
Aerial view of the U.K.'s Sellafield site.

Accelerating High-Hazard Reduction at Sellafield

The highest priority for the Sellafield site is accelerating high-hazard and risk reduction of the legacy facilities on what is inarguably the largest and most complex nuclear cleanup site in the world, with 170 major nuclear facilities and 2200 other buildings, comprising activities that cover the entire nuclear fuel cycle.

By Ali McKibbin and Lucy Watson

Sellafield, on the northwest coast of England, has been an integral part of the nuclear industry for more than five decades. Originally established during the early 1940s to home the Royal Ordnance factories that had been developed to produce explosives for World War II, the site was identified by the British government as the ideal location for developing an independent nuclear capability to harness atomic energy for commercial use.

By the early 1950s, Britain's scientists and engineers had joined forces to develop the world's first civil nuclear program. Over the next five decades, a number of plants were constructed to manage the waste from the Pile Fuel reactors and Calder Hall as well as from the growing number of commercial nuclear power stations being built around the United Kingdom. Designed and built over a short time span to address the immediate needs of the nuclear program, these facilities grew with limited thought to the practicalities of emptying and decommissioning them in the future.

Nuclear Management Partners (an international consortium comprising URS, Amec, and Areva) took the helm at Sellafield in November 2008, and today the highest priority for the site is accelerating high-hazard and risk reduction of the legacy facilities on what is inarguably the largest and most complex nuclear cleanup site in the world, with 170 major nuclear facilities and 2200 other buildings, comprising activities that cover the entire nuclear fuel cycle.

Some of the greatest decommissioning challenges include the following:

- Degraded legacy plants with nuclear inventories dating back to the 1940s.
- Diverse and highly constrained decommissioning activities because of the close proximity of plants and the radiological conditions.
- The requirement to upgrade and improve aged facilities prior to decommissioning to allow removal of the radioactive inventory.
- A lack of current plans, drawings, or records; furthermore, much of the work is unique and has never been done before.

Sellafield is a U.K. government–owned site under control of the Nuclear Decommissioning Authority (NDA), which has confirmed Sellafield funding of £1.5 billion ($2.25 billion) for 2010–11. This comes from a total annual budget of £2.8 billion ($4.2 billion) across the NDA's estate of 19 sites built in the postwar days of the U.K.'s early nuclear program—a clear indication of the priority of the work that has to be carried out at the site.

The cleanup of the Sellafield site is one of the most important and demanding managerial, technical, and environmental challenges for the United Kingdom. Consequently, some of the most innovative and complex nuclear decommissioning projects in the world are being carried out at Sellafield.

