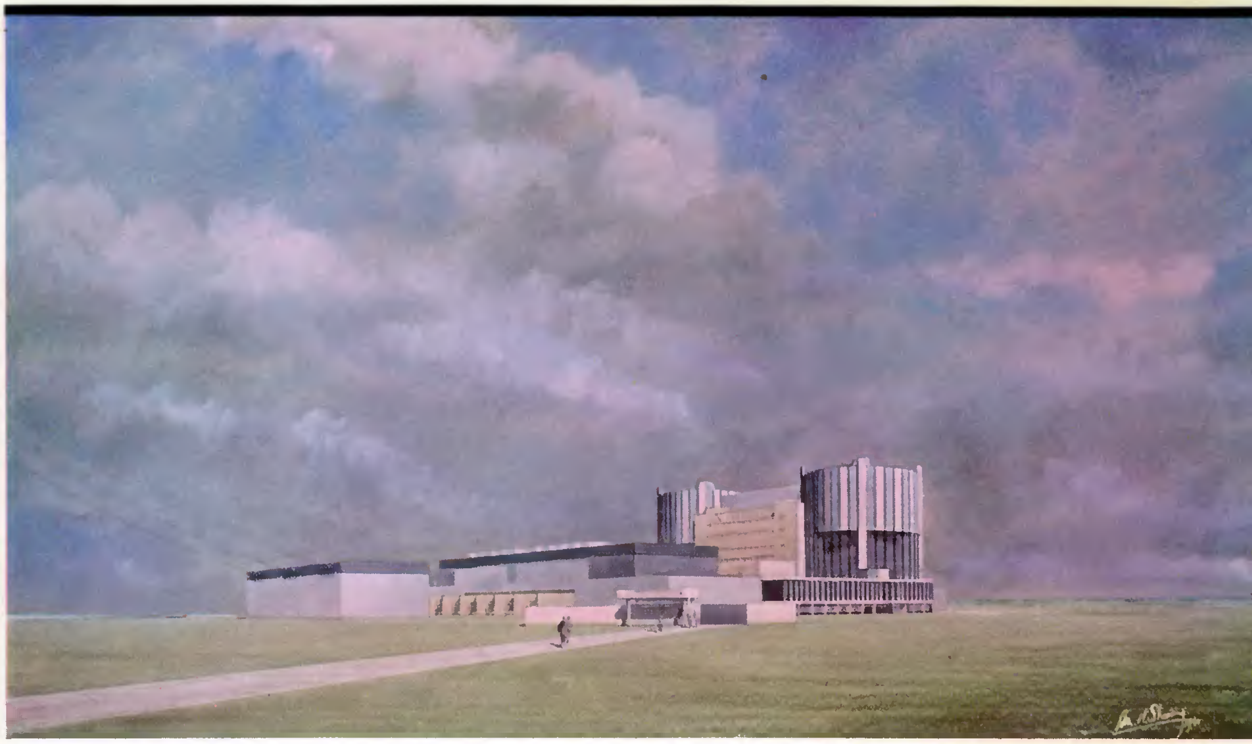
CENTRAL ELECTRICITY GENERATING BOARD

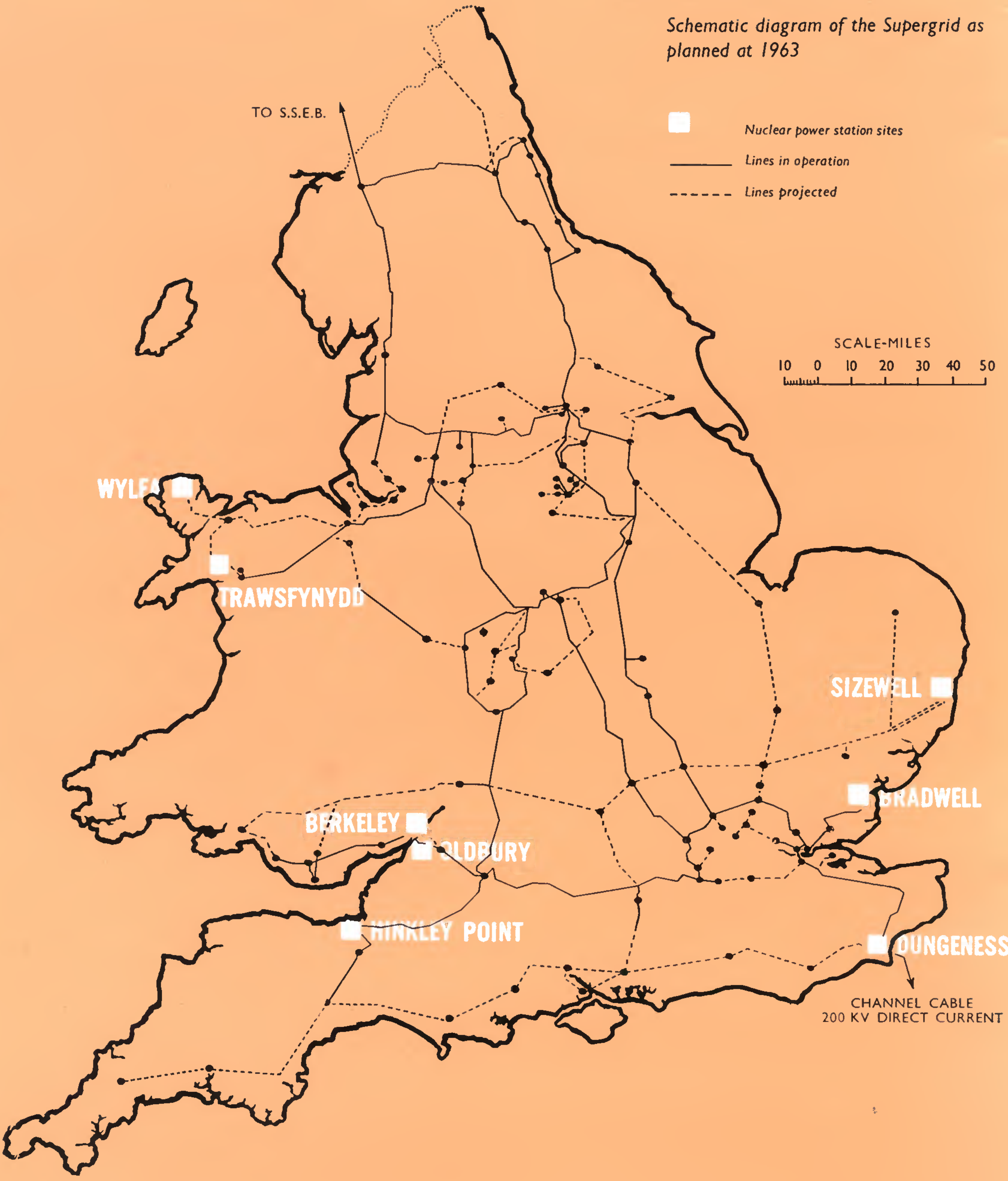
OLDBURY



NUCLEAR POWER STATION

SUPERGRID TRANSMISSION AND NUCLEAR DEVELOPMENT IN ENGLAND AND WALES

Schematic diagram of the Supergrid as planned at 1963



National Electricity Supply

ALL over the world the demand for electricity is steadily rising. Not only do modern industrial methods call for more and more electrically driven machinery but the rising standards of living are reflected in the domestic consumer's increasing use of the many forms of electrical labour-saving devices.

It is no surprise that the industrial and domestic demands for electricity continue their smooth and continuous rising trend and in England and Wales the slope of this increasing trend may even be getting steeper.

The undoubted success of the electricity supply industry has, however, brought with it serious problems. Electricity cannot be stored, so when the housewife switches on a fire or the factory worker starts up a machine, the generating plant has to be running at that instant to meet the additional load.

There must therefore be an enormous building programme to provide the power stations to meet the rapidly growing demand; the rate of growth is such that to meet it, about every ten years as much additional plant has to be built as the total capacity available at the beginning of the period.

In 1953, the maximum output capacity of the system was just over 14,500 megawatts; ten years later in 1963 it was over 31,600 megawatts.

Very large sums of money have to be spent constructing this new generating capacity; £1,350 million was spent on generating plant in the ten years up to 1963, quite apart from the industry's investment in transmission and distribution facilities.

Three Fuel Economy

Electricity generation is essentially a fuel-processing industry, the refined end-product of which is electrical energy. The Generating Board's power stations burnt approximately 69 million tons of coal-equivalent in 1963 and by 1970 will be burning more than 100 million tons a year. Of this, about 70 million tons will be burnt at stations already built or for which firm plans exist. The remaining tonnage allows the CEGB some flexibility in their choice of fuel during the later years of this decade. The proportion of this tonnage eventually claimed by each of the three fuels depends largely on their relative prices, but about one eighth of the total fuel required by the Generating Board in 1970 will probably be taken as oil and perhaps another eighth as nuclear energy.

