A LARGE DECOMMISSIONING PROJECT WITH ADDED VALUE

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ABSTRACT

The East Tennessee Technology Park (ETTP) in Oak Ridge, Tennessee, is a centerpiece for the Department of Energy's Reindustrialization program, which seeks to convert formerly used facilities for broad, industrial purposes. BNFL and its partners have been charged with the decommissioning and decontamination of three large gaseous diffusion buildings. BNFL's prior experience with a similar site, Capenhurst, in the United Kingdom was successful in reducing the quantities and costs of low level wastes for disposal. In that program, over 99% of 160,000 tonnes of surface-contaminated materials were safely and cost-effectively treated. Resulting materials could thus be recycled for complete unrestricted re-use within the UK. Decommissioning and decontamination at the ETTP site will be informed by the prior experience and lessons learned. Specialized technologies and approaches developed at Capenhurst will find expression at ETTP. The result will be safe, cost-effective techniques that permit maximum recycle and further use of presently contaminated buildings for industrial purposes.

INTRODUCTION

This report describes DOE's objectives for the East Tennessee Technology Park (ETTP), located near Oak Ridge, Tennessee, as well as experience that BNFL and their partners have to bring to the table to decommission and decontaminate (D&D) the ETTP (K-25) Site Gaseous Diffusion K-33, K-31, and K-29 Buildings safely and cost effectively. BNFL's experience with a similar site in the United Kingdom also involved the decommissioning of buildings and decontamination of materials. That experience led directly to a significant reduction in the quantities and costs of low level wastes for disposal. Adaptations of similar technologies and approaches will yield benefits for the ETTP project.

ETTP DECOMMISSIONING PROJECT

The purpose of the ETTP (formerly the K-25 Site) Three-Building D&D and Recycle Project is to dismantle, remove, decontaminate, and economically maximize the recycle of process equipment and material within the Gaseous Diffusion Plant (GDP) buildings K-29, K-31, and K-33. D&D of the three buildings shall be accomplished by the contractor dismantling and removing the process equipment and related support systems, recycling the metals to the extent economically practical, and cleaning up the interior of the buildings to a specified end point criteria for unrestricted industrial re-use.

The ETTP is part of the Oak Ridge Reservation in East Tennessee. The ETTP, previously known as the K-25 Site and the Oak Ridge Gaseous Diffusion Plant (ORGDP) (see Figure 1), supplied enriched uranium for nuclear weapons production. To obtain the Uranium 235 (U-235) enrichments achieved in the fully operable ORGDP equipment, thousands of separate barrier elements, thousands of feet of piping to carry the uranium hexafluoride (UF_6), and thousands of pumps were required to propel the gas.

Figure 1 Oak Ridge Gaseous Diffusion Plant.

The K-29, K-31, and K-33 Process Buildings were originally designed and built to house the low enrichment part of the ORGDP cascade. These three buildings, referred to as the LEU Process Buildings, were shut down in 1985, and permanently closed in 1987. These buildings are in structurally sound condition and are prime candidates for industrial reuse. However, many areas in the three buildings and much of the equipment are contaminated with radiological and hazardous substances from past operations. This contamination poses a health risk to workers and a potential risk to the public. The contaminants are contained within the buildings themselves; therefore, risk to the environment and the public is negligible. However, over time the probability of future contaminant release to the environment will increase because of inevitable structural failure and subsequent contaminant migration. Due to the potential for nuclear criticality from deposits of uranyl fluoride in the process equipment, the three LEU Process Buildings are categorized as Hazard Category 2 Nuclear facilities.

The K-29 Building began operation in 1951. It was the first diffusion process addition to make use of axial flow compressors and evaporative process cooling using the refrigerant R-114. This two-story building is 170-m long x 159-m wide. The gaseous diffusion process equipment is located on the cell floor level (see Figure 2). This equipment includes axial flow gas compressors, stage gas diffusers, process piping, process valves, booster stations, and the coolant and recirculating cooling water piping systems. The operating floor contains the central control room. The operating floor also contains the lubrication oil drain tanks, circulating pumps, coolers and filters; electrical transformers and switch gear; and ventilation fans and ducts. K-29 has six 9-tonne bridge cranes servicing the entire cell floor area.

