3 Assumptions Used in Making Cost Estimates

The following assumptions were made in preparing cost estimates for the different alternatives:

- These will be no impact on the HWCTR decommissioning from possible environmental restoration activities in the vicinity ,
- The 12-foot wide, 17-foot high opening in the containment building will have to be further enlarged to facilitate removal of large equipment such as the reactor vessel and steam generators
- Refurbishment of the 25-ton polar crane would prove cost effective compared to use of other lifting apparatus for removing equipment,
- Waste volumes would be as estimated in section 5.12,
- Equipment would be recycled as described in section 5.13.2.

5.15 Schedule

5.15.1 Dismantlement

The schedule for the dismantlement alternative appears in Appendix C. Please note the following points:

- It is divided into five broad phases.
- Phase I, which entailed demolishing outbuildings, has been completed.
- Phase II is presently underway, with tasks 5 through 8 completed. It is scheduled for completion with selection of the preferred decommissioning alternative by September 30, 1996.
- Phase III would start with the beginning of FY 97 and end 24 months later with removal of all piping and equipment completed, except for the reactor vessel, steam generators and large pumps.

- Phase IV, which would entail removal of the large equipment, would start on October 1, 1998 and complete on March 1, 2000.
- Phase V would extend from January 1, 1999 until September 30, 2002, ending with dismantlement completed and the property in a "greenfield" condition.

Overall, the planning and preparation portions of the project would take approximately three years and three months, with most of this period already completed. The execution phases would span five years and six months. This schedule is similar to the one which appears in the *Decommissioning Project Plan*, reference 2. It also is comparable to the actual completion schedule for the EBWR decommissioning project.

5.15.2 Partial Dismantlement and Interim Safe Storage

Appendix D shows the schedule for this approach. Note that:

- Phases I and II are identical to the dismantlement alternative.
- Phase III runs until October 1, 1998, as with the dismantlement alternative.
- Phase IV, which entails isolating the reactor vessel and steam generators, overlaps Phase III, proceeding from April 1, 1998 until January 1, 1999.
- Phase V, which completes the cocooning of the reactor ends on May 15, 2000.

With this alternative, the planning and preparation work schedule is similar to the schedule for dismantlement. The execution phases of the partial dismantlement and interim safe storage process would take approximately three years, one and one-half months.

5.15.3 Partial Dismantlement and Building Reuse

Appendix E shows the schedule for this approach. Note that:

- Phases I and II are identical to the dismantlement alternative.
- Phase III runs until October 1, 1998, as with the dismantlement alternative.
- Phase IV, as with the dismantlement alternative, proceeds from October 1, 1998 until March 1, 2000.
- Phase V, which ends with materials stored in the facility, finishes on May 1, 2002.

With this alternative, the planning and preparation work schedule is similar to the schedule for dismantlement. The execution phases would take approximately five years and one month.

5.15.4 Entombment

Appendix F shows the schedule for the entombment approach. Note that:

- As before, phases I and II are identical to the dismantlement alternative.
- Phase III runs until January 30, 1998.
- Phase IV - removing the underground tank, the muffler, the underground steam line and the dome - proceeds from February 2, 1998 until July 1, 1998.
- Phase V, which includes filling the cavity with concrete, finishes on June 1, 1999.

With this alternative, the planning and preparation work schedule is similar to the others. The execution phases would take approximately two years and two months.

6.0 REMOVAL ALTERNATIVE COMPARATIVE ANALYSIS

Table 7 on the next page reflects the results of the analysis, ranking the alternatives in 11 different areas. These areas include those which reference 1 recommends taking into account: effectiveness, "implementability" and cost. The highest total represents the optimum alternative.

Table 7 Ranking of Alternatives Studied

Attribute	Weight	Dismantle	PD&ISS*	Reuse	Entomb
1. Protects environment	4	4	2	2	3
2. Minimizes risk to public	4	4	3	3	3
3. Minimizes risk to workers	3	2	3	2	4
4. Meets Applicable or Relevant and Appropriate Requirements	3	4	4	4	4
5. Flexibility in future use of property	3	4	2	2	2
6. Ease of Implementation	3	3	4	3	4
7. Minimizes capital costs	4	2	4	2	4
8. Minimizes surveillance and maintenance costs	1	4	2	2	3
9. Minimizes scheduled time for accomplishment	2	2	3	2	4
10. Value as demonstration project	3	4	2	3	2
11. Recycles materials	1	4	3	3	2
Total points	-	38	31	29	35
Total points (weighted)	-	103	92	79	101

* PD&ISS is Partial Dismantlement and Interim Safe Storage.

Note that this table assigns relative weights of either one, two, three or four to each attribute, depending upon its importance. The alternatives are ranked from one to four to reflect the degree to which each attribute satisfies the removal action objectives, with four being the highest value.

6.1 Protecting the Environment

Because only moderate amounts of radioactive materials remain in the HWCTR, and considering that handling of this material will be closely controlled as explained previously, all four approaches protect the environment well.

The dismantlement alternative, the only approach which would result in an unrestricted release of the property, ranks highest in this category. One can consider that the radioactivity in the HWCTR facility is merely being moved from one part of the SRS to another, to E-Area. But E-Area has been devoted to radioactive waste storage and the

radioactive waste from the HWCTR project would make up only a small fraction of the amount disposed of there. The disposal of radioactive waste in E-Area has been evaluated in detail in connection with the *SRS Waste Management Final Environmental Impact Statement*.

The partial dismantlement and interim safe storage and the beneficial reuse options rank lowest in protecting the environment because radioactivity remains on the HWCTR property in both cases. The entombment approach was assigned a medium value because of the durability of the concrete monolith in which the radioactivity would be imbedded.

6.2 Minimizing Risks to the Public

Each alternative would do an effective job of minimizing risks to the public. Risk to the public would be low in every case because the HWCTR facility contains only moderate amounts of radioactive materials and it is located three miles from the nearest SRS property boundary. The results of studying risks inherent with the decommissioning work as described in section 5.4 reflect this conclusion.

Once again, the dismantlement approach ranks highest because it would leave the site with no significant residual radioactivity; radioactivity would remain on the property in each of the other cases

6.3 Minimizing Risks to Workers

Risks to those performing the decommissioning work would be low with any alternative as discussed in section 5.4. Such risks come chiefly from the industrial activity involved and the occupational radiation exposure to the workers.

Entombment ranks highest in this category because it would entail the least work and the lowest worker radiation exposure. The dismantlement and beneficial reuse approaches rank lowest because the opposite is true in those cases. Partial dismantlement and interim safe storage ranks in between.

6.4 Meeting Requirements

All alternatives would satisfy the Applicable or Relevant and Appropriate Requirements identified in section 5.9.

6.5 Flexibility in Use of the Property

The dismantlement alternative ranks highest in this regard because it would leave the property effectively restored to its pre-construction state, with no restrictions on its use. In each of the other cases, restrictions would apply. The partial dismantlement and interim safe storage approach would require continuing institutional controls. The beneficial reuse

option would as well. The entombment approach would also necessitate limited institutional controls for a long period.

One can argue that consideration of future uses of a two-acre site on a 310-square-mile federal reservation carries little importance. But the location of the HWCTR site inside of B-Area increases the importance of this factor. B-Area lies outside of the central nuclear industrial zone of SRS, as well as outside of the SRS radioactive materials storage and disposal area (E-Area), and future SRS property use plans indicate that B-Area will be utilized for administrative purposes only.

6.6 Ease of implementation

Any of the four alternatives could be implemented without special difficulties. Precedents exist for each one. Necessary equipment and support services are available. A number of companies have extensive experience with such nuclear decommissioning work. There are no major differences among the different alternatives in ease of implementation.

6.7 Minimizing Capital Costs

The partial dismantlement and interim safe storage approach ranks highest in this area, having the lowest estimated capital cost of \$8,692,523. The entombment alternative ranks essentially the same at \$8,950,641. Dismantlement at \$15,821,949 ranks third. The estimated costs of the dismantlement and beneficial reuse alternative are highest at \$14,424,291, plus the expense of setting up the facility for an alternate use - approximately \$2,600,000 based on the EBWR experience.