Oil supplies seem more reliable and costs are lower than some years ago. Nevertheless, while it is reasonable for power stations to burn heavy residual oils produced as a by-product in British refineries, it may not be desirable to increase the consumption of heavy oils to the point where importation of this by-product of overseas refineries becomes necessary.

The electricity supply industry looks forward to a period soon after 1970, when electricity will be generated from three economically comparable fuels—coal, oil and nuclear power. The electricity supply industry should be able to manoeuvre with reasonable freedom within this "three fuel economy" to choose the proportions of these three fuels in such a way that a minimum cost for electric power is achieved.

Siting of Coal-fired Power Stations and Grid System

Thirty years ago the Grid system first linked power stations in local areas so that they could help each other over difficult periods and transfer some energy when it was economical to do so. It was not until the 1939-45 war that the role of the Grid changed from an area to a national facility and electricity was first transmitted over long distances.

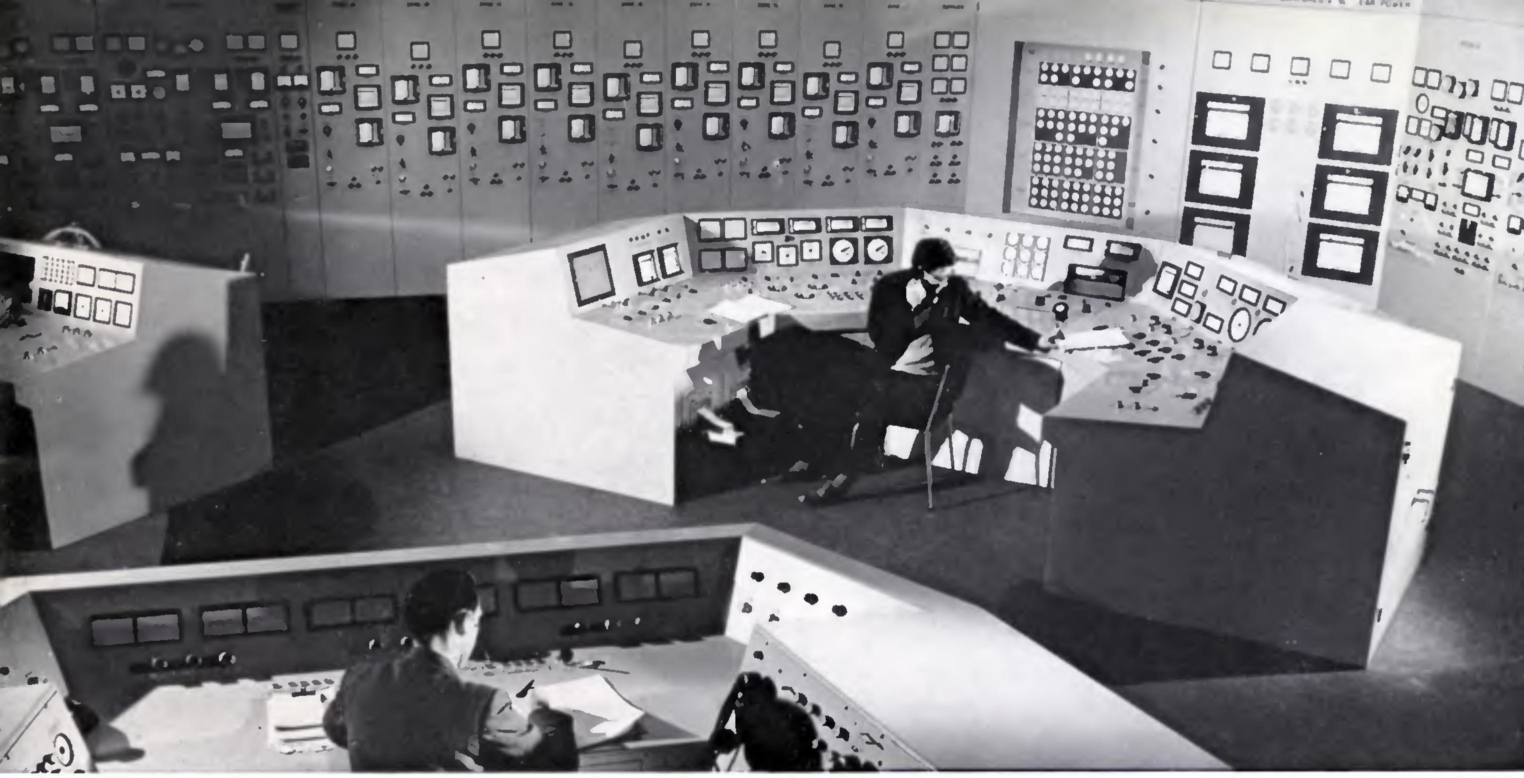
Big modern 1,000 MW and 2,000 MW stations burn enormous quantities of coal; in full production, the furnaces of a 1,000 MW station like High Marnham, Nottinghamshire (completed in 1962) consume 10,000 tons a day. Economic logic requires that this huge appetite should be met from the country's most productive coalfield—the East Midlands—and stations sited as near as possible to the fuel source. But Britain's population is increasing most rapidly in the South and there is a consequent sharp rise in demand for electricity from the coal-deficient area lying south of a line drawn from the Bristol Channel to the Wash. The answer has been to build stations close to the coalfield and transfer the electrical power south along overhead transmission lines. Development of this system of bulk transmission has given the East Midlands a new product—electric power. In 1948, the output of all the stations in the East Midlands was only 780 megawatts. Since then, a whole chain of stations has been built along the River Trent and in fifteen years the East Midlands area has been transformed from a power-deficient area to Britain's biggest power exporter, with a capacity of over 5,000 megawatts.

