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2600 Bull Street
Columbia, SC 29201-1708

June 8, 2000

Mr. Paul Lohaus, Director
Office of State and Tribal Programs
U.S. Nuclear Regulatory Commission
Washington, DC 20555

Dear Mr. Lohaus:

As I mentioned recently, the Department has terminated SC Radioactive Material License No.144 issued to Allied General Nuclear Services (AGNS) Barnwell Nuclear Fuel Plan after a lengthy decommissioning process.

I have enclosed the Technical Evaluation Report (TER) supporting the license termination and an article by Mr. Jim McNeil which will be published in *Radwaste Solutions.* I know there are NRC staff who may be interested in the final closure and decommissioning of the facility due to their involvement in licensing hearings and the construction permit issued by NRC which was terminated years ago.

Should you or the NRC staff have any questions, please do hesitate to contact me at (803) 896-4244.

Very truly yours,

Virgil R. Autry, Director
Divison of Radioactive Waste Management
Bureau of Land and Waste Management

Enclosures

cc: Richard Woodruff NRC Region II w/enclosures

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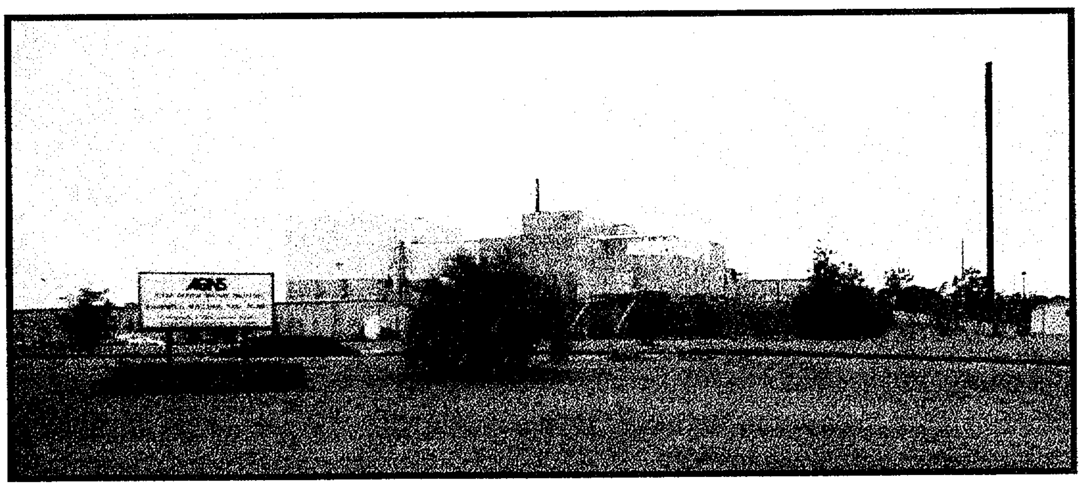
TECHINICAL EVALUATION REPORT FOR THE TERMINATION OF

South Carolina Radioactive Material License Number 144

ISSUED TO

ALLIED GENERAL NUCLEAR SERVICES BARNWELL NUCLEAR FUEL PLANT BARNWELL, SOUTH CAROLINA



May 2000

South Carolina Department of Health and Environmental Control
Division of Radioactive Waste Management

EXECUTIVE SUMMARY

The Barnwell Nuclear Fuel Plant lies about six miles west of Barnwell, SC. Owned by Allied-General Nuclear Services, the plant was built in the early 1970s to reprocess spent nuclear fuel from commercial power reactors. While it was never used for this purpose, the plant became contaminated with natural uranium used for testing systems and transuranic radionuclides used in plant laboratories for research and development purposes.

The South Carolina Department of Health and Environmental Control (SCDHEC) regulates radioactivity associated with the plant. The Department issued Radioactive Material License 144 for this purpose. As of March 2000, the license reflected the presence of 10 grams of plutonium and 600 kilograms of natural uranium at the plant, the maximum amounts of these materials identified during the decommissioning.

In 1997, Allied-General proceeded with decommissioning of the plant. A contractor team* characterized the plant for residual radioactivity and planned the decommissioning. SCDHEC recommended the following radioactivity cleanup criteria: (1) no more than 15 millirem per year radiation exposure from residual radioactivity and (2) no more than four millirem per year from groundwater and surface water. These criteria became the principal residual radioactivity limits for the project.

The contractor prepared five decommissioning plans for different areas of the plant in accordance with SCDHEC Regulation 61-63, *Radioactive Material (Title A)*, and obtained the regulator's approval on the plans. The contractor then accomplished the decontamination and decommissioning work required by these plans.

In March 2000, the contractor completed the decommissioning and achieved the cleanup limits so that the radioactive material license could be terminated. The technical basis for termination of the license is as follows:

- Thorough historical assessments were performed for each plant area to assemble the information needed to effectively plan the decommissioning.

- Each plant area was characterized for residual radioactivity using a variety of proven techniques to support the planning.

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* Contracting details appear on page 2

- Site-specific cleanup guidelines were developed using proven, widely-accepted computer modeling techniques to support field measurements to achieve the radioactivity cleanup criteria, and approved by SCDHEC. The assumption was made that the facilities would be restricted to only commercial/industrial use. To ensure this the deed for the property included this restriction.

- A decommissioning plan was developed for each plant area and approved by SCDHEC.

- The decommissioning work was accomplished in accordance with these plans, which were revised with SCDHEC approval to reflect a number of changes identified during the course of the work.

- The ALARA principal was followed during the work to reduce residual contamination levels well below the guideline values, when practicable.

- All radioactive wastes were removed from the site.

- Final radiological status surveys and sampling were performed in all plant areas by the contractor, following an SCDHEC-approved Final Status Survey Plan; these surveys showed that the cleanup guidelines have been achieved.

- A Final Status Survey Report was compiled by the contractor to document in detail the results of the surveys and sampling, with sections provided to SCDHEC as they were completed. This report also describes the actual work accomplished during the decommissioning.

- Independent verification surveys performed by SCDHEC have verified the contractor's survey results and confirmed that the cleanup guidelines were achieved.

- The licensee is required to notify the buyer that the Department should be notified prior to the recycling of materials from the plant. The U.S. Nuclear Regulatory Commission is in the process of promulgating regulation for the release and recycling of contaminated materials. Until this issue is resolved, the Department will evaluate whether recycling materials is allowed under the current state and federal policies.

- A condition has been placed in the deed for the property restricting the use of the property to industrial, manufacturing, commercial or warehousing purposes.

1. PURPOSE

The purpose of this document is to explain the technical basis for termination of Radioactive Material License Number 144 issued by the Division of Radioactive Waste Management of the South Carolina Department of Health and Environmental Control (SCDHEC)*. This license was issued to Allied-General Nuclear Services (AGNS) for radioactivity associated with the Barnwell Nuclear Fuel Plant (BNFP). On May 31, 2000, the license was terminated with Amendment 26 of the license. The amendment required that the following restriction should be included in the deed: "No portion of the Premises shall be used for any purpose other than for industrial, manufacturing, commercial or warehousing purposes." The restriction is included in the deed.

2. BACKGROUND

The BNFP lies approximately six miles west of Barnwell, South Carolina. The plant property, mostly wooded, comprises 1632 acres. The plant is shown in Figure 1.

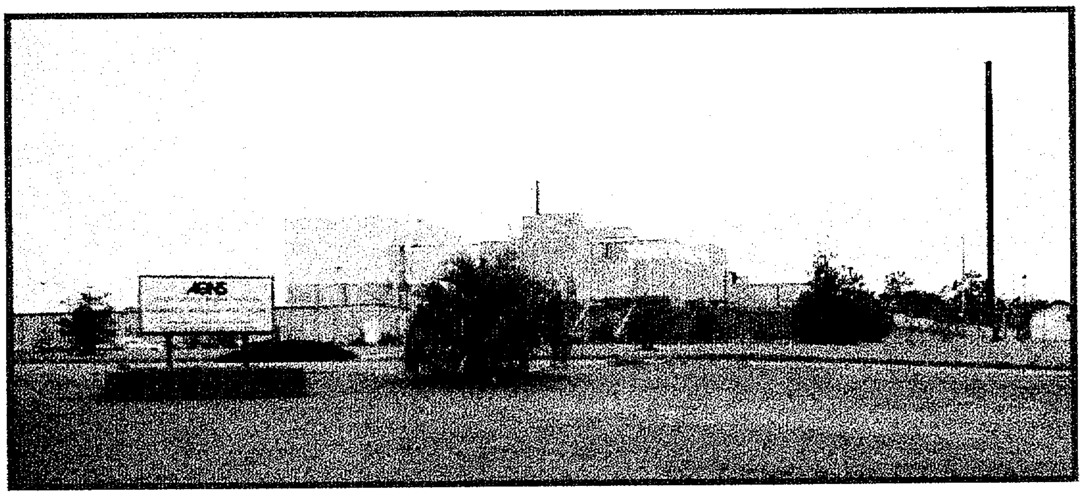

Figure 1. The Barnwell Nuclear Fuel Plant

At the beginning of the decommissioning project, the plant was owned by AGNS. In early 1999, the Savannah River Site Redevelopment Authority acquired the undeveloped AGNS property and subsequently transferred it to the Tri-County Economic Development Authority, who plans to establish an industrial park at the site. The deed for the 200 developed acres is being held in escrow until completion of the decommissioning project and termination of the radioactive materials license.

The plant was built in the early 1970s to process spent nuclear fuel from commercial power reactors. It was never used for this purpose. It was tested using natural uranium as a surrogate material from 1976 through 1983. Research

* SCDHEC refers to the Division of Radioactive Waste Management of the SCDHEC Bureau of Land and Waste Management, unless otherwise specified.

and development work using plutonium and other transuranics was also performed at the plant.

In 1983, the plant was shut down and partially decontaminated. Decontamination efforts at that time included removing bulk uranium compounds, decontamination of the facilities and flushing process equipment with nitric acid and water to remove residual contamination. But significant radioactive contamination remained inside much of the processing equipment and inside gloveboxes and fume hoods located in the laboratory building. Some facility surfaces also remained contaminated. A report (reference 1) describing the 1983 decommissioning and related radiological surveys is on file at SCDHEC.

In 1997, AGNS decided to proceed with completing decommissioning of the plant to terminate the radioactive material license. AGNS hired a contractor team — U S ENERGY Corporation of Aiken, SC and Life Cycle Engineering (LCE) of Charleston, SC — to plan the decommissioning, the first phase of the decommissioning project. U S ENERGY served as the prime contractor for this phase of the work, which was completed in February 1998.

In March 1998, AGNS employed a team, which included the key people who had planned the decommissioning, to decontaminate and decommission the plant. LCE served as prime contractor during this phase, providing project management, engineering and health physics support. TRIAD, Inc., a Barnwell, SC environmental services firm established by key people from U S ENERGY, provided planning support and radiological controls, and accomplished the actual decommissioning fieldwork. Additional support was provided by a number of other companies. In this document, the contractor team, regardless of phase of the work, is collectively referred to as "the contractor."

In 1997, at the start of the decommissioning project, the radioactive materials license reflected the presence at the plant of one gram of plutonium and five kilograms of uranium. Several times during the project SCDHEC amended the license to specify increasingly larger quantities of these radioactive materials, based on estimates made by the contractor using characterization measurements. The maximum amounts reached during the decommissioning were 10 grams of plutonium and 600 kilograms of uranium.