Decommissioning Projects

The Windscale Piles

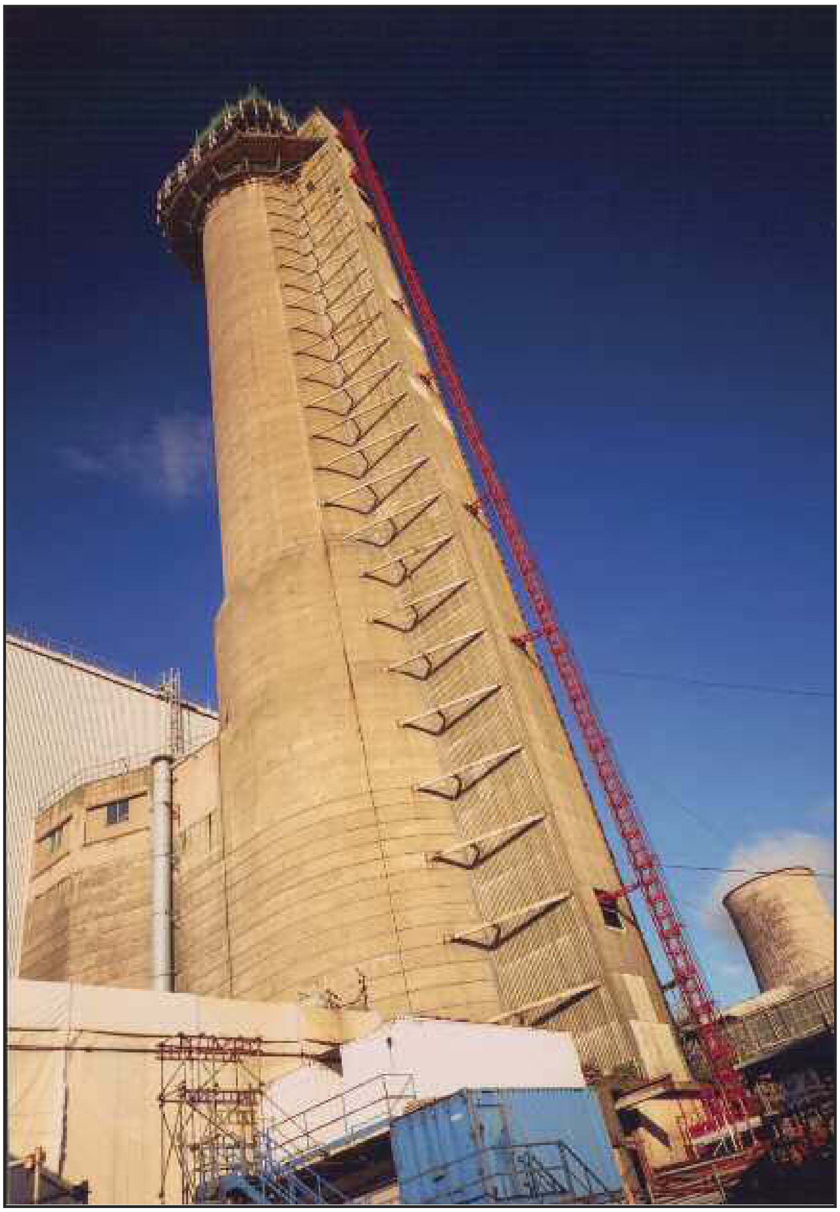
The two Windscale Piles were among Britain's earliest nuclear reactors, built shortly after World War II and operated between 1950 and 1957. They were constructed to produce plutonium for the U.K.'s nuclear defense program, providing radioisotopes for medical and industrial use and testing materials for civil reactors.

Each reactor has 3440 horizontal fuel channels in a graphite core. Reactivity was controlled using steel rods inserted into holes in the reactor core. Used fuel elements were ejected into skips in a water duct and then transferred to a cooling pond before being consigned for reprocessing.

In October 1957, after a second application of heat to Pile One during an annealing process, the reactor caught fire, causing extensive damage to the core. Both piles were immediately shut down and defueled—Pile Two completely but Pile One only partially, because it contains a quantity of damaged material. The fire damage within the Pile One reactor core has made the project one of the most technically complex decommissioning projects.

Initial decommissioning removed much hazardous material, and reactor control equipment was made permanently safe. The chimneys were sealed at the top, contaminated filters removed, and the air inlet ducts isolated. The reactors were then placed under care and maintenance until Phase 1 decommissioning started in the 1980s. Pile One was safely isolated from the environment with seals and dams in the air and water ducts. The Pile Two chimney was demolished to the 35-meter level.

Current work is focusing on refining decommissioning strategy and finalizing technology readiness. Proving of a prototype fuel channel retrieval tool, which will be deployed in the reactor to retrieve the contents of fire-damaged core, is now complete. This will be followed by the removal of the reactor's operating mechanisms, the graphite core, and the biological shield before final conventional demolition of the containment building.



Associated with the Windscale Pile Reactor, the Pile chimney is among the Sellafield site's most iconic landmarks.

Calder Hall

The world's first commercial nuclear power station, Calder Hall, which operated at Sellafield for 47 years, was shut down in 2003. Since then, the early stages of decommissioning have been undertaken with considerable success.

The station comprises four Magnox reactors, each of which has four heat exchangers. The station also includes four cooling towers and two turbine halls, together with ancillary buildings.

The most obvious achievement so far was the demolition of the four 88-m-high concrete cooling towers in September 2007. The cooling towers were collapsed using explosive demolition in such a way to enable the structures to fall within their own footprint, minimizing disruption to the immediate area.