6.8 Surveillance and Maintenance Costs

The dismantlement approach obviously ranks highest here because it would have no surveillance and maintenance associated with it. Entombment, which entails minimal costs, ranks second. The surveillance and maintenance costs associated with the partial dismantlement and interim safe storage approach would be somewhat greater but also small, since inspections of the inside of the facility would be limited to five-year intervals. The beneficial reuse approach ranks lowest in this area because the building would continue to be an active facility which would require higher costs for more frequent surveillance and maintenance. But even in this case, the costs involved would be small compared to the capital cost of the decommissioning work.

6.9 Schedules

The schedule for each alternative appears below:

*PD&ISS is Partial Dismantlement and Interim Safe Storage.

Figure 34. Schedule Comparison

As can be seen, entombment ranks highest in this category by having the shortest schedule. Partial dismantlement and interim safe storage is ranked second. Dismantlement and beneficial reuse both have relatively long schedules compared to the other two approaches.

6.10 Value as a Demonstration Project

This factor compares how well procedures, methods and experience from the HWCTR project could be applied to decommissioning of the five large nuclear weapons material production reactors at the site. As noted previously, the HWCTR decommissioning is intended by DOE to serve as a prototype for the SRS nuclear reactor decommissioning program.

Attempting to judge the different alternatives in this area is complicated by a lack of definitive plans for decommissioning of the other five reactors. That is, the best approach to follow with those facilities has not yet been determined.

But even given this situation, one can roughly estimate the relative value of the different alternatives for the HWCTR decommissioning in serving as a demonstration project for this work. All four alternatives would provide some benefit. The dismantlement approach would provide the most because it would entail a broader range of activities, including removal of the reactor vessel and total dismantlement of the facility. The entombment approach would provide the least value as a demonstration project because it would entail the least number of different activities. The other two HWCTR alternatives would rank between these two extremes.

6.11 Recycling Materials

The dismantlement option ranks highest in the category because it affords the most opportunities for recycling of materials, including the 170 tons of steel in the containment dome. The entombment approach would afford the fewest opportunities to recycle materials. The other two alternatives fall in between these extremes, and are approximately equal in this area.

7.0 RECOMMENDED REMOVAL ALTERNATIVE

For reasons explained below, dismantlement has been selected as the preferred removal action alternative for the HWCTR decommissioning. Option 1, which entails removal of the concrete structure five feet below grade, is preferred because of lower costs.

7.1 The Highest Ranking in the Comparative Analysis

As shown in Table 7, dismantlement ranked the highest of the four alternatives studied when 11 different factors were compared. These factors include those recommended by DOE in reference 1 for such comparisons.

7.2 The Best Prototype for Reactor Decommissionings

Since DOE intends for the HWCTR decommissioning to serve as the prototype for decommissioning of the other, larger SRS reactors, this factor, even though it was not afforded greater weight in the comparative analysis, remains an especially important one in the alternatives selection process. Dismantlement ranked highest in this category because it would entail a broader range of decommissioning activities than the other approaches, and, consequently, provide a better learning experience.

7.3 Greatest Flexibility in Use of the Property

Of the four alternatives studied, only dismantlement would result in the HWCTR property becoming available for unrestricted use. Each of the other choices would entail restrictions. The partial dismantlement and interim safe storage and the beneficial reuse options would result in continued radiological controls of the facility. Entombment would leave radioactivity imbedded in a concrete monolith in the middle of the HWCTR property.

7.4 Most Compatible With SRS Property Reuse Plans

The dismantlement approach is most compatible with reuse plans for the SRS property. These plans call for B-Area, within which HWCTR is located, to serve as an administrative area. This property is outside of the area at SRS where most nuclear facilities are located. Allowing radioactivity to remain with B-Area is therefore counter to present plans for future use of this area.

7.5 Impact on the Environment Is Small

While the potential environmental impacts of all alternatives are small, removing all of the radioactivity from the HWCTR property by adopting the dismantlement alternative would leave the environment inside U-Area and B-Area in the most pristine condition. The radioactivity from the decommissioning would end up in E-Area, inside engineered trenches and the E-Area Vaults. The amount of radioactivity from the HWCTR project would be small compared to that present and planned for these facilities. It would be disposed of within the central area of SRS near other nuclear facilities. Studies documented in reference 3 show that radioactive materials in these disposal facilities do not pose a significant environmental threat.

7.6 Risks to the Public Are Low

As with the other alternatives, risks to the public associated with the dismantlement approach are minimal. Because all radioactivity would be removed from the HWCTR property, risks to the public after the dismantlement is completed would be somewhat lower than with the other approaches.

7.7 Risks to the Workers Are Low

Risks to the workers from the dismantlement process are low, as with the other alternatives.

7.8 Adequate funding Should Be Available

The dismantlement alternative is estimated to cost approximately \$15.8 million. Sufficient funding for carrying out this alternative is expected to be available.

7.9 The Partial Dismantlement and Interim Safe Storage Option Leaves Most Radioactivity In the Facility

The partial dismantlement and interim safe storage alternative would leave the reactor vessel, which contains more than 99 percent of the radioactivity in the facility, in place. Even though the vessel would be effectively sealed, this situation does not represent a long-term solution to disposition of the radioactivity. Eventually, more work would be needed to complete the decommissioning process of the HWCTR. Note that DOE plans to eventually remove the radioactive reactor block from the cocooned 105-C Reactor at Hanford, which served as a model of this concept for the HWCTR.

7.10 The Beneficial Reuse Option Is Not Cost-Effective

The beneficial reuse option is expensive, with an estimated cost, including the expense of setting up the facility for an alternate use, of approximately \$17 million. The facility would have only about 12,000 square feet of effective floor space for storing material. Using just the \$2.6 million figure from setting up the EBWR as a storage facility for storing transuranic

waste, the cost would be \$217 per square foot. If the cost of the decommissioning work were figured in as well, this amount would rise to \$1,416 per square foot.

To date, no material to be stored in the HWCTR facility has been identified. And there are other, less-expensive storage areas available at SRS.

7.11 The Entombment Approach Has Major Disadvantages

While entombment is considered to be a technically-viable approach with certain advantages, it also has major drawbacks. For the HWCTR project, equipment inside of the entombed structure would remain radioactive by today's standards for hundreds of years. And, as the Air Force found in its study of the entombed reactor at Wright-Patterson Air Force Base, removing radioactivity from an entombed reactor, should this ever become necessary, is an extremely costly undertaking.

Appendix A

Illustrations and Photographs

Figure 2. Location of the HWCTR on the Savannah River Site. The HWCTR property, shown in the lower part of the inset, comprises U-Area. U-Area lies within B-Area, which is designated an administrative area in long-term site property plans.

ANALYSIS OF HWCTR REMOVAL ALTERNATIVES

Figure 3. The HWCTR Property

Figure 4. Cutaway View of the HWCTR Facility. The containment structure is 70 feet in diameter and 125 feet high. The steel dome rises approximately 65 feet above ground level. The below ground section is made of reinforced concrete.

Figure 5. The HWCTR Model. This model was used in determining equipment layouts when the facility was being built. This view shows the above-ground part of the containment building with the steel shell removed. Note the 25-ton polar crane inside of the dome. The spent fuel basin is in the lower part of the picture. The black shapes on the 0-level floor are ten removable plugs, which are presently in place. The reinforced concrete floor is five feet thick.

Figure 6. The HWCTR Model - Underground View. The area in the upper part of this view is the left pump room at the -16-foot level. The room below is the left generator room at the -37-foot level. Steel grating on the floors is not shown. On the right you can see the reactor vessel. The stairs at the bottom right lead to the pin room below the vessel. You can see the left steam generator in the center of the photograph.