3. APPLICABLE REGULATIONS

The regulation that governs the decommissioning is SCHDEC Regulation 61-63, *Radioactive Materials (Title A)* (reference 2). South Carolina, as an "agreement state" with the Nuclear Regulatory Commission (NRC) under the Atomic Energy Act of 1954, regulates the radioactivity associated with the BNFP.

Part II, Section 2.11 of Regulation 61-63 governs decommissioning activities for SCDHEC licensees. It contains requirements for decommissioning plans. It also contains requirements for certifying the disposition of all licensed material and conducting a radiation survey of the premises, providing to SCDHEC a report of the results. It indicates that a license will be terminated by written notice to the licensee after SCDHEC determines:

(1) That radioactive material has been properly disposed of;

(2) That reasonable effort has been made to eliminate residual radioactive contamination; and

(3) That a radiation survey has been performed that demonstrates that the premises are suitable for release in accordance with SCDHEC requirements, or other information has been submitted by the licensee that will be sufficient to demonstrate that the premises are suitable for release in accordance with SCDHEC requirements. Residual contamination levels must be ALARA* and must be approved by SCDHEC.

This report addresses each of these matters as follows:

(1) It explains in Section 10 that the five BNFP decommissioning plans meet the Regulation requirements.

(2) It certifies the proper disposition of all licensed material in Sections 12 and 14, which address radioactive waste and final status surveys, respectively.

(3) It explains in Section 14 how final status surveys were conducted and in Section 16 how the results of the surveys were presented in a Final Survey Report.

(4) It describes in Sections 11 how reasonable effort was made to eliminate residual radioactive contamination.

(5) It explains in the Section 8 discussion on site-specific radioactivity cleanup guidelines how these guidelines were approved by SCDHEC as ALARA cleanup guidelines.

As can be seen in the following sections of this report, the BNFP decommissioning project not only met the requirements of the Regulation but exceeded the requirements where appropriate, owing to the complexity of the plant and the work related to its decommissioning. The contractor requested no exceptions to Regulation 61-63 in connection with the BNFP decommissioning and none were granted by SCDHEC.

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* Special terms associated with radioactivity, nuclear decommissioning and the BNFP, such as ALARA, are defined in the Glossary of Appendix A. ALARA means As Low As Reasonably Achievable.

Figure 2 below shows a simplified view of the process for terminating the plant radioactive material license. The following sections summarize the major steps in this process.

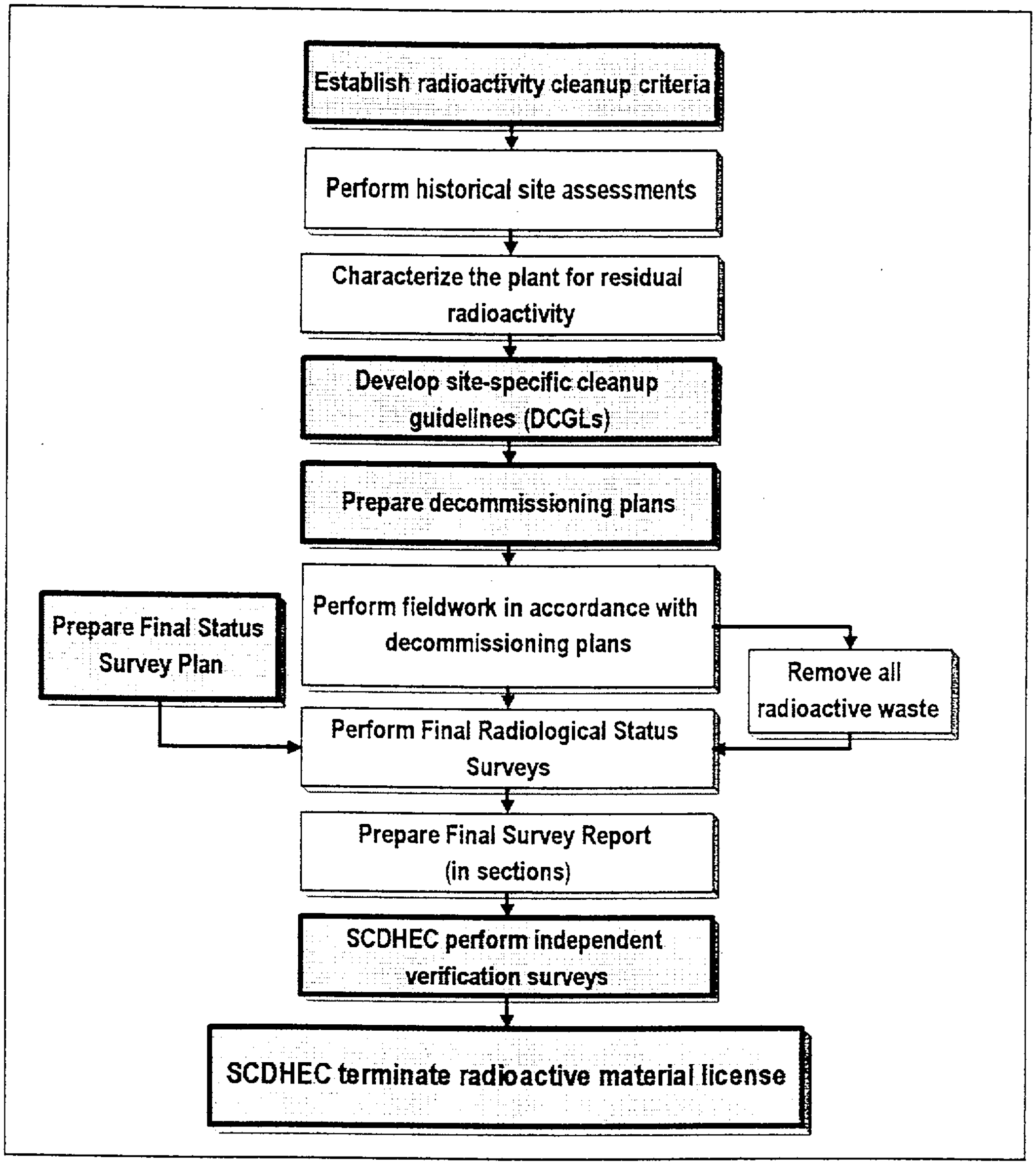

Figure 2. Flow Chart Showing Process For License Termination. *Note that steps which SCDHEC approved or performed appear as shaded blocks. More detail on the major steps involved appears below in Sections 6 through 17 of this document.*

4. RADIOACTIVITY CLEANUP CRITERIA

SCDHEC proposed the following criteria of primary limits for residual radioactivity at the beginning of the project:

> **No more than 15 millirem per year total effective dose equivalent to an average member of the critical group.** This limit falls below the 25 millirem per year limit established in May 1997 by the U. S. Nuclear Regulatory Commission (NRC) in the Code of Federal Regulations (10 CFR 20, reference 3). It is consistent with the limit proposed by the U. S. Environmental Protection Agency (EPA) in preliminary rulemaking efforts, but never formally established by that agency. SCDHEC established the annual dose limit for the BNFP below the NRC limit in the interest of conservatism.
>
> **No more that 4 millirem per year from radioactivity in groundwater or surface water.** This is the limit utilized by the EPA in 40 CFR 141 (reference 4). The NRC does not utilize a separate limit for groundwater or surface water.

These limits were incorporated into the five BNFP project decommissioning plans, which were approved by SCDHEC. Refer to Section 10 for a description of the decommissioning plans.

For perspective, the 15 millirem per year limit is approximately equal to the radiation dose that one would receive in two typical chest X-rays. It is less than five percent of the dose (approximately 360 millirem) that a typical resident of the United States receives each year from natural background radiation.*

5. THE FIVE AREAS OF THE PLANT

In the early planning, the contractor, with the assistance of the AGNS Site Administrator, divided the plant into five distinctly different areas, which are shown in Figure 3 on the next page:

> **The Uranium Hexafluoride (UF_6) Facility**. The eight-story steel-framed UF_6 Building stands on the northwest corner of the developed property.
>
> **The Hot and Cold Laboratory Area (HCLA)**. The laboratory building is connected to the north side of the Separations Building in the center of the developed property.

* *The Health Physics and Radiological Health Handbook*, Revised Edition, Bernard Shleien, ed., 1992, gives a value of 8 millirem for a chest X-ray and 360 millirem per year for average background dose, citing National Council of Radiation Protection Handbooks 93 and 100, respectively.

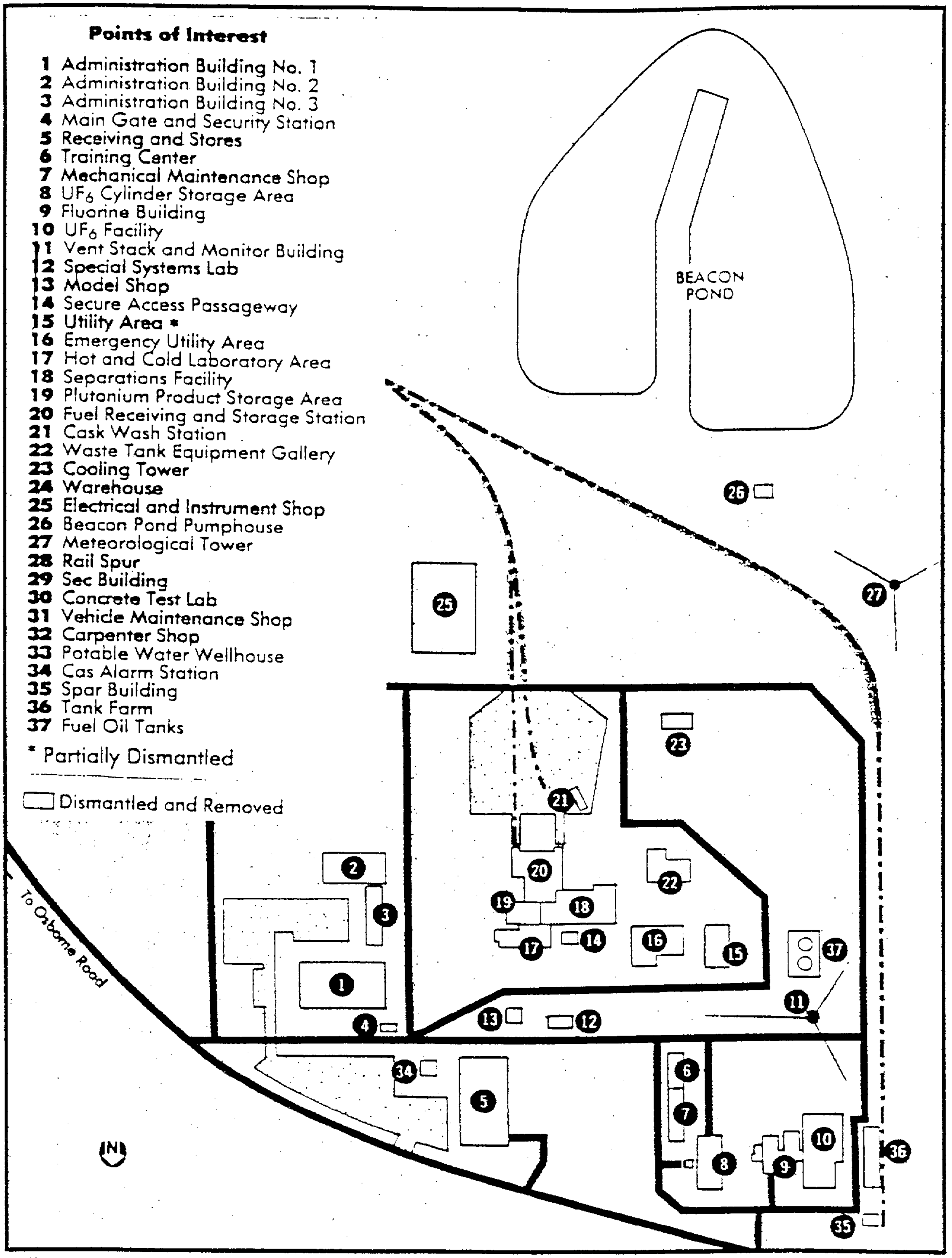

Figure 3. Barnwell Nuclear Fuel Plant Layout

The Separations Facility. The large multi-story reinforced concrete Separations Building, where the primary plant processes were to have taken place, stands in the center of the developed property.