The Sellafield site measures only a mile by a mile and a half, holding hundreds of buildings. One of the biggest challenges was therefore to safely demolish the towers while not adversely affecting any of the operating nuclear facilities, such as the U.K.'s Fuel Handling Plant situated only 40 m from the base of the towers.

In March 2010, as part of decommissioning Calder Hall, Sellafield completed one of the largest asbestos removal projects. In all, 2300 metric tons of asbestos cladding was removed in what was a five-year project from start to finish, involving almost 1 million person-hours of work.

Project Manager Ian Williams said, "People always think that the most hazardous work at Sellafield involves managing radioactivity, but this is not always the case. Asbestos is a dangerous material, and we have had to employ specialist contractors to help with this work. Not only did the project involve working with a known carcinogen, but much of the work was also carried out at height, with scaffold towers over 36 m tall built around the 16 heat exchangers on the outside of the reactors. At any one time, we had some 100 men working in arduous and confined conditions, and at no time were any workers exposed to asbestos."

Windscale Advanced Gas-Cooled Reactor

Decommissioning operations on the golf ball–shaped Windscale Advanced Gas-Cooled Reactor (WAGR)—probably the most iconic of the facilities on the Sellafield site—are also under way.

Built as a prototype, the WAGR facility was the forerunner to the 14 commercial AGR stations across the United Kingdom that followed.

Constructed in 1958, WAGR became operational with full design output achieved in 1963. The reactor was built as a demonstration project to explore the potential of high-pressure and -temperature gas-cooled reactor fuel, coolant gases, and reactor components and to prove commercial viability of this type of reactor.

The experience gained from constructing and operating WAGR has proved invaluable, as it was the forerunner to 14 commercial AGRs built on seven sites throughout the United Kingdom. The facility operated at an electrical output of 33 MWe for 18 years and was shut down in 1981, upon successful completion of the research and development objectives.

The reactor then became a demonstration decommissioning project, aiming to prove that a full-sized power reactor can be decommissioned safely, cost effectively, and in an environmentally acceptable manner, providing learning to be applied to future power reactor decommissioning activities.

The reactor was defueled following shutdown, and during the remainder of the 1980s and into the 1990s, Sellafield undertook a program of peripheral dismantling, modification of the reactor building, and new construction to prepare for the challenge of remotely dismantling the reactor core and pressure vessel.

The original cooling towers were demolished to make room for a new intermediate-level waste store as an interim solution pending the availability of a national disposal facility.

Workers constructed a remote dismantling machine on the reactor operating floor to deploy dismantling tools. Since 1998, the remote operations to remove the reactor core and pressure vessel have been continuing. Working top down in a series of 10 campaigns, each associated with a reactor component, 80 different tools have been deployed. The operations team has now completed 9 of the 10 campaigns and expects to complete the final dismantling campaign, the removal of the outer ventilation membrane and thermal columns, during 2010.

Upon completion of the 10 campaigns, the plant will be cleared of any remaining radioactive components, and then the waste route will be cleaned of asbestos residues. The site strategy is to place the facility in care and maintenance while resources are deployed elsewhere before returning to decontaminate and demolish the iconic structure by 2028.

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Silos

The Magnox Swarf Storage Facility and Magnox Solid Waste Storage Silo are both legacy storage facilities, containing mainly wastes associated with Magnox fuel decanning operations and AGR fuel dismantling.

The Magnox Swarf Storage Facility comprises concrete compartments in which a large volume of waste is stored underwater. The last waste was sentenced to the facility in the late 1980s. The Swarf Retrieval Facility emptied the most modern compartments, and new Silo Emptying Plants will be used to empty the remaining compartments of the various waste materials.

The Magnox Solid Waste Storage Silo has separate compartments holding a large amount of waste. Sentencing of waste to this facility ceased in 1965, and in 2001 the silos were filled with inert argon gas. This has ensured that the waste continues to be stored safely and also allows retrieval with minimal combustion risk.

