CALDER HALL

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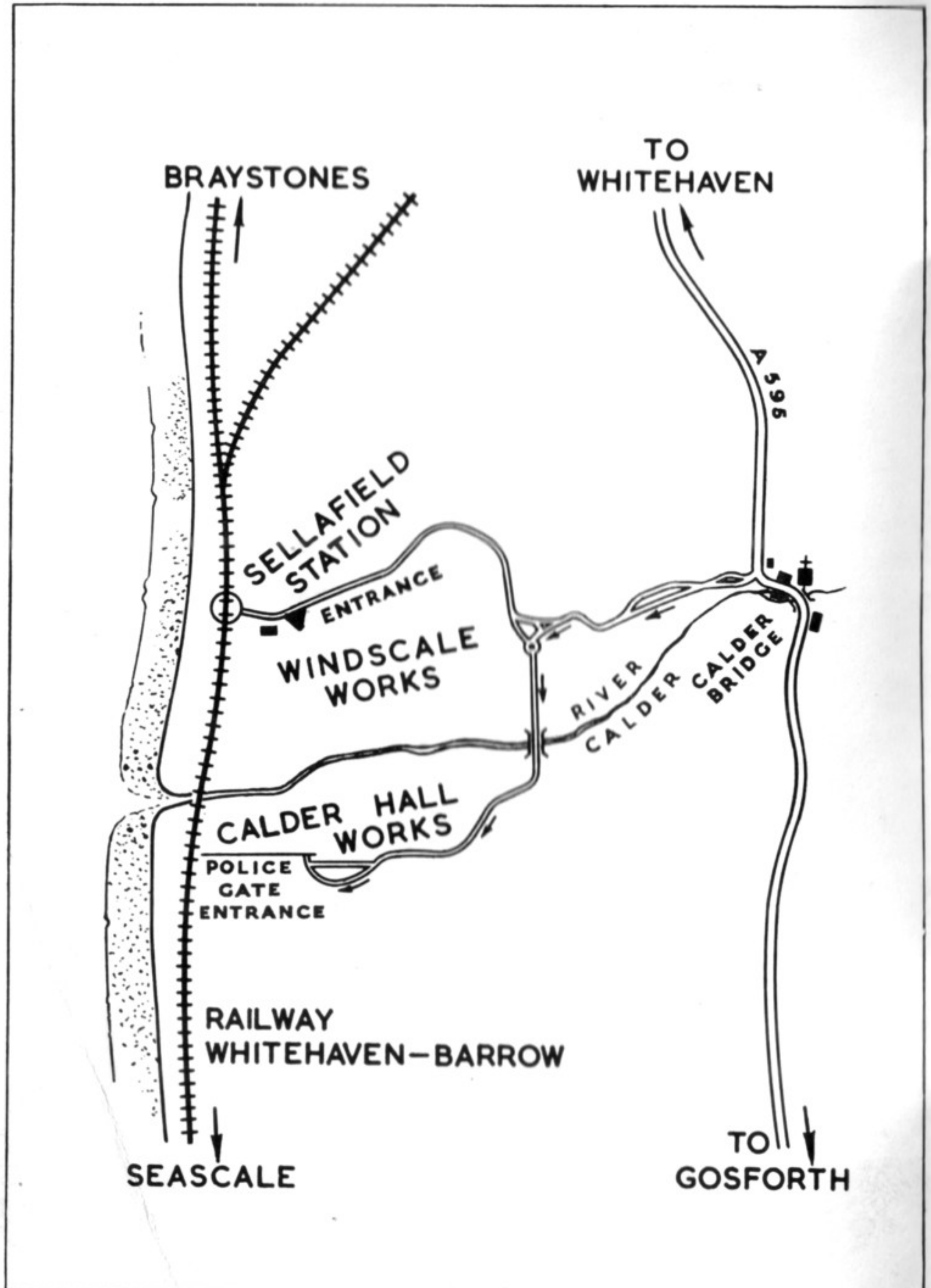
HOW TO GET TO CALDER HALL



1 INTRODUCTION

CALDER HALL, Britain's first nuclear power station, and the first in the world to supply electricity to a national supply network on an industrial scale, stands on the Cumberland coast, separated only by the River Calder from the plutonium factory at Windscale. To the visitor, whether arriving by road or rail, the most prominent features are the twin towers of the Windscale reactors and the massive but graceful cooling towers of the power station, 300 feet high.

The approach by road is along what used to be a country lane branching off the Whitehaven-Barrow road (A595) at the village of Calderbridge. The density of factory traffic has necessitated the construction of a second roadway along most of its length, however, converting it to a dual carriageway. Coming over the brow of a hill the road appears to be plunging straight into the Windscale factory, but the visitor to Calder Hall branches off to the left. Those who come by train travel along the very edge of the sea to the typical country station of Sellafield, where the road from Calderbridge reaches a dead end. Emerging from the station one is faced with a short, steep hill over the crest of which appear in succession, as it is climbed, the various buildings of Windscale. The entrance to this factory is on the right and the road sweeps round its perimeter for over a mile, with the Lakeland fells forming a distant backcloth. Under the shadow of the massive reactor buildings the road forks, the left hand branch continuing to Calderbridge, whilst ahead lies the way to Calder Hall. The two approaches, from the sea and the hills, combine at a roundabout which seems incongruous in a setting which, in spite of the surrounding factory buildings, contrives to retain its rural appearance.

The road slopes gently downward to a bridge over the River Calder, a bridge which the visitor should observe carefully, for this bridge is the only means of access to the Calder Hall power station. Over it was brought all the material needed for its construction, all the equipment piece by piece and over it too, will be carried all the fuel needed for its operation. In place of the acres of railway sidings, or extensive wharves needed by a conventional power station, Calder Hall needs only this bridge, this road and a few vehicles.