The Waste Tank Equipment Gallery (WTEG). Located just southwest of the Separations Building, the WTEG complex includes three 300,000-gallon underground waste storage tanks.

Other Areas. The "Other Areas" include the remainder of the plant. Among the facilities included are the Fuel Receiving and Storage Station (FRSS) and the Plutonium Nitrate Storage and Loadout Station (PNSL), both structures which are contiguous with the Separations Building, along with the plant main stack

6. HISTORICAL SITE ASSESSMENTS

Due to the size and complexity of the plant, knowledge of the processes used which involved radioactivity formed an important part of the foundation of the plans for terminating the plant radioactivity license, as did knowledge of problems involving radioactivity that occurred during the plant construction and testing period. To develop and document such knowledge the contractor performed five historical site assessments, one for each part of the plant.

These assessments followed guidance in the *Multi-Agency Radiation Survey and Site Investigation Manual (MARSSIM)*, NUREG 1575 (reference 5). (The MARSSIM provides guidelines for planning, conducting, evaluating and documenting radiological surveys for demonstrating compliance with dose-based radiation cleanup regulations. It is a national consensus document developed jointly by the NRC, EPA, Department of Defense and Department of Energy.)

The AGNS Site Administrator set up a filing system for information needed in the assessments. The assessments began with a review of records, which were found to be complete and well organized. The records review included evaluation of all available radiological survey data, including that in the 1983 Consultant's Final Report (reference 1). Contractor personnel also evaluated detailed records related to flushing of the process equipment in 1983 to help determine how much residual radioactivity remained in plant systems.

The assessments also included interviews with former plant workers, inspection of the facilities, photographs and radiological "scoping" surveys to provide information for design of the characterization program. A former plant engineer assisted with assessment of the Separations facility. The contractor utilized a detailed AGNS scale model of the plant as an effective aid during the assessments and in later planning for the decommissioning.

The results of the assessments were documented in five detailed reports, one for each plant area. Significant information developed in the assessments was incorporated into subsequent planning documents, including the decommissioning plans. The unusually complete records and the thoroughness of the assessments helped establish the basis for plans to terminate the plant radioactive material license.

7. CHARACTERIZATION OF THE FACILITIES

The developed plant property was characterized in detail to determine the nature and extent of the radioactive contaminants. Techniques employed included:

- The use of detailed sample and analysis plans,
- Laying out grids on building floors,
- Alpha and beta-gamma scan measurements,
- MicroR and MicroRem meter surveys of facility surfaces and equipment,
- Smear and large area wipe surveys for removable radioactivity,
- Samples of materials such as concrete, floor covering and soil,
- Laboratory analysis of smears and material samples,
- Opening various pieces of equipment for surveys of internal surfaces and
- In-situ gamma spectroscopy of installed equipment.

Toward the end of the characterization program, plutonium was unexpectedly identified at the main stack area. This finding led to additional investigation for the presence of plutonium in the Main Stack area and in the Separations Building.

The contractor also characterized plant materials to be removed during the decommissioning for hazardous constituents. This characterization related to handling of waste associated with the decommissioning, rather than terminating the radioactive materials license.

Results of the characterization program appear in the following reports, all of which are on file at SCDHEC:

- Site Characterization Report for the Uranium Hexafluoride Facility of the Barnwell Nuclear Fuel Plan (reference 6)
- Site Characterization Report for the Hot and Cold Laboratory Area of the Barnwell Nuclear Fuel Plan (reference 7)
- Site Characterization Report for the Separations Facility of the Barnwell Nuclear Fuel Plan (reference 8)
- Site Characterization Report for the Waste tank Equipment Gallery of the Barnwell Nuclear Fuel Plan (reference 9)
- Site Characterization Report for the Other Areas of the Barnwell Nuclear Fuel Plan (reference 10)
- Canberra Insitu Gamma Spectroscopy Data, Report dated February 1998 (reference 11)
- Canberra Insitu Gamma Spectroscopy Data Taken at the AGNS Barnwell Nuclear Fuel Plant, AGNS Report dated March 25, 1999 (reference 12)
- Addendum to the Characterization Reports for the Barnwell Nuclear Fuel Plant, Revision 1 (reference 13)

The contractor made more than 18,000 field measurements for residual radioactivity during the characterization program.

8. SITE-SPECIFIC RADIOACTIVITY CLEANUP GUIDELINES

To provide a means for achieving the principal residual radioactivity limits, the contractor developed derived concentration guideline levels (DCGLs) as recommended in the MARSSIM. The DCGLs were developed using the RESRAD and RESRAD-BUILD computer codes.

Developed for the Department of Energy by Argonne National Laboratory, these codes provide widely-accepted methods for calculating radiation exposure from residual radioactivity, and cleanup guidelines that can be readily measured with field instruments. RESRAD models the transport of radionuclides in soil to determine the resulting radiation dose to humans. RESRAD-BUILD evaluates potential doses to an individual who lives or works in a building contaminated with radioactive material.

The results of the computer modeling appear in two contractor reports: (1) *Residual Radioactivity Guidelines for the Barnwell Nuclear Fuel Plant*, Revision 1, dated February 1998 (reference 14) and (2) *RESRAD and RESRADBUILD Modification for Areas With Transuranic Contamination (Excluding HCLA)*, dated March 23, 1999 (reference 15). SCDHEC reviewed and concurred in both reports and retains copies on file. The SCDHEC approval letters were dated January 27, 2000 and June 24, 1999, respectively.

In developing the DCGLs, the contractor considered various possible future uses for the different plant facilities. The contractor also considered the possibility of piping and equipment being removed and recycled for their salvage value. Significant factors in calculating the DCGLs included:

- The only restriction on the property following license termination would be a limitation to commercial-industrial type uses.*

- The basic RESRAD exposure pathway scenario was adapted for commercial-industrial use of the property. The following pathways were considered: (1) direct gamma exposure from contaminated soil, (2) internal exposure from inhalation of dust, (3) internal dose from inhalation of radon, (4) internal dose from ingestion of soil and (5) drinking water and irrigation of the property. In this application, the following exposure pathways were *not* considered in the calculation: (1) meat ingestion, (2) plant ingestion, (3) milk ingestion and (4) aquatic foods. (In these latter pathways, it would be assumed that the meat, plants, milk and aquatic food were produced on the property as with a family farm.)

* A prohibition against water wells less than 200-feet deep was also included in the property limited warranty deed.

- The contractor identified no plausible reuse scenario for the UF_6 Building, due to the nature of its construction, and assumed in the RESRAD-BUILD calculations that regular tours of the building would be taken by an individual at a frequency and duration that would amount to a total of 300 hours per year occupancy.**

- The RESRAD-BUILD scenarios for the Separations facility and the WTEG building entailed 40-hour-per-week occupancy by industrial workers.

- The RESRAD-BUILD scenarios for the HCLA entailed 40-hour-per-week occupancy by office workers.

- Each of the RESRAD-BUILD scenarios entailed consideration of renovation workers. The renovation worker scenario was used to estimate potential radiation exposure from possible future uncontrolled cutting of piping and, thereby, to establish appropriate DCGLs for radioactivity on internal surfaces of piping and equipment.

- Due to the similarities of the structures, the results of the RESRAD-BUILD modeling in the Separations Building were applied to the buildings associated with the Other Areas of the plant, such as the Fuel Receiving and Storage Station and the Plutonium Nitrate Storage and Loadout Station. The radioactive contamination levels in these buildings were much lower than those in the Separations Building.

- The results of the RESRAD-BUILD calculations for the UF_6 Building and the resulting DCGLs were applied to the plant Main Stack area. The technical basis for this approach is explained in *Applying UF_6 Building DCGLs to the Main Stack Area* (reference 16), a copy of which is on file at SCDHEC.

Assumptions used in the details of the calculations were considered realistic but on the conservative side. In some cases further conservatism was used in establishing the DCGLs. For example:

- The contractor calculated the DCGL for the UF_6 Building as an average contamination level that would produce 10 millirem per year during the year of highest exposure. The contractor stated the DCGL as a maximum value rather than an average to add further conservatism.

- The contractor calculated for the UF_6 facility that a DCGL of 250 picocuries per gram total natural uranium in concrete and soil would produce

** Because this assumption was less conservative than reuse assumptions for the other plant facilities, the contractor performed additional calculations using 40-hour-per-week occupancy and actual radioactive contamination levels measured during the final status surveys of the building. These calculations showed that regular occupancy at 40 hours per week would result in less than 15 millirem per year exposure. A copy of the report of these calculations (reference 17) is on file at SCDHEC.

approximately six millirem per year. The contractor then set the DCGL as a *maximum* of 250 picocuries per gram to add further conservatism.

- The DCGL of 250 picocuries per gram total natural uranium (maximum) in concrete foundations and soil was used for the Separations facility even though the calculations showed that this average contamination level would produce much less than one millirem per year in this facility.

The DCGLs selected for the different areas of the plant appear in the five decommissioning plans and in the Final Status Survey Plan, all of which were approved by SCDHEC. These plans are discussed further in Sections 10 and 13, respectively. A copy of each plan is on file at SCDHEC.

9. RECYCLING OF PLANT MATERIALS

Although recycling of plant materials does not directly affect termination of the plant radioactive materials license, the contractor studied potential exposures which could be associated with such an effort in case one were undertaken in the future. The study showed that any radiation exposure would be very small.

The plant contains large amounts of stainless steel contaminated with low levels of natural uranium, which might be salvaged for recycling as scrap metal. The contractor studied the potential radiation doses that could be associated with recycling this stainless steel. This study showed that average contamination levels of 92,000 dpm/100 cm^2 total uranium would produce 10 microrem per year to a person in the critical group (a slag worker). A copy of the report of this study (reference 18) is on file at SCDHEC, along with a copy of the Argonne National Laboratory report (ANL/EAD/TM-50, reference 19), on which the contractor study was based.

Information from the contractor study appears in the Separations Facility Decommissioning Plan (reference 20). But AGNS decided not to salvage any plant materials in connection with the decommissioning. So the 92,000 dpm/100 cm^2 total uranium DCGL was not included with the other DCGLs associated with the radiation cleanup limits.
The Separations Decommissioning Plan and the other four decommissioning plans do contain criteria for release from radiological controls of potentially contaminated materials. These criteria, which apply to natural uranium, are as follows:

5000 dpm/100 cm^2 (average fixed plus removable radioactivity)

1000 dpm/100 cm^2 (removable)

These values, the nuclear industry's standard release limits for potentially contaminated materials, first appeared in NRC Regulatory Guide 1.86 (reference 21).