Decommissioning of these facilities is a technically difficult task because of the structure and condition of the buildings. Significant improvements to the infrastructure have been necessary to facilitate safe waste retrieval operations. This has included the replacement of the building crane in the Magnox Swarf Storage Facility and the export of redundant equipment to free up space for retrieval equipment.

A new retrieval facility is being built alongside the Magnox Solid Waste Storage Silo; the foundation slab for this was completed in December 2009. The site is surrounded by the adjacent silo, pipe bridges, and service trench, which increase both the nuclear and conventional safety concerns for carrying out such work. The retrieval facility building is a key enabler in the strategy to reduce the risks of the plant and accelerate the eventual waste retrieval from the building. This is a significant step forward for the project in its aim to safely remove the historical waste from the building.

Ponds

Of the six spent fuel storage pond facilities at Sellafield, two of the earliest are currently being decommissioned. The Pile Fuel Storage Pond was built in the 1940s and was succeeded by the First-Generation Magnox Fuel Storage Pond, built in the 1950s.

These two open-air storage ponds were designed without regard to their eventual decommissioning and are high on the priority list of decommissioning projects. Both ponds and their associated storage bays still contain a significant radioactive inventory, including legacy spent fuel and radioactive sludge. The decommissioning of these facilities will involve progressively retrieving, processing, and disposing of the radiological inventory, followed by the eventual drainage of the ponds.

Sellafield Ltd. has pioneered the use of remotely operated submersible vehicles (ROVs) to carry out underwater inspections of the pond inventory. The ROVs are used in areas of high radiation to survey the contents and condition of spent fuel in the ponds.

Radioactive sludge on the floor of the ponds poses a significant challenge to the decommissioning teams. Retrieval and packaging of this sludge is necessary to reduce the radioactive inventory in the buildings. At the same time, a program to remove redundant fuel skips from the Pile Fuel Storage Pond is progressing well, with a total of 16 now retrieved. The skips are exported via a skipwash facility, before being sent to Sellafield's Waste Monitoring and Compaction facility for size reduction and eventual disposal at the U.K.'s National Low-Level Waste Repository.

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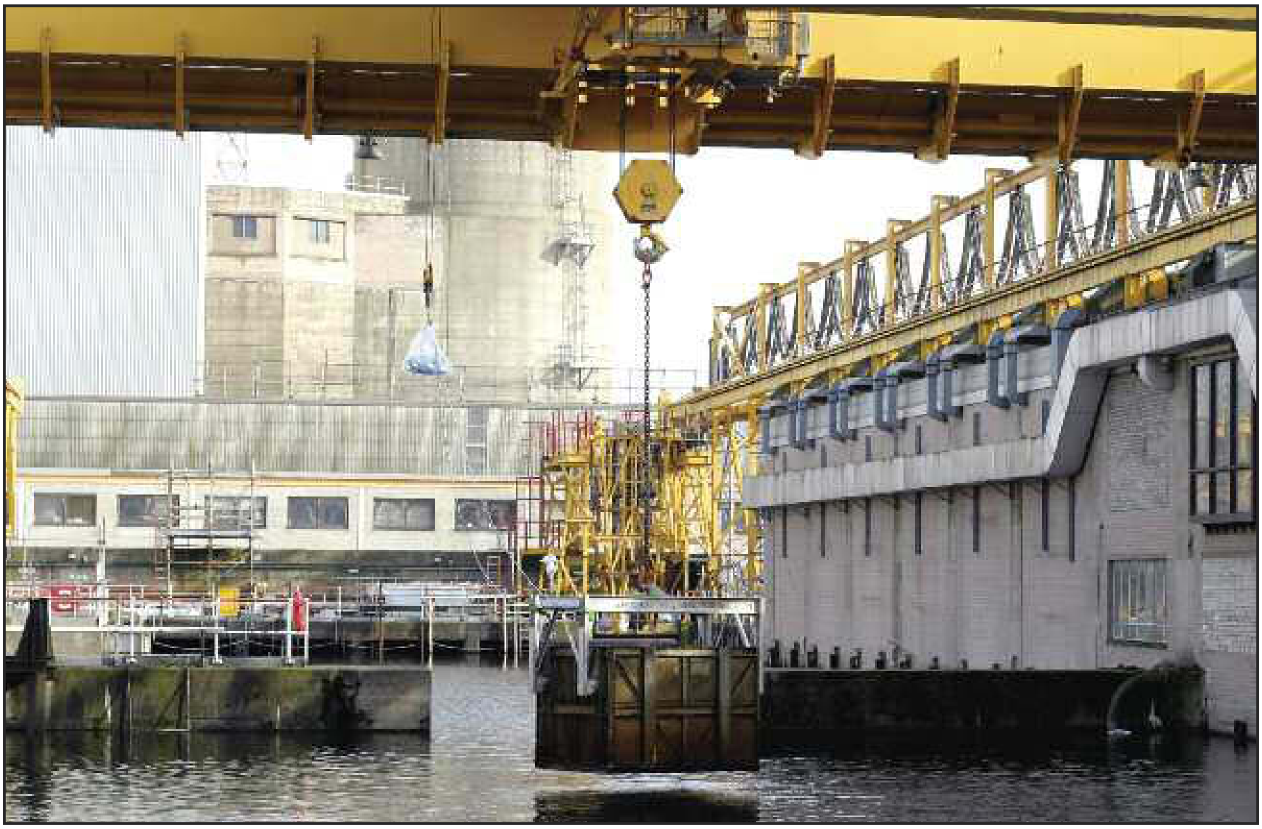