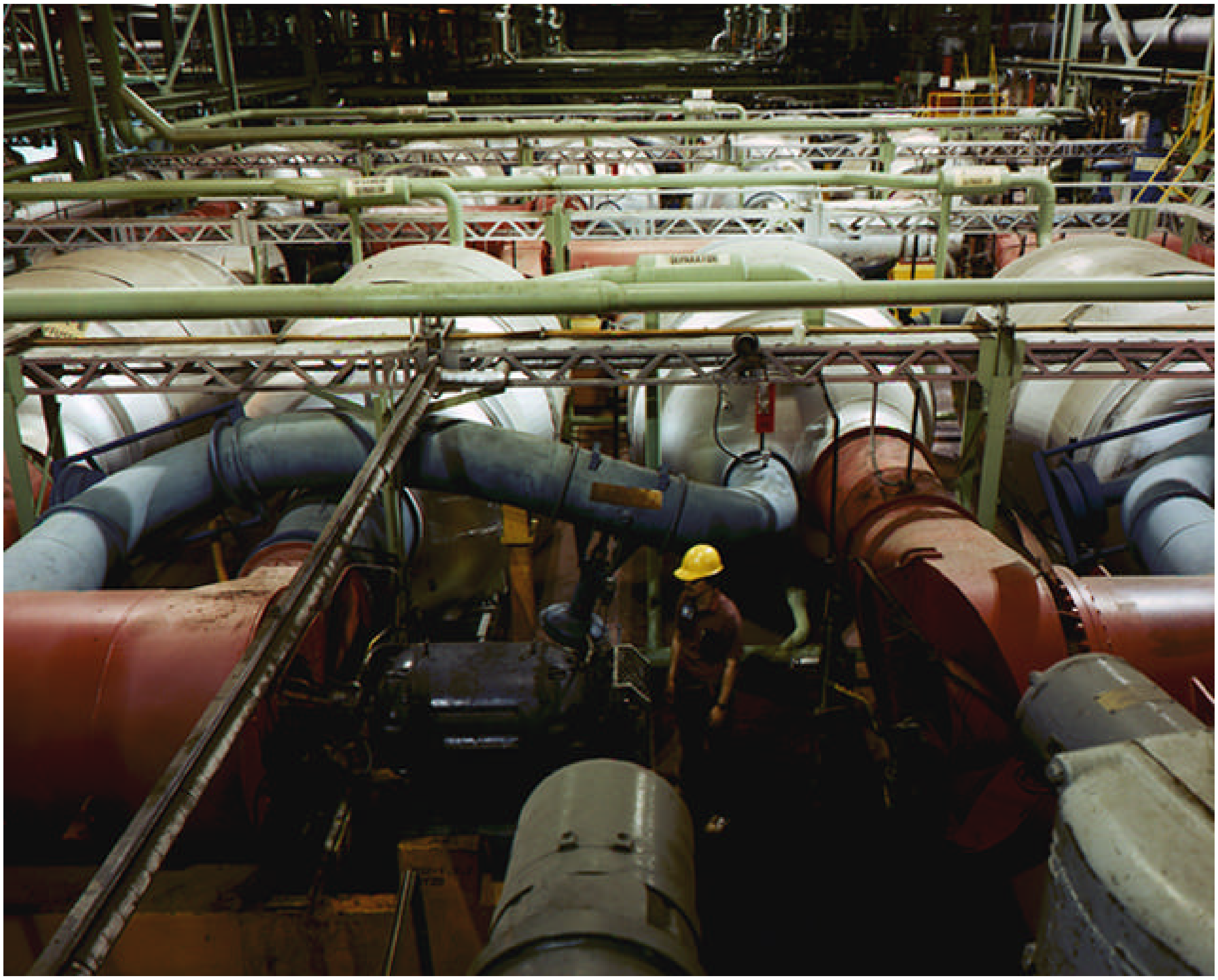

Figure 2 Process Equipment at K-29

The K-31 Building began operation in 1951. The K-31 Building is a two-story building and is 366-m long x 190-m wide. Similar to the K-29 Building, the gaseous diffusion process equipment is located on the cell floor. In K-31, however, individual groups of ten diffusion stages are individually enclosed in insulated sheet metal cell enclosures. The operating floor contains the process control room, offices, shops and auxiliary equipment.

The K-33 Building was placed into operation in 1954. The K-33 Building is a two-story building. K-33 is 442-m long x 296-m wide of floor space on two floors and a volume of 3,258,800 m^3. K-33 consists of eight units. The process equipment located on the cell floor is enclosed in insulated sheet metal cell enclosures. Cell by-pass piping runs above the cells. The process equipment in K-33 is the largest employed in the GDPs. Process support equipment, as in K-29 & K-31, is located on the operating floor.

The three buildings are currently unusable and require continuous surveillance and maintenance activities estimated to cost approximately $80 million over the next ten years. The challenge for this project is to simultaneously remove equipment/material, clean up the buildings, and perform economically viable salvage/recycle of the equipment/material. Salvaging and recycling would lower the overall cost to the government and taxpayer, yet cost recovery from selling salvaged or recycled materials from the project is limited at present. This is due to the contamination present, the classified nature of much of the valuable material, and the limited market for previously contaminated material. There are approximately 114,000 tonnes of potentially contaminated metal within the process equipment in the three buildings. The scope of the ETTP Three-Building D&D and Recycle Project is the following:

