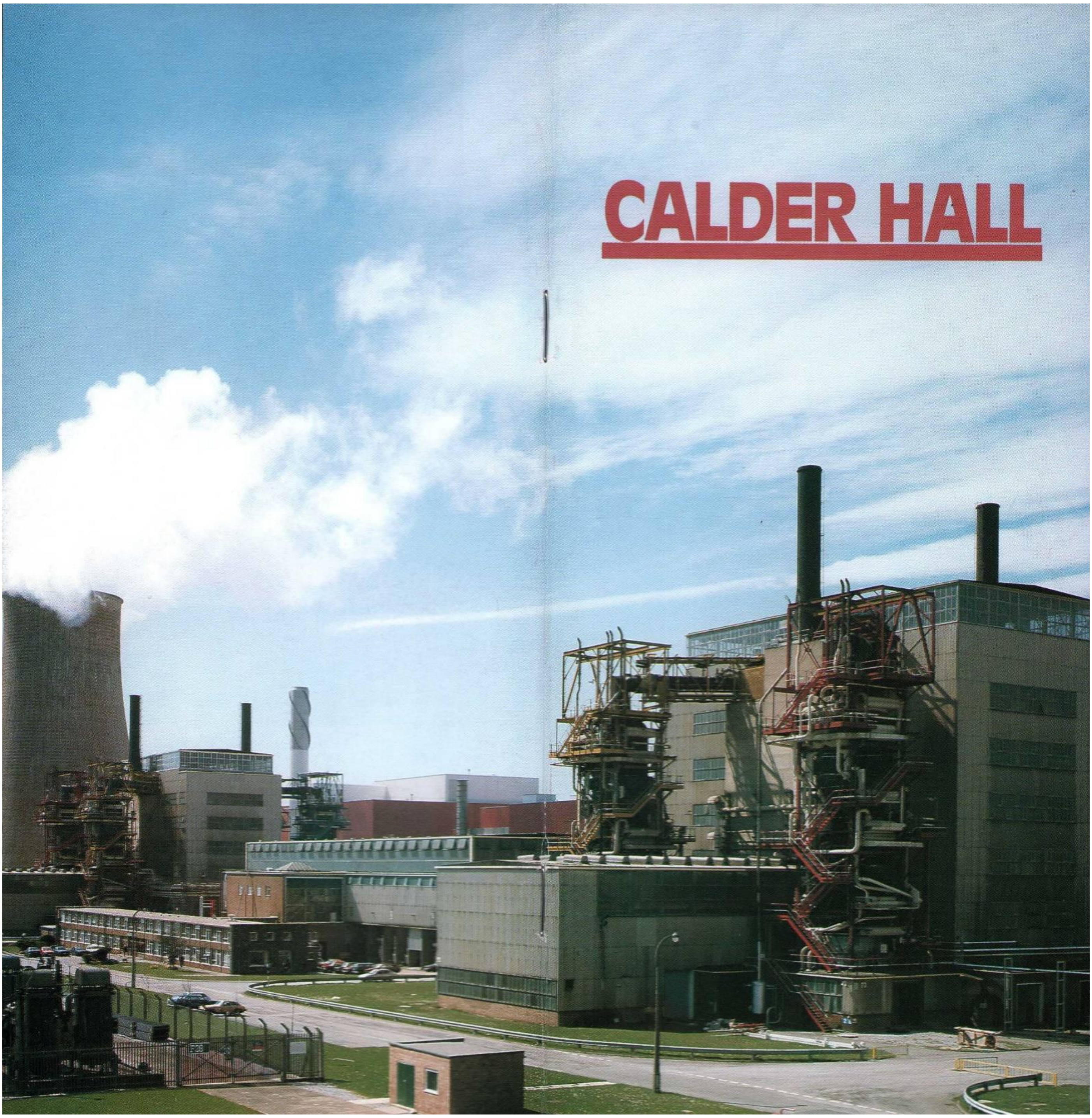
CALDER HALL



INTRODUCTION

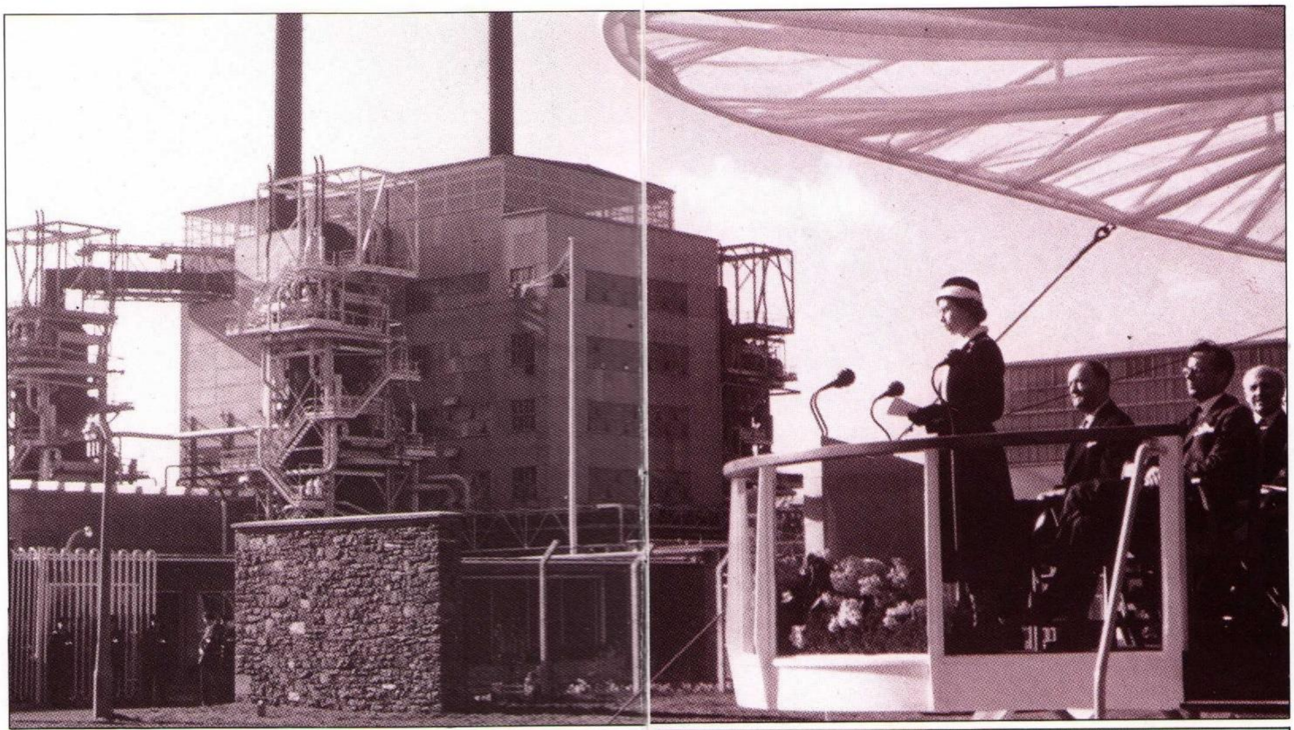
Nuclear energy is now part of our everyday life as a safe and reliable means of producing electricity. In Great Britain as a whole nuclear power stations provide about one fifth of our electricity – in Scotland the proportion is nearly half.

Calder Hall nuclear power station was the first industrial-scale station in the world to demonstrate the commercial potential of generating electricity through nuclear energy. On 17 October 1956, Her Majesty Queen Elizabeth II officially opened the station by pressing a switch to feed electricity from nuclear energy into the National Grid for the first time.

Since this first achievement, Calder Hall's reliable and safe operation over more than thirty years has served to demonstrate the commercial viability of nuclear energy in the production of electricity.

The former Industrial Group of the Department of Atomic Energy, Ministry of Supply at Risley in Cheshire was given the responsibility for designing and building Calder Hall. The design team of about 70 people began work on 7 April 1953 and a little over three years later the world's first industrial-scale nuclear power station came into operation. Originally Calder Hall was built to produce both plutonium for weapons purposes and electricity as a commercially valuable by-product which could be exported to the National Grid. Subsequently, changing defence needs led to a concentration on electricity generation, although plutonium has been produced on occasions for defence purposes.