The HCLA Decommissioning Plan also contains the following criteria for release from radiological controls of materials potentially contaminated with alpha emitting plutonium:

100 dpm/100 cm^2 (average fixed plus removable radioactivity)

20 dpm/100 cm^2 (removable)

These values also appear in NRC Regulatory Guide 1.86 (reference 21).

Note that the Regulatory Guide 1.86 guidelines were applied only to potentially contaminated equipment and materials to be removed from the facilities during the course of the decommissioning work. These guidelines cannot be directly compared to the DCGLs for facility surfaces, which were developed to ensure that the primarily cleanup criterion of 15 millirem per year was achieved.

The termination amendment cover letter included a requirement that AGNS notify the buyer of the facility that they must contact SCDHEC prior to recycling any material from the facility. This is to ensure that materials which contain residual amounts of radioactivity are considered on a case-by-case basis for recycling by the SCDHEC until a national standard for release of these materials for recycling is established.

10. THE DECOMMISSIONING PLANS

The contractor prepared and issued with SCDHEC approval five different decommissioning plans, one for each area of the plant. A copy of each is on file at SCDHEC. These plans were:

Decommissioning Plan for the Uranium Hexafluoride Facility of the Barnwell Nuclear Fuel Plant, reference 22.

Decommissioning Plan for the Hot and Cold Laboratory Area of the Barnwell Nuclear Fuel Plant, reference 23.

Decommissioning Plan for the Separations Facility of the Barnwell Nuclear Fuel Plant, reference 19.

Decommissioning Plan for the Waste Tank Equipment Gallery of the Barnwell Nuclear Fuel Plant, reference 24.

Decommissioning Plan for the Others Areas of the Barnwell Nuclear Fuel Plant, reference 25.

These plans were used to identify the decommissioning work necessary to terminate the radioactive material license, and to describe basic controls over the work. They are consistent with guidance found in SCDHEC Regulation 61-63 *Radioactive Materials (Title A)* and NRC Manual NUREG/BR-0241, *NMSS*

Handbook for Decommissioning Fuel Cycle and Materials Licensees (reference 26). Each decommissioning plan included:

- A detailed description of the facility, its history and its status,
- A discussion of decommissioning alternatives,
- A detailed description of the required decommissioning actions,
- A discussion of project management, including training,
- Requirements for worker and environmental protection,
- Requirements for waste management,
- Requirements for quality assurance,
- Requirements for the Final Status Survey plan, and
- Information on planned schedule and costs.

The decommissioning plans refer to a number of other project control documents used during the decommissioning, such as the TRIAD Health and Safety Plan (reference 27) and the Quality Assurance Project Plan (reference 28). Copies of these plans are on file at SCDHEC.

11. THE DECOMMISSIONING WORK

Work required by the decommissioning plans was carried out in accordance with written work packages. The work packages included copies of supporting procedures prepared by the contractor that provided detailed guidance for accomplishing the work. Copies of these procedures are on file at SCDHEC.

The workers who accomplished the decommissioning fieldwork were trained and qualified in accordance with the TRIAD Site-Specific Radiological Control Plan (reference 29) and related training plans, which were approved by SCDHEC in a letter dated May 27, 1998. All TRIAD workers were qualified radiological control technicians. Workers supplied by other contractors were qualified radiation workers.

Decontamination of the plant facilities involved the use of techniques such as wiping contaminated surfaces with damp cloths, scrubbing them with non-hazardous cleaning agents, flushing equipment with nitric acid and, in the case of concrete, using a mechanical device to remove the surface material. The contractor also used tools such as jackhammers to remove contaminated concrete. Workers cut contaminated piping and equipment into pieces using commercially-available cutting tools. Appropriate radiological controls were used during this work for personnel protection. Radioactive wastes generated in these processes were packaged and removed from the site as explained in Section 12.

Radioactive liquids removed from plant facilities during the course of the decommissioning work were processed with an onsite evaporator operated under Wastewater Treatment Unit Construction Permit Number 18,369-IW issued on March 25, 1999 by the SCDHEC Bureau of Water. Processed liquid meeting SCDHEC-approved limits for radioactivity was transported to the Aiken County Public Service Authority Horse Creek Pollution Control Facility at North Augusta, SC for disposal. Residuals from the liquid processing were stabilized and disposed of as low-level radioactive waste as described in Section 12.

In some cases, such as stabilizing in place a thin layer of sediment on the bottom of 300,000-gallon underground waste Tank 425, the contractor submitted specific written proposals for SCDHEC approval. In another case, imbedded piping containing low levels of radioactivity was filled with grout to make it inaccessible. The contractor generally revised the decommissioning plans with SCDHEC approval to incorporate such approved changes. The Final Status Survey Report discussed in Section 16 accurately describes the decommissioning work actually accomplished.

Due to the types of radioactivity at the plant, i.e., the absence of high-energy gamma radiation, the amount of personnel radiation exposure associated with the decommissioning was small. The total was less than one person-rem.

To ensure that all work specified in the decommissioning plans and project work packages was properly completed, the contractor conducted a final review of each work package.

To independently confirm that the work was being completed satisfactorily, SCDHEC health physics personnel observed the results of decommissioning fieldwork on a regular basis.

12. USE OF THE ALARA PRINCIPAL

The contractor followed the ALARA principal in the decommissioning of the BNFP. The following examples show how this is done:

- Conservatism was sued in establishing the cleanup guidelines as explaned in Section 8 on page 11.
- Areas were generally decontaminated well below the cleanup guidelines. As a rule, removable radioactivity, especially, was reduced far below the cleanup guidelines whenever this could be practically done.
- The contractor exceeded the requirements of the Final Status Survey Plan in a number of ways, as explained in Section 15 on page 18

13. RADIOACTIVE WASTE

Radioactive wastes associated with the decommissioning were packaged and transported to several different facilities located off the plant property. No radioactive wastes were allowed to remain at the plant. The contractor implemented the requirements for managing radioactive wastes contained in the decommissioning plans with other planning documents and with various supporting procedures. The two principal planning documents were the Waste Management Plan (reference 30) and the Waste Characterization and Certification Plan (reference 31). Copies of these plans are on file at SCDHEC, along with the supporting procedures.

The final status surveys described in Section 14 verified that all radioactive waste had been removed from the plant.

14. THE FINAL STATUS SURVEY PLAN

The contractor developed the BNFP Final Status Survey Plan (reference 32) following guidance in SCHEC Regulation 61-63, and in NRC Manual NUREG/BR-0241. The plan is also consistent with NUREG/CR-5849, *Manual for Conducting Radiological Surveys in Support of License Termination* (reference 33) and follows many elements of the MARSSIM.

This plan was approved by SCDHEC and a copy is on file in the SCDHEC office. Contents of the plan include:

- A description of facility characterization results and decommissioning activities,
- A description of the site release criteria and the implementing DCGLs,
- A description of the 163 survey units in various areas of the plant, along with the classification and required surveys for each unit,
- Requirements for instrumentation and survey techniques,
- Data quality objectives,
- Quality assurance requirements,
- Data evaluation requirements, and
- Documentation and reporting requirements.

The contractor also prepared implementing procedures to support the plan. A copy of each procedure is on file at SCDHEC.

One innovative technique covered in the plan that facilitated the final status surveys involved performing radiation dose rate surveys of the exterior of piping and equipment contaminated internally with natural uranium to determine whether the DCGLs for internal radioactivity were achieved.

The technique entailed the use of instruments capable of measuring very low radiation levels, a Bicron MicroRem survey meter or equivalent. Such instruments could be used to scan piping and equipment to detect internal contamination levels in excess of the DCGL. The technical basis for use of this technique is described in four reports, all of which were reviewed by SCDHEC and are on file in the SCDHEC office.

The first report, *Technical Basis for 5 MicroR/hr on 1" – 6" Piping* (reference 34), describes calculations performed to establish the survey method for use on piping from one-inch to six-inches in diameter. SCDHEC concurred in this report in a letter dated June 11, 1998.

The second report, *Small diameter Pipe Dose Response Investigation,* (reference 35) and the third report, *Technical Basis for using Dose Rate Measurements to Assess Natural Uranium Activity Inside Small Diameter Pipes,* (reference 36) were provided to SCDHEC in support of recommended changes to the Final Status Survey Plan. SCHEC concurred in the recommended changes in a letter dated September 21, 1999.

The fourth report, *Technical Basis for Use of Dose Rate Measurement Technique on Large Diameter Piping Contaminated Internally With Natural Uranium* (reference 37), a copy of which is on file at SCDHEC, showed that the survey method was acceptable for Schedule 40 piping up to 24 inches in diameter.

The contractor also developed two special investigative techniques to be used in connection with dose rate surveys to measure internal uranium contamination levels in piping.

One involved use of a G-M pancake probe, Ludlum Model 44-9 or equivalent, for measuring beta radiation emitted from the open end of a small-diameter pipe contaminated internally with uranium. The contractor had a nationally-recognized expert on radiation modeling conduct a study of beta detection capability for such an arrangement. The contractor then established a correlation between instrument readings and internal contamination in pipes of various sizes. SCDHEC has on file a copy of this study (reference 38) and the contractor's implementing procedure.

The other special technique entailed use of an instrument known as a pipe probe. This instrument is a Ludlum Model 44-6 side-window G-M detector. The pipe probe can be inserted into a pipe to measure uranium contamination on the inside of the pipe. The contractor developed a technical basis document on use of the pipe probe including the development of calibration factors (reference 39). SCDHEC has on file a copy of this report.

15. FINAL STATUS SURVEYS

The contractor performed final status surveys in accordance with the Final Status Survey Plan and associated procedures. These surveys proved that the approved radioactivity cleanup guidelines were achieved. The contractor made more than 50,000 field measurements during the final surveys, and analyzed approximately 300 samples of materials such as concrete and soil. (These figures do not include the thousands of additional field measurements associated with the decommissioning work.)

The surveys were carried out by radiological control technicians trained and qualified in accordance with the TRIAD Site-Specific Radiological Control Plan. The surveys were documented on photographs by importing digitized photographs of areas and equipment into a standard survey sheet.

In connection with the surveys, some samples of materials such as concrete and soil were analyzed by the contractor using an onsite gamma spectroscopy system. The others were analyzed by a qualified laboratory, General Engineering Laboratory of Charleston, SC

In performing the final surveys, the contractor exceeded the requirements of the Final Status Survey Plan in several ways:

- In areas where only natural uranium contamination was present, the contractor measured and recorded total alpha contamination levels as well as the required total beta contamination levels. This approach did not entail extra effort because the instrument probes used simultaneously measured alpha radiation as well as beta radiation. The contractor documented and evaluated the alpha data; this practice added further assurance that the facilities met the cleanup criteria.

- In many areas, such as the UF_6 Building, the contractor measured dose rates at one meter above each floor grid square surveyed during the final surveys. These data were recorded, evaluated and included in the Final Survey report. This approach provided further assurance that the cleanup criteria were met in these areas.