Beyond the river the road swings to the right past the second half of the station which was only started in 1955, and will be completed in 1958. The road makes a final semi-circular sweep to bring the visitor to the entrance to the power station itself. This section, known as "The Duke's Way," was first used by H.R.H. the Duke of Edinburgh when he visited the station on November 23rd, 1955 and along it, on the sunny morning of October 17th, 1956, came H.M. Queen Elizabeth II to switch electricity from this station into the national grid for the first time.

2 HOW A NUCLEAR POWER STATION WORKS

AN ELECTRICITY generating station consists of four main parts : a source of heat, a boiler in which water is converted to steam, turbines which are driven by the steam, and alternators which are driven by the turbines and generate the electricity. It is only in the first of these parts, the source of heat, that there is any fundamental difference between a conventional power station and a nuclear power station. In a conventional power station heat is produced by burning coal or oil, a chemical reaction in which the atoms concerned are rearranged but are not permanently changed. In a nuclear power station the heat source is a nuclear reactor and the heat is produced by the actual splitting of atoms, a process known as nuclear fission.

There is only one kind of atom occurring in nature in which this splitting will take place, and that is a kind of uranium atom which has a weight of 235 units on the atomic scale and is written in scientists' shorthand as U235. When we produce uranium from its ores it consists almost entirely of two kinds of atoms, chemically indistinguishable from each other, but differing slightly in weight. One in every 140 is U235, and can be made to release heat on splitting ; the rest are nearly all 3 units heavier and are called U238 atoms.

To cause fission the central core or nucleus of the U235

atom has to be struck by a neutron, one of the particles which occur in all atomic nuclei except those of hydrogen. When this happens the nucleus splits into two roughly equal parts called fission products, heat is released and also two or three new neutrons are shot out at very high speed. This last fact is most important, because if we can arrange that one of these neutrons strikes another U235 atom the splitting process will continue and a "chain reaction" will be set up, giving a steady production of heat. However, if the neutron strikes a U238 atom, it is absorbed and has no opportunity to split another atom of U235. In natural uranium, of course, there are so many more U238 atoms than U235 atoms that the chance of one of the new neutrons striking a U235 atom is very slight and a chain reaction is impossible. Some means of increasing this chance has therefore to be devised if we are to succeed. Soon after the original discovery of the fission process, it was found that if a neutron was travelling comparatively slowly it was much more likely to cause fission in a U235 atom and much less likely to be absorbed by a U238 atom ; this led to the realisation that if pieces of uranium were separated by the right amounts of a material which would slow down the neutrons without absorbing them, it should be possible to redress the balance and produce a chain reaction. The slowing down material is called a moderator, and the most suitable material available in Britain for the purpose is carbon in the form of graphite.

One question which often puzzles the non-scientist is "Where does the first neutron come from to start it off?" One answer to this is that there are always a few neutrons about, some produced by the action of cosmic rays reaching the earth from outer space, and others released spontaneously by uranium atoms, a few of which disintegrate without any outside influence. But apart from these sources it is usual to install a "neutron source" in a reactor to enable certain tests to be carried out in the initial stages. This source often consists of a mixture of radium with beryllium or lanthanum, and produces a steady supply of neutrons as the radiations from the radium act on the other material. The source is left in position and provides the first few neutrons from which the reaction can be built up.

Essentially, then, a nuclear reactor which uses natural uranium consists of a mass of moderator with pieces of uranium in it and a device to control the fission reaction. This device usually consists of a group of rods containing boron (which readily absorbs neutrons) arranged to move in and out of the reactor, and adjust the number of neutrons available to cause fission so as to keep the reaction, and hence the production of heat, at a steady level. Means must also be provided for removing the heat from the reactor, normally by circulating a gas or liquid through it. Because of the intense radioactivity generated inside the reactor it has to be surrounded by a biological shield, so called because it reduces the radioactivity to a level which is biologically safe for the operators outside. It must be realised that just as the human body can withstand a certain amount of sunlight without injury, so it is able to tolerate a certain amount of radioactivity ; and just as excessive exposure to the sun can cause illness and even death, so an overdose of radioactivity can produce damage which may be fatal. Moreover, man has always been exposed to some radioactivity throughout his life ; some comes from outer space in the form of cosmic rays, some from radioactive material in the earth's crust, and a slight amount is present actually in our bodies in the form of radioactive potassium.

It was pointed out earlier that neutrons which collide with the commonest type of uranium atom, U238, are absorbed, but although they do not help to maintain the fission chain and produce heat, they are not wasted. A U238 atom which captures a neutron undergoes a different reaction which converts it, after a time, into a new artificial element called plutonium, and plutonium, like U235, can undergo fission and produce heat. It is a new fuel for reactors, and like U235, is a highly concentrated one.

The heat output of these nuclear fuels compared with ordinary chemical fuels like coal, oil or gas is millions of times greater. In fact, the heat obtained from the splitting of one pound of U235 or plutonium is roughly equal to that produced by burning 1,000 tons of coal. From this it might appear that a small pellet of uranium would run a power station for a considerable time, but this unfortunately is not so. Unless the reacting core is greater than a certain size, called the critical size, so many neutrons escape from its surface that a chain reaction is impossible and for a reactor using natural uranium, which is a very dilute fuel, this size is several feet wide and high, requiring tons of uranium to make it work. Moreover, the pieces of uranium fuel, generally in the form of bars, have to be sealed in containers before they can be put into the

reactor, partly to prevent the fission products, which are highly radioactive, from escaping and partly to prevent the uranium itself from being oxidised. The uranium bar, in its can, is called a "fuel element". This means that the fission products —the "ash" of the nuclear fire—remain in the reactor and many of them absorb neutrons. Consequently, the longer the uranium is left in the reactor the fewer atoms of U235 are left and the more neutrons are lost by wasteful absorption and after a time these two effects combine to make it impossible to maintain the chain reaction. The fuel element must then be removed, even though it still contains a lot of U235, but by reprocessing, the plutonium and fission products can be removed and the uranium made suitable for use again.