This advanced economic policy for electric power depends on the bulk transfer of power by the 132,000 volt Grid and the 275,000 volt Supergrid which was introduced in 1953. This was one of the most notable developments in the industry.

As a result of the drift of population and the build-up of industry, the rate of increase in demand for electricity in the South is appreciably above the national average. This means there must be increasingly heavy transmission of power from the Midlands. With the future in mind, the 275,000 volt Supergrid was originally designed so that the operating voltage could be raised, and the Generating Board have decided to re-insulate these lines and use them at 400,000 volts where increased transmission capacity is needed.

The adoption of the 400,000 volt system means that the carrying capacity at this voltage will be four times greater than at 275,000 volts and as fewer new transmission lines will be required to carry the increased load the amenity problem will be lessened.

Sizewell A nuclear power station



Sizewell nuclear power station—main control room
(by courtesy of English Electric Ltd.)

Generation in the South and Siting of Nuclear Power Stations

The deficit of electricity and coal in the south-east and London areas is made good by the transmission of power from the Midlands and by generating electricity in the South from heavy fuel oil, from a limited amount of coal shipped coastwise, and from nuclear power.

The total amount of power generated in the Midlands and exported to the South is strongly influenced, not only by amenity problems posed by the expanding Grid system but by the amount of cooling water available on the East Midlands and South Yorkshire coalfields.

The relatively limited quantities of heavy fuel oil available come from refineries in the Thames Estuary, Southampton Water and South Wales. Generation from fuel oil will evidently be most economic in the vicinity of these refineries at sites chosen to minimise the transport charges on bulk oil.

Transport charges for nuclear fuels are negligible and the siting of nuclear power stations is not governed by this economic consideration. Main factors, besides the all-important amenity consideration, affecting the choice of site are the availability of the large quantities of cooling water necessary, geological substrata which can support the very heavy station structure and plant, and a reasonable degree of remoteness.

The Generating Board's nuclear stations have accordingly been sited on the Severn Estuary, North Wales and the east and south coasts.

Amenity considerations are of over-riding importance; if public opinion permitted the construction of power stations on any favourable site and if transmission lines could be put up wherever they were needed, it would be less difficult to meet the ever-increasing demand for electric power.

The problem of meeting the demand for greater material amenity without too great a loss of visual amenity is one of the most difficult the Generating Board have to face. The greatest possible care is taken at all stages of major construction works to ensure that power stations and transmission lines are harmonised as far as possible with their immediate surroundings.

However, the electricity supply industry is spending more money on capital works than any other single industry in this country and this cannot be done without some effect on the countryside.

The Nuclear Programme

The first large-scale reactors were built in 1950 at Windscale, in Cumberland, to produce plutonium for defence purposes. They were graphite-moderated natural uranium reactors.