Figure 7. The HWCTR Model - Right Cyclone Room at the -52-Foot Level. Looking in from the outside of the model, you can see portions of the spent fuel basin purification system. This system was also used to process water from the building sump.

Figure 8. The HWCTR Model - Left Purification Room at -52-Foot Level. Here you can see the main cooling system heavy water storage tank, which provided makeup water to the plant and fed the hydraulic seal head tanks. The tank and all fluid systems connected to it are contaminated with radioactivity.

Figure 9. Part of the 0-Level Main Floor. Wooden planks covering the spent fuel basin can be seen on the right. Note the polar crane hook at upper right. During spent fuel handling in the basin, the hook was immersed in the basin water. The hook and crane cables remain radioactively contaminated.

Figure 10. Detail of 0-Level Floor Beside Spent Fuel Basin. Here you can see one of the removable floor plugs. Because the spent fuel basin overflowed, radioactive contamination is present in crevices in the floor. In this view the basin is on the upper right.

Figure 11. The Reactor Vessel Head. Covers for thermal insulation on top of the pressure vessel head can be seen here. The smaller pipes are pressure thimbles for the control rod drive mechanisms. The HWCTR operated at 1200 pounds per square inch (gauge). Pressure was maintained by a helium blanket inside of the vessel head. The reactor vessel assembly weighs 98 tons. It presently contains the control rods but no nuclear fuel, which was removed shortly after the final reactor shutdown in December of 1964.

Figure 12. The Refueling Machine. Known as the transfer coffin, this container was used about 70 times to remove fuel assemblies from the reactor and transfer them to the spent fuel basin. The refueling machine contains lead radiation shielding and weighs, with its movable support platform, approximately 80 tons. It is contaminated with radioactivity.

Figure 13. Right Pump Room at the -16-Foot Level. The top of the right steam generator can be seen here. Each of the two steam generators stands 23 feet high and weighs approximately 19 tons. Asbestos thermal insulation has been removed from the generators and in all but a few places in the HWCTR facility.

Figure 14. Main Coolant Piping. This section of ten inch diameter carbon steel piping runs near the ceiling in the left generator room. The hole in the pipe was cut during a 1975 radiological characterization study. This study showed low levels of cobalt-60, cesium-137 and plutonium-239 in the main coolant system, as well as in the two isolated coolant loops.

Figure 15. Shielded Casks. These two casks in the left purification room once held a deionizer vessel and a filter used in the spent fuel basin purification system. Because they contain lead radiation shielding, these casks, if radioactively contaminated, could become a mixed waste. Mixed waste, which is both hazardous and radioactive, presents special disposal problems. There are five other similar shielded casks in the HWCTR facility.

Figure 16. Radiation Hot Spot. This piping in the right cyclone room at the -52-foot level was determined to have a radiation level of 110 millirem per hour on contact, the highest accessible beta-gamma radiation level measured in recent years in the HWCTR facility. Radiation levels in most areas are less than one millirem per hour.

Figure 17. The Monitor Room at the -52-Foot Level. This room is located beneath the pin room. On the left you can see the sample station. In the middle stands the building sump pump, with the 350 gallon sump below. The box to the right in the picture contains delay coils for a photoneutron monitoring instrument. Lead bricks on the box could become mixed waste.

Figure 18. The Steam Muffler. This seven-foot-diameter silencer lies in a wooded area 100 meters east of the reactor building. It contains low levels of radioactive contamination which entered the steam system through leaking joints in the steam generators.

Figure 19, Construction Photograph Showing Base Mat. Here you can see the base mat - the reinforced concrete floor at the -52-foot level. In the center of the floor stand the monitor rooms walls.

Figure 20. The New HWCTR Reactor Vessel.

Figure 21. Construction Photograph Showing Reactor Vessel Outside of Building. In 1959, the vessel is positioned for movement into the containment building.

Figure 22. Construction Photograph Showing Outside of Dome. The mobile crane used to install the reactor vessel can be seen inside the opening. The equipment hatch presently in this location measures seven feet by seven feet. A larger opening will be cut to facilitate removal of large equipment during the decommissioning work.

Figure 23. Construction Photograph Showing Reactor Vessel Being Moved Into Position. The vessel stands 30 feet high with a maximum inside diameter of seven feet. It is made of carbon steel clad on the inside with 0.25 inch stainless steel. The ellipsoidal upper head contains 20 nozzles, the lower head 43. The shell contains 24 nozzles ranging from 0.75 inch to 16 inches in diameter.

Figure 24. Construction Photograph Showing Inside of Biological Shield.
This view shows the reinforced concrete shielding prior to installation of the reactor vessel. The outer walls are 42 or more inches thick. The thickness of the inner wall below the ledge is 30 inches.

Figure 25. Construction Photograph Showing Reactor Vessel Being Lowered Into Position.

Figure 26. Construction Photograph Showing Interior of Reactor Vessel. At this point a number of vessel components were not yet installed. Note the piping to the isolated coolant loop "bayonet" on the lower right. Two such bayonet fixtures were installed to test fuel assemblies under different conditions from those found in the vessel. Only one - the isolated liquid loop - was actually used.

Figure 27. The Reactor Vessel Head. In this view the ellipsoidal head has just been installed. The hold-down bolts and thermal insulation are not yet in place, nor are the control rod pressure thimbles connected to the standpipes.

Figure 29. Concepts of Alternatives

Figure 32. Engineered Trench for Low-Level Radioactive Waste. A trench like this in the Savannah River Site Solid Waste Disposal Facility may be used for disposal of the HWCTR reactor vessel and steam generators if they are removed during the decommissioning. Located in E-Area, this facility is approximately three miles from the HWCTR property.

Figure 33. E-Area Vaults. Other low-level radioactive waste from the HWCTR project is expected to be disposed of in vaults like this at the Savannah River Site. Most of the waste will be packaged in steel boxes such as those in the upper photograph. Each vault is 55 feet long, 150 feet wide and 30 feet high. Once full, they will be covered with clay to form a mound with a plant cover.

