England’s Atomic Age.
Securing its Architectural and Technological Legacy

Wayne D. Cocroft

Introduction

This paper presents a brief overview of places in England that have been associated with atomic research, including the early nuclear weapons programme, and especially those places that have been afforded statutory protection. It describes the infrastructure of the civil nuclear power industry and how this legacy is being remediated to release land for new uses. It concludes with a discussion of how Historic England‘s strategy for the documentation of post-war coal and oil-fired power stations that might be applied to the nuclear sector.

Early history

From the late 19th century scientists in the United Kingdom were part of an international community of pioneers working to understand the structure of the atom. Important centres included the physics building at the University of Manchester, built in1900, where Ernest Rutherford, a New Zealander, worked with colleagues, such as Niels Bohr. The Cavendish Laboratory at Cambridge, built in 1878, was another important hub, firstly under J J Thomsom who discovered the electron in 1897; in 1919 Rutherford moved from Manchester to become its director. It was under his leadership in 1932 that John Cockcroft and Ernest Walton split the atom. Both laboratories are protected as listed buildings; the primary reason for their selection was their architectural interest, although the historical significance of the research carried out in the buildings is acknowledged.

During the 1930s the numbers of this already cosmopolitan group was swelled by émigré European scientists fleeing Nazi oppression. They included Rudolf Peierls and Otto Frisch, who while working at the University of Birmingham, wrote a paper ‘On the construction of a super bomb’, alerting the British government to the possibility of a uranium bomb.[1] The idea apparently originated from a conversation between Frisch and his aunt Lisa Meitner, formerly of the Kaiser Wilhelm Institute for Chemistry, Berlin.[2]

A government committee was quickly established to examine the feasibility of constructing such a weapon. It reported back in July 1941, and in September Churchill authorised work to proceed. Most of the research was carried out on the government’s behalf by ICI, university departments, and in a poison gas factory at Rhydymwyn in North Wales where a pilot uranium isotope separation plant was constructed.[3] The building has been listed by Cadw.

For many reasons, including cost, the threat from aerial bombing and concerns that vital resources would be drawn away from more pressing tasks British knowledge and scientists were transferred to the US atomic bomb project – the Manhattan Project. But, after the passing of the McMahon Act in 1946 the UK was denied access to US atomic work and embarked on its own nuclear weapons programme. During this period the weapons and civil research programmes often worked closely together drawing on a relatively small pool of scientific experts.

The development of the British atomic bomb

The early research facilities allocated to the project were modest and included a small section of the Royal Arsenal, Woolwich, and a redundant 19th century fortification, Fort Halstead, Kent. At the latter site a number of specially designed buildings survive and represent some of the earliest structures associated with a nuclear weapons programme (Fig. 1). On the Thames marshes the project was allocated an enclave within a larger military firing range. Here too a series of unprepossessing test structures were built, including the building in which the United Kingdom’s first atomic bombs were assembled in summer of 1952 before they were shipped to the Monte Bello Islands, Australia, for testing (Fig. 2).

In common with many other post-war British high tech projects, through its association with defence there was close government involvement in the development of the nuclear industry. There was obvious national pride in technological achievement; science and high politics also came together as successive British prime ministers sought to re-establish the special nuclear relationship with the United States. If this goal was to be achieved the efforts of British scientists and industry was crucial. At the heart of these efforts lay the research establishments, which in turn created new and alien landscapes. In preparation for the 1956 Buffalo Trials, in which the United Kingdom would detonate her first air dropped atomic bomb, a requirement was identified for facilities to simulate the conditions a bomb might experience during flight. New laboratories were built on the east coast at Orford Ness, Suffolk (Fig. 3). This site is now scheduled

Fig. 1: Fort Halstead, Kent, the purpose-built building in which the components for Britain's first atomic bomb – Blue Danube – were assembled (2008). The building is listed.

Fig. 2: Atomic Weapons Research Establishment, Foulness, Essex, building X6 in which the live high explosive elements of Britain's first atomic bomb were assembled (2007). The building is scheduled.