In these plutonium-producing reactors, the object was not to use the heat from fission to generate power but only to remove it from the reactor as economically as possible.

Progress at the experimental nuclear power station at Calder Hall looked so promising that in 1955, the Government outlined a bold provisional programme of nuclear power production for public supply. A White Paper* stated that the main objective of the programme during the first ten years was to enable the electricity authorities and industry to obtain the practical experience in designing and building the nuclear power stations required for an expansion in later years. It also stated that the programme would be subject to frequent and major changes, according to the speed of technical development and the success of the early stations.

This White Paper provided that the electricity supply authorities should, by the end of 1965, have constructed 12 nuclear power stations with a total output of 1,500-2,000 megawatts. But by 1957, experience and technological progress was such that it, together with a growing concern over the national energy position, led the Government to announce an expansion of the target nuclear capacity to 5,000-6,000 megawatts by 1965—the actual number of stations to depend on the pace of technical development, the trend of capital costs, and the financial resources available. The programme has since been twice re-phased. As part of the restriction on capital expenditure announced in October 1957 the target date was extended to 1966 and in 1960 it was further extended.

The Generating Board's contribution to the programme continued with the decision to construct a station at Wylfa. This nuclear programme is now nearing completion. Six of the Generating Board's nuclear power stations are completed, generating over 2,700 megawatts of electricity and the remaining two are on schedule.

A second nuclear programme, based on the Advanced Gas-cooled Reactor, has been agreed by the Government and work on the first AGR power station, Dungeness 'B' of 1,200 MW capacity, has started. The position is summarised in the table below.

The influences which have caused this extension of the target dates are essentially economic. General conditions have altered considerably since early 1957; the serious shortage of small untreated coals which was then affecting both Britain and Europe has given place to a surplus. In 1963, there was a world surplus of oil and delivered prices have been further reduced by severe competition in tanker freight rates. Added to this, the costs of electricity generated from coal and oil have continued to fall: higher steam temperatures and larger generator units have led to significant improvements in thermal efficiency.

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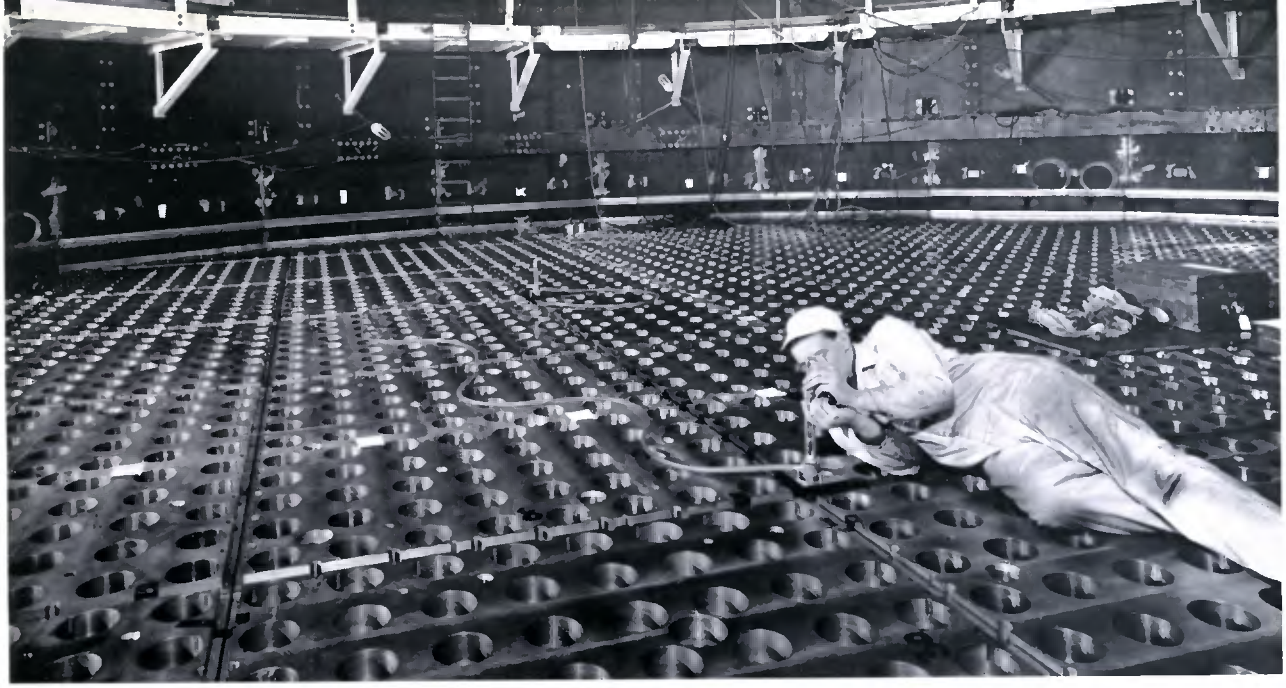
* *A Programme of Nuclear Power 1955 H.M.S.O. 1s. 3d. (Cmd 9389).*