Appendix B

List of HWCTR Equipment

Analysis of HWCTR Removal Alternatives

EQUIPMENT PIECE NUMBER	COMPONENT NAME	LOCATION	WEIGHT	SIZE	VOLUME Cu. Ft.	REMOVED FOR COCOONING	REMOVED FOR REUSE	REMOVED FOR ENTOMBMENT
EP- 1	REACTOR VESSEL	0' - 0"	98 TONS	37' x 10' 5" x 7' 9"	3000	N	Y	N
EP- 20.1	STEAM GENERATOR	(-)16'-3", (-)37'-6"	38,000 POUNDS	23' 3" x 6' 1" x 6' 1"	860	N	Y	N
EP- 20.2	STEAM GENERATOR	(-)16'-3", (-)37'-6"	38,000 POUNDS	23' 3" x 6' 1" x 6' 1"	860	N	Y	N
EP- 21.1	MAIN PUMP *	(-)16' - 3"		12' 8" x 7' 6" x 7' 6"	546	Y	Y	Y
EP- 21.2	MAIN PUMP *	(-)16' - 3"		12' 8" x 7' 6" x 7' 6"	546	Y	Y	Y
EP- 22	SEAL SUPPLY TANK	+52'	1,075 POUNDS	5' x 30" x 26"	27	Y	Y	Y
EP- 40.1	MAIN PURGE COOLER	(-)37' - 6"		19' x 2' x 2' 6"	95	Y	Y	N
EP- 40.2	MAIN PURGE COOLER	(-)37' - 6"		19' x 2' x 2' 6"	95	Y	Y	N
EP- 41	MAIN STORAGE TANK	(-)52' - 6"	9100 POUNDS (EMPTY)	20' 6" x 9' x 9'	1660	Y	Y	N
EP- 42	INTERMITTENT MAKE-UP PUMP	(-)52' - 6"	3,000 POUNDS	7' x 5' 9" x 2' 10"	113	Y	Y	N
EP- 43	SEAL POT	(-)37' - 6"	2,100 POUNDS	13' x 2' 8" x 2' 8"	92	Y	Y	N
EP- 44.1	MAIN SYSTEM DEIONIZER	(-)37' - 6"	*29,600 POUNDS	5' 8" x 4' 8" x 3' 8"	97	Y	Y	N
EP- 44.2	MAIN SYSTEM DEIONIZER	(-)37' - 6"	*29,600 POUNDS	5' 8" x 4' 8" x 3' 8"	97	Y	Y	N
EP- 45	MAIN AFTERFILTER	(-)37' - 6"	1,900 POUNDS	3' 5" x 2' x 2'	14	Y	Y	N
EP- 46	PURIFICATION PUMP					Y	Y	N
EP- 47	PURIFICATION COLLECTION TANK	(-)37' - 6"	250 POUNDS	5' 1" x 26" x 26"	24	Y	Y	N
EP- 50	PLATFORM SCALE						Y	N
EP- 51	DRAIN TANK	(-)52' - 6"	275 POUNDS (EMPTY)	4' x 32" x 32"	28	Y	Y	N
EP- 53	HOLD TANK	(-)52' - 6"	540 POUNDS (EMPTY)	11' 8" x 21" x 21"	36	Y	Y	N
EP- 54	MAIN SYSTEM PREFILTER	(-)37' - 6"	11,150 POUNDS	6' x 3' x 3'	54	Y	Y	N
EP- 55	DRAIN TANK PUMP					Y	Y	N
EP- 60	POISON TANK	+52'	2050 POUNDS (EMPTY)	6' 9" x 2' x 2'	27	Y	Y	Y
EP- 84.1	SEPARATOR	0'-0"	344 POUNDS	5' 2" x 14" x 14"	7	Y	Y	Y
EP- 86	GAS RECOMPRESSOR	(-)52' - 6"		8' 6" x 5' x 4'	170	Y	Y	N
EP- 87	GAS RECOMPRESSOR	(-)52' - 6"		8' 6" x 5' x 4'	170	Y	Y	N
EP- 92	CATCH POT	(-)52' - 6"		46" x 30" x 30"	24	Y	Y	N
EP-101.1	SPENT FUEL BASIN COOLER	(-)52' - 6"	2,800 POUNDS	13' x 26" x 13"	30	Y	Y	N
EP-101.2	SPENT FUEL BASIN COOLER	(-)52' - 6"	2,800 POUNDS	13' x 26" x 13"	30	Y	Y	N
EP-102.1	SPENT FUEL BASIN CIRC. PUMP					Y	Y	N
EP-102.2	SPENT FUEL BASIN CIRC. PUMP					Y	Y	N
EP-103	SPENT FUEL BASIN DEIONIZER	(-)52' - 6"	*24,775 POUNDS	5' 7" x 4' 4" x 4' 4"	105	Y	Y	N
EP-104	SPENT FUEL BASIN FILTER	(-)52' - 6"	*24,000 POUNDS	5' 7" x 4' 4" x 4' 4"	105	Y	Y	N
EP-105	HOLD TANK	(-)16' - 3"	640 POUNDS (EMPTY)	9' 2" x 3' x 3'	83	Y	Y	N
EP-106	DISPOSAL PUMP					Y	Y	N
EP-159	BLDG. SUMP PUMP					Y	Y	N
EP-176	BOILING LOOP QUENCHER					Y	Y	N
EP-178.1	BOILING LOOP CIRC. PUMP	(-)37' - 6"	4,000 POUNDS	7' 1" x 4' 4" x 3' 4"	102	Y	Y	N
EP-178.2	BOILING LOOP CIRC. PUMP	(-)37' - 6"	4,000 POUNDS	7' 1" x 4' 4" x 3' 4"	102	Y	Y	N
EP-180	ISOLATED COOLING LOOP SEAL PUMP	(-)52' - 6"		35" x 29" x 38"	22	Y	Y	N
EP-181	ISOLATED COOLING LOOP SEAL SUPPLY TANK	+52'	1,400 POUNDS	4' x 24" x 24"	16	Y	Y	Y
EP-185	BAYONET					Y	Y	N
EP-186.1	LIQUID LOOP PUMP	(-)16' - 3"	4000POUNDS (EMPTY)	7' 1" x 4' 3" x 3' 4"	102	Y	Y	N
EP-186.2	LIQUID LOOP PUMP	(-)16' - 3"	4000POUNDS (EMPTY)	7' 1" x 4' 3" x 3' 4"	102	Y	Y	N
EP-187	LIQUID LOOP COOLER	(-)16' - 3"	2400POUNDS (EMPTY)	12' 10" x 2' 2" x 2' 2"	52	Y	Y	N
EP-191	LIQUID LOOP PURGE COOLER	(-)37' - 6"	275 POUNDS	32" x 23" x 25"	11	Y	Y	N
EP-192.1	ISOLATED COOLING LOOP DEIONIZER					Y	Y	N
EP-192.2	ISOLATED COOLING LOOP DEIONIZER					Y	Y	N
EP-193	ISOLATED COOLING LOOP AFTERFILTER	(-)37' - 6"	1,900 POUNDS	4' x 2' 7" x 2'	21	Y	Y	N

Analysis of HWCTR Removal Alternatives

EQUIPMENT PIECE NUMBER	COMPONENT NAME	LOCATION	WEIGHT	SIZE	VOLUME Cu. Ft.	REMOVED FOR COCOONING	REMOVED FOR REUSE	REMOVED FOR ENTOMBMENT
EP-194	D2O STORAGE TANK	(-)52' - 6"				Y	Y	N
EP-195	ISOLATED COOLING LOOP SEAL PUMP	(-)52' - 6"		35" x 29" x 38"	22	Y	Y	N
EP-197	PURIFICATION PUMP					Y	Y	N
EP-198	ISOLATED COOLING LOOP SEAL HOLD TANK	+52'	1,400 POUNDS	4' x 24" x 24"	16	Y	Y	Y
EP-256	ROD DRIVE PLATFORM	0'-0"		8' x 14' 6" x 9' 4"	1090	Y	Y	Y
EP-270	TRANSFER COFFIN	0'-0"		25' 4" x 2' 8"D	192	Y	Y	Y
EP-278	SPENT FUEL BASIN GANTRY					Y	Y	Y
EP-519	25 TON BUILDING CRANE					Y	Y	Y
EP-913.01	TANK	+52'		3' x 24" x 24"	12	Y	Y	Y
	LOWER AXIAL SHIELD	1 FT. BELOW RV	6 TONS	58" x 37 "	57	Y	Y	N
	REACTOR NOZZLES			ABOUT 240' OF 10" PIPE	20	Y	Y	N
	REINFORCED CONCRETE	BIOLOGICAL SHIELD			500	Y	Y	N
	FOUR PROCESS VALVES	(-)16'-3", (-)37'-6"		4'8" x 3' x 2'	112	Y	Y	N
	ONE PROCESS VALVE	(-)16' -3"		3' x 2' x 2"	12	Y	Y	N
	10 IN. PROCESS PIPING	(-)16'-3", (-)37'-6"		250'	180	Y	Y	N
	4 IN. PROCESS PIPING	(-)16'-3", (-)37'-6", (-)52'-6"		1000'	110	Y	Y	N
	12 IN. & 8 IN. PROCESS PIPING	0 FEET		100'	60	Y	Y	Y
	TRANSFER COFFIN PLATFORM	0 FEET		6'8" x 7'4" x 2'	100	Y	Y	Y
	REINFORCED CONCRETE	BIOLOGICAL SHIELD			800	Y	Y	N
	EIGHT FAILED FUEL ELEMENT CONTAINERS	TOP OF SPENT FUEL BASIN		12"D x 12'	64	Y	Y	N
	COMPONENT RECEPTACLE	TOP OF SPENT FUEL BASIN			48	Y	Y	N
	CRANE RAILWAY							
	6 IN. MOTOR OPERATED VALVE							
	10 IN. MOTOR OPERATED VALVE							
TOTAL					12920			