- The DCGLs for uranium were established based on field measurements for total surface radioactivity made using a probe with an effective surface area of 15.5 cm^2. DCGLs for removable contamination were 20 percent of the total DCGL. But in practice, the difference in area between the 15.5 cm^2 probe area and the 100 cm^2 area used in measuring removable contamination was disregarded in the interest of conservatism. For example, 20 percent of 47,000 dpm/15.5 cm^2 would be 9400 dpm/15.5 cm^2. But 9400 dpm/100 cm^2 was actually used as the removable contamination

DCGL. The value of 9400 dpm/15.5 cm^2 is equivalent to 60,645 dpm/100 cm^2. This approach, therefore, resulted in the DCGLs for removable uranium contamination being conservative by a factor of 6.45, the ratio between 100 and 15.5.

- In some areas, such as the roofs of the Separations Building, the contractor surveyed a significantly greater percentage of the area than required by the Final Status Survey plan. This approach, too, added an extra measure of assurance that the cleanup criteria were met.

All data from the final surveys were documented on survey record forms in accordance with the TRIAD Site-Specific Radiological Control Plan. The Radiological Program Manager reviewed these records. The data were incorporated into a computer database. Tables of data from the database were then complied into sections of the Final Status Survey Report. These report sections were reviewed by project management and provided to SCDHEC in draft form in support of the SCDHEC independent verification surveys.

16. GROUNDWATER AND SURFACE WATER SAMPLING

As indicated in Paragraph 5.10 of the Final Status Survey Plan, radioactive contamination of groundwater below the plant property from plant testing is extremely unlikely. The results of analysis of groundwater samples taken during characterization from 13 locations appear in Tables 2-13 and 2-14 of the Final Status Survey Plan. These results showed no evidence of radioactive contamination.

Sixteen additional sample obtained as part of the final surveys also showed no evidence of radioactive contamination.

The only surface water located on the developed plant property is Beacon Pond, a 17.6-acre man-made lake located south of the Separations Building as shown in Figure 2. Although process knowledge and plant records did not indicate any possible radioactive contamination in Beacon Pond, water samples were obtained from the pond and analyzed for radioactivity. No radioactivity associated with the plant was detected in the samples.

17. FINAL STATUS SURVEY REPORT

The contractor compiled data gathered during the final surveys into a detailed Final Status Survey Report (reference 40). As a survey unit was completed, the report section for that unit was prepared by the contractor. As indicated previously, these report sections have been provided to SCDHEC in draft form as they have been completed.

The Final Status Survey Report comprises six volumes:

- Volume I describes the decommissioning work accomplished along with the final survey process and requirements, and summarizes the overall results,
- Volume II.A contains the detailed survey data for the UF_6 Facility and summarizes the results of the UF_6 surveys,
- Volume II.B contains the detailed survey data for the Separations Facility and summarizes the results of the Separations surveys,
- Volume II.C contains the detailed survey data for the HCLA and summarizes the results of the HCLA surveys,
- Volume II.D contains the detailed survey data for the WTEG Facility and summarizes the results of the those surveys and
- Volume II.E contains the detailed survey data for the Other Areas and summarizes the results of the surveys in those areas.

Volumes II.A, II.B, II.D and II.E have been completed and approved by SCDHEC, and are on file at SCDHEC. Volume I and Volume II.C have been provided to SCDHEC in draft form. The contractor will finalize these volumes after completion of the last SCDHEC confirmatory surveys and provide them to SDHEC.

18. SCDHEC INDEPENDENT VERIFICATION SURVEYS

After the contractor completed final status surveys of a survey unit, SCDHEC representatives performed independent verification surveys. Included were scan surveys for alpha and beta-gamma radiation, smears for removable radioactivity and material samples analyzed in a qualified laboratory. DHEC took approximately 1670 surveys, 1722 swipes and 96 solid samples to verify that the facilities met the decommissioning criteria.

In some cases, the SCDHEC representatives requested the contractor to take additional samples or measurements as well; the results appear in the Final Status Survey Report.

The results of the SCDHEC surveys and samples analyses have closely agreed with the contractor's results.

SCDHEC has documented satisfactory completion of independent verification surveys area by area as follows:

UF_6 facility – letter dated April 24, 2000

Separations facility – letter dated May 30, 2000

HCLA – letter dated May 30, 2000

WTEG – letter dated April 24, 2000

Other Areas – letter dated May 30, 2000

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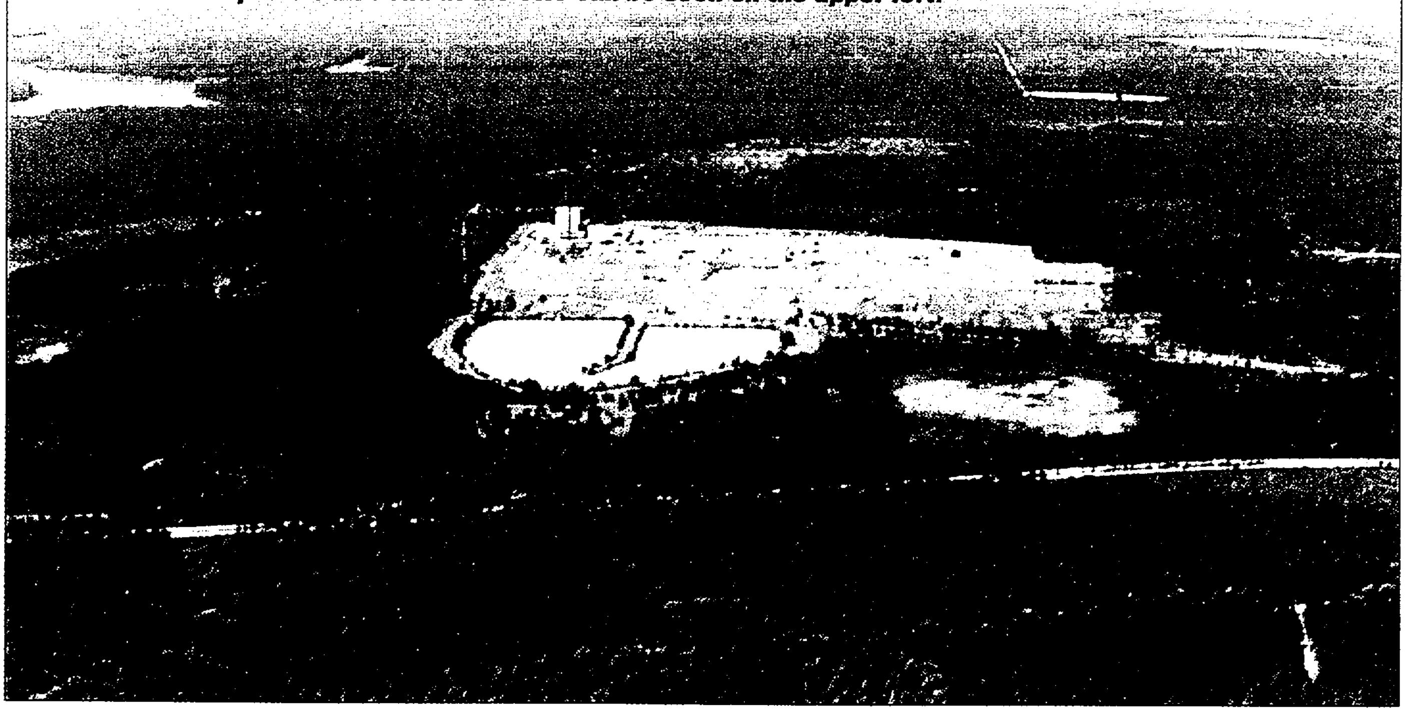
The sign at the plant entrance now reads "South Carolina Advanced Technology Park." The Barnwell Nuclear Fuel Plant, stillborn relic of the glory days of nuclear power, is no more. Allied-General Nuclear Services has finally divested itself of its white elephant. And a regional development group has acquired a valuable industrial property to market in an underdeveloped part of the state.

Aerial view of the plant. PaR Pond at the SRS can be seen on the upper left.



Closing the Book

The Decommissioning of the Barnwell Nuclear Fuel Plant

By Jim McNeil

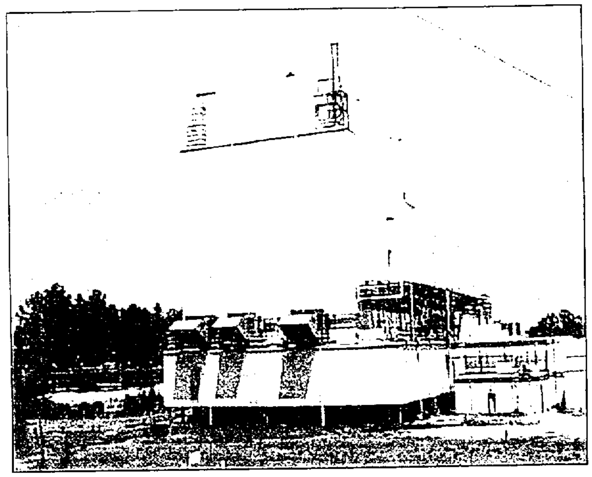
In the early 1970s, Allied-General Nuclear Services (AGNS), a partnership of private companies, invested more than $250 million to build the sprawling Barnwell Nuclear Fuel Plant (BNFP). It looked forward to substantial returns on its investment as the plant processed commercial power reactor fuel, recycling the costly materials used to produce much of the nation's electricity. But instead, the nation turned its back on this process. President Carter's 1977 executive order banned commercial reactor fuel reprocessing and sounded the death knell for the BNFP.

The owners had put together a highly skilled technical staff. They had hired and trained operators. Even after the 1977 executive order, the owners clung to the hope that the federal government would change its mind. They tested and retested the various parts of the plant, using tons of natural uranium in solution as a surrogate for dissolved reactor fuel. To utilize the plant engineers and laboratory staff, they undertook extensive research and development (R&D) work for the U.S. Department of Energy.

But with the passing years, hopes faded. In 1983, AGNS stopped the test program and the R&D work and partially decontaminated the plant. Then, for more than a decade, the owners sought other uses for the plant. Discussions about this abounded. People from the Savannah River Site (SRS) and elsewhere came to look over the facilities time and time again, but to no avail.

The Decision to Decommission

Finally, in spring 1997, the owners met with the plant regulator, the South Carolina Department of Health and Environmental Control (SCDHEC), to discuss the requirements for decommissioning the plant. Then they hired a team—U S Energy Corp. of Aiken, S.C., and Life Cycle Engineering (LCE) of Charleston, S.C.—to characterize the plant for residual radioactivity and to plan the decommissioning. The team began in August 1997 and finished these tasks, Phase I of the decommissioning project, seven months later. (This project was recounted in "The Final Chapter: Planning the Decommissioning of the Barnwell Nuclear Fuel Plant," *Radwaste Magazine*, May/June 1999, p. 51.)



The UF_6 Building at the BNFP.

The owners' aim was to terminate the plant radioactive materials license. The property was to be released for commercial-industrial use, with radiation exposure from residual radioactivity not to exceed 0.15 millisieverts (15 millirems) per year, with no more than 0.4 mSv (4 mrems) from groundwater and surface water contamination. To attain these limits, the contractor team developed site-specific cleanup guidelines for uranium and transuranics in different parts of the plant using the RESRAD and RESRAD-BUILD computer codes. The decommissioning program focused on achieving these guidelines and, where practicable, surpassing them—that is, the as-low-as-reasonably-achievable concept would be an integral part of the process.