The site chosen for the new power station was Calder Hall, adjacent to the Windscale atomic piles in Cumberland. Originally only one reactor was planned but a second was authorised later. Subsequently, two further reactors were added to the design. With two steam turbines and electricity generators for each reactor, the station was designed to have an electrical capacity of 168 Megawatts.

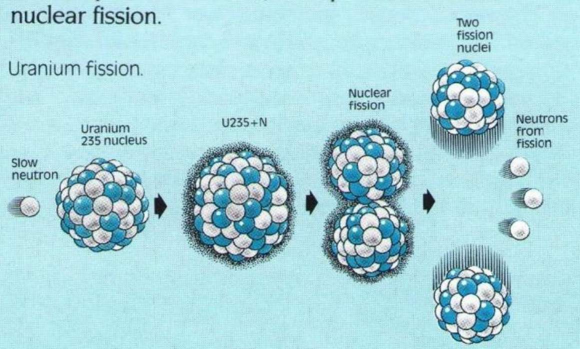


Her Majesty The Queen opens Calder Hall.

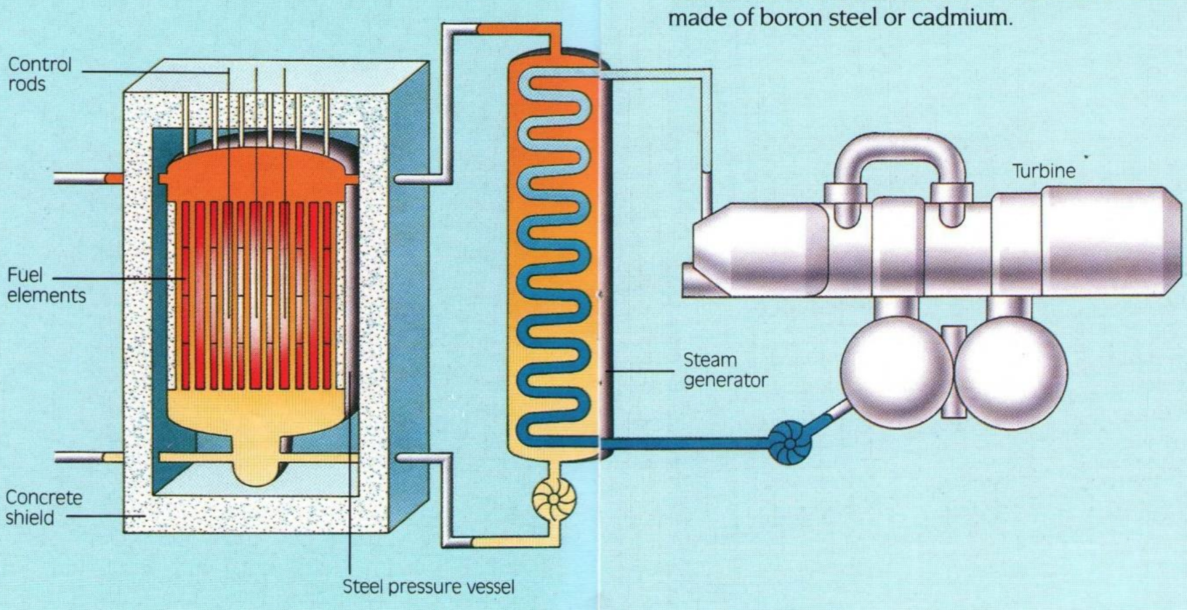
HOW NUCLEAR ENERGY PRODUCES ELECTRICITY

Nuclear power is based on the use of uranium which is found widely in the earth's crust and in the sea and which has no significant commercial use except for nuclear energy. It is also, like much of our environment, naturally radioactive and its atom has a tendency to split spontaneously into two parts releasing energy as heat as well as several neutrons (a small part of the atom). This process is called nuclear fission.

Uranium fission.



How a Magnox reactor works.



This release of neutrons during fission is the key to nuclear power since if they strike the nucleus of other uranium atoms they can also be induced to split, releasing more neutrons and more heat. Eventually the reaction becomes self-sustaining and if enough atoms of the correct type are present a continuous supply of heat can be produced in this way. This is the principle used in all nuclear power stations, including Calder Hall.