ANALYSIS OF HWCTR REMOVAL ALTERNATIVES

Project:
Date: 6/16/96

Task

Progress

Milestone

Summary

Rolled Up Task

Rolled Up Milestone

Rolled Up Progress

ANALYSIS OF HWCTR REMOVAL ALTERNATIVES

ID	Task Name	Start	Finish	'94	'95	'96	'97	'98	'99	'00	'01	'02	'03	'04
16	Remove hazardous materials	4/1/97	10/1/98			4/1			10/1					
17	Remove underground tank, muffler, st. line	1/1/98	10/1/98				1/1		10/1					
18	PHASE IV	10/1/98	3/1/00											
19	Remove large components, except vessel	10/1/98	6/1/99				10/1		6/1					
20	Remove and ship reactor vessel	6/1/99	3/1/00				6/1		3/1					
21	PHASE V	1/1/99	9/30/02											
22	Remove and dispose of radioactive concrete	1/1/99	3/1/01				1/1			3/1				
23	Remove dome	3/1/01	8/1/01						3/1		8/1			
24	Remove building to below grade	8/1/01	1/1/02						8/1		1/1			
25	Perform final radiological survey	1/1/02	5/1/02						1/1		5/1			
26	Final Independent Verification, DHEC & EPA	5/1/02	7/1/02						5/1		7/1			
27	Backfill and grade site	7/1/02	8/30/02						7/1		8/30			
28	Landscaping and project closeout	9/1/02	9/30/02						9/1		9/30			

Project:
Date: 6/16/96

Task

Progress

Milestone

Summary

Rolled Up Task

Rolled Up Milestone

Rolled Up Progress

ANALYSIS OF HWCTR REMOVAL ALTERNATIVES

ID	Task Name	Start	Finish	'94	'95	'96	'97	'98	'99	'00	'01	'02	'03	'04	'05
1	ALTERNATIVE 2- PART. DISMANTLEMENT, INTERIM SAFE STORAGE	1/1/94	5/15/00												
2	PHASE I	1/1/94	12/31/94												
3	Demolish outbuildings	1/1/94	12/31/94												
4	PHASE II	8/4/95	10/1/96												
5	Mobilize at site	8/4/95	2/28/96												
6	Demolish control building	10/1/95	4/30/96												
7	Decommissioning Project Plan	1/1/96	3/15/96												
8	Hazards assessment	3/1/96	5/1/96												
9	Detailed characterization of the facility	2/1/96	9/16/96												
10	Analysis of Removal Alternatives	5/1/96	10/1/96												
11	Selection of preferred Alternative	9/30/96	9/30/96												
12	PHASE III	10/2/96	10/1/98												
13	Decommissioning Plan	10/2/96	3/1/97												
14	Readiness evaluation	3/1/97	4/1/97												
15	Removal of piping and equipment	4/1/97	10/1/98												
16	Removal of hazardous materials	4/1/97	10/1/98												

Task

Progress

Milestone

Summary

Rolled Up Task

Rolled Up Milestone

Rolled Up Progress

Project:
Date: 7/25/96

ANALYSIS OF HWCCTR REMOVAL ALTERNATIVES

ID	Task Name	Start	Finish	'94	'95	'96	'97	'98	'99	'00	'01	'02	'03	'04	'05
17	Remove underground tank, muffler, steam line	1/1/98	10/1/98				1/1	10/1							
18	PHASE I V	4/1/98	1/1/99												
19	Cut piping to reactor vessel/steam generator	4/1/98	10/1/98				4/1	10/1							
20	Weld plugs in reactor nozzles, steam generator openings	10/1/98	1/1/99				10/1	1/1							
21	PHASE V	10/1/98	5/15/00												
22	Remove and dispose of contaminated concrete	10/1/98	10/1/99				10/1	10/1							
23	Cleanup and verification of lower levels	10/1/99	2/1/00				10/1	2/1							
24	Restore dome and weld equipment opening shut	2/1/00	5/1/00					2/1	5/1						
25	Install remote monitoring equipment	2/1/00	5/15/00					2/1	5/15						

Task
Progress
Milestone

Summary
Rolled Up Task
Rolled Up Milestone

Rolled Up Progress

Project:
Date: 7/25/96

ANALYSIS OF HWCTR REMOVAL ALTERNATIVES

ID	Task Name	Start	Finish	'94	'95	'96	'97	'98	'99	'00	'01	'02	'03
1	ALTERNATIVE 3 - BENEFICIAL REUSE	1/1/94	5/1/02										
2	PHASE I	1/1/94	12/31/94										
3	Demolish outbuildings	1/1/94	12/31/94										
4	PHASE II	8/4/95	10/1/96										
5	Mobilize at site	8/4/95	2/28/96										
6	Demolish control building	10/1/95	4/30/96										
7	Decommissioning Project Plan	1/1/96	3/15/96										
8	Hazards assessment	3/1/96	5/1/96										
9	Detailed characterization of the facility	2/1/96	9/16/96										
10	Analysis of Removal Alternatives	5/1/96	10/1/96										
11	Selection of preferred alternative	9/30/96	9/30/96										
12	PHASE III	9/30/96	10/1/98										
13	Develop and obtain necessary approvals for a waste storage plan .	9/30/96	4/1/97										
14	Decommissioning Plan	10/2/96	3/1/97										
15	Readiness evaluation	3/1/97	4/1/97										

Project:
Date: 6/16/96

Task

Progress

Milestone

Summary

Rolled Up Task

Rolled Up Milestone

Rolled Up Progress

ANALYSIS OF HWCTR REMOVAL ALTERNATIVES

ID	Task Name	Start	Finish	'94	'95	'96	'97	'98	'99	'00	'01	'02	'03
16	Remove hazardous materials	4/1/97	1/1/98				4/1	1/1					
17	Remove piping and equipment	4/1/97	10/1/98				4/1	10/1					
18	Remove underground tank, muffler, steam line	1/1/98	10/1/98				1/1	10/1					
19	PHASE IV	10/1/98	3/1/00										
20	Remove large components, except vessel	10/1/98	6/1/99				10/1	6/1					
21	Remove and ship reactor vessel	6/1/99	3/1/00				6/1	3/1					
22	PHASE V	1/1/99	5/1/02										
23	Remove and dispose of radioactive concrete	1/1/99	3/1/01				1/1	3/1					
24	Cleanup and verification of lower levels	3/1/01	6/1/01										
25	Strengthen floors as needed for storage	6/1/01	8/31/01										
26	Refurbish building, meeting current building codes	6/1/01	3/1/02										
27	Install ventilation system	11/1/01	3/1/02										
28	Restore dome to close equipment access	9/3/01	3/1/02										
29	Place materials to be stored into building	3/1/02	5/1/02										

Project:
Date: 6/16/96

Task

Progress

Milestone

Summary

Rolled Up Task

Rolled Up Milestone

Rolled Up Progress

ANALYSIS OF HWCTR REMOVAL ALTERNATIVES

ID	Task Name	Start	Finish	'94	'95	'96	'97	'98	'99	'00	'01	'02	'03	'04
1	ALTERNATIVE 4 - ENTOMBMENT	1/1/94	6/1/99											
2	PHASE I	1/1/94	12/31/94											
3	Demolish outbuildings	1/1/94	12/31/94											
4	PHASE II	8/4/95	10/1/96											
5	Mobilize at site	8/4/95	2/28/96											
6	Demolish control building	10/1/95	4/30/96											
7	decommissioning Project Plan	1/1/96	3/15/96											
8	Hazards assessment	3/1/96	5/1/96											
9	Detailed characterization of the facility	2/1/96	9/16/96											
10	Analysis of Removal Alternatives	5/1/96	10/1/96											
11	Selection of preferred alternative	9/30/96	9/30/96											
12	PHASE III	10/2/96	1/30/98											
13	Decommissioning Plan	10/2/96	3/1/97											
14	Readiness evaluation	3/1/97	4/1/97											
15	Removal of piping, equipment above 0-level	4/1/97	1/30/98											
16	Remove hazardous materials	4/1/97	1/30/98