- perform D&D and recycle under fixed-price contract
- perform surveillance and maintenance services
- remove all process equipment and materials from the three buildings
- decontaminate vacant areas within the buildings to brownfield status
- decontaminate and recycle the majority of materials and equipment
- dispose of all waste

The three building concept is the beginning of full D&D of the five ETTP GDP buildings. The concept directly supports Reindustrialization of ETTP, which is targeted as a key mission by the DOE. Reindustrialization is expected to accelerate cleanup, yield cost savings for DOE, and provide indirect benefits to the Oak Ridge work force and community. The intent of this project is to find the most cost-effective way to meet the government's desire to have the three buildings cleaned up and available for alternative use. BNFL, in fulfilling this charge, brings its expertise in cleaning up similar diffusion facilities in Great Britain, along with its business acumen, financial backing, and industrial contacts, to take over the surveillance and maintenance of the buildings, execute cleanup, and tailor the entire process to minimize the quantity of material shipped for disposal. The decontamination and recycle enterprises will be negotiated and established by BNFL. Recyclable materials will be recovered and delivered to these enterprises in forms that are acceptable and that fulfill the specialized and focused needs of BNFL's business associates. BNFL and its subcontractors have expertise in each of the D&D, recycle, and waste disposal areas needed to perform the work described above. The work will be performed utilizing external licensing by the Tennessee Department of Environment and Conservation (which has NRC oversight responsibilities in Tennessee) and under OSHA rules for off-site work and DOE oversight for on-site work utilizing Work Smart Standards.

BNFL'S EXPERIENCE

The Capenhurst Diffusion Plant was built in the early 1950s, at which time it was the largest industrial building in Europe under a single roof (see Figure 3). Some 1,219-m long and 152-m wide, the plant consisted of a cascade of 4,800 "stage units" of various sizes connected by 1,815 km of process gas pipework up to 56 cm dia., with numerous valves and associated process services (see Figure 4).

Figure 3 An aerial view of the Capenhurst plant.

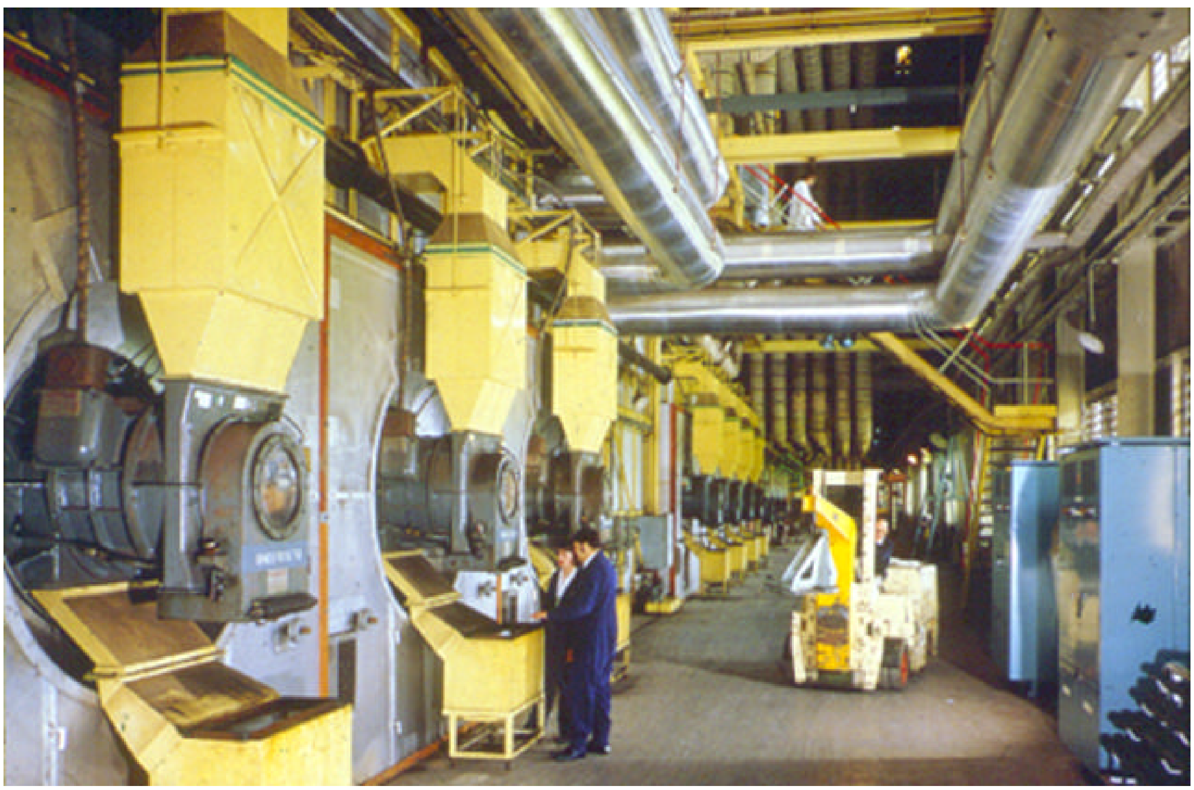

Figure 4 An example of some of the large stage units and associated pipework that had to be dismantled.