Empty fuel skips being retrieved from the Pile Fuel Storage Pond.

Progress as of mid-April 2010 on the Sludge Packaging Plant at Sellafield, which will receive legacy sludge from the First-Generation Magnox Fuel Storage Pond.

Desludging activities using water jet lance technology are also well under way in the Pile Fuel Storage Pond wet bays, having commenced in 2008. To date, 6 out of the facility's 12 decanning bays have been completed, with the sludge moved from the bays into the main pond area. One of the next key milestones for the team is due later in the year when the team will collect and transfer the sludge from the pond into the in-pond corral, before it is removed from the facility and eventually sent to a new treatment plant.

To deliver decommissioning of existing facilities, it is often necessary to construct new plants. Across the Sellafield site today, construction of a number of new facilities is under way. For instance, new facilities are being built alongside the ponds to process the retrieved sludge. Installation work is continuing at the Local Sludge Treatment Plant, which will process the sludge retrieved from the Pile Fuel Storage Pond, currently being stored in a new in-pond sludge corral. Also, Sellafield's Local Effluent Treatment Plant has been commissioned to control pond water activity levels. Likewise, the Sludge Packaging Plant 1 buffer store is being built alongside the First-Generation Magnox Fuel Storage Pond and, once completed, will hydraulically receive legacy sludge from the pond and store it prior to its ultimate disposal.

Work commenced on site clearance in November 2005 and involved the demolition and clearance of a number of redundant facilities. A major early success was to clear and reclassify the site, taking it out of the radiologically controlled Separation Area so that it could be managed as a conventional construction project. The first concrete pour took place in May 2008, and since then, the project has fixed more than 820 metric tons of steel and poured more than 3300 m^3 of concrete.

Despite the complexities associated with restrictions due to the sensitivity of adjacent facilities—which preclude the use of many conventional construction techniques such as large telescopic boom cranes, tower cranes, or placement booms for concrete—the team continues to deliver the project safely and on April 1, 2010, achieved six years and almost 700 000 person-hours without a recordable injury or reportable incident.

Separation Area Ventilation Project

Sellafield's Separation Area consists of the site's historical facilities for spent fuel storage, reprocessing, and waste management, which are undergoing decommissioning, along with the operational plants necessary for Magnox reprocessing.

The Separation Area Ventilation (SAV) project, which has been in progress since 2008, represents another example of a decommissioning enabling project under way at Sellafield. Two of the historical stacks within the Separation Area of the site—namely, the Pile chimney and stack associated with the Primary Separation Plant—are nearing the end of their effective operational lives and are scheduled for demolition. Prior to demolition, however, a new discharge capability for aerial effluents arising from the Separation Area must replace the existing stacks and provide a long-term facility for future decommissioning operations. The main contract to complete the detail design and construction was awarded in November 2008.