Project:
Date: 6/16/96

ANALYSIS OF HWCTR REMOVAL ALTERNATIVES

ID	Task Name	Start	Finish	'94	'95	'96	'97	'98	'99	'00	'01	'02	'03	'04
17	Remove refueling machine	4/1/97	1/30/98			4/1	1/30							
18	PHASE IV	2/2/98	7/1/98				2/2	7/1						
19	Remove underground tank, muffler, steam line	2/2/98	7/31/98				2/2	7/31						
20	Remove dome	2/2/98	7/1/98				2/2	7/1						
21	PHASE V	7/1/98	6/1/99											
22	Fill cavity with concrete	7/1/98	2/1/99				7/1	2/1						
23	Perform final radiological survey	2/1/99	4/1/99				2/1	4/1						
24	Landscaping and project closeout	4/1/99	6/1/99				4/1	6/1

Project:
Date: 6/16/96

APPENDIX G - REFERENCES

No.	Subject
1.	<i>Decommissioning Resource Manual.</i> U.S. Department of Energy, Office of Environmental Management Manual DOE /EM-0246, August 1995.
2	Fricke, V. R. <i>Heavy Water Components Test Reactor Decontamination and Decommissioning Project Plan</i> , WSRC Report WSRC-IM-96-144 Revision 0, Savannah River Site, Aiken, SC 29808, March 27, 1996
3	<i>Heavy Water Components Test Reactor Screening Characterization Report</i> , U S Energy Corporation, April 1996.
4	Field, F. R. <i>A Decommissioning Plan for the Heavy Water Components Test Reactor</i> , U. S. Energy Research and Development Administration Report DPST-75-417, Dupont Savannah River Plant, January 1976.

APPENDIX H - GLOSSARY

105-C Reactor: An old, graphite-core nuclear weapons materials production reactor located at the Department of Energy's Hanford Site in the state of Washington. The planned "cocooning" of this reactor served as a model for a somewhat similar concept for cocooning of the Heavy Water Components Test Reactor, one of the decommissioning alternatives studied.

Activity: A measure of the rate at which radioactive material is undergoing radioactive decay, usually given in terms of the number of nuclear disintegrations occurring in a given quantity of material over a unit of time. This is also known as Radioactivity. The unit of activity is the *curie (Ci)*.

Air Force Nuclear Engineering Center (AFNEC) Reactor: A small, water-cooled nuclear reactor located at Wright-Patterson Air Force Base in Dayton, Ohio. This reactor, which was entombed in the early 1970s, served as a model for the entombment decommissioning alternative studied for the Heavy Water Components Test Reactor.

Alpha Particle: A positively charged particle emitted by some radioactive materials undergoing radioactive decay. Alpha particles are the least penetrating of the three common forms of radiation (alpha, beta, gamma); they can be stopped by a sheet of paper and cannot penetrate skin.

Applicable or Relevant and Appropriate Requirements (ARAR): (1) Those cleanup standards, standards of control, and other substantive requirements, criteria, or limitations, promulgated under federal environmental, state environmental, or facility siting laws that specifically address a hazardous substance, pollutant, contaminant, remedial action, location, or other circumstance found at a CERCLA site. Only those state standards that are identified by a state in a timely manner and that are more stringent than federal requirements may be applicable. (2) Requirements promulgated under Federal or state law that specifically address the circumstances at a Superfund site. (3) A requirement that environmental laws other than those under CERCLA, may be either "applicable" or "relevant and appropriate", but not both. Identification of ARARs must be done on a site-specific basis and involves a two-part analysis: first, a determination whether a given requirement is applicable; then, if it is not applicable, a determination whether it is both relevant and appropriate.

ASTM: The American Society for Testing and Materials. Society established to provide materials standards and testing procedures.

B-Area: One of the developed areas of the Savannah River Site. Located in the northwest part of the site, B-Area is designated an administrative area in long-term site property use plans. The Heavy Water Components Test Reactor is located in U-Area, which is inside of B-Area.

Background Radiation: Background radiation is naturally occurring radiation in the human

environment. It includes cosmic rays, radiation from the naturally radioactive elements, and man-made radiation from global fallout.

Barytes Concrete: Special high density (13% iron by weight) concrete used in portions of the biological shield.

Beneficial Reuse: The reactor vessel and steam generators would be removed, the facility would be fully or partially released from radioactive controls, and the facility would be reused for a beneficial purpose, such as storage of radioactive material or equipment.

Beta Particle: An electron emitted from the nucleus during radioactive decay. Beta particles are easily stopped by a thin sheet of metal or plastic.

Biological Shield: The shielding structures consisting of ordinary concrete, Barytes concrete, lead or steel designed to reduce the anticipated radiation levels at various locations in the reactor building to levels ranging generally from 1 mR/hr to 300 mR/hr during reactor operation.

Boiling Loop: One of the two isolated coolant loops. In this loop, D₂O was to be pumped as a liquid to test fuel elements and removed as liquid-steam at reactor pressure. The loop allowed for testing of fuel elements under liquid-steam conditions. It was never used for this purpose.

Characterization Survey: Facility or site sampling, monitoring, and analysis activities to determine the extent and nature of contamination. Characterization provides the basis for acquiring the necessary technical information to develop, analyze, and select appropriate cleanup techniques and characterize materials to be recycled or disposed of as waste.

Chemical Addition System: A part of the purification system used to add deuterium and lithium to maintain proper system chemistry.

Chlorofluorocarbons (CFCs): A family of inert, non toxic and easily liquefied chemicals used in refrigeration, air conditioning, packaging and insulation, or as solvents and aerosol propellants.

Clean Air Act: Passed in 1970, and amended in 1977 and 1990, its purpose is to " protect and enhance the quality of the Nation's air resources. "

Clean Water Act of 1977: This act, which applies to surface water only, is designed to "restore and maintain the chemical, physical and biological integrity of the Nation's waters".

Clean-up: Actions taken to remove a hazardous substance that could affect humans and/or the environment. The term " clean-up " is sometimes used interchangeably with the terms remedial action, remediation, and decontamination.

Comprehensive Environmental Response, Compensation and Liability Act (CERCLA): A federal statute, also known as Superfund, that provides the statutory authority for clean-up of hazardous substances that could endanger public health, public welfare or the environment. The Heavy Water Components Test Reactor decommissioning project is being performed under this statute by agreement between the U. S. Environmental Protection Agency and the U. S. Department of Energy.

Coolant Sampling System: Part of the purification system. Sample lines from various points run to a hooded sample sink in the monitor room.

Contamination: The presence of residual radioactivity in excess of levels which are acceptable for release of a site or facility for unrestricted use.

Corrosion Coupons: Small test samples of various metals installed in the reactor vessel and D₂O tank to determine corrosion characteristics of the materials under operating conditions.

Criteria (release criteria): Combination of numerical activity guideline levels and conditions for their application. If criteria are satisfied, the site may be released without restrictions.

Curie: A measure of the rate of radioactive decay. One curie (Ci) is equal to 37 billion disintegrations per second (3.7×10^{10} dps), which is approximately equal to the decay of one gram of radium-226. Fractions of a curie are levels typically encountered in the decommissioning process, e. g., picocurie (pCi) or 10^{-12} Ci and microcurie (μ Ci) or 10^{-6} Ci.

D₂O Storage Tank: The 7165 gallon heavy water storage tank located at the -52' level which supplied makeup water to the reactor cooling systems and the seal supply system.

Deactivation: The placing of a facility in a safe and stable condition to minimize the long-term cost of a surveillance and maintenance program that is protective of workers, the public and the environment until decommissioning is completed.

Decay: The spontaneous radioactive transformation of one nuclide into a different nuclide or into a lower energy state of the same nuclide. Also, known as radioactive decay.

Decommissioning: The process of removing a facility from operation, followed by decontamination, and license termination.

Decommissioning Plan: A document for a decommissioning project which specifies the work to be done.