Just as Oak Ridge's K-25 plant, Capenhurst was originally built to produce highly enriched uranium for defense purposes, but in the early 1960s the high enrichment section was isolated, emptied, and put under care and surveillance. The rest of the plant was then modified to produce low enriched uranium for civil use.

In 1982, a decommissioning project was begun to deal with over 160,000 tonnes of suspect surface contaminated metal, concrete, and other potentially hazardous materials. As with K-25, the significant nuclides involved in the contamination were Uranium and its daughter products, together with Technetium 99 (Tc-99) and Neptunium-237 (Np-237) from re-enrichment of reactor-recycled uranium. Less than 1% of the total mass of materials arising from this project has been consigned for burial as low level waste. Over 99% has been successfully treated and recycled. Less than 725 tonnes have been despatched for land burial.

UK DECOMMISSIONING PHILOSOPHY

The main aim of the Capenhurst project was to recycle as much of the above material as possible for unrestricted reuse, while minimizing the impact on the environment and the dose commitment to the workforce.

It was recognized from the outset that a significant "up-front" investment would be required to develop suitable techniques to achieve this aim at minimum cost. The first two years of the project were therefore focused on research and development into cost effective dismantling decontamination and decommissioning techniques. This R&D investment has provided BNFL with the expertise to help the U.S. design, build, operate, and maintain specialized decommissioning plants and equipment, without "reinventing the wheel."

SPECIALIZED TECHNIQUES

Plant Pre-treatment

Before the Capenhurst Diffusion Plant was shut down, exploratory test work provided radiological and criticality data for subsequent use. A fluorination process was then employed to convert solid deposits within the plant to volatile fluoride compounds that could be safely disposed of. With the plant at standstill, further local operations dealt with any significant remaining pockets of solid or gaseous contamination. Because the ETTP process buildings are already shut down, these techniques cannot be applied at Oak Ridge.

Plant Dismantling

The main dismantling task was to break down the process plant into manageable units, many of which were then stored pending the availability of size reduction and decontamination facilities. Economical methods for safe penetration and in-situ cutting were developed. Units were then removed, sealed, and placed into managed outside storage of over 7,000 tonnes of material.

Much of the material from the dismantled main buildings—including the cells that had originally housed the plant and ancillary structures such as eleven cooling towers, pumphouses and an electrical substation—was demolished, monitored, and sold as clean scrap. Floor slabs were decontaminated, ground samples checked and confirmed to be free from contamination, and the area returned to greenfield status.

Stage units ranged from small, 748 kg steel shells to aluminum fabrications weighing 7 tonnes and occupying $27m^3$. Some 19,355 km of piping, 3,500 tonnes of electric motors, and 800 tonnes of process valves were removed and treated. Although larger in size, the ETTP plant equipment comprises similar shapes, materials, and configurations.

Size Reduction

When removed from the plant, most items were too large and complex to be monitored or decontaminated without cutting. For each type of item, a cutting plan specified how to dismantle it further and, for wet decontamination, how to fill the baskets used in the decontamination equipment so as to expose all surfaces to the cleaning liquors. Most cutting was repetitive and was therefore automated using dedicated equipment installed in inactive areas of the Diffusion Plant. A wide spectrum of cutting options was examined and the most appropriate selected for each case. A major lesson learned from the UK was to locate cutting stations close to the source of plant equipment, thereby reducing handling costs.

The following examples list some of the varied size reduction techniques used at Capenhurst.

- Robotic plasma cutting—The size and complexity of 750 aluminum stage units posed particular problems. After studying all the available options, it was decided to develop a facility based around two large industrial robots adapted for plasma arc cutting. A special ventilation system, which dealt with the large volumes of fumes generated, and fully remote operation minimized operator exposure (see Figure 5).
- Remote gas cutting—1,400 of the nickel plated steel stage units were cut up using semi-automatic gas cutting, again using special ventilation and remote operation.
- Large bandsaw—2,200 tonnes of aluminum pipework up to 56 cm dia were satisfactorily reduced in size using a large capacity bandsaw with rollerbed feeding.
- Tube trepanning and stripping—2,500 heat exchangers contained a total of 98,000 uncontaminated cupronickel tubes sheathed with contaminated aluminum fins. Special equipment was developed to trepan the tubes out of the tube plates and then strip the clean tubes away from the fins without cross-contamination.
- Routing—Where hot cutting was inappropriate, routing was an economical alternative. Special facilities were needed to contain swarf and minimize operator intervention.

At ETTP, a combination of effective hot and cold cutting techniques is to be employed in a purpose-built size-reduction workshop located within the Plant building.