STATIONS	NUMBER OF REACTORS	MAXIMUM ELECTRICAL OUTPUT (MEGAWATTS)	DATE WORK STARTED	YEAR OF COMMISSIONING FIRST REACTOR
Berkeley (Gloucestershire)	2	275	Jan. 1957	1962
Bradwell (Essex)	2	300	Jan. 1957	1962
Hinkley Point (Somerset)	2	500	Nov. 1957	1965
Trawsfynydd (Merionethshire)	2	500	July 1959	1965
Dungeness 'A' (Kent)	2	550	July 1960	1965
Sizewell (Suffolk)	2	580	April 1961	1966
Oldbury-on-Severn (Gloucestershire)	2	600	May 1962	1967*
Wylfa (Anglesey)	2	1,180	Sept. 1963	1969*
Dungeness 'B' (Kent)	2	1,200	Feb. 1966	1970*

* Estimated



Number 1 Reactor—levelling graphite support plates with Watts Water Level

Remembering that, for a conventional station, capital charges account for only 20 per cent of the cost of power, whereas for a nuclear station they account for 67 per cent, the adverse effect of a period of high interest rates on the cost of nuclear power is evident.

This can be seen in another way by comparing the very high capital cost of nuclear power stations (£106 per kilowatt) with the cost of under £40 per kilowatt for modern coal or oil fired plant.

As a result of these high interest rates and high capital charges, the cost of electricity from Berkeley and Bradwell is 1·27 and 1·11 pence per unit respectively, compared with the current figure of 0·70 to 0·55 pence per unit for conventional stations.

The cost of nuclear power is, however, coming down. The nuclear power station at Oldbury is expected to produce electricity at about 0·68 pence per unit.

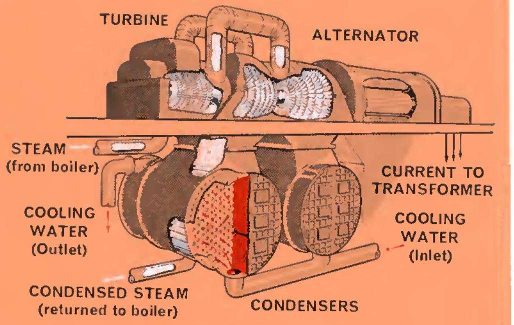
But despite this, it is clear that the long-term rate of interest in Britain, which has risen appreciably since 1955 and seems likely to remain at a fairly high level, must have the effect of postponing the date at which the cost of nuclear power is reduced to that of conventional power. This means that the development period, during which nuclear power is uneconomic, will be prolonged.

The Future

The future cost of electricity from nuclear generating plant will certainly fall as a result of the introduction of the advanced gas-cooled type of reactor. In addition, improved civil engineering techniques, such as the use of pre-stressed concrete pressure vessels and the housing of two reactors in one building, have reduced capital costs.

Since nuclear stations have relatively low fuel costs, they must be run as continuously as possible to justify their high initial capital cost.

Electricity from Nuclear Energy

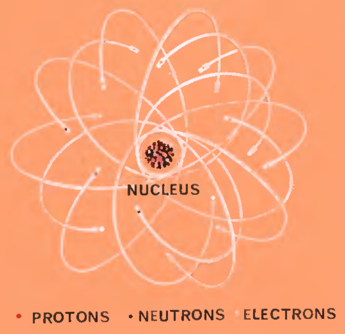


Nearly all of the electricity which the Generating Board produces is generated by turbine-generators. For these steam is required to drive the turbines.

Nuclear power stations differ from the conventional installations in that, instead of burning coal or oil, the heat from nuclear energy is used to boil water and generate steam.