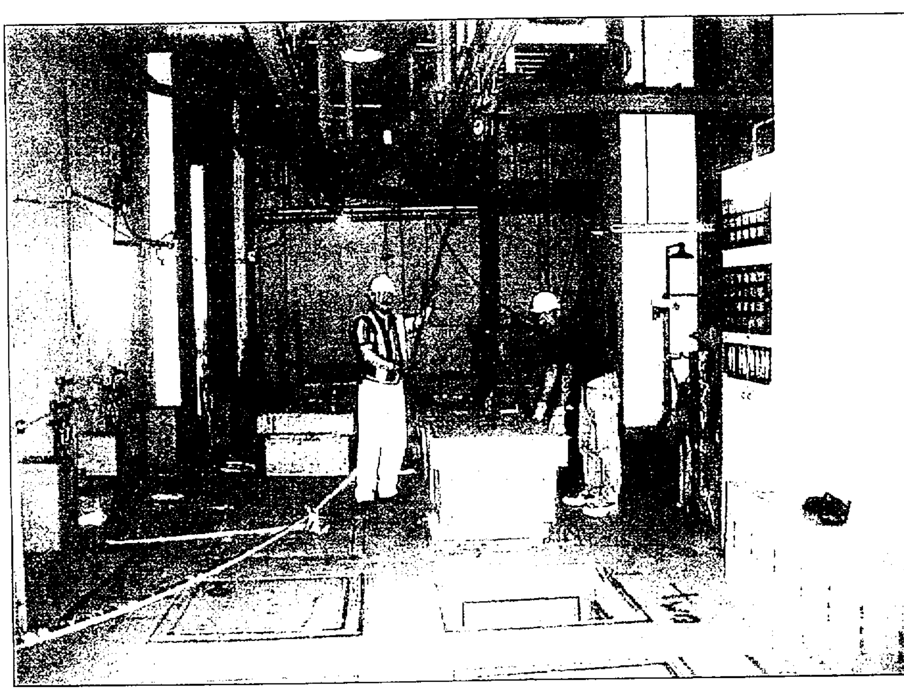
Those of us associated with the project would like to share with the nuclear decommissioning community some of the experiences from Phase II of the project, the actual decommissioning and final status surveys.

Getting to Work

In spring 1998, the decommissioning team (see sidebar, p. 60) mobilized. We assembled equipment and materials and put into place the project control documents. We prepared the Site-Specific Radiological Control Plan, the Quality Assurance Project Plan, and training plans, all of which were approved by the regulator. We developed the Waste Management Plan and the Waste Characterization and Certification Plan, which were approved by the SRS office. Because the DOE had furnished natural uranium used to test the plant and the transuranics used in the R&D work, the department accepted the low-level radioactive waste and transuranic (TRU) waste associated with these materials.

In June 1998, TRIAD Inc. instructors trained radiological control technicians and other staff members in radiological controls. After completion of other site-specific training, the fieldwork commenced.

Decommissioning the Uranium Hexafluoride Facility

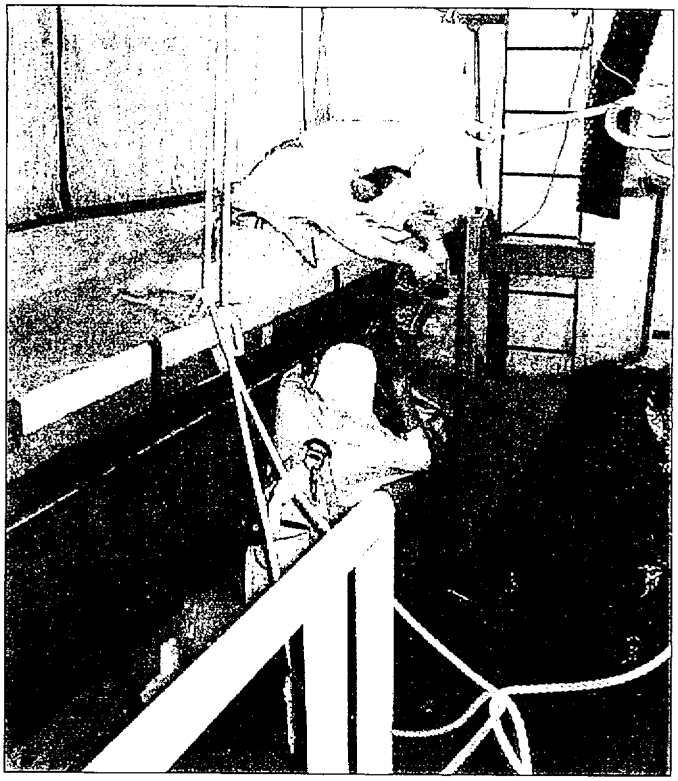


Removing shield plugs from the floor of the Lower Viewing and Operating Station in the Separations Building.

Early in the planning process, the team had decided to divide the plant into five separate areas. This arrangement resulted from significant differences among the five areas and from guidance by the AGNS site administrator, who knew the plant well, having worked there from the time construction began in 1971. The first area of the plant to be decommissioned—the UF_6 Facility—consisted of an eight-story building, a nearby tank farm, and several related structures.

The building itself contained approximately 76 000 square feet of floor space. A steel-framed structure with outer wall of fiberglass panels, the building contained piping, vessels, materials elevators, and other uranium processing equipment.

Detailed characterization had shown that the UF_6 Building contained significant natural uranium contamination. Much of the equipment remained internally contaminated, even though AGNS



Dismantlement of a 25-ft-tall plutonium glovebox at the BNFP.

workers had flushed the systems with nitric acid and water before the plant was laid up in 1983. Some facility surfaces were also contaminated above the cleanup guidelines. The highest levels appeared in the sixth-floor decontamination room, where during the plant testing phase, tons of uranium trioxide had been mixed with nitric acid to form uranyl nitrate, the liquid used in testing the plant. Another significantly contaminated part of the building was the waste treatment area on the first floor. Dave Deibler, TRIAD work control manager, describes the process for decommissioning the UF_6 Building: "A small crew of cross-trained TRIAD technicians decontaminated the building working from the top down. They performed external dose rate surveys of piping and equipment, determining which exceeded the cleanup guidelines. Based on the surveys, they cut out the piping and parts of equipment that exceeded the cleanup guidelines. They used a scarifier, grinder, and rotary hammer to decontaminate the floors of the decon room and the waste treatment area. They decontaminated the facility using a variety of techniques. We found Easy-Off Oven Cleaner® to be among the most effective surface cleaning agents.

"As the technicians completed decontamination of a floor of the building, they performed the final status surveys of that floor and isolated it. They completed decommissioning of the UF_6 Building in April 1999. Health physicists from SCDHEC performed independent confirmatory surveys of the building floors after TRIAD technicians completed their surveys. The last SCDHEC independent survey of the building was finished in November 1999."

Decommissioning the Separations Facility

Decommissioning the Separations Building posed a genuine challenge to the team. Designed for processing spent reactor fuel and handling solutions containing fission products, uranium and plutonium, the various systems displayed a complexity that was initially intimidating.

The building itself contains seven shielded cells where the primary processes of fuel separation were to take place. It also contains numerous piping galleries, operating stations, and support equipment. Constructed of heavily reinforced concrete, the building is 224 ft long and 118 ft wide and is divided into four major levels.

Tim Schatzer of TRIAD, project manager during Phase I, served as operations manager during Phase II. About the Separations Facility, Tim says: "Because understanding the design, processes, and testing in the Separations Facility was key to assessing the building, a former site engineer was hired during characterization. In addition, two of the workers we hired during the physical decommissioning of the building were former plant employees who brought invaluable detail during the decontamination and removal of equipment.

"Removal or decontamination of the building and building components was relatively straightforward, despite the wide variation in specialized equipment in the facility. However, where and how the equipment was installed proved to be as much of a challenge as the equipment itself. Many large vessels were set in place as the Class 1 seismically qualified structure was poured,

Pilot PUREX processing equipment removed from the glovebox.

meaning that significant displacement was required to remove equipment. In addition, stairwells and access hatches were not always conveniently placed for rigging out piping, equipment, and waste. Innovative rigging and material handling practices were employed throughout the facility as a result.

"Due to the complex layout of the building and its limited means of ingress and egress, it was essential that the decommissioning be well thought out. This was so that the areas of the building that were being decommissioned first could be secured from the rest of the facility without restricting movement of personnel and equipment. This was important so that we did not find ourselves carrying potentially contaminated materials through a part of the building that had already been decommissioned and surveyed.

"Additionally, the various areas of the building were designed for very specific purposes so that each room or area of the plant bore little resemblance to another. For this reason, it was important to have a diverse and well cross-trained staff of technicians who could easily switch from one type of task to another with minimal disruption. In addition, where contamination levels were low and well characterized, radiological control technicians who were trained in the use of power tools such as band saws, rotary hammers, etc., were utilized. This helped keep the staffing size down and also helped keep the morale of the workforce high by minimizing boredom from repetitive work. Naturally, high morale leads to pride in the work product."

Among the more difficult areas of the building to decontaminate was the Service Concentrator Gallery. The Service Concentrator, a 15-ft-high stainless steel vessel, was highly contaminated internally and contained a dimester. We flushed the vessel with nitric acid and still had to cut open the bottom to manually decontaminate the lower portion.

We began decommissioning of the Separations Facility in November 1998. We completed the last area in early February 2000.

Raymond "Frosty" Almers, the LCE engineer who planned most of the metal cutting work, explains how it was done: "We used two types of variable-speed electric saws to cut stainless steel piping and tanks into sections for disposal: a portable band saw and a Milwaukee Sawzall. We found that Lenox premium reciprocating saw blades outperformed others we tried. We slowed down the saws to reach the most effective cutting speeds for cutting stainless steel up to ½ inch thick. We found the household product Scrubbling Bubbles® to be a great lubricant for all saw cutting. In addition, the product was found very effective as a decon solution.

"We had to bore 4-in.-diameter holes approximately 3 in. deep into lead shielding on two filters to allow installation of a Canberra in-situ gamma spectroscopy detector. We used a Lenox wood boring bit, along with a magnetic-base drill and a specially designed adapter. We replaced the bit's self-feeding lead screw with a piece of round bar stock to allow controlled boring. We used Lenox ProTool lube as a lubricant.

"In cutting 10-gauge stainless steel sheet metal on gloveboxes and fume hoods, we used electric nibblers on the straight runs and either a reciprocating saw or portable band saw for glovebox corners and framing. We found it worthwhile to have two nibblers on hand in the event one became pinched on the larger sheets."

The Alpha Lab

The laboratory building connects to the north side of the Separations Building. Known as the Hot and Cold Laboratory Area (HCLA), it contains 17 laboratories. These laboratories contained a total of 37 gloveboxes, many contaminated with plutonium and other transuranics, and numerous contaminated fume hoods. In-situ gamma spectroscopy detected transuranic contamination levels inside gloveboxes exceeding 10^{10} disintegrations per minute per 100 square centimeters.

From the beginning of fieldwork, we expected the project critical path to reside in one room of the HCLA: the Alpha Lab. This lab contained three gloveboxes, each highly contaminated with plutonium and other transuranics. The simplest design, known as Glovebox B and the first to be removed, consisted of four 3-ft-long units joined together. Another, Glovebox C, standing 10 ft high, was packed with highly contaminated PUREX pilot processing equipment. The third glovebox, designated Glovebox A, stood 25 ft high and contained the vacuum pump used with all three gloveboxes.