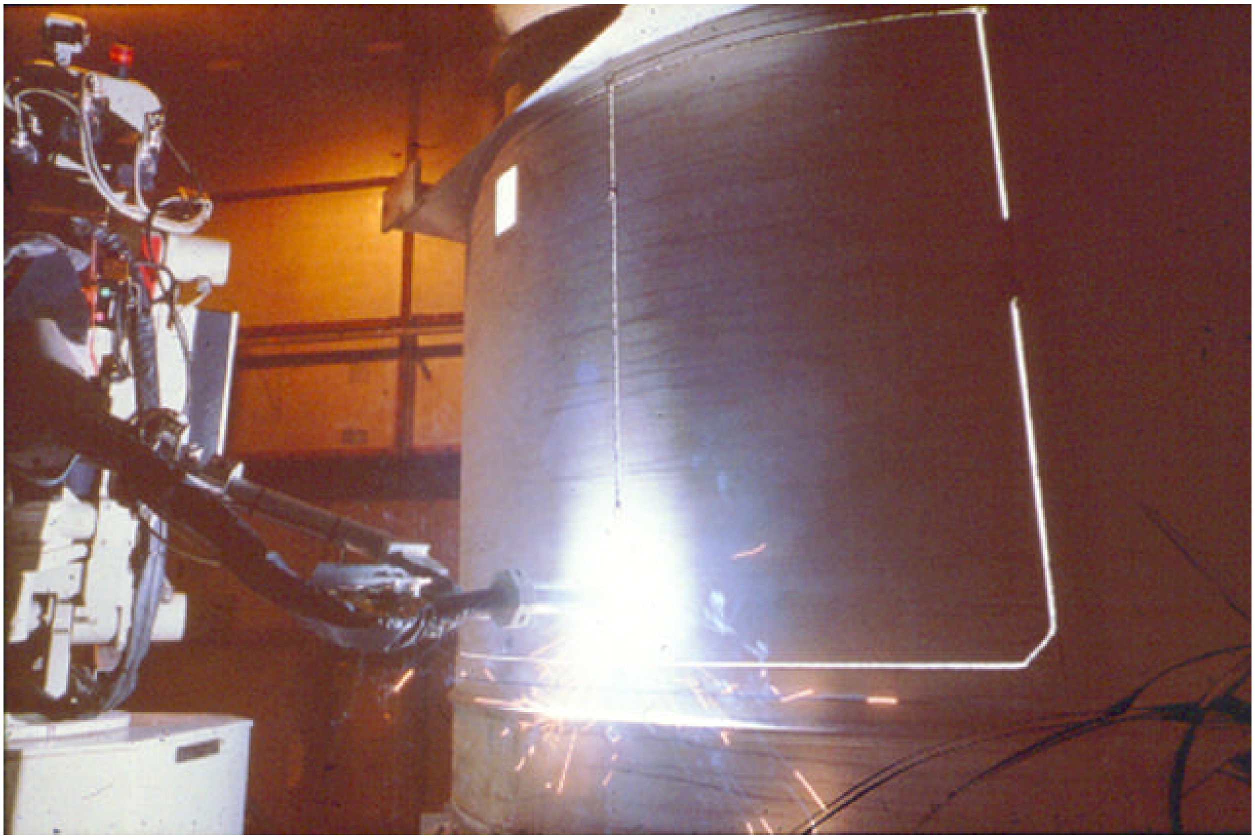

Figure 5 One of the two plasma arc cutting robots developed for cutting up the larger stage units.

DECONTAMINATION

The success of the Capenhurst project depended crucially on development of a decontamination process to remove surface contamination from a wide variety of metals and surface textures, ranging from bright wrought aluminum plate to heavily rusted steel. As noted earlier, the full range of nuclides resulting from handling reactor recycled uranium had to be removed, including Tc-99 and Np-237, the most obstinate sources of contamination.

Following extensive laboratory and pilot plant investigation, a full-scale wet decontamination plant was developed, and finally completed in 1989 (Figure 6). As probably one of the largest decontamination facilities in the world, it remains in operation and is capable of processing up to 100 tonnes per week. Suitable size-reduced items were loaded into baskets (nominally 1.8-m x 0.9-m x 1.5-m) and then automatically passed through successive stages of washing in specially formulated process liquors, which entrained the nuclides for subsequent transfer into ion exchange resins. The resins—which represented relatively small and manageable volumes of active residues, and other solid and liquid wastes of acceptably low activity and toxicity—were later encapsulated in a cement matrix. Similar processes and surveying techniques will be employed at ETTP.