In a reactor the heat produced during the fission process is transferred to boilers by a coolant, either gas or liquid, which is pumped around the hot fuel. In the boilers water is converted to steam to rotate turbines and so generate electricity. The Calder Hall reactors use a gas (carbon dioxide) as a coolant. The only difference between a coal or oil-fired power station and a nuclear power station is the source of heat used to boil water to drive turbo-generators.

A substance called a moderator is used to slow down the speed of the neutrons, as neutrons travelling at slower speeds are more likely to cause fission. The moderator in the Calder Hall reactors is graphite. The fuel elements and the moderator constitute the reactor core.

The nuclear reaction must also be controlled and this is done by inserting a neutron absorbing material into the reactor core causing the reaction to stop. The neutron absorbers are called control rods and can be made of boron steel or cadmium.

THE CALDER HALL REACTORS

The reactors themselves are made up of the reactor core enclosed within a steel pressure vessel, which in turn is surrounded by a thick concrete shield. The heat exchangers are connected to the pressure vessel by steel ductwork which passes through the concrete shield.

The fuel used in the Calder Hall reactors is natural uranium metal, encased in a can made of magnesium alloy known as Magnox, which gives its name to this type of reactor. The heat generated within the reactor is transferred from the fuel to four heat exchangers (boilers) by carbon dioxide gas blown through the reactor under pressure. Each reactor has four heat exchangers, giving a total of sixteen for the whole power station. The steam produced in the boilers is used to drive the turbines to produce electricity.

Each reactor at Calder Hall contains about 10,000 fuel elements stacked five or six to a channel, one above the other. The elements are surrounded by the graphite moderator which slows down neutrons to the right speed for nuclear fission. The reaction is controlled by boron steel rods which absorb neutrons, and can be lowered into the reactor to slow down the reaction. The rods can also be used to stop the reaction altogether whenever necessary.

The first reactor at Calder Hall supplied electricity to the National Grid in October 1956, followed by the other three at intervals over the next three years, the last reactor coming into use in April 1959. Meanwhile construction was underway on a sister station to Calder Hall at Chapelcross in Dumfriesshire, Scotland. Chapelcross began to export electricity in January 1959 and the last of its reactors came on power in March 1960.

Based on the successful operation of the Calder Hall reactors, improvements have been made to the station's electrical output over the years. Even in the early stages, heat output was 10-15 Megawatts more than expected. Later, improvements were made such as increasing the gas blower speeds, re-designing the fuel elements to give more heat output and modifying the turbo-generators to produce 30 MW of electricity. These mean that the station is now able to produce approximately 50% more electricity than was originally envisaged – enough to meet the continual electricity needs of a town the size of Brighton. Calder Hall also supplies all the electricity and process steam requirements for the Sellafield site, making it the world's first industrial complex to fully utilise nuclear energy.

Calder Hall nuclear power station.

Discharging spent fuel from one of the reactors.

SAFETY

Calder Hall, like the rest of the Sellafield site and British Nuclear Fuels' other industrial sites, is licensed to operate by the Health and Safety Executive under the terms of the Nuclear Installations Act 1965. Under the terms of the licence, the Executive's Nuclear Installations Inspectorate is closely involved with the plant's operation and safety.