We began work in the Alpha Lab in June 1998 with disassembly of Glovebox B. This work proceeded slowly and was finished in February 1999. We then tackled Glovebox C. After this work was finished, we turned our attention to Glovebox A.

Jimmie Mizell, the LCE field support specialist who did much of the disassembly work, recalls: "To install the containment tent, we had to cut out the wall behind the Glovebox C. This glovebox was unique in that it still had all of the equipment installed that had been used for various testing. This included numerous glass vessels, stainless tanks, tubing and piping, electric motors, pumps, conduit, and equipment foundations. We determined that the most economical and safest path would be to remove as much equipment through glove ports and transfer sleeves as possible. All of the tubing, conduit, and some of the small glass vessels were removed through the transfer sleeves. Once all of the small components were removed, we established exhaust ventilation on the box for removal of the windows. Once a window was removed, all of the equipment located in that area was removed and a temporary cover installed prior to proceeding to the next window. The temporary cover enabled us to maintain adequate negative pressure on the glovebox.

"The glass vessels remaining were too large to fit into transuranic waste shipping containers and had to be size reduced. To eliminate the potential for puncture wounds, we wrapped the glass vessels in foam and placed them in special tear-resistant bags inside the glovebox. We used a dead-blow hammer to shatter the vessels. We placed the glass vessels in another package upon removal from the glovebox and deposited them directly in a waste shipping container.

"We size-reduced the remaining piping by cutting with portable band saws. However, the equipment foundations were more difficult. Initial surveys indicated that the foundations would be transuranic waste and that conventional deconning was not working. They were too large to fit inside the shipping containers. We decided that it would be more economical to perform metal removal deconning than it would be to size-reduce them. A sanding block was used to decon the foundations below transuranic waste levels, and the entire platform, minus the legs, was removed as a unit. The legs were welded to the floor of the glovebox and had to be cut with a band saw for removal.

"We deconned the interior of the glovebox below transuranic levels using ordinary oven and bathroom cleaner. We removed the glovebox support structure and walls utilizing nibblers and band saws.

"Glovebox A was intimidating just due to its size. Consideration had to be given to any support braces attached to the mammoth box. Removing support braces too early in the dismantlement process could result in the box toppling over and causing high spread of contamination or worse, serious injury. To make removing this box even more difficult, once you started dismantlement of the box, fall protection was required in addition to radiological controls.

"We fogged the glovebox to help fix the contamination. Entering the glovebox through a large transfer device, we then removed the equipment—which amounted to a stainless steel tank, a glass vessel, a vacuum pump, and numerous tool trays. Since there were sharp objects within the confines of the box, special polyurethane suits that were more tear-resistant than normal suits were used. After all of the equipment was removed, the entire interior of the box, as far as a person could reach, was deconned. This could be accomplished because the bottom portion of the box had the highest levels of contamination. After deconning the interior of the box, we dismantled the glovebox structure and walls using band saws and nibblers."

Michael Littleton, the project radiological safety officer, describes the radiological controls used in dismantlement of the Alpha Lab gloveboxes: "External exposure was almost nonexistent on the project. The main radiological concern on the site, especially in the Alpha Lab, was the potential intake of transuranics by inhalation or injection.

"Our first line of defense against intake of transuranics was to prevent our workers from contact with the transuranics. We decontaminated the boxes to the maximum extent practical using new gloves on the existing glove ports and fixed radioactive contamination using an aerosol coating. When further decontamination became impractical, we used temporary ventilation and primary containments to minimize airborne radioactivity during glovebox dismantlement. Canberra Sentry® continuous air monitors were used to warn workers of deteriorating conditions, and personal air samples measured worker exposure to inhaled radioactivity.

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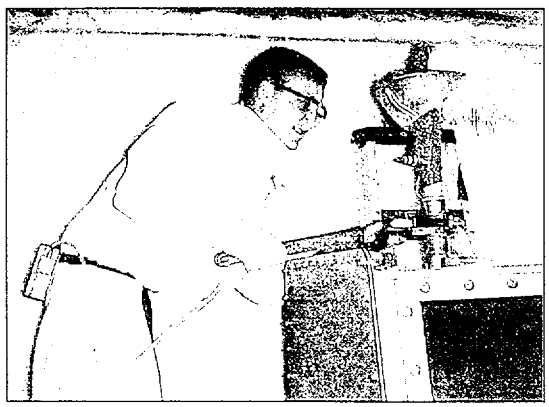

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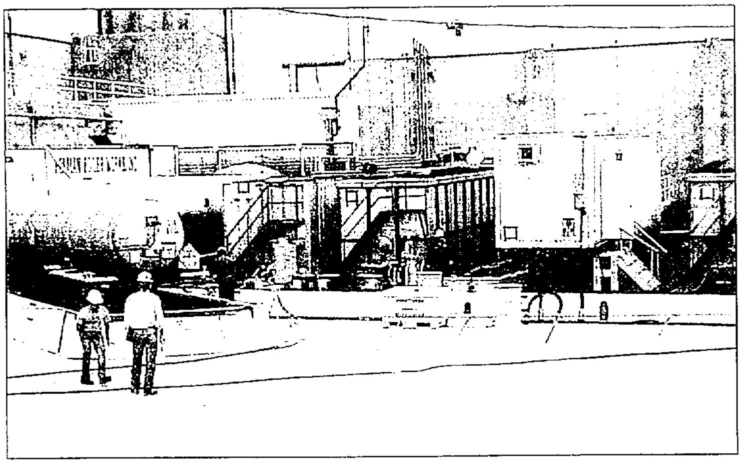
1) Removing PUREX processing equipment from a glovebox in the Alpha Lab at the BNFP. 2) Preparing to remove glovebox from the lab. 3) Cutting piping in the Hot and Cold Laboratory Equipment Station.



Liquid waste processing equipment.

"During some parts of the work it was necessary for workers to use supplied air hoods and plastic suits. During the highest-potential work, they wore suits made of polyurethane, for higher cut and tear resistance. During some work they also wore Kevlar gloves for the same purpose."

The Rest of the Laboratory Building

Although less challenging than the Alpha Lab, decommissioning of the other HCLA laboratories also involved dealing with gloveboxes and fume hoods with high contamination levels. Schatzer decided to first decommission the rooms on the south side of the second floor of the building. These rooms and the equipment within them had lower levels of contamination, and the nuclide of concern was uranium. Thus, the technicians and engineers had the opportunity to determine the best methods for separating the gloveboxes and fume hoods.

Phil Worley, the LCE decommissioning manager for the project, remembers: "The most challenging work on this floor came in four individual laboratory rooms on the north side of the east-west corridor. Each of these rooms contained multiple gloveboxes and fume hoods, and these components were contaminated with transuranic contamination. Total activity levels up to 10^{10} dpm/100 cm^2 transuranics were known to exist inside the various components.

"Our initial thought was to decontaminate and size-reduce these components in place using a combination of personnel protective equipment, containment tents, and HEPA-filtered ventilation. However, we recognized that cutting the components into pieces that were small enough to handle would potentially expose the technicians to very high levels of removable contamination. In addition, the cut metal would have sharp edges that could cause puncture wounds and lead to significant internal doses.

"After considering our options, we decided the best route was to use the fume hoods and boxes as they had been designed. Using existing ventilation piping, we connected temporary HEPA-filtered exhaust ventilation to the gloveboxes and fume hoods. Then we changed all of the gloves on the gloveboxes.

The Decommissioning Team

The owners were well pleased with the planning phase of the project. Accordingly, they hired the same team to decommission the plant. Life Cycle Engineering (LCE) would serve as prime contractor, providing project management, engineering, and health physics support. TRIAD Inc., a new radiological and environmental services company located in Barnwell, S.C., would furnish planning, work control support, and the health and safety program. TRIAD would also provide radiological control support and decommissioning workers. TRIAD was formed by key people from the U S Energy group who characterized the plant and helped plan the project.

These two companies made up the core group that carried out the decommissioning. Additional firms provided support: S. W. Jones Inc., of Little Mountain, S.C., managed the waste associated with the project; Orazor LLC, of Knoxville, Tenn., provided the Radiological Safety Officer; Omega Consultants, of Aiken, S.C., provided additional radiological control and radiological engineering support; ThermoRetec, of Chapel Hill, N.C., provided a team to process the liquid waste associated with the project; Canberra assayed the transuranic waste; and Chem-Nuclear Systems Inc. compacted compressible low-level waste.

One noteworthy aspect of the project organization concerned the decommissioning workers. With a single exception, TRIAD radiological control technicians performed the actual decommissioning work. This arrangement resulted in a high degree of radiological knowledge and experience in the workforce. The one exception was an LCE field support specialist. This person, an experienced tradesman and instructor, helped train the technicians in work such as metal cutting and helped perform some of the high-risk work, such as dismantlement of special-design plutonium gloveboxes.

To optimize efficiency, the decommissioning team size was kept to a minimum; at its peak, the core group numbered 33 people, including 15 radiological control technicians. With subcontractors onsite, the total workforce peaked at about 70 people during processing of radioactive liquid.

Working through the new gloves and with negative pressure on the gloveboxes and with proper airflow through the fume hoods, the technicians decontaminated the internals of the various components. After the decontamination was complete, a fixative was applied to the internals of the components. Then the components were disconnected over a drape with work site exhaust. Openings in the separated components were sealed, and the components were packaged for shipment to the Chem-Nuclear Consolidation Facility where the components were placed intact into a B-1000 container and crushed with a hydraulic press."

With the thin sheet metal and Plexiglas construction of the gloveboxes and fume hoods, the compaction process substantially reduced the waste volume.

Another room in the HCLA that required significant effort to decontaminate and decommission was the Analytical Equipment Station. Tanks in this room, which is located partially below ground, received discharges from piping in the labs. We thought initially that we could effectively decontaminate one or more of the tanks. This did not prove to be the case. Each tank had to be cut apart and moved from the room in pieces.

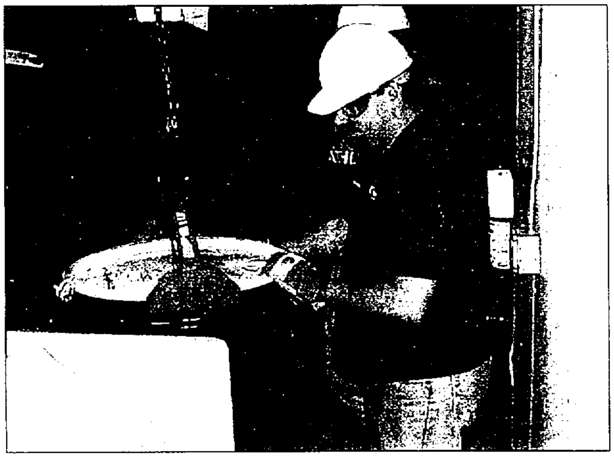
Gloveboxes and fume hoods headed for supercompaction.