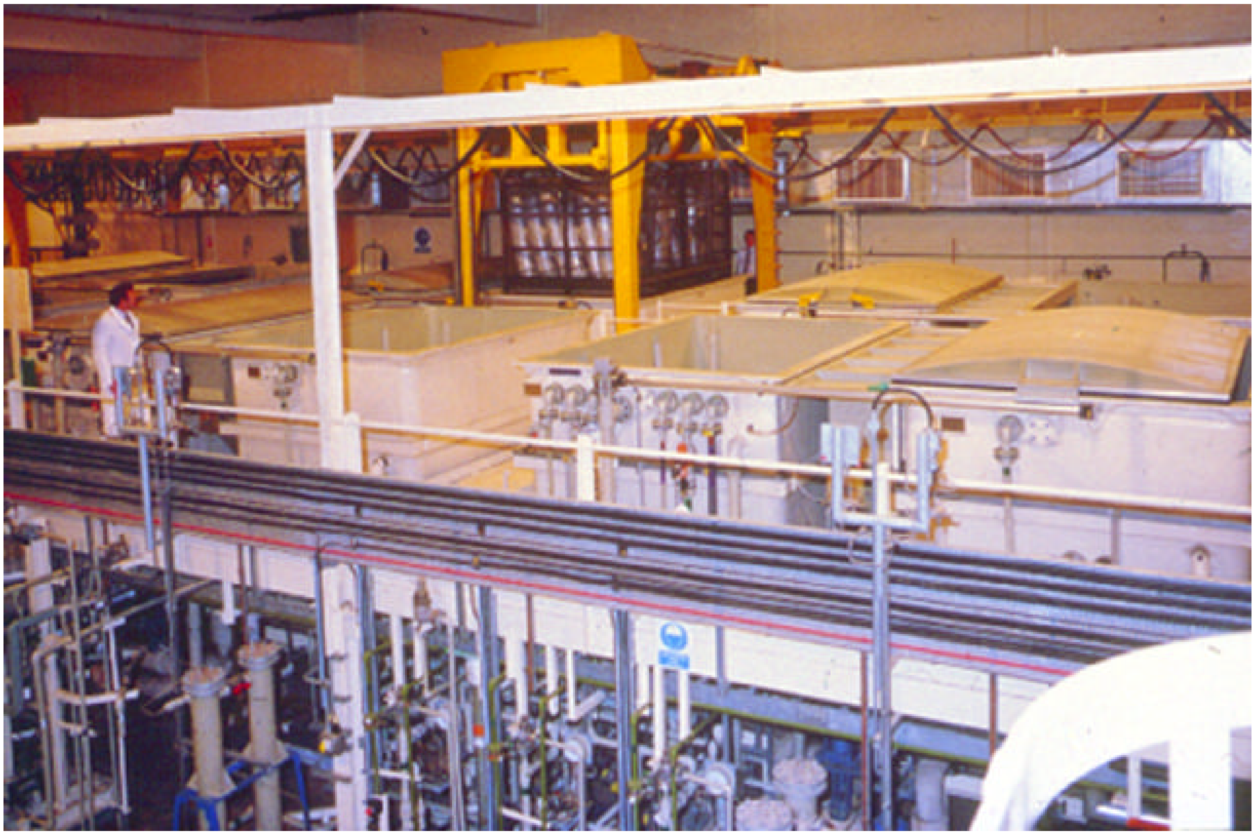

Figure 6 The wet decontamination facility now at Capenhurst.

MELTING

The Capenhurst melting facility primary aims were to produce ingots that were below free-release levels for unrestricted re-use. This was achieved by first decontaminating the feedstock as described above, and then using melting to produce metals in a form such that they could easily be monitored to confirm the level of contamination was at or below free-release levels. Melting produced a homogeneous ingot, samples from which could be monitored to confirm for free release or sentenced for burial. In the latter case, there was still a value in reducing burial volume and in fixing activity within the ingot.

Following pilot trials, a full-scale melting facility was developed and installed (see Figure 7) to process a range of contaminated metals, including items with non-metallic additions. Aluminum, lead, copper, bronze, cast iron, steel, and nickel were melted, and it was possible to separate lower melting point metals from higher melting point metals. Non-metallics have been incinerated with full environmental protection.