At Calder Hall each reactor consists of a mass of graphite 36 feet across and 27 feet high, built up of 58,000 bricks of various shapes, with about 1,800 vertical channels running through it : 1,696 of these channels contain fuel elements, 40 inches long stacked one above the other six high. Other holes accommodate the control rods and instruments. The uranium bars are roughly an inch in diameter and are sealed in magnesium alloy cans with spiral fins to assist in dissipating the heat. The heat is removed from the reactor by pumping carbon dioxide through it at a pressure of 100 pounds per square inch. To maintain this pressure the whole of the reactor has to be encased in a cylindrical steel tank, the "pressure vessel", two inches thick, which is 37 feet in diameter and 70 feet high. Four large ducts near the top carry the hot carbon dioxide to the four heat exchangers, or boilers, and four similar ducts return the cooled gas to the bottom of the reactor. The flow through the core is about a ton of carbon dioxide every second. In the roof of the pressure vessel are the tubes through which the fuel elements are loaded and unloaded and the control rods are raised or lowered as required. These tubes come through the concrete shield roof to the floor above, and when not actually in use are sealed with concrete plugs. To avoid having too many openings in the pressure vessel, each tube is arranged to supply 16 channels. The biological shield for the reactor is octagonal, consisting of reinforced concrete 7 feet thick, lined with a thermal shield of 6 inch steel plates to prevent the concrete from getting too hot. Between the two shields is a 6 inch air gap through which cold air is continually flowing.

All the time the reactor is working various instruments are taking measurements and these are shown on the rows of dials and recorders in the control room. One very important piece of equipment takes samples of gas in turn from the channels and measures the amount of radioactivity in it.

Occasionally one of the fuel element cans develops a slight crack or pinhole and some of the gaseous fission products will begin to escape. As these are radioactive the particular gas sample from that channel will show a small increase in activity and give warning of the leak. The operator is thus able to identify the channel containing the faulty can and that stack of fuel elements is replaced.

The ducts which carry the hot carbon dioxide from the reactor pass through the shield walls and are connected to the tops of the heat exchangers, tall tubular structures 80 feet high and 17½ feet in diameter, encased in insulation and surrounded by a maze of pipes. Inside they contain banks of tubes which, near the bottom, carry water and near the top superheated steam. Thus, when the gas is hottest it is raising the steam temperature and when it has given up some of its heat it is still capable of boiling the water in the lower tubes. This increases the efficiency, and to increase it still further two separate steam circuits are provided, a high pressure circuit which produces steam at 200 pounds per square inch and a low pressure system in which it is 52 pounds per square inch. At the foot of each heat exchanger a duct carries the carbon dioxide to a large fan which drives it back into the base of the reactor vessel. The steam is conveyed along overhead pipes to the turbine hall, situated between the two reactor buildings.

It should be noted that the heat exchanger provides a physical barrier between the nuclear sources of heat and the generating plant. The importance of this is that the generating plant cannot normally be brought into contact with any material which may have been carried out of the reactor in the gas stream. It should, therefore, be free of any radioactive contamination and can be operated and maintained just as if it was in a conventional power station.

The turbine hall contains four identical units, each consisting of a two stage turbine connected to an alternator, and capable of producing 23,000 kilowatts of electricity. (A single bar electric fire uses 1 kilowatt.) The steam from one set of four heat exchangers is sufficient to drive two turbines and the pipes and valves are arranged so that either reactor can feed any two turbines. With the exception of one item, all the

equipment in the turbine hall is similar to that which can be seen at any conventional power station, and this is only natural since the process is exactly the same. The turbine consists essentially of a shaft carrying blades set at an angle contained in a casing. The high pressure steam is admitted at one end and by pushing against the blades forces the shaft to revolve just as wind rotates the sails of a windmill. When the steam has had its pressure reduced by the first group of blades, the low pressure steam is mixed with it and together they are fed against further blades increasing the force rotating the shaft. The shaft is connected to an alternator, a kind of dynamo, which generates the electricity.

The item which is special to this turbine house is a "dump condenser", which can be used to condense the steam produced in the heat exchangers if for any reason the turbo-alternators are not in use. This enables a reactor to work independently of the turbo-alternators, of importance at Calder Hall where the primary purpose is the production of plutonium.

The cooling towers are again a conventional piece of power station equipment on a site where there is not a sufficient supply of cooling water for the condensers to permit its use once only. In the cooling towers this water is sprayed into the upward draught of cold air and collects in the pond at the foot of each tower cooled ready for re-use.

3 THE BUILDING OF CALDER HALL

THE CONSTRUCTION of Calder Hall demanded the solution of a number of difficult technical problems, the maintenance of an unusually high standard of accuracy and workmanship, and adherence to a very tight timetable. This timetable required the first reactor to be in operation less than three years from the date when work started on the site in August, 1953, and it was realised that this could only be achieved by going straight ahead with the construction of the concrete shield while the plates of the pressure vessel were still being shaped, delivered and welded into sections outside. This meant that these sections, six to each reactor and weighing up to 90 tons had to be lifted over the completed walls and lowered into place inside. When the pressure vessel was welded together the roof, consisting of 8 feet of concrete with the six inch thick steel thermal shield suspended below it, had to be put on without allowing concrete to escape into the space between. A similar problem had arisen in building the Windscale reactors and the same solution was adopted. Bailey Bridge sections were built across the roof space and the thermal shield suspended from them.

Following the excavation, the foundation slabs for the reactors were laid. Each was 130 feet long, 104 feet wide, and 11 feet thick, and each contained 10,000 tons of concrete. On this foundation was built the octagonal shield, 7 feet thick and 46 feet between opposite walls. Throughout its height of 90 feet it had to be within half an inch of truly vertical and the density of the concrete had to be maintained at 158 pounds per cubic foot. This last requirement was most important, since the purpose of the concrete is to cut off the radiation which escapes from the reactor and any voids or cracks might allow some of this radiation to leak through. To ensure this, samples were taken of every batch of concrete and tested for density and strength. Concrete shrinks as it dries and to avoid distortion as little water as possible was used in preparing it and the shield was built in alternate sections, the intermediate ones being poured after the first had dried. The work had to be carefully planned so that there was continuous employment for all the different trades concerned : the scaffolders, the men who put up the "shutters"—the wooden frames which form a mould for the concrete, the men who fixed the steel reinforcing bars and the men who actually poured the concrete. One aspect of this was the provision of enough cranes and hoists to keep an adequate supply of materials without allowing the lifting equipment itself to get in the way. This was achieved by careful planning in advance with accurate scale models of the buildings, cranes, etc. Work on the second reactor was six months behind the first, so that men and equipment could be transferred from the first to the second.