Decommissioning Project Plan: The document that defines the decommissioning project and sets the initial cost, schedule, and technical baselines for the project.

DECON: An acronym for "decontamination".

Decontamination: The removal of unwanted radioactive material from facilities, soils, or equipment. Also, known as remediation, remedial action and clean-up.

Deionizer: A part of the Purification System. One deionizer contained mixed-bed resins which removed dissolved corrosion products and replaced them with lithium hydroxide and deuterium. Another deionizer operated as necessary to maintain alkalinity within limits by removing lithium. Another deionizer is installed in the Spent Fuel Basin purification system.

Dismantlement: The disassembly or demolition and removal of any structure, system, or component during decommissioning and satisfactory interim or long-term disposal of the residue from all or portions of a facility.

Dose Equivalent (Dose): A term used to express the amount of effective radiation when modifying factors have been considered. It is the product of absorbed dose (rads) multiplied by a quality factor and any other modifying factors. It is measured in rem (roentgen equivalent man).

E-Area: One of the developed areas of the Savannah River Site. Located in the northcentral part of the site, E-Area is designated as a waste management area.

E-Area Vaults: The above ground area at SRS expected to be used for disposal of most low-level radioactive waste generated by the decommissioning work. The vaults are located in E-Area.

Effective Dose Equivalent: See dose equivalent.

Emergency Deluge System: The system designed to condense steam generated by a major reactor leak. The primary component of the system is a 15,000 gallon water tank at the top of the dome of the containment building.

Emergency Poison System: A system, never used, designed for emergency shutdown of the reactor should the safety and control rod systems become inoperable. This system was designed to inject potassium tetra borate into the reactor to suppress the nuclear reaction.

Energy Research and Development Administration: The federal agency which was the predecessor of the Department of Energy.

Entomb: To enclose an object or objects in a strong, durable material such as concrete.

Entombment: The encasement of radioactive materials in concrete or other structural material sufficiently strong and structurally long-lived to ensure retention of the radioactivity until it has decayed to levels that permit restricted release of the site.

Environmental Assessment (EA): A written environmental analysis which is prepared pursuant to National Environmental Policy Act to determine whether a federal action would significantly affect the environment and thus require preparation of a more detailed environmental impact statement.

Environmental Impact Statement (EIS): A document required for Federal Agencies by the National Environmental Policy Act for major project or legislative proposals significantly affecting the environment. A tool for decision making, it describes the positive and negative effects of undertaking and lists alternative actions. The statement documents the information required to evaluate the environmental impact of a project. Such a statement informs decision makers and the public of the reasonable alternatives which would avoid or minimize adverse impacts or enhance the quality of the environment.

Exhaust Stack: The 80-foot high steel stack through which the building ventilation system and gaseous radioactivity were vented. It is designated as Building 791-U.

Experimental Boiling Water Reactor (EBWR): The EBWR is located at Argonne National Laboratory and is being considered for conversion for reuse as a long-term waste management facility. EBWR was the first boiling water type nuclear power plant to produce electricity. Decommissioning work was completed in 1996. Radioactive equipment was removed, the reactor vessel was cut into pieces, and the radioactive concrete biological shielding was taken out.

Facility Characterization Screening Report: A detailed report of the results of the process history of the HWCTR facility. Information for the report is drawn from various sources such as health physics logs and interviews with former HWCTR employees. This report forms part of the basis for the scope of the facility characterization work.

Gamma Radiation: Penetrating high-energy, short-wavelength, electromagnetic radiation (similar to X-rays) emitted during radioactive decay. Gamma rays are very penetrating and require dense materials (such as lead or uranium) for shielding.

Half-Life: The time it takes for one-half of the atoms of a quantity of a particular radioactive element to decay into another form. Half-lives of different isotopes vary from millionths of a second or less to billions of years.

Hazardous Substance: Any material that poses a threat to human health or the environment.

Hazardous Waste: Wastes regulated under RCRA that can pose a substantial or potential hazard to human health or the environment when improperly managed.

Heavy Water: Water containing significantly more than the natural proportions of heavy hydrogen (deuterium) atoms to ordinary hydrogen atoms. Heavy water is used as a moderator in some reactors because it slows down neutrons effectively and has a low probability for absorption of neutrons.

Helium Gas System: The system used to maintain pressure in the reactor by maintaining a pressurized helium blanket above the heavy water in the reactor vessel.

Instrument Air System: A system designed to supply air to initiate the poison injection into the system.

Interim Safe Storage: The process of placing a nuclear reactor in long-term storage by sealing the reactor core or vessel and removing the other radioactive equipment from the facility. This technique is being used with the 105-C Reactor at the Department of Energy's Hanford Site in the state of Washington.

Ionizing Radiation: Alpha particles, beta particles, gamma rays and other radiation capable of producing ions (electrically charged atoms or molecules). Ionizing radiation does not include visible light, radio waves or microwaves.

Isolated Coolant Loops: Two coolant loops in the primary system. These two loops are the liquid loop and the boiling loop. They were to be used to test fuel elements under a wide variety of operating conditions.

Liquid Loop: One of the two isolated coolant loops. In this loop, the heavy water was circulated at pressures up to 500 psi higher than that in the reactor vessel. This loop was used to test fuel elements at higher pressure conditions than those present under normal operating conditions.

Main Circulating System: (Also known as the Main Coolant System). This system provided cooling water to the reactor core and reactor components. The system consists of two primary loops. D₂O was circulated in the primary loops by independent pumping systems at about 10,000 gallons per minute. The water was cooled by two steam generators.

Millirem: One-one thousandth (0.001) rem, the unit of effective dose equivalent for ionizing radiation. See *REM*.

Mixed Waste: Waste which is both radioactive and contains hazardous constituents as defined

by RCRA.

Monitor Pin Plate: The plate in the reactor bottom where the monitor pins mount.

Muff (shield muff): A fixture at the top of the fuel through which D_2O entered the fuel assembly.

Muffler: The 7-foot diameter stainless steel tank which served as a silencer for venting steam to the atmosphere. It is located 100 meters from the reactor building.

National Environmental Policy Act (NEPA): The national charter addressed to federal agencies for protection of the environment. NEPA establishes policy, sets goals, and provides means for carrying out policy. Under NEPA, federal agencies must examine the environmental impact of proposed actions and compare them with reasonable alternatives.

Partial Dismantlement and Beneficial Reuse: Remove all radioactivity except for that in the reactor vessel biological shield, which would be sealed and left in place. The imbedded piping in the biological shield and in the floor drain system would remain in place. The containment dome would remain standing and the structure would be set up for a purpose such as storage of radioactive material, equipment, or waste.

Partial Dismantlement and Cocooning: Placing the reactor in long-term storage by removing all radioactivity except for that in the reactor vessel, the reactor vessel biological shield, and the steam generators, which would be sealed and left in place. The imbedded piping in the biological shield and in the floor drain system would remain in place. The containment dome would remain standing and all openings welded closed.

Person-rem: The common unit for radiation exposure to a group of people. An estimate of four person-rem would be the total expected radiation exposure to all of those exposed to the *ionizing radiation* of interest. See also *REM*.

Polychlorinated Biphenyl's (PCBs): A group of persistent, toxic chemicals. PCBs are commonly found in old electrical equipment.

Purification System: A system which continuously removed particulate and dissolved ionic impurities from the heavy water and controlled the chemical composition of the heavy water to minimize corrosion in the high-pressure system.

Radioactive Contaminants: A term used for the radioactivity in the HWCTR facility associated with its operation. Radioactive contaminants include both radioactive contamination and induced radioactivity from neutron activation.

Radiological Buffer Area: An area used to separate an area of known contamination from an uncontrolled area.

Radioisotope: A radioactive isotope, usually artificially produced by the bombardment of naturally occurring atoms with nuclear particles, such as neutrons, electrons, protons and alpha particles utilizing devices like the particle accelerator. They are used in physical and biological research and therapeutic applications.