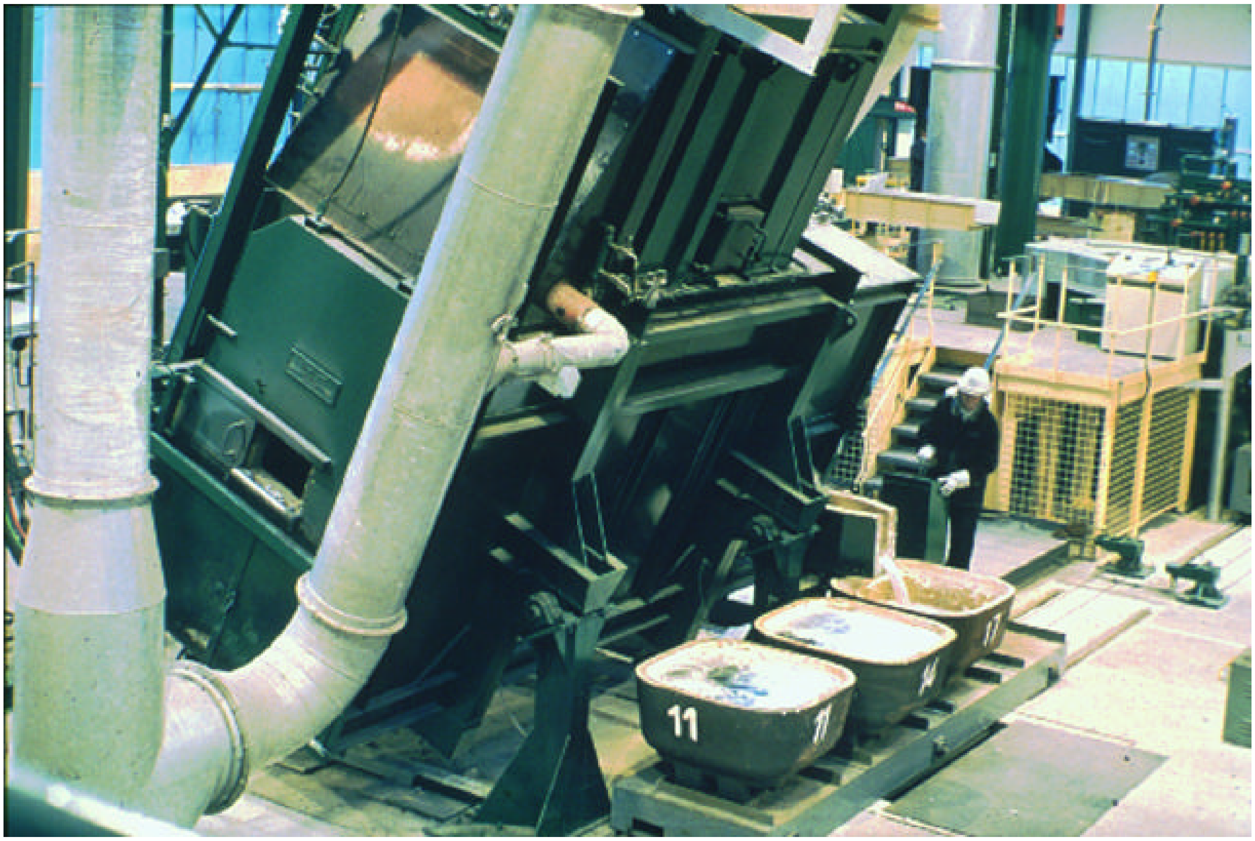

Figure 7 The melter has been used to process a range of contaminated metals.

The facility, which had a throughput of up to 150 tonnes per week, was a controlled active area with full radiological engineered safety systems. These included a highly sophisticated fume containment and treatment system, which removes all particulate and volatile radioactive and toxic substances in strict compliance with Environmental Protection Regulations. A facility control system, including dual redundant programmable controllers, ensured safe shutdown of the facility on detection of any excursion from defined limits, thus minimizing the risk of personnel dose uptake and preventing undesirable environmental discharges.

The initial decontamination campaign treated around 4,000 tonnes of metals which were decontaminated to relatively low levels of contamination. They still could not be released, however, because their complex geometry prevented full, cost-effective surveying. Examples included small bore pipework never exposed to process gases, closed voids within weldments, and re-entrant surfaces generally. Following successful demonstration of the containment of contamination within the melting facilities, these metals qualified for unrestricted free release.

ENCAPSULATION OF WASTE

The small volume of waste destined for land burial comprised both solid metals and a variety of less easily packaged materials. These included secondary waste such as evaporated process liquors, ion exchange resins, melting drosses and slags, filter media, swarf, and floor sweepings. A skid-mounted, transportable encapsulation plant was designed by BNFL and put into operation at Capenhurst. This plant immobilized the wastes into an ideal non-leachable form for low level waste disposal at the UK's only landfill repository. Metals and secondary wastes were mixed with a specially formulated cement encapsulant and sealed in standard 170 liter drums.

RECYCLED MATERIALS AND WASTE STREAMS

Solid Products

Once plant contamination had been characterized, it was essential to define the waste streams for which process routes had to be established, and with which all other decommissioning decisions had to be consistent. It was then necessary to identify the disposal options for the original contaminated material, as well as any secondary waste streams arising from the process routes utilized.

The UK has clearly established criteria for unrestricted release of material into the external market. The criteria exempt substantially insoluble solids with specific activity below 7.63 $x10^{-2}$ Bq/kg of any nuclide, with additional exemption for uranic activity below 2.35 Bq/kg. While international rationalization of clearance levels will ultimately lead to a more nuclide-specific set of release criteria, with higher limits for soft beta emitters such as Tc99, such legislation was not in place and the operations at Capenhurst were carried out in line with the more restrictive application of the current regulations. The development of cost-effective techniques to confirm the criteria met was also a very important consideration for melted ingots.