Fig. 3: Ordfordness, Suffolk, in the distance is an early 1960s test laboratory, or pagoda, used for the physical testing of nuclear weapons and their components (2007).

and in the care of the National Trust. Although not the direct subject of this paper, a number of sites associated with the storage, maintenance, and deployment of nuclear weapons have also been protected in England.

The civil nuclear programme

At a time when the country was virtually bankrupt from its wartime expenditure, the decision of January 1947 to proceed with a British atomic bomb project required a large industrial base of novel factories. To speed up construction the new facilities were built on sites already owned by the government, including airfields and munitions factories, which offered basic infrastructure as well as accommodation for work force. In the north west of England a uranium enrichment plant was built at Capenhurst, Cheshire, and a fuel production facility at Springfields, Lancashire. In August 1947, the Ministry of Supply announced that the country's plutonium factory was to be built on the site of a former TNT factory at Sellafield, Cumbria (Fig. 4).[4]

Initially, the assumption was that the plutonium plant would follow the design of wartime United States' Hanford piles, which were graphite moderated and water-cooled. However, there were safety concerns about this design, and although gas cooled technology appeared to be a promising line of research, due to the need to bring the reactors quickly into service air-cooling was chosen. Construction began in September 1947 and just over three years later in October 1950 Pile 1 went critical. These piles were exclusively for plutonium production and by August 1952 sufficient plutonium was available for Britain's first nuclear test in October of that year.

In addition to its warlike potential, the British government and scientists were keen to exploit this new technology to create new wealth and as a source of power. In October 1945, it was announced that Britain was to build an atomic research and experimental establishment. The site chosen was at a former airfield at Harwell, Oxfordshire. The main purpose of the establishment was to study and develop reactor technology. In its heyday Harwell boasted 14 research reactors, and later an additional research centre was built at Winfrith, Dorset. At Culham, Oxfordshire, a new centre was established devoted to cold fusion technology, and today is home to JET, the Joint European Torus.

Although, gas cooling had been rejected for the first plutonium production piles, for power generation it offered many advantages. Pressurised gas is more efficient in removing heat, especially if combined with finned fuel cans. It was this design that was chosen for the next generation of plutonium production reactors, which would also produce electricity as a by-product.

Fig. 4: Sellafield, Cumbria, in the late 1940s the site of a disused wartime TNT was taken over for the Windscale Piles built for the production of plutonium (1954).
In 1957, they were to achieve notoriety as the scene of Britain's worst nuclear accident.

Fig. 5: Map showing the principal nuclear sites in the United Kingdom.

The first station of this design was built adjacent to the Windscale piles at Calder Hall, Cumbria, and was opened by the Queen in October 1956, and was the world's first large nuclear power plant connected to a national electricity grid. However, along with Chapelcross, Dumfriesshire, it was also part of the weapons programme and ran on a plutonium production cycle until 1964, and for a short time during the 1970s.

In 1955, the government announced it was to embark on a major civil nuclear programme (Fig. 5). Following on from Calder Hall, the first series of stations were graphite moderated and gas cooled, and used natural uranium fuel encased in a magnesium alloy – hence the family name of Magnox for this group of stations.

Essays in technology, architecture, and landscape

During the late 1940s and early 1950s, a combination of post-war austerity and the urgency of bringing the atomic facilities into operation gave rise to buildings with a simple utilitarian appearance. In the research establishments some of the earliest buildings associated with the nuclear weapons programmes were simply brick built. At the research and production establishments the main concern was to bring the plant into production as quickly as possible. Many of the early facilities were specified and designed by teams of architects in the Ministry of Works, but built by private contractors. Following experience gained in designing and erecting large wartime factories and defence facilities, prefabrication was widely applied. New and special building materials, such as aluminium, stainless steel, chrome alloys, special mineral aggregates, resistant paints, and plastics were employed. For shielding, large amounts of steel and reinforced concrete were required. Most of the early production buildings were steel-framed structures and clad in asbestos or pressed metal sheeting. There were few concessions to aesthetics nor was thought given to later dismantling.

As the post-war demand for electricity grew, there was also increasing disquiet about the effect of new large power stations on the environment. The first generation of post-war conventional power stations, such as Giles Gilbert Scott's Bankside power station, London, now Tate Modern, were brick and monumental in character. But, in the 1950s an official report recommended that new stations should be based on clear functional expressions and make full use of modern construction materials.

