Curtains for BEPO

Can Harwell awaken the long-dormant memories of its "old-timers" to help speed up the demolition of its biggest pile? **By David Fishlock**

A unique long-term experiment has just begun at Harwell, expected to last a decade, perhaps longer. It concerns Europe's first big reactor, the first outside the USA, built 1946-48.

Harwell showed as much ingenuity in naming its experimental reactors as in designing them. BEPO stood for British Experimental Pile with the "O" added to create an acronym that recalled the popular Marx Brothers.

But it was no joke. BEPO was the UK counterpart of the pile assembled at Oak Ridge, Tennessee, by Clinton Engineering Works to scale up Enrico Fermi's first successful pile demonstration in Chicago in 1942. (Fermi coined the term "pile" for what literally was a pile of graphite bricks.) The Clinton precursor preceeded the huge reactors built by du Pont at Hanford to produce plutonium for atomic bombs.

Britain had not been privy directly to the project and post-war was banished from further nuclear collaboration with the USA. But work had begun on the design of a British pile at Chalk River, the Anglo-Canadian-US collaboration. This was the origin of BEPO. When John Cockroft returned from Chalk River in 1946 to set up the Atomic Energy Research Establishment, Harwell, he asked those left behind to start designing a pile.

In its day this was a colossal engineering achievement, comparable with anything Britain achieved in the second World War (see Box). Completed in July 1948, it served as Harwell's premier research tool and isotope source for the next 20 years, before being shut down and sealed in 1968.

Old-timers gather in BEPO's hanger on the 40th anniversary of its shutdown to share recollections with the decommissioning team. Photo copyright UKAEA

Four decades on, BEPO has again become a focus of Harwell's attention, as plans take shape to decommission and demolish the pile. To assist this process Dr. Ed Abel, manager of Harwell's three remaining reactors – the others are the much smaller piles PLUTO and DIDO – has assembled the original construction drawings and photographs. "However, they do not reveal the way in which the reactor was operated," says Abel (pictured with the author on p3). For example:

- they don't say what construction or operational difficulties arose that might be important in decommissioning;
- they don't explain how day-to-day experience was gained and how it influenced operations;
- they don't explain or reconcile inconsistencies between different reports, drawings or files;
- some aspects of construction and operation are missing altogether.

He believes the missing data could have an important bearing on the approach, duration and eventual cost of decommissioning. He had the idea of recruiting surviving constructors, operators and experimenters to share recollections with his decommissioning team.

"Some piece of information – such as knowledge about the use of the slug store and how it was sealed and put into safe care and maintenance 40 years ago – might give us more confidence than having to assume the worst," he suggests. "I want to suck your brains dry."

Late last year Abel assembled about 70 former Harwell employees at BEPO to announce his plans and invite them to complete an initial three-page questionnaire. They gathered in Hanger 10, BEPO's home, now at the edge of a site known today as Harwell Science and Innovation Campus. Current plans – dependent on funding from the Nuclear Decommissioning Authority – are to start decommissioning in 2015.

BEPO, in essence, is a cubic reinforced concrete box with walls nearly 7 inches thick and nearly 50-ft. long. This box is packed with 28,000 graphite blocks, totalling about 700 tonnes, punctuated with holes – channels for its uranium fuel slugs, control rods, and experimental access.

BEPO provided the first experience both of the problems of reliable fuel element canning and of detection of failed fuel, recalls Bob Jackson, its first reactor manager. Its main contribution to the future of nuclear energy had been to suggest to his colleague, the late Dick Moore, that "a gas-cooled reactor system could substitute for a fossil-fuelled boiler." Moore outlined this idea in 1947 and it triggered design of Calder Hall and the Magnox reactors.

Jackson, who later became Harwell's chief engineer, also reports that late in BEPO's construction designers had added a heat exchanger to the air coolant outlet duct to heat the adjacent buildings: "nuclear power." And an outlet air filter "which Windscale then copied on their stacks – with great benefit when one reactor caught fire."