Radionuclide: An unstable nuclide that undergoes radioactive decay.

Readiness Review: A management review of documents, organizational structure, personnel qualifications, physical preparations and other factors to confirm that decommissioning operations (removal action, if under CERCLA) are ready to proceed. If the facility being commissioned is classified as a nuclear facility per DOE-STD-1027-92, a graded operational readiness review (ORR) may be required in accordance with DOE Order 5480.31.

Reactor Gas Pressure Relief System: A secondary pressure relief system consisting of two independent groups of self-actuating relief valves that relieve high pressure helium and D₂O vapor from the gas space of the reactor vessel.

Reactor Gas Purge System: Part of the Helium gas system. Helium was periodically admitted to the reactor to purge the gas space.

Reactor Vessel: The 98 ton, 30-foot high carbon steel pressure vessel which contained the reactor fuel. Clad with stainless steel, it is 3-5" thick.

Receiving Basin for Off-site Fuel: A facility, not located at the HWCTR site, where spent fuel is sent for storage pending processing. All of the spent fuel from the HWCTR reactor was transferred from the HWCTR spent fuel basin to this facility.

Recompression System: A system used to recompress D₂O-He from the storage tank for return to the reactor to make up for gasses discharged in the purge streams.

Refueling Machine (transfer coffin): The heavily-shielded container used to transfer spent fuel from the reactor to the spent fuel basin.

REM (Roentgen Equivalent Man): A quantity used in radiation protection to express the effective dose equivalent for all forms of ionizing radiation. It is the product of the absorbed dose in rads and factors related to relative biological effectiveness (see Dose Equivalent).

Remedial Action: Action taken to remove contaminants from a site. Also known as remediation and decontamination.

Remediation: The removal of contamination from a site. Also known as remedial action and decontamination.

Removable Activity: Surface activity that can be removed and collected for measurement by wiping the surface with moderate pressure.

Removal Action: Under CERCLA, this means "The cleanup or removal of released hazardous substances from the environment, such actions as may be necessarily taken in the event of the threat of a release . . . , such actions as may be necessary to monitor, assess, and evaluate the release or threat of release . . . , the disposal of removed material, or the taking of such other actions as may be necessary to prevent, minimize, or mitigate damage to the public health or welfare or to the environment, which may otherwise result from a release or threat of release."

Resource Conservation and Recovery Act (RCRA): The federal law that regulates the management of hazardous waste, solid waste and underground storage tanks to minimize the present and future threat to human health and the environment.

Roentgen (R): Unit of radiation exposure. One roentgen is the amount of gamma rays or x-rays required to produce one electrostatic unit or charge of one sign (either positive or negative) in one cubic centimeter of dry air under standard conditions.

Safe Storage: Those actions required to place and maintain a nuclear facility in such a condition that future risk to public safety from the facility is within acceptable bounds and that the facility can be safely stored for as long a time as desired.

SAFSTOR: An acronym for Safe Storage.

Savannah River Site (SRS): A Department of Energy (DOE) facility for production, reprocessing, and storage of radioactive material and disposal of radioactive waste. SRS is located near Aiken, South Carolina.

Seal Head Tank: Part of the Seal Supply System. The tank is located in the dome of the building and supplies D₂O to the Seal Supply System. Two other seal head tanks provide D₂O to the pump seals in the isolated loops.

Seal Supply System: The system which supplies pressurized D₂O to the pump and rod drive seals.

Shippingport Atomic Power Station: The world's first large-scale nuclear power plant. The plant was located in Beaver County, Pennsylvania and was a pressurized water reactor. It was decommissioned in 1989 and was the first complete decontamination and decommissioning of a

power-producing reactor in the nation.

Solid Waste: Non-liquid, non-soluble material ranging from municipal garbage to industrial waste that contains complex, and sometimes hazardous, substances. Solid waste also includes sewage sludge, agricultural refuse, demolition wastes, and residues. Technically, solid waste also refers to liquids and gases in containers.

Solid Waste Disposal Facility: The SRS shallow land burial facility used for disposal of low-level radioactive wastes. It is expected that large components such as the reactor vessel and steam generators, if removed, will be disposed of in this facility.

Spent Fuel Basin: A stainless steel-lined concrete-walled pit used to temporarily store spent fuel on site. The top of the basin is at the 0 level. It is 27' deep with a cask pit which extends to the -42' level.

Spent Fuel Basin Purification System: A recirculating system where water from the spent fuel basin passed through a deionizer and filter to remove radioactivity.

Steam Generators: The major components of the Steam System. Two steam generators are present in the main coolant system. Made of carbon steel, each is about 23 feet high and weighs some 19 tons.

Steam Generator Feedwater System: The system which provides makeup water to the steam generators.

Steam System: The secondary portion of the reactor fluid system where steam is produced in the steam generators and exhausted through the muffler to dissipate heat from the reactor.

Superfund Amendments Rehabilitation Act (SARA): The reauthorization of CERCLA (1986) to provide increased funding and regulations for clean-up of inactive waste sites.

Surface Activity: Radioactivity found on building or equipment surfaces and expressed in units of activity per surface area [typically disintegrations per minute per 100 cm² (dpm/100 cm²)].

Survey: Evaluation of a representative portion of a population to develop conclusions regarding the population as a whole. In the decommissioning process, several different types of surveys are conducted, including Background, Scoping, Characterization, Remediation Control, Final Status, and Confirmatory surveys.

Thermal Shield: The thermal shield is within the reactor vessel and consists of the top shield which has an 18" thick stainless steel calandria-filled with stainless steel balls and a series of ten, 1" stainless steel annular rings and the radial and downward (bottom) direction shields made of

3" stainless steel. The thermal shields are cooled by D₂O.

Toxic Substances Control Act (TSCA): The law and implementing EPA regulations governing the use and management of toxic substances. PCBs are regulated under TSCA.

Transuranic Waste: Waste that is contaminated with alpha-emitting transuranic nuclides with half-lives greater than 20 years and concentrations greater than 100 nanocuries per gram of waste. Contract-handled TRU waste does not require shielding and has a surface dose rate of less than 200 millirem per hour. Remote-handled TRU waste has a surface dose rate greater than 200 millirem per hour and requires additional shielding because it presents an exposure hazard, the dose rates at the surface of remote-handled TRU waste packages within 200 millirem to 1000 rem per hour range. Some TRU waste was buried before these ranges were established.

U-Area: One of the developed areas of the Savannah River Site. Located in the northwest part of the site, U-Area is designated an administrative area in long-term, site property use plans. The Heavy Water Components Test Reactor is located in U-Area, which is inside of B-Area.

Underground Tank: The 8000 gallon waste water collection tank buried on the HWCTR property. Water from the reactor building sump could be pumped directly to the tank. This was done on occasion.

U. S. Atomic Energy Commission (AEC): The commission set up by the Atomic Energy Act of 1954 for the production and control of nuclear materials.

U. S. Department of Energy (DOE): DOE superseded the AEC and has responsibility for the production and control of nuclear materials.

U. S. Environmental Protection Agency (EPA): The U. S. Environmental Protection Agency was established in 1970, bringing together parts of various government agencies involved with the control of pollution. Oversees the investigation and development of remedial actions to reduce the risk of exposure to contaminants.

Volatile Organic Compounds (VOCs): Carbon-containing substances, released by both natural processes and human activities, which readily produce fumes.

Waste Minimization: The reduction, to the extent feasible, of radioactive and hazardous waste that is generated before treatment, storage, or disposal of the waste. Waste minimization includes any source reduction or recycling activity that results in either: 1) reduction of total volume of hazardous waste; 2) reduction of toxicity of hazardous waste; or 3) both.

ANALYSIS OF HWCTR REMOVAL ALTERNATIVES

Water Relief System: A system designed to relieve excessive pressure by allowing escape of heavy water to the storage tank. The primary components of this system were two self-actuating relief valves.

Westinghouse Savannah River Company (WSRC): The prime contractor for operating the Savannah River Site.