The early Magnox stations, such as Chapel Cross, clearly show their familial links with the research establishments. The reactors were surrounded by simple steel framed structures covered in asbestos sheeting. In an era emerging from wartime drabness and smoke pollution, externally and internally colour was an integral part of the design of the new installations. A contemporary journal predicted that the 'nuclear revolution will add a splash of brightness and cheerfulness to the industrial scene'.[5] At night artificial light shone through their often glass clad exteriors creating beacons of a new technological age, often in parts of the country where domestic electricity was still a novelty.

There is no one overall architectural style that characterises the British nuclear stations. Technically, each of the Magnox stations was unique and the buildings were designed by the in-house architectural teams of the private companies awarded the various construction contracts. The design of the nuclear stations reflected the increasingly close working relationships between engineers, architects, and landscape designers. In many cases leading contemporary architects, including Giles Gilbert Scott, Basil Spence, and Frederick Gibberd were retained as advisors.

Factors that influenced the final appearance of a station included their technology and construction techniques. One of the most significant factors was the evolving engineering consideration of the relationship between the reactor and the heat exchangers. So that, in later stations by placing the heat exchangers within the biological shield a more compact design was possible. Different construction techniques might also influence the final appearance of a station. The heaviest parts were the prefabricated sections of the early steel pressure vessels and associated heat exchangers. In most cases these were prefabricated and brought to the site for completion, although in some instances fully assembled heat exchangers were floated to the construction sites by sea. At some of the early stations, such as Berkeley, Gloucestershire, mono-tower cranes were used, which restricted the loads that could be lifted. At some of the later stations, for example, Dungeness, Kent, large goliath cranes were constructed to span the entire reactor building (Fig. 6).

Different design solutions and philosophies were employed to blend these huge buildings into their local landscapes. At Bradwell, careful attention was paid to the facing materials, which included aluminium sheeting that weathers to a dull grey, Leicester Lilac bricks, exposed natural aggregate gravel in the concrete panels, and its doorways and other openings were painted in maroon and olive greens. Glass panels also allowed an observer to almost see through the buildings that enclosed the heat exchangers (Fig. 7).[6]

In contrast to the light and often glass covered 1960s Magnox stations the designers of the later advanced gas cooled reactors sought to minimise their visual impact by presenting their main components as simple shapes. At Heysham, Lancashire, the three main levels of the reactor building are expressed as three coloured blocks, corresponding to the reactor shield, mechanical zone and the upper charge area.

For most of the industrial age industry exploited its surroundings with little regard to the visual impact or the pollution it was creating. In contrast to many conventionally coal fired power stations, which were located close to their consumers, most nuclear power stations were placed on relatively isolated sites. Factors that influenced their location

Fig. 6: Dungeness, Kent, to the right are the two Magnox reactors and to the left the later advanced gas cooled reactor (2016).

Fig. 7: Bradwell, Essex, Sylvia Crowe described it as 'huge, clean, light and floating almost like one of the clouds over the estuary' (2003).

included nervousness about new technology, the presence of ground that could bear the weight of the reactors, and access to vast amounts of cooling water. As a consequence of these requirements they were often placed in remote and untouched landscapes noted for their natural beauty. In their favour, in comparison to contemporary coal fired stations, most nuclear stations have a compact ground plan. Most also relied on sea water for cooling, obviating the need for massive cooling towers. In common with conventional stations transmission lines marched across the landscape from the stations. These were, however, the people's power stations, built by a nationalised industry, and placed in a countryside that had been invoked during the war as something worth fighting for. This concern was reflected in the 1957 Electricity Act that required the designers of new stations to consider their impact on the local environment.

One of the most sensitive locations for a nuclear station was in a National Park at Trawsfynydd, Gwynedd (Fig. 8). The design of this station was entrusted to the noted post-war architect, Basil Spence, and its surroundings to the leading contemporary landscape designer Sylvia Crowe. To provide a seamless link between the local landscape and the station careful attention was given to tree planting that was brought into the station's compound. The large scar created by the construction camp was later softened by the creation of tree-covered artificial mounds that also had the effect of hiding the station. Closer to the station Sylvia Crowe created two smaller gardens for the enjoyment of the workforce; Cadw has registered these as historic gardens.