With the completion of the concrete shield, work proceeded on the steel lining and simultaneously the great steel legs, shaped like inverted A's, which would support the pressure vessel itself were being rolled to shape at the maker's works,

delivered to the site, and welded together into sections. First the bottom manifold, to which the return ducts were to be joined, was lowered into the shield wall. The bottom dome, which was welded together upside down for greater convenience, had to be turned over, lifted in and seated accurately on the supporting legs. The lower ring section followed and was welded to the bottom dome : then the "diagrid", with its criss-cross steel girders which carry the whole weight of the graphite and uranium fuel, well over 1,000 tons in all, was lowered inside the vessel to rest on support plates inside the bottom dome exactly opposite the struts outside. The upper ring section, to which the gas outlet ducts are attached, and finally the top dome of the pressure vessel were placed on and welded up. To achieve these lifts a 100-ton derrick was built on top of a 90-foot tower ; it was affectionately known on the site as the "big stick".

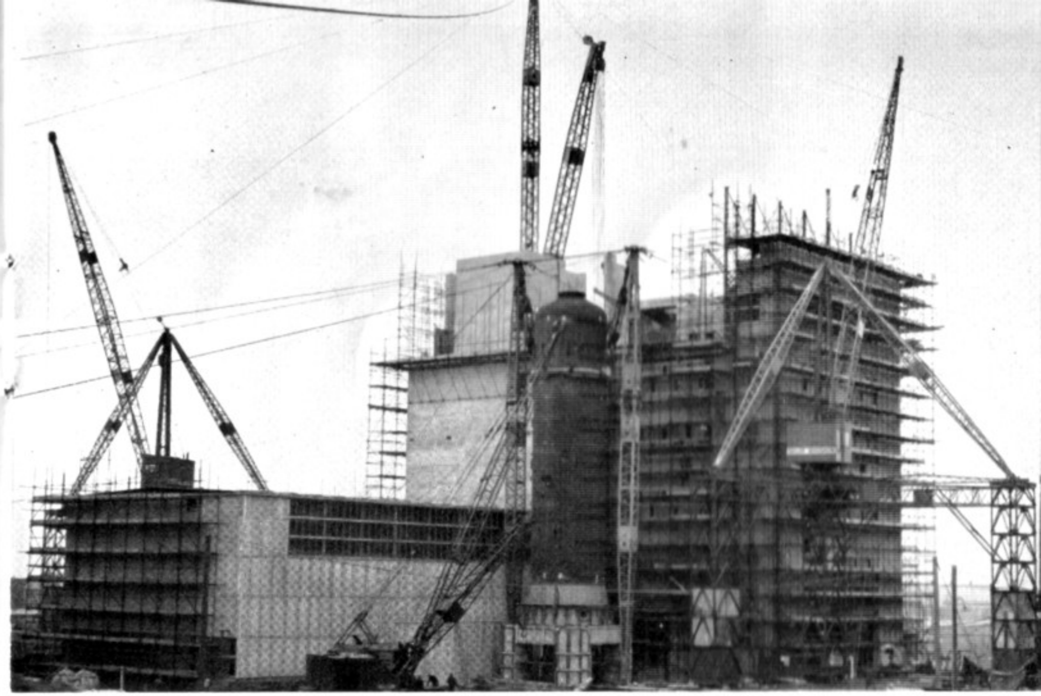
To relieve the stresses set up in the steel of the pressure vessel by the welding operations a wire grid was built inside it through which 1,500 kilowatts of electricity passed—"the biggest electric fire in the world"—and the whole vessel was gradually heated to 500°C and then allowed to cool slowly. It was then given an air pressure test at 135 pounds per square inch. Having checked that the pressure vessel was completely satisfactory, the inside was scrupulously cleaned and the building up of the graphite structure began. To prevent any dirt, or indeed anything at all which should not be there, getting into the reactor, every man who worked there changed his clothing completely before going in and everything he took with him, tools, pencils, even glasses and rings, had to be checked in and out. Every brick of graphite was numbered to indicate its position, it was vacuum cleaned just before being passed into the vessel through one of the gas ducts and was handled with gloves to avoid any trace of moisture reaching it. It was checked after being put in position and each layer was given a final rigorous inspection. With the graphite structure complete the sample tubes for the burst fuel element detection gear were installed and the inside of the reactor was complete.

While the inside of the reactor was being completed the charge tubes through which the fuel elements are loaded and unloaded were welded to the stubs in the top dome. These tubes had to be set with extreme accuracy to ensure that they were truly vertical and then the roof shield, consisting of eight feet of reinforced concrete with the steel thermal shield suspended below it, had to be placed over the concrete box containing the pressure vessel. As there was no room to build scaffolding below it, this was a difficult problem, overcome by hanging supports from Bailey Bridges temporarily erected to span the top of the walls. First, a series of angle strips was hung in place, to provide ledges on which the six inch steel plates of the thermal shield would rest. With these in position more angles were fixed to support a steel floor six inches above the plates ; this became the permanent shuttering for the concrete, which was poured on to this floor. Two factors increased the complexity of the job : the Bailey Bridges would sag slightly under the weight of the steel and concrete and to counteract this the shuttering had to be given an upward bulge initially so that the roof would finally be flat. Also, the presence of the charge tubes made the working space extremely cramped and necessitated careful sealing arrangements to avoid leakage of concrete round the tubes. The roof was built up in four "pours", or separate layers, and when it had set the hangers from the Bailey Bridges were cut off and the bridges removed.