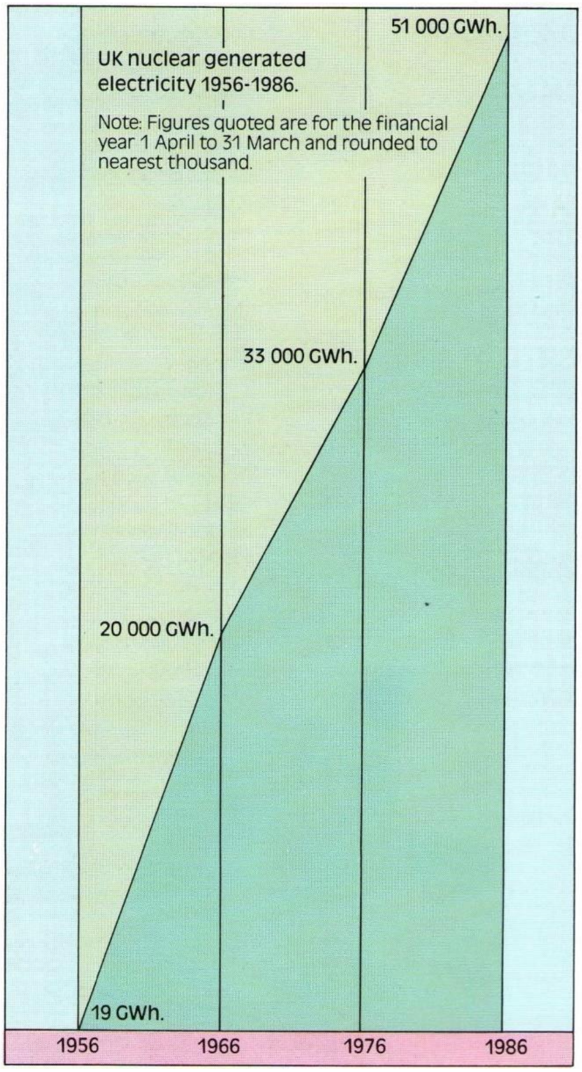
There are extensive facilities to ensure the safety of employees, the general public and the environment through sound design and construction, safe working practices and operating procedures, thorough operator training and rigorous maintenance and inspection procedures. Extensive monitoring of people and the environment both inside and outside the site is regularly carried out.

Like all other nuclear power stations Calder Hall and Chapelcross undergo extensive routine maintenance, inspection and testing. Each reactor at the two stations is closed down annually for maintenance and re-fuelling. Nevertheless, both stations operate at approximately 85% full capacity averaged over the full year and they have regularly operated at over 95% during the winter months when demand is highest.

A considerable amount of experimental work was undertaken on the Calder reactors in the early years of operation, particularly in support of the commercial power programme. The performance of fuel elements has been tested and a great deal of information has been provided on safety aspects and reactor physics characteristic of the Magnox system.

NUCLEAR ENERGY IN BRITAIN

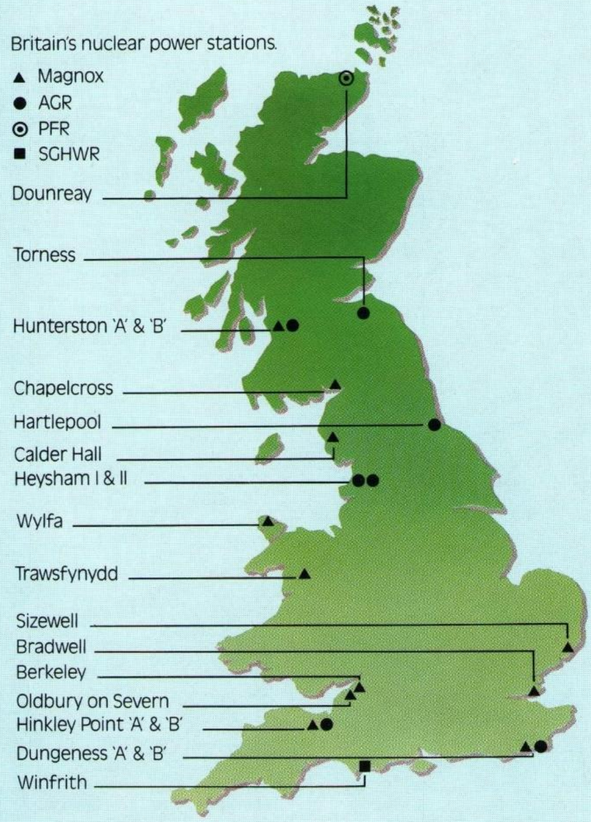
The highly successful design and operation of Calder Hall and Chapelcross were used as the basis for further reactors in the UK and abroad. The first station based on the Magnox design came into operation at Berkeley in Gloucestershire in 1962, and was followed by a further eight stations, each with two reactors. It was also used as a basis for reactors at Latina in Italy and at Tokai Mura in Japan.



Later British nuclear power stations, based on the experience gained from the operation of Calder Hall and the other Magnox stations, are known as Advanced Gas-cooled Reactors (AGRs). The fuel used in this type of station is enriched uranium oxide pellets in stainless steel pins, leading to higher temperatures and so greater efficiency. Like the Magnox reactors, the AGRs use a graphite moderator and carbon dioxide coolant. The first AGR at Hinkley Point began operation in 1976, followed shortly afterwards by one of the reactors at Hunterston in Scotland.