The High-Level Waste Facility

The HLW facility consists of three underground 300 000-gallon tanks, located partly beneath a reinforced concrete building that housed tank piping and support equipment. The tanks were constructed of stainless steel and contained in a stainless steel–lined reinforced concrete vault. We understood from review of records and from talking to some of the plant operators that the two tanks used during the plant testing would have a small heel of liquid containing low levels of natural uranium. We assumed that this would be the case and, considering the safety issues associated with confined space entries, did not open the tanks during the characterization program.

The operations manager decided to open the tanks early during the fieldwork, in case conditions turned out different from those expected. They did. One tank was actually floating. Rainwater had leaked into the tank vault, filled the annulus

[Left] In this photo from around 1980, Jimmie Baxley, AGNS supervisor (right), shows plant visitors how the manipulators in the Separations Building work. [Right] Now, Baxley, as a TRIAD radiological control technician, performs final radiological surveys in the same area of the Separations Building where he showed visitors how to use the manipulators 20 years before.



Canberra assayed TRU waste associated with the decommissioning.

between the tank and the vault wall, and spilled into the tank. Instead of dealing with a small heel, we were faced with 120 000 gal of rainwater in the vault and some 70 000 gal of radioactive liquid in the tank.

Nor did the other tank turn out as expected. It contained about 5000 gal of mixed waste, with some 300 kilograms of uranium.

With these conditions the radioactive liquid processing effort took on new importance. ThermoRetec and its subcontractors set up an evaporator processing system near the Separations Building in spring 1999, under a SCDHEC permit. Over the next few months they processed approximately 87 000 gal of radioactive liquid. The resulting nonradioactive liquid went to a publicly owned treatment works.

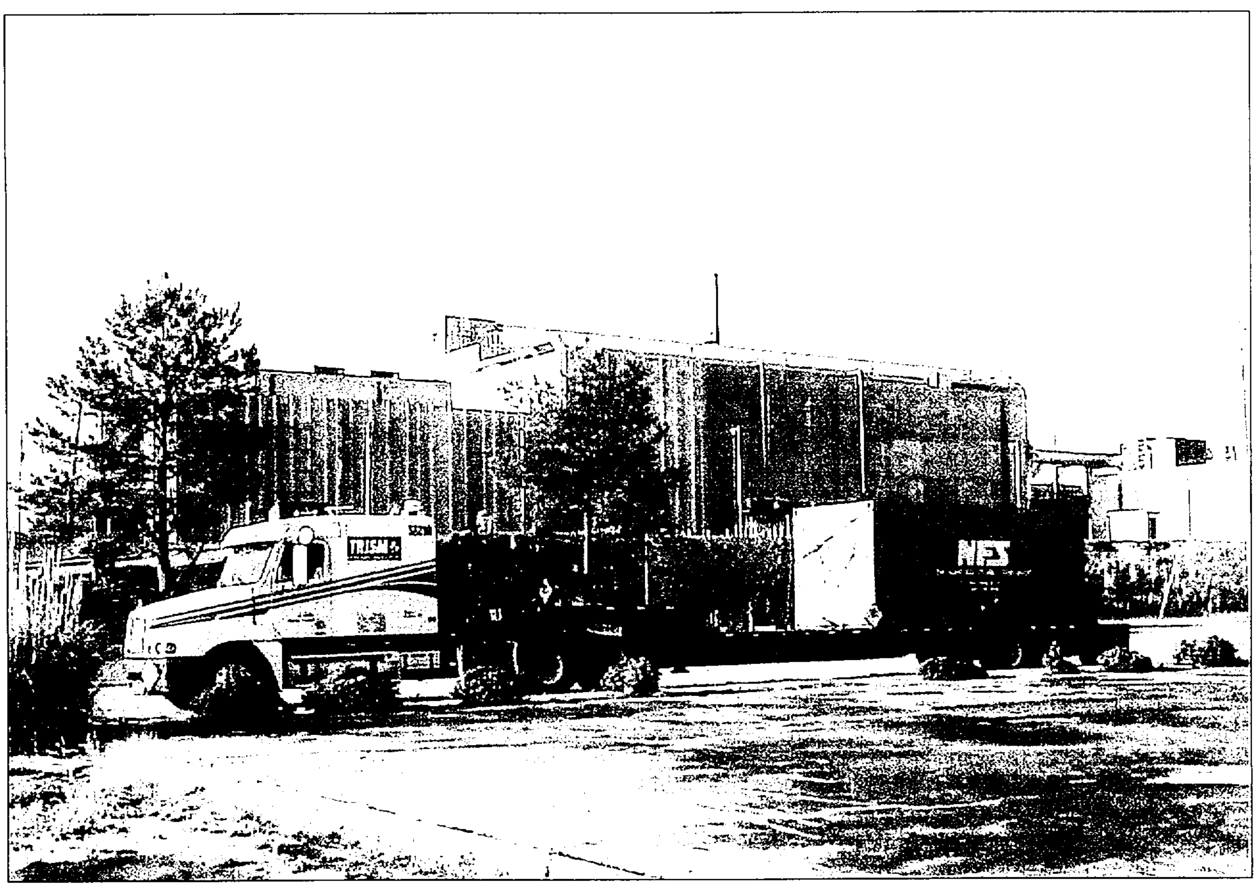
Later, a PermaFix team came onsite and stabilized the residues from the process. The stabilized residues were disposed in 55-gal drums and B-12 boxes as LLW.

Waste Associated with the Decommissioning

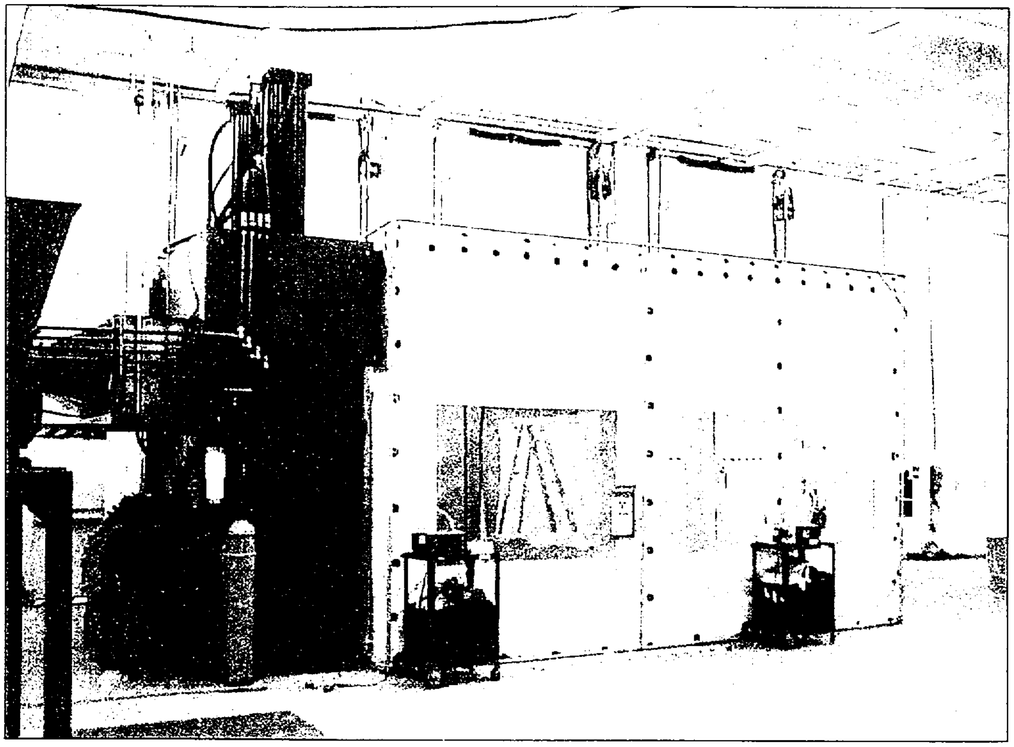
Waste volumes associated with the decommissioning were as follows: TRU waste, 250 ft^3; LLW, 15 000 ft^3 (prior to volume reduction, about 6000 ft^3 afterwards); and mixed waste, 300 ft^3. We sent the mixed waste to the Envirocare facility in Utah.

Scotty Jones, the project waste management coordinator, notes: "I think one of the most significant aspects of the project from a waste management standpoint was the interface with the SRS. For the LLW and transuranic waste to be acceptable for disposal at SRS, our waste management program had to be certified by the site's waste management personnel. This certification process involved preparation of waste management procedures, a detailed audit of our program, and plant visits and inspections.

"Additionally, a 'waste certifying official' was assigned by the DOE facility to oversee and provide an



Type B TRU waste bound for the SRS in a Nuclear Fuel Services Super Tiger container.



Chem-Nuclear Consolidation Facility Super Compactor, set up for BNFP plutonium waste.

and could review our results before performing independent surveys. This process worked well throughout the final survey program.

We completed the last of our final surveys in April 2000. The regulator's last surveys were finished not long afterward and the radioactive materials license terminated.

And Now It's Over

The BNFP decommissioning is the largest nuclear facility decommissioning project yet undertaken in South Carolina.* The approach used—which included detailed planning, development of site-specific cleanup guidelines, close liaison with the regulator, and the use of small crews of radiological control technicians to perform the fieldwork—paid off in terms of efficiency. ■

interface with the SRS Waste Management Program. This arrangement worked remarkably well. Problems that arose were quickly and easily managed—no major problems or complications resulted from this arrangement."

Another element of the interface with SRS was a biweekly conference telephone call. These calls, started early in the project and continued until all the LLW and TRU wastes were transported to SRS, allowed the DOE to keep close tabs on what was happening during the decommissioning and on the support being provided by the SRS people. All in all, the SRS waste interface turned out to be one of the bright spots during the decommissioning.

Final Status Surveys

We designed the Final Status Survey Plan following the protocols of the *Multi-Agency Radiation Survey and Site Investigation Manual (MARSSIM)*, NUREG-1575, and obtained the regulator's approval. We divided the plant into 166 survey units, classified the survey units by potential for contamination, and then specified survey detail accordingly. We took credit for data generated during the characterization program, where appropriate.

After final surveys and sampling of a survey unit were completed, we entered the data in a database and wrote a chapter for the Final Status Survey Report describing the survey unit and the results and sent it to SCDHEC in draft form. Therefore, the regulator had in hand all the pertinent information about the survey unit, including the characterization data,

Jim McNeil is LCE's decommissioning project manager. He served as the assistant project manager for the BNFP decommissioning.

Many people on the decommissioning team contributed to this article. Those same people played key roles in the project. The author wishes to thank especially the following: Stan Massingill, of the DOE-SR Solid Waste Division, who helped throughout the project in arrangements to send the LLW and TRU waste to the SRS, as did Glenn Siry, of Westinghouse Savannah River Co.; Virgil Autry and Henry Porter, of SCDHEC, and their people, who showed how a responsible regulator can provide both truly outstanding support and effective independent review; and Larry Hargrove, the LCE project manager, who effectively managed the business side of the project and provided his usual excellent support to the technical staff.

Finally, the client, AGNS, could not have provided better support. Georgia Fields, the AGNS site administrator, helped every day of the project from beginning to end. Her knowledge of the site and her assistance contributed immeasurably to the project's success. And Kent Rogers, the AGNS project manager, recently retired from a distinguished career at Shell Oil Co., helped us stay on track with insightful, common-sense questions and red-tape-cutting support.

*This statement does not take into account the nuclear decommissioning of Charleston Naval Shipyard, a different type of project carried out under the auspices of the Naval Nuclear Propulsion Program.