The only available disposal option within the UK for materials exceeding the criteria for unrestricted release is land burial at Drigg, the BNFL Low Level Waste Disposal Site near Sellafield. Burial of large volumes of contaminated material would have imposed massive cost penalties on the project, as well as occupied an unacceptable and unnecessary proportion of the valuable low level waste site capacity. Effective decontamination and sentencing of the maximum amount of material to free release levels was therefore highlighted as an essential part of the project.

Against this background, solid products arising from the project were categorized as follows:

- **Clean scrap**—materials which could be proved by monitoring to be suitable for free release.
- **Metals for decontamination**—metals which could be decontaminated and subsequently proved by monitoring to be suitable for free release.
- **Metals for decontamination and subsequent melting**—metals which could be decontaminated but, because of complex shapes/surfaces, could not be economically or effectively monitored, yet were suitable for melting and recasting as ingots. After melting, the material was then in a form capable of being monitored to confirm its suitability for free release.
- **Materials not suitable for free release**—materials (the remaining small quantities of material including some secondary waste products) which were not suitable for free release and were therefore consigned to land burial.

Other Products

The main source of liquid waste was from the decontamination process and was subject to discharge authorizations covering radionuclides and toxic metals, which limit discharge into local water courses to below 1.17 x 10^{-3} Bq/l /day and to below 1.8 ppm total metals. Other liquid wastes up to 1.17 Bq/l were acceptable to the regulators for landfill disposal. Gaseous discharges were limited by the discharge authorization for the whole Capenhurst site to less than 2.5 Bq annually. Actual emissions were less than 5.0 x 10^{-2} Bq annually. A comprehensive routine sampling and analysis program existed to monitor and confirm environmental discharges. Compliance was further supported by regular audits by relevant Government Departments.

PROJECT SAFETY

An overriding concern throughout the project was to minimize risks of radiation exposure to decommissioning operators, personnel on site, and the public generally. Alpha in-air monitoring, with an alarm level set at 3.07×10^{-3} Bq/m^3, was used extensively throughout the facility as was routine surface monitoring. A criticality detection system was installed, and strict criticality control procedures applied at every stage. Specialized workshops were constructed using redundant cells from the Diffusion Plant itself for the various operations, with dedicated and effective ventilation.

Operators used personal air samplers, respiratory protection, and full protective clothing as appropriate, and the BNFL personnel radiation protection program confirmed exposure levels at less than 0.2 mSv/yr. Full account was also taken of non-radiological hazards, particularly those associated with other toxic or hazardous materials removed during dismantling.

COST DRIVERS AND SAVINGS

The total cost of the project on a historical cost basis was less than $160M— in the order of $1,000 per tonne of material processed. About 20% of that total (representing a major investment), was applied to decommissioning R&D. Major costs drivers for BNFL included external purchases of hardware, costs of burial at Drigg, labor, and charges for health physics and radiochemical analyses. The decommissioning of the Diffusion Plant was completed within budget. The following features all contributed to this major achievement:

- Early investment in identifying and categorizing the various wastes was vital in laying the foundation for well-focused investment in specific decommissioning techniques .
- Most importantly, the efficiency of wet decontamination avoided burial costs and generated income from sales of metals for unrestricted re-use.
- Where the shape or surface structure of cleaned metals did not allow cost-effective monitoring, melting, supported by cost effective techniques to confirm that the UK criteria for unrestricted release of material into the external market had been met, proved an ideal adjunct to facilitate further recycling.
- Value engineering was used to good advantage throughout the project.
- Finally, the value of a well-motivated, well-trained, and enthusiastic workforce contributed substantially to the successful outcome.

The experience gained from designing, building, operating, and introducing these cost-saving features provides a basis for the methodology to be employed at ETTP.

CONCLUSIONS

The philosophy and techniques described above are very relevant to a wide range of nuclear processing plants throughout the world, particularly large plants such as those at K-25 with low levels of primarily surface contamination.

Of the 160,000 tonnes of metals and concrete comprising the structure and contents of the Capenhurst plant, over 99% were recycled for unrestricted re-use as clean material.

The project demonstrated how the Capenhurst Diffusion Plant, a major nuclear processing plant facility, was safely and cost-effectively decommissioned.

The experience gained from this project has resulted in methodologies being developed to minimize the amounts of nuclear and other hazardous wastes arising from decommissioning activities and has demonstrated safe, cost-effective D&D techniques well-suited for use at the ETTP site.

ETTP will benefit from experience gained at Capenhurst, including lessons learned on **how to do** D&D and **how not to do** D&D. There will be no need to re-invent the wheel on this Three-Building D&D and Recycle Project.

The large-scale ETTP decommissioning project, with its added value of reusing the buildings for industrial purposes, is considered to be a major DOE initiative.