To create a nuclear power station often required remodelling the existing landscape for the construction of temporary on-site assembly shops and accommodation camps for thousands of men. On completion these temporary facilities were cleared away, leaving large areas of levelled and barren land, or in other instances their sites have been reformed to break up the lines of the stations.

The nuclear industry was also an important maker of new places. At Thurso, in the north Scotland, new estates comprising over 1000 houses and flats were built for 'The Atomics' of the Dounreay research centre. To serve the Sellafield complex a new estate at Seascale was designed around curving roads with verges, and larger grassed areas. One of the

Fig. 8: Trawsfynydd, Gwynedd, Wales, to emphasise the station's rural character, it was given a winding access road devoid of footpaths and lighting (2005).

few concessions to local character were panels of local stone used in some porches. Generally, they followed contemporary public housing designs, although with social stratification matching that of the factory hierarchy.

The legacy

These historic nuclear sites are now owned by the Nuclear Decommissioning Authority, the NDA, which controls 17 former civil nuclear sites in England, Wales and Scotland, including research facilities, fuel production sites and the Magnox power stations. It was formed in 2005, is wholly funded by the government and its main task is to clear these sites with the ultimate aim of releasing the land for brownfield development. The NDA is a relatively small executive agency of around 200 people setting strategy, planning, contracting, monitoring performance, and quality assurance. It accomplishes its mission through a series of subsidiaries, such as Sellafield Ltd, and Site Licence Companies, whose task is to remediate the individual sites (Fig. 9).

In regards to most of the research reactors and power stations, the policy is to clear all the non-nuclear structures, such as administration and welfare buildings, and electricity generating and distribution plant. Within the reactor buildings the fuel rods are removed and the reactor buildings reduced in size and reclad with the intention that they will be left to 'cool down' for around 80 years before final dismantling (Fig. 10).

Unsurprisingly, in such a heavily regulated industry each establishment has accumulated a vast archive of building and plant drawings, station log books, and health records. For the NDA's largest site at Sellafield, it is estimated that there are 80,000 boxes of archived records. Some records they are legally obliged to retain and others are required to assist in dismantling, which may not occur for decades. To hold these records the NDA has recently opened the £21 million 'Nucleus' archive at Wick, Caithness, in the north of Scotland.

Many of the early policy documents and other high level administrative records are held by the UK's National Archives; a legacy of a time when the nuclear industry was state owned.[7] However, this potentially leaves many records at each site that are vulnerable to destruction, such as drawings of buildings not connected with handling radioactive materials, detailed plant drawings and photographs, and records of the social history of these places. It is this group of records that is of most concern; although they are no longer critical to the NDA's business they may have future historic interest. It is unrealistic to expect that they will all be retained, but nor can we know what may be of interest to future historians.

To underpin its business the NDA has a comprehensive information management strategy to manage its legacy archives and to ensure the essential knowledge is readily accessible in the future. The capture of this data is summarised in a 645 line table.[8] The last line of which acts as a catch-all for purely historical material, although at present the interpretation of this line is left to the discretion of each site.

Another challenge posed when developing heritage strategies for large scale 20th century industries is the division of organisational responsibilities for different aspects of this heritage. Generally, museums will be concerned with their artefactual legacy, which may include training models and aids, and clothing; archives will collect documents, film and photographs, although not always technical records and building and plant drawings. Thirdly, it is generally the state and local authority heritage agencies that will be concerned with their built and landscape heritage.