B.T. (Terry) Price, a physicist whose calculations had led to these air filters, recalls how staff worked under safety conditions that would horrify today's Health & Safety Executive. "They consisted merely of a cardboard notice hung on the master switch: DO NOT SWITCH ON – MEN INSIDE."

Price, who in the mid-1970s became founding secretary-general of the Uranium Institute (now the World Nuclear Association), used BEPO for experiments for three years. Compared with other Harwell reactors it had a wealth of experimental capacity – 100 holes for the scientists to use. In one kind you poked things in to expose them to the intense radiation within the graphite pile. From the other you released a beam of neutrons for measurements outside the pile.

One of Price's main occupations had been to measure the neutron capture cross-sections of three isotopes of crucial interest to the bomb-makers: ^{235}U, ^{239}Pu and ^{241}Pu. For ^{241}Pu there was no published information avail-

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able. When in 1955, the Russians published their measurements Price had been very relieved to learn that they tallied with his.

Decommissioning was first considered when the reactor was closed in 1968. Such imaginative options as excavating a huge hole beneath the pile and lowering it into this hole were considered. Another was to wrap the reactor in plastic and entomb it, having demolished its hanger. These options are not acceptable today, says Abel.

The issues that confront planners today are well known he says. The most radioactive parts of the reactor are the 6-inch thick steel thermal shield plates that line the concrete box. Also the 28,000 graphite blocks are above the ILW/LLW threshold because of ^{14}C and tritium activity.

When BEPO was closed and sealed, the large area once occupied by its charge face was devoted to the development of remote handling technology for radioactive activities throughout UKAEA sites. The current decommissioning plan expects to use many such techniques, unavailable 40 years ago. "The advantages of using these types of technologies is that the awkward decommissioning tasks – decanting and processing the graphite, orienting and handling the thermal shield plates – become a well-defined logistics problem similar to that found in flexible automated production lines or warehouses," Abel believes.

He plans access to the pile through the unload (west) face, through a 26-ft. square opening. So robustly was the containment designed, its stability will survive this massive intrusion. The big opening will improve rates of material removal and allow access to the whole pile at its place of easiest decant, he says. Roof-top plant will be limited to dealing with the thermal column doors and sackhole emptying.

Today, the site boundary is close to three sides of Hanger 10. To ensure that the impact on the critical dose group is minimised debris will first be taken below floor level into the area occupied by the biological lab, hoist pits and inlet and exhaust ducts.

Here the waste will be assayed, with some processing (including removal of any particulate) and where appropriate packed. The graphite will need heat-treatment to ensure absence of any residual Wigner energy, in order to meet long-term disposal criteria. The thermal shield activation is due to ^{60}Co so its classification as ILW will depend on just when it is delivered to storage.

Abel's current plan calls for a start on decommissioning in 2015. Radiological characterisation, scheme design, financial sanction, regulatory approval, procurement and mobilisation of the decommissioning team will take 2-5 years. Mostly these activities have to be carried out in series since they depend on previous steps and they fit a gated process.

The plan expects decommissioning of the slug store and the pile itself to be completed by 2022. The following year Hanger 10 will be demolished and the site restored to a delicensable state.

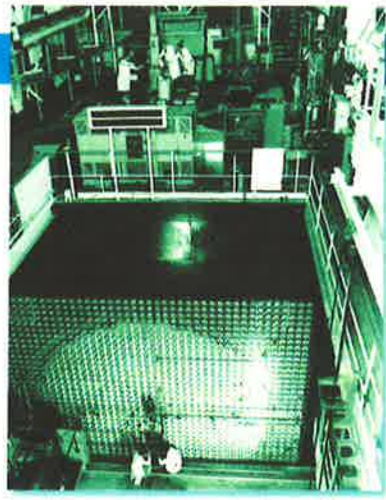
Dick Francis, formerly from Harwell and now an executive of the Nuclear Decommissioning Authority which will pay for the project, describes Abel's interrogation of Harwell's old-timers as "an excellent example of NKM in action". NKM stands for "nuclear knowledge management," a term used by the International Atomic Energy Agency (IAEA).