The heat exchangers were also delivered to site in sections, welded together, stress relieved and pressure tested. Each one when assembled weighed 200 tons and was lifted into position on its concrete plinth by two gin poles. A change room was built on the top, for cleanliness is just as important here as in the reactor, and the banks of studded tubes, shot blasted to remove every trace of scale and dirt, were fitted in place. To minimise the risk of a leak inside the heat exchangers they were designed so that all the welds made on site were outside the vessels.

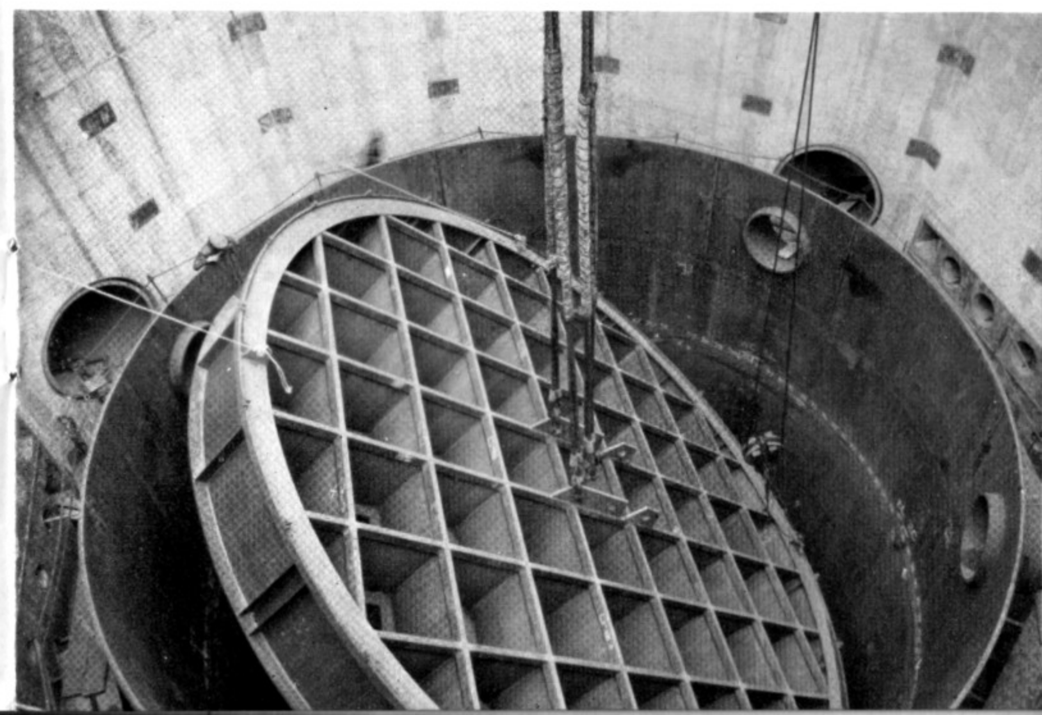
Around the biological shield of the reactor are the control rooms and blower houses, the latter housing the large fans which pump the carbon dioxide between the heat exchangers and reactor. The building and equipping of these was going forward simultaneously with the rest of the work, and this made careful planning most necessary to ensure that different jobs did not interfere with each other.

The turbine hall, cooling towers, electrical sub-station and office building do not differ materially from the similar components of conventional stations and their construction presented no particular problems, though it is interesting to note that the massive concrete plinths of the turbo-alternators, 24 feet high and weighing 1,800 tons, were each poured in one continuous operation in six hours.



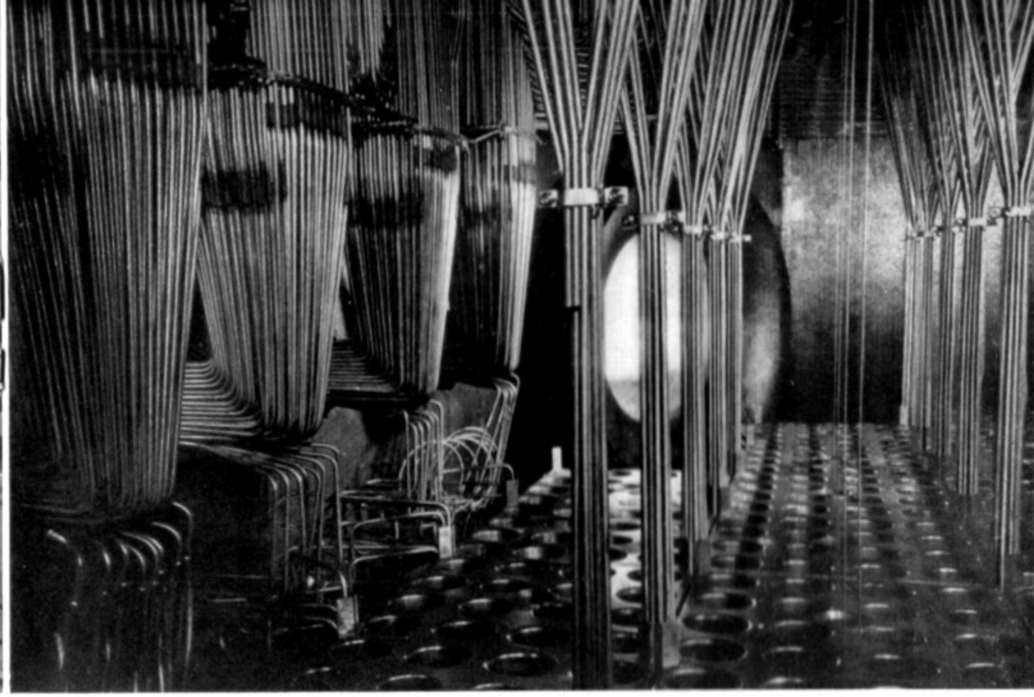
Calder Hall showing the first of the 80 ft. high Heat Exchangers.