Documenting conventional post-war power stations

Around the same time as the construction of the new nuclear stations a new generation of huge coal and oil-fired stations

Fig. 9: Sellafield, Cumbria, the largest nuclear site in Europe. To the right are cooling towers of the Calder Hall power station (1990s).

was also built. Over the last decade or so many of these have also reached the end of their operational lives and measures to reduce carbon emissions will see the remainder close by the early 2020s. They have been described as the 'great temples of the carbon age' and had a profound impact on England's landscape and helped to transform the country's post-war society and economy.[9]

The selection of post-war buildings for listing is particularly rigorous and it's very unlikely that any power stations or their landscapes will be protected. Given that ultimately they will all be lost, how do we secure a record of these stations? Historic England has issued guidance on minimum recording standards and the expectation is that the power companies will fund surveys of the stations at the point of closure and before demolition begins.[10] This can be required (rather than requested) where the asset in question is recognised as a heritage asset and is being dealt with through the planning system.

At most stations there are often very extensive photographic records, many of these are highly technical and were often taken during construction. Where further photography is required the most effective time for a photographic record to be undertaken is prior to closure, where the use of space may be documented and how, for example, the workers interacted with the control rooms. Careful attention should also be paid to the use of colour, texture and finish of the buildings, and modifications that have taken place since opening. Low level oblique aerial photography is particularly effective in recording a station's buildings, layout and its relationship with the local landscape. Where resources

Fig. 10: Bradwell, Essex, after defueling the former reactor building has been reduced in height and reclad. It will probably remain in this form for a generation before final dismantling occurs (2017).

allow, video adds another dimension to documenting of processes and working regimes. In some areas of the nuclear industry 3D scanning technology is used to guide demolition robots; the data clouds for these tasks may potentially form an important historical record.

Most sites will also hold thousands of records, only a small number of these will be of lasting historic interest. The sorting and long-term storage of the records represents a cost to the power companies. The cheapest solution is to destroy the records when they are no longer needed. At present the sifting of records is usually undertaken by non-specialists within the power companies and our guidance is designed to inform their selections.

Historic England recognises the contribution that nuclear power stations have made to the nation's energy needs and their technological interest. In common with our approach towards conventional power stations, our stance is to work with the NDA to argue for the retention of records to secure a proportionate record of all buildings on their sites, as well as key plant, and the social history of these places; supplemented by additional recording at the point of closure. It also requires collaboration with others in the museum and archive sectors, and academia to ensure the historic evidence is secured, while ultimately accepting that long-term physical survival of any civil nuclear sites and their associated landscapes is very unlikely.

Summary

As the civil nuclear research establishments and power stations are being cleared we are witnessing a process analogous to a living ecosystem being reduced to a fossil assemblage with a corresponding loss of knowledge. The management of information is of a critical concern to the NDA who need to secure knowledge to ensure regulatory compliance and to assist in the final dismantling of the stations. However, the sorting and retention of information has a cost and is managed by tight commercial contract terms.

Bibliography

Anon 'Editorial', Nuclear Engineer 1958, 132.

Peter Bone, Kirsty Nichol, Nigel Pearson, and Timothy Peters. The Valley Site, Rhydymwyn, Flintshire Historic Environment Management Plan 2006 Volumes 1–3 Birmingham Archaeology Report No. 1377.

Brian Cathcart, Test of Greatness. Britain's struggle for the atom bomb, London 1994.

Historic England 2016, England's Redundant Post-War Coal-and-Oil-Fired Power Stations.

Neil Cossons, 'Inherited infrastructure', Conservation Bulletin, 2010, 65, p. 6.
Sylvia Crowe, 1960 'Power and landscape', Journal Institute of Landscape 52, pp. 3–6.
Gino Segré, G Faust in Copenhagen: the Struggle for the Soul of Physics and the Birth of the Nuclear Age, London 2007.
The National Archives, Kew.
AB6/326 Windscale (Sellafield) 1947–1948, Draft minute 11/1/1/46
BP2/145 Request to erect a 400ft high chimney stack at Windscale (formerly Sellafield) Atomic Station 01 December 1947–30 June 1949, letter 12 January 1948.