Now there are seven AGR stations in the UK in use or nearing completion.

Britain's nuclear power stations.



THE CONSTRUCTION PROGRAMME

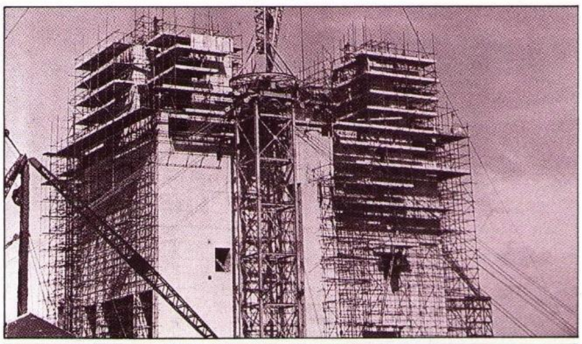
August 1953

Early preparation work at the site of Calder Hall, Number 1 reactor.

November 1953

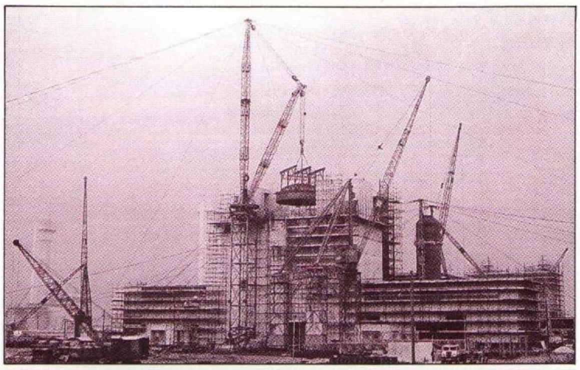
Foundations for Number 1 reactor take shape.

August 1954



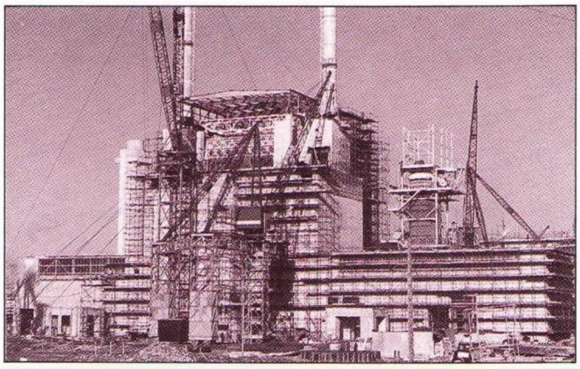
Number 1 reactor under construction, general view.

December 1954



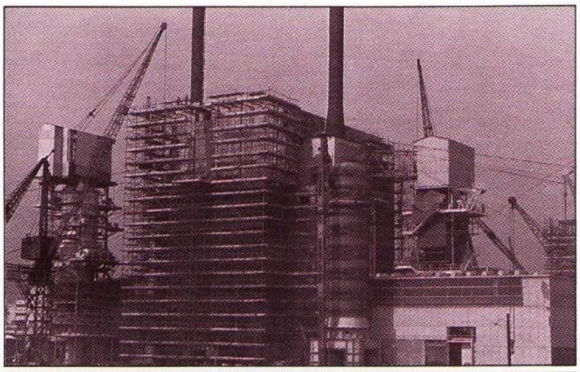
Top dome of Number 1 reactor being lowered into position.

January 1955



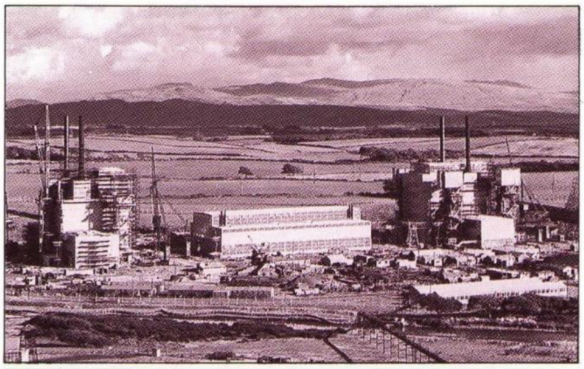
Reactor progress.