In advance of the main construction work of the new 120-m-high stack, associated plant room, monitoring room, and substation, a contract was awarded to prepare each of the ventilation streams for diversion to the new

Work on the Separation Area Ventilation project progresses well, with the foundations of the substation now complete.

Once used as a ventilation route, the HANO cell is currently undergoing stabilization work to secure the steel internal beams, which have significantly corroded over time due to prolonged exposure to the acidic ventilation stream.

plant. This involved shutting down each vent stream and replacing a section of ductwork with a tee piece.

Because of the complex interactions between the different plants at Sellafield, significant coordination was required to arrange a suitable outage. By the end of 2009, six of the seven planned tie-ins had been completed.

Construction of the new facility commenced in early 2010, with the electrical substation foundations installed at the beginning of March 2010. The facility is due for completion in 2012 and, following commissioning, will be fully operational in 2014.

Primary Separation Plant

Alongside the construction of the new SAV facility, work to decommission Sellafield's Primary Separation Plant is progressing well. Constructed in the early 1950s, the separation plant was historically used to process spent fuel from the Windscale Piles and laterally as a Head End plant to reprocess small quantities of oxide fuels. Standing at 61 m high, the plant consists of four cells with a 61-m stack on top of the facility.

Once used as a ventilation route, the High Active North Outer (HANO) cell is currently undergoing stabilization work to secure the steel internal beams, which have significantly corroded over time due to prolonged exposure to the acidic ventilation stream. This is being done by using a specially designed lightweight foam grout that Sellafield Ltd. developed in conjunction with the University of Dundee, Concrete Technology Unit, and Westlakes Engi-

Coring and bursting operations of an "instrument bulge" (historically used to extract process liquor for analysis in the Primary Separation Plant) prior to removal from the facility.

neering. The grout has an air bubble consistency. This consistency minimizes the weight loading on the building and will minimize the volume of waste produced when full-scale decommissioning operations begin in 2018.

Similarly, work is also progressing in the High Active South Outer cell, with the entire inventory held in the top section of the facility now removed. This included material such as radioactive vessels and contaminated pipework that had been used as part of the reprocessing operations, as well as contaminated wooden scaffolding boards dating back to the 1970s.

A three-dimensional laser scanning N-Visage™ modeling system helps identify high-radiation "hot spot" areas within the plant's shear cell. The N-Visage software and scanner system, developed by local firm REACT Engineering Ltd., takes data from the facility and constructs a map of locations of radioactive sources. This map can then be used to investigate the worker dose consequences of potential decommissioning plans.

Speaking about the characterization program, Project Manager John MacGregor said, "We needed to establish whether concentrated high-dose hot spots could be removed and shielded to allow staff access to this part of the facility. Although the N-Visage dose scenarios revealed that the ambient dose was still too high for personnel access, the information on radiological distribution is very valuable and will help us to plan future decommissioning programs."

Program Delivery Manager Jeremy Hunt added, "Early characterization of the Shear Cave has enabled us to form a sensible baseline for the future decommissioning operations. This particular technology is also very useful in visualising the survey results and is a powerful tool in communicating plant conditions to stakeholders."

"Absolutely Excellent Work"

"The decommissioning work at Sellafield presents us with significant challenges; however, by applying modern techniques and treatments to the decommissioning process, we are able to deliver some absolutely excellent work and deliver it safely," said Russ Mellor, executive director of Decommissioning.

The diversity of the groups' portfolios and the challenges that the decommissioning teams face cannot be overestimated. Sellafield is the custodian of some of the United Kingdom's most hazardous nuclear wastes and many of the legacy plants with high-hazard nuclear inventories. Given the extent of the decommissioning program on the Sellafield site, it is obvious that there are still many more hurdles to overcome and challenges that are yet to emerge, but it would appear from the capability within the decommissioning teams on the Sellafield site that they are both ready for, and moving forward into, the future. ■

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