Zusammenfassung

Englands Atomzeitalter.
Die Sicherung seines architektonischen und technischen Erbes

Ende des 19. Jahrhunderts waren Wissenschaftler von britischen Universitäten Teil einer dynamischen Gruppe internationaler Forscher, die die Struktur des Atoms erforschten. Im frühen 20. Jahrhundert revolutionierte Ernest Rutherford, damals an der Universität Manchester, die Erkenntnis über das Atom, später gelang John Cockroft und Ernest Walton die Atomspaltung im Cavendish Labor in Cambridge. In den späten 1930er Jahren traten viele, auf der Flucht vor der Unterdrückung durch die Nazis emigrierte Wissenschaftler dieser bereits weltläufigen Forschergruppe bei. Zwei von ihnen – Otto Frisch und Rudolph Peierls – erregten die Aufmerksamkeit der britischen Regierung mit der Möglichkeit, die Kernspaltung zu nutzen, um eine „Superbombe" herzustellen. Die Forschung auf diesem neuen Gebiet begann in Großbritannien, siedelte aber später in die Vereinigten Staaten von Amerika über. In der unmittelbaren Nachkriegszeit übernahm Großbritannien eine Vorreiterrolle sowohl im Bereich atomarer Waffen als auch in der Anwendung der Nukleartechnik für zivile Zwecke einschließlich der Stromerzeugung.

Die fast 80 Jahre andauernden Aktivitäten in diesem Bereich hinterlassen ein komplexes Erbe an Forschungseinrichtungen und Produktionsstätten sowie Kraftwerke, von denen einige in herausragenden Landschaften liegen. Anlagen, die mit dem Einsatz nuklearer Waffen in Verbindung gebracht werden, sind zum großen Teil von dieser Diskussion ausgenommen. Die Mehrheit der Einrichtungen hat entweder das Ende ihrer Betriebszeit bereits erreicht oder wird es bald erreichen, sodass Programme zur Beseitigung der Anlagen aufgelegt werden. Ziel ist es, das Land einer Nutzung wieder zugänglich zu machen, z. B. durch eine neue Generation von High-Tech-Forschungszentren oder Kraftwerken. Nach anfänglicher Dekontaminierung könnten einige Anlagen jahrzehntelang gesichert und verbleibende radioaktive Kontaminierung so ihrem natürlichen Verfall überlassen werden, bevor die Anlagen endgültig zurückgebaut werden.

Historic England ist der vorrangige Berater der Regierung Großbritanniens in Belangen des historischen Erbes. Viele der aktuellen Programme der Organisation sind durch die Prioriäten der britischen Regierung geprägt, wirtschaftliche Aktivität dadurch zu steigern, dass große Infrastrukturprojekte wie neuer Straßen- und Schienenbau, Wohnungsbau, erneuerbare Energien, insbesondere Windparks, und saubere Kraftwerke einschließlich Gas- und neuen Kernkraftwerken gefördert werden.

Eine der größten Herausforderungen derer, die für den Schutz des Industriedekulturerbes eintreten, ist es, die Bedeutung der Industrie des 20. Jahrhundert zu verstehen. Das gilt insbesondere für die großen und technisch komplexen Industrien der Nachkriegszeit, für die Strategien zu entwickeln sind, um dieses historische Erbe entweder durch physische Erhaltung oder durch Aufzeichnungen zu bewahren. Die zivile Nuklearindustrie steht beispielhaft für eine dieser Industrien. Der Artikel zeigt einen kurzen Überblick dazu in England auf. In der Erkenntnis, dass der physische Erhalt unwahrscheinlich ist, werden andere Strategien notwendig sein, um das architektonische und technische Erbe der Atomindustrie zu sichern.

1 Cathcart, Test of Greatness, 1994, p. 40.
2 Segré, Faust in Copenhagen, 2007, pp. 258-9.
3 Peter Bone, et al The Valley Site, Rhydymwyn, 2006.
4 TNA AB6/326 Draft minute 11/1/1/46; BP2/145 letter 12 January 1948.
5 Nuclear Engineer 1958, 132.
6 Crowe, 'Power and landscape, 1960, 3–6.
7 For their policy see http://www.nationalarchives.gov.uk/documents/information-management/osp-57.pdf https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/643852/IMP09_NDA_Archive_Acquisition_Policy_Rev1.pdf accessed 20 January 2018.
8 https://www.gov.uk/government/publications/nda-records-retention-schedule accessed 20 January 2018
9 Cossons, 'Inherited infrastructure', 2010, p.6.
10 Historic England 2016.