May 1955



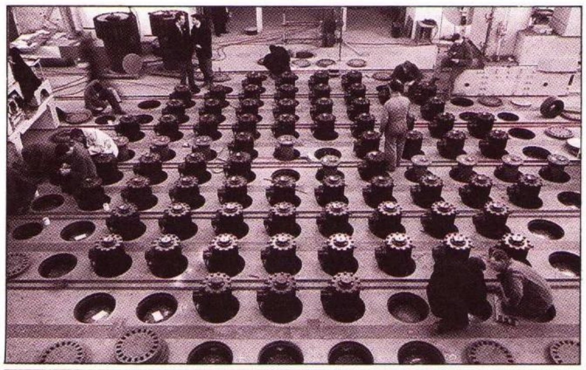
Fourth heat exchanger, Number 1 reactor, in position.

September 1955



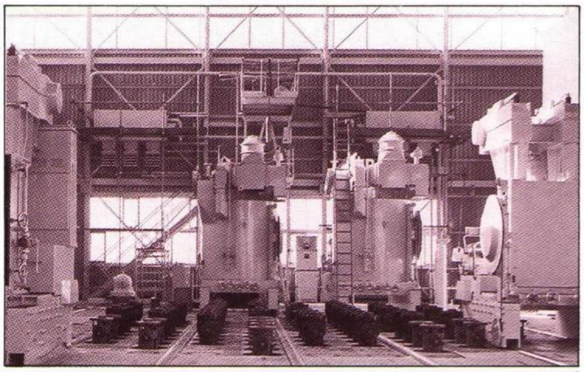
Calder Hall site. Number 1 reactor is on the right and Number 2 is on the left of the turbine hall.

March 1956



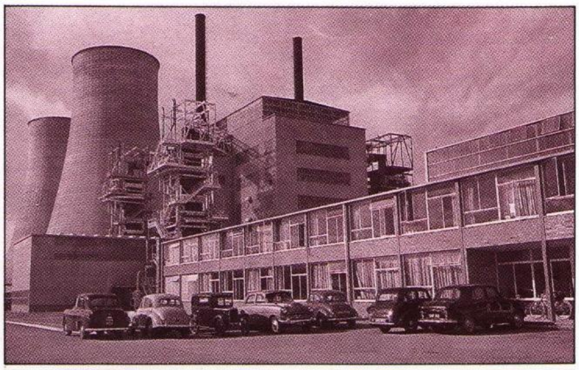
Pile cap of Number 1 reactor with control rod mechanisms and flux scanners in position.

September 1956



Fuel charge machine on the pile cap.

September 1956



Calder Hall administration building with Number 1 reactor in the background.

CALDER HALL – KEY INFORMATION

Location Sellafield, Cumbria.
Commissioning Reactors 1 and 2, 1956; Reactor 3, 1958 and 4, 1959.

The station consists of four reactors housed in cylindrical mild steel pressure vessels which are about 21.5m high and 11.3m in diameter. Five or six fuel elements are stacked vertically in each of the 1,696 channels per reactor. Each reactor has four heat exchangers generating high and low pressure steam simultaneously. Generating plant comprises eight 3,000 rpm turbo-generators.

The outstanding feature of Calder Hall and its sister station at Chapelcross has been their overall reliability. Even with off-load refuelling and a large experimental programme, load factors have consistently been over 90%.

Reactor Type Magnox

DATA FOR EACH REACTOR

Reactor Power 268 MW (Th), 50 MW (e) net

Fuel Element Natural uranium in herringbone-type Magnox cans.

Number of Fuel Elements Five or six elements in each of 1,696 channels; total 110-115 tonnes natural uranium.

Moderator 1,113 tonnes graphite in 58,000 bricks.

Coolant Carbon dioxide, outlet temperature 345°C. Absolute pressure of 7.9 bars.

Core Size Polygonal prism: 9.45m diameter, 6.40m high.

Specific Power 2.40 kW/kg uranium.

Steam Conditions Dual pressure steam cycle with superheat but no preheat or reheat. HP steam 320°C, absolute pressure 15.5 bars at TSV.

Published by Information Services
British Nuclear Fuels plc
Risley
Warrington WA3 6AS

Kynoch Graphic Design
Printed in England
Revised and reprinted September 1988
M24/75m/IR/988