Terry Joslin, representing BEPO's neighbours around Harwell, recalls how the community became aware of the pile's utility in making radioisotopes available for medical and industrial purpose. The community also became aware of BEPO's musical properties. Its 200-ft air exhaust stack became known as the world's largest organ pipe, until the scientists found ways of controlling the five tonnes of air it released every minute. Joslin recounts a local scare story that urged folk to "run like stink upwind of the stack" if they ever saw smoke issuing from it. None ever did.

The stack was demolished in 1999 and its base is now used as a car park. Inspectors found the top-most section as clean as new. Joslin ranks BEPO "one of Oxfordshire's proudest achievements,"

Among those invited was BEPO's operator at the time of its closure. He brought with him a framed certificate with which he had been presented in 1968. It testifies to the fact that he's proved himself to be a fit, proper and sober person "entitled to call himself a Pile Driver, and all lesser beings shall treat him with respect due to his status." The certificate is signed by Plutonius Rex. We want to relearn the lessons learned in the 1940s by operators, no less than the scientists and designers, says Ed Abel.

Official history of BEPO



Harwell's first pile was the low-power 100kW experiment GLEEP, similar to one operated at Chalk River. But a more powerful pile was needed, around 6000kW, recorded Professor Margaret Gowing in *Independence & Deterrence: Britain & Atomic Energy 1945-52, Vo. 2.* The fundamental design of this pile was done by British scientists in the Montreal Laboratory in the months before and just after the end of the war.

Various uses were foreseen: as an essential research tool and test-bed for instruments, for shielding designs and for radiation effects on materials. It would also provide data for the design of bigger piles for plutonium production.

BEPO's designers were restricted to using natural uranium as fuel, graphite as moderator, and air as the coolant. "BEPO was therefore similar in all main respects to the first American experimental pile at Clinton, Oak Ridge," Gowing concluded.

Christopher Hinton's production organisation at Risley was responsible for BEPO's design and construction. From early summer 1946 Risley engineers worked closely with what then was a very small band of Harwell reactor physicists – notably J.V. Dunworth, F.W. Fenning and C.A. Rennie. Construction began in June 1946 and BEPO went critical in July 1948.

The pile itself is a 26-ft. graphite cube built of 28,000 blocks of nearly 15,00 different types, all machined in an adjoining hanger to an individual tolerance of ±0.0025 inch, then built to the correct height by carefully selecting over- and under-sized blocks. The biological shield is of reinforced concrete 6½ ft. thick, of a specific gravity much higher than normal concrete. An inner thermal shield of 6-inch steel plates protects the concrete from overheating. The pile shield had to be assembled so that the 3800 holes common to both the shield and the graphite blocks were accurately aligned. This was achieved through a system of permanent steel shuttering with an elaborate support structure – a very complicated maze of steelwork fabricated and created by the Admiralty dockyards at Plymouth.

Gowing recorded that there were surprisingly few difficulties in design and construction given the novelty of the project. Two minor crises were both non-nuclear: one concerned the centrifugal compressors that sucked hot air from the pile; the other the hydraulic hoists for the charge and discharge platforms.

Professor Gowing concluded: "From the time BEPO went into operation, it worked without any breakdown and continued to do so until it was finally closed down in December 1968. The engineers learned a great deal in designing and building BEPO. It was their professional art to find the cheapest and simplest way of producing the results required, but in this, the first pile, they were dependent on the physicists, and at the end they realised that the scientists had demanded higher standards of accuracy and perfection than were necessary. This in itself was valuable experience and gave the engineers far more confidence when they came to design the large-scale piles which were to produce plutonium."