The Reactor Core rests on this Diagrid which is shown being lowered into Pressure Vessel.



A Reactor Charging Floor.

The Control Room of a Calder Hall Reactor.

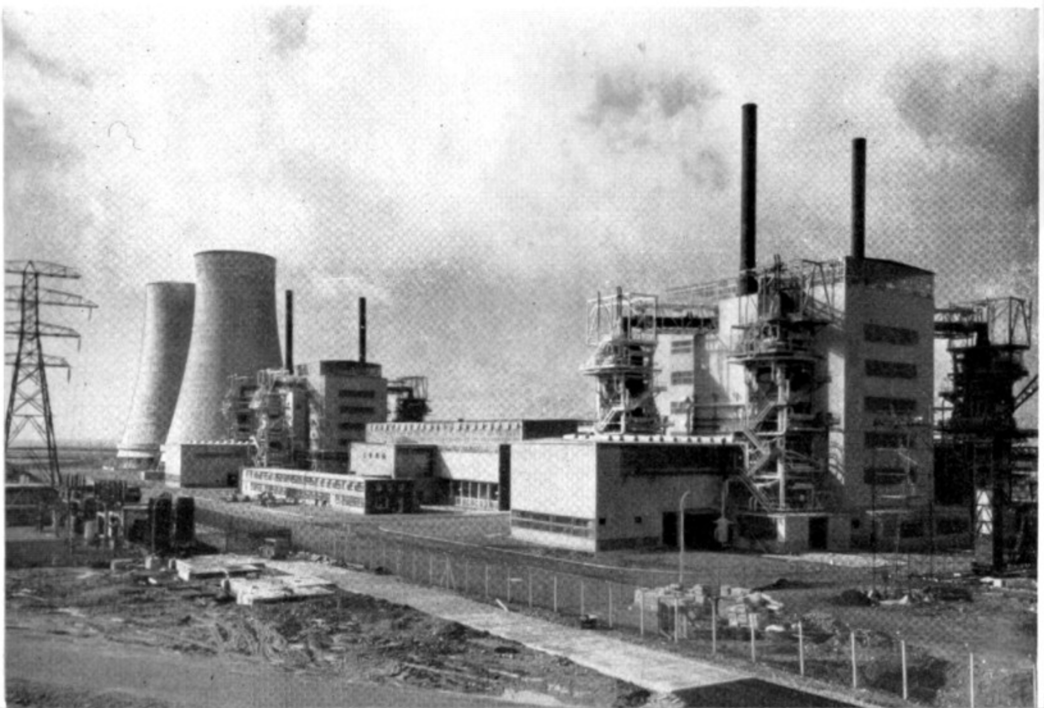


Top of the Reactor Graphite Core showing gas sempling pipes of the Burst Slug Detection Gear.

The Burst Slug Detector Gear.

General view of the Turbine Hall.

General view of Calder Hall showing Reactors 1 and 2.



4 A TOUR OF CALDER HALL

NOTE : *The tour described follows the logical sequence ; when large parties are visiting the Station it is not always possible to arrange for them all to follow the some route, but visitors will see the sections described at same stage of their tour.*

IN ADDITION to the reactor itself in its concrete box, each reactor building contains blower houses on two opposite sides and control rooms on the side facing the turbine hall. The entrance is on this—the "control side"—and from immediately inside, stairs and a lift rise 90 feet to the charge floor.

The Reactor Charge Floor

Entering the charge floor from the control side the most prominent objects are the charging and discharging machines, two of each for each reactor. They run on rails let into the floor and between the rails are the rows of charge tubes, covered with small boxes. Some of these boxes, the "blue tops", contain the driving mechanisms for the control rod cables. The control rods themselves, 23 feet long, hang from these cables inside the reactor vessel and can be lowered into the heart of the reactor to shut it down or raised to allow the reaction to proceed. The cables pass through concrete plugs inserted in the charge tubes and are wound on to drums driven by electric motors contained in the boxes. In addition to having variable speed drives and a release mechanism which allows the rod to fall quickly under its own weight and so shut down the reactor in case of emergency, the equipment includes a device which indicates in the reactor control room the precise position of the control rod. Other charge tubes, the "red tops", carry the leads from instruments which indicate the temperature or the number of neutrons at certain points inside the reactor, and these too are connected to indicators in the control room.

On the right hand side, between the entrance and the actual reactor roof, is the hole in the floor through which the "baskets" of fuel elements, each carrying 24 rods, are raised from the preparation room below and loaded into the charging machine. These new fuel elements are not appreciably radioactive—they can be handled quite safely—and so no shielding is necessary. After they have been in the reactor they contain highly active fission products and when removed by the discharging machine they have to be collected in a thick cast iron container. The unloading and reloading proceeds as follows : A discharging machine is located on the rails appropriate to the charge tube serving the channels to be emptied, the plug is removed and the charge chute inserted. The charge chute is like a pair of compasses, with a tube in place of the arm which carries the pencil. Each charge tube serves 16 channels in a square with a central hole directly below the charge tube. The leg of the chute corresponding to the pointed leg of the compasses locates in this central hole and the tube can be set at different angles and rotated so as to locate on any of the sixteen channels. The discharge machine is then located over the charge chute, the valve at its top opened and a grab lowered on a cable to "fish" out the fuel elements one by one. When the magazine of the discharging machine is full the valve on the chute is closed and the machine is run on to the traversing truck at the far side of the roof, and moved into position over the discharge shaft. This is a tube running through a thickened portion of the shield wall to its foot ; the discharged fuel elements are lowered into a transit container, called a "coffin", which again is thick cast iron shielded, and carried in this to Windscale for storage and later processing.

In galleries on either side of the charge floor are fans which suck air continuously through the gap between the steel thermal shield and the concrete biological shield of the reactor. This gap extends all over the floor, walls and roof and the purpose is to keep the concrete cool. The air from the fans is passed out through the twin chimneys on top of the reactor building.

Fuel Element Preparation Room

Leaving the charge floor by the control side door and going down one floor brings the visitor to the room in which new fuel elements are unpacked from the containers in which they are delivered from Springfields. They are given a final examination and loaded into the baskets ready for the charging machine. Sample fuel elements are on show. They consist of uranium bars, 40 inches long and just over an inch in diameter encased in hermetically sealed cans of magnesium alloy. The cans have a spiral fin running from end to end, the purpose of which is to help to transfer the heat generated in the uranium to the carbon dioxide as it flows past, in the same way as the fins on a motor cycle engine help to keep it cool. Each fuel element weighs about thirty pounds.

Burst Cartridge Detection Room

On the floor below the fuel element preparation room is the room housing the equipment for detecting any fuel element which may develop a leak. Although these are commonly referred to as "burst cartridges" this gives a misleading impression for usually the "burst" is a minute crack or pinhole in the can, barely visible to the naked eye. If left in the reactor, however, it will gradually increase in size and this leads to two effects. The uranium, exposed to carbon dioxide, will begin to oxidise and flake away ; also, fission products will escape. Both these effects will lead to radioactive material being carried round the gas circuit and possibly deposited in other places, such as the heat exchangers, where it would prove a nuisance if any maintenance were needed. To avoid this, pipes are provided which take a sample of the gas from each channel and bring it to selector valves in the detection room. These valves take successive samples from 53 groups of 4 channels and feed them to a chamber carrying an electrically charged wire. After exposure to the sample during which the wire collects the solid "decay products" produced by disintegration of the radioactive gases from the channel, the wire is moved to a detector instrument which measures the amount of activity collected. The first sight which meets the visitor on entering the detection room is the row of 11 dark blue cylindrical tanks ranged along one side. These contain the detection equipment and behind them are the selector valves and banks of feed pipes. The general silence in the room is broken by intermittent clicks as the electric motors driving the charged wire are switched on and off to locate the various samples under the detection equipment. In front of each detector is a row of indicators which tell the operator which channel is being sampled. The results of the measurements are "reported" to recorders in the reactor control room below and enable the reactor controller to keep himself informed directly. When a defective fuel element is suspected by reason of a higher reading it is possible to interrupt the normal scanning and make a check for the affected channel and even to follow the progress of a "burst" to obtain information on how quickly it develops.

It should be appreciated that this development is normally slow, and in fact it would be possible to keep the reactor in operation for a day or two if necessary after the first detection of a defect without any material harm resulting.

To give some indication of the rarity of these defective fuel elements, it is worth recording that when the first charge of 10,000 was removed in February 1957, after being in operation for about eight months, only three defects had been detected.

The Reactor Control Room

Descending a further floor from the burst cartridge detection room the visitor comes to the reactor control room. At a desk in the centre sits the control engineer, surrounded by the most important instruments, with an emergency button by his hand, which he can press to shut down the reactor immediately in an emergency. Round three walls are ranged the various other instruments, recorders and indicators which supply him with the rest of the information he needs.

In front of him on the desk is the reactor power level recorder with beside it a more sensitive instrument which indicates the minor deviations from the pre-set level which are taking place continuously.

Along the left hand wall are the recorders on which appear the information on the activity level of the cooling gas samples measured in the room above. Each recorder keeps a continuous record of the 53 samples handled by one valve on a single sheet.

On the far wall is a "mimic diagram" of the reactor and heat exchangers showing the position of the main valves, with instruments indicating temperatures and pressures at various points in the coolant circuit and the water and steam circuits.

In the section representing the reactor are panels which light up if a fault occurs and remain so until it is rectified.

Next comes a panel giving information about the control rods. There are a number of positions in the reactor where control rods can be inserted and not all are used. Each of the possible positions are marked on a plan and for each of those which contains a control rod, a dial is provided which indicates how far into the core that rod is inserted.

On the right hand wall are the banks of relays which operate trip mechanisms and shut the reactor down if certain faults develop. To guard against the reactor being shut down unnecessarily by a failure in the relay circuit, the relays are in triplicate and only if two fail does the trip mechanism operate. Provision is made for the regular testing of these safety devices while the reactor is in operation. Alongside the relays are a series of indicators which supply information about the level of radioactivity at various points in the reactor.

Some explanation should perhaps be given why a separate control room is provided for each reactor, rather than a single central one for both reactors and the electrical side. One of the most important considerations in the design of Calder Hall was to achieve the greatest possible degree of simplicity ; also, because its primary purpose is the production of plutonium, the operation of the reactors is more important than the generation of electricity. For both these reasons it is most convenient to treat each reactor as an individual unit, and consequently to provide it with its own control room.

The Reactor Blower House

There are in fact two blower houses, one on each side of the reactor, each containing two of the centrifugal blowers which pump the carbon dioxide round its circuit. These blowers each of 1500/2200 horse power, are placed in the circuit between the foot of the heat exchanger and the base of the reactor. The gas enters from the outer side of the blower and leaves it going away from the reactor ; it then travels round two right angled bends to reverse its direction. The object of this apparently complicated arrangement is to allow for the expansion of the gas ducts when they become heated by the carbon dioxide as the reactor power builds up. The temperature of the gas is controlled by the rate at which it is pumped round the circuit, that is, by the speed of rotation of the blowers and this can be varied by what is known as the Ward Leonard system. The pairs of motors and speed controllers stand side by side and in one blower house there are also diesel-driven standby generators for use in case the electricity supply fails. These are brought into operation automatically but there is also a bank of storage batteries which maintain the supply for the brief period during which the diesel-driven generators are working up to speed.

Heat Exchangers and Pipe Bridge

Immediately outside the blower house stand the heat exchangers, swathed in lagging and surrounded by pipes and steam drums. The concrete stools on which they are supported have been boxed in and converted into pump houses. In here are the pumps which circulate the water from one section of the heat exchanger to the next. It will be recalled that in each heat exchanger steam is raised at two different pressures, 200 pounds per square inch at 310°C. and 52 pounds per square inch at 170°C and the large drums, or tanks, in which the steam collects can be seen, on opposite sides of the heat exchanger and near its top. From these come the steam pipes which are carried across to the turbine hall on the steel frame pipe bridge. There are four pipes on each bridge, the upper pair carrying high pressure steam and the lower pair the low pressure steam.

The Turbine Hall

The Turbine Hall containing the four turbo-alternator sets which generate electricity from the steam produced in the eight heat exchangers of both reactors, is not dissimilar from the corresponding section of a conventional power station. The ground floor, entered by a door opposite the reactor building, contains the various manifolds and valves which enable steam to be diverted to different turbines or to the dump condensers when the turbines are not running. One dump condenser is situated at each end of the building and can handle the entire steam output of a reactor when working at full load.

Also rising from the ground floor are the massive concrete plinths supporting the turbo alternators themselves and carrying the condensers in which the waste steam from the turbines is condensed to water before being re-circulated to the heat exchangers.

Stairs lead from the ground floor to the upper floor on which the turbo-alternators stand, each with its control panel indicating the steam temperatures and pressures.

Each set consists of a turbine linked to an alternator, and apart from the aluminium casing of the steam pipes, each has its individual colour corresponding with the colours of the heat exchangers round each reactor. Each alternator has a maximum capacity of 23,000 kilowatts.

The cables carrying this electricity are taken through an underground duct across to the sub-station outside the factory fence, where the voltage is transformed to grid level.

One noteworthy aspect of Calder Hall, which should be a feature of all nuclear power stations, is its cleanliness, due to the absence of coal, ash and smoke. This encouraged the designers to make liberal use of colour, particularly pastel shades, both inside and outside the buildings. Experience has shown that a clean and colourful plant encourages tidiness and leads to a reduction in the number of industrial accidents.

We hope that the visitor to Calder Hall will carry away, not only an appreciation of its importance to the future prosperity of the country, but an impression of an establishment in which it would be pleasant to work, and one which would be acceptable as a neighbour.

5 BRITISH NUCLEAR POWER PROGRAMME

THE EVER-GROWING demand for electricity, which at present is doubling approximately every ten years, is rapidly outstripping our resources of conventional fuels, coal and oil. It is for this reason that the need to use nuclear power—atomic energy as it is popularly known—is so urgent. In February, 1955, when Calder Hall was only half built, the Government felt sufficiently confident of its success to plan a ten year programme based largely on this type of reactor. It proposed that by 1965 twelve stations should be in operation, generating between 1500 and 2000 megawatts and saving 5 or 6 million tons of coal a year.

At the end of 1956, the Central Electricity Authority announced that they had accepted tenders for the first two of these stations, at Bradwell, Essex and Berkeley, Gloucestershire and hoped to let a third later in the year for a site they were considering in Somerset. At the same time the South of Scotland Electricity Board announced the acceptance of a tender for a station on the Ayrshire coast. These announcements put the 1955 programme out of date, for the three stations already accepted are planned to generate about 900 megawatts, half the total planned for twelve.

In March, 1957 a new programme was published, according to which the number of stations to be in operation by 1965 was increased to nineteen, their combined generating capacity to 5000-6000 megawatts, and the coal saving to about 18 million tons a year. (It should be understood that this saving is really "coal equivalent" and almost certainly the saving will be in imported oil and not coal.) The first few stations will be developments of the Calder Hall type ; they will be gas-cooled and use graphite as moderator. Later, it may prove economic to change to some other type, for example a graphite moderated reactor cooled by liquid sodium instead of a gas, though as our experience and study of the Calder Hall type increases, the more promising appears its potential future.

This programme of nuclear power stations depends for its fulfilment on British industry. They will build the stations and the electricity authorities will operate them. To facilitate this, four groups of firms were formed in 1955 to design and build such stations. They set up design teams who were given training by the Atomic Energy Authority, in the Reactor School at Harwell, in the design offices at Risley, and at the works of the Industrial Group. More recently, a fifth group of firms has joined together to form a similar team, and they too will be trained by the Atomic Energy Authority.

The responsibility of the Atomic Energy Authority for training extends also to those who will operate reactors, and to meet this need a Reactor Operations School was set up at Calder Hall early in 1957. It is housed in the building outside the police gate and provides both theoretical tuition in the form of lectures and practical instruction on the plant.

In addition to training industry and the electricity undertakings, the Atomic Energy Authority will contribute to the nuclear power programme in three other ways. It will manufacture the fuel elements for the civil power reactors and process them after use ; it will undertake research investigations which require specialised facilities for individual firms ; it will investigate alternative reactor systems which may eventually prove more economic than the Calder Hall type. Quite apart from this, the Authority's reactors at Calder Hall and Chapel Cross will, by 1960, be contributing about 250 megawatts of electricity to the national system.

On the question of cost, Sir Christopher Hinton, Managing Director of the Industrial Group, speaking in Stockholm in March, 1957 gave estimates of the cost of power from Calder Hall type stations as they were likely to be developed over the next 30 years. These showed that while the cost per unit from the first stations, at 0.66 pence, was slightly higher than the cost from the conventional stations which will come into operation in 1960, the balance will quickly be in favour of the nuclear power stations. By 1990 the cost from these will be approximately halved, while the rising cost of coal and oil may well make electricity from conventional stations 50% more expensive, giving a ratio of about 3 to 1 in favour of the

nuclear power stations. This, of course, is based only on the Calder Hall type of station, and may therefore be regarded as pessimistic, since one can reasonably expect by then that it will have been superseded by more economic systems.

Although the White Paper of February, 1955 is already almost completely outdated, its final paragraph remains as true now as when it was written : "This formidable task must be tackled with vigour and imagination. The stakes are high, but the final reward will be immeasurable. We must keep ourselves in the forefront of the development of nuclear power so that we can play our proper part in harnessing this new form of energy for the benefit of mankind."

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PLAN OF CALDER HALL