To explain what happens in a nuclear power station many words are used which some of us may not fully understand.

It is proposed to take such words in a certain order and by carefully defining them to present a fair idea of the general procedure.

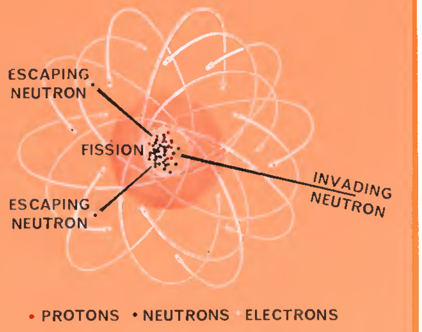


Elements are chemical substances which cannot be broken down into other substances. There are 92 natural elements.

Atoms are the smallest possible parts of an element. They are so small that in a glass of water there are sufficient to provide millions of atoms for every square inch of the earth surface of the globe.

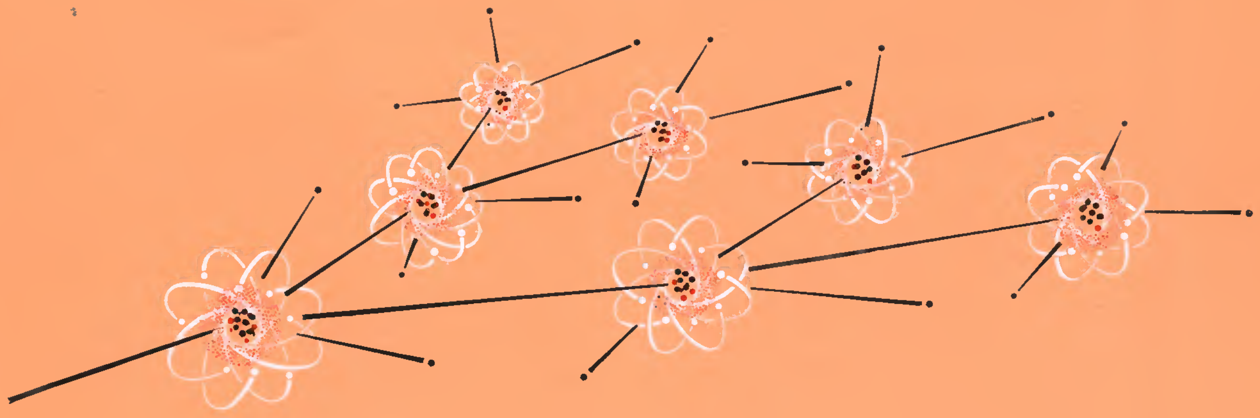
Each atom consists of PROTONS (positively charged particles) and NEUTRONS (uncharged particles), constituting the NUCLEUS which is surrounded at relatively vast distances by ELECTRONS (negatively charged particles).

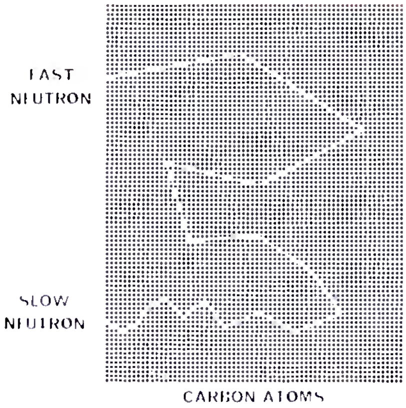
Nuclear fission is the process whereby a free neutron is made to penetrate the nucleus so that it is caused to break up. This releases other neutrons and energy in the form of heat.



So great is this nuclear energy potential that the atoms in a piece of uranium the size of a pin-head could produce as much heat as the burning of 5,000 tons of coal.

The atoms of most materials are quite stable, but the nuclei of some very heavy elements are not. If a uranium nucleus is struck by a neutron it is liable to break up, and to release two or three free neutrons. If these are slowed down some of them will be caught by other uranium nuclei, which will then break down and continue the process of chain reaction. This slowing down of the freed neutrons is accomplished by using a moderator.





Neutrons emerge from fissioning uranium nuclei at a speed of 10,000 miles a second, at this rate their chances of hitting another nucleus are diminished, but if we can reduce the speed to about 1 mile a second, the possibility is 10,000 times improved. When we imprison the uranium fuel rods in graphite, the neutrons cannot escape. They collide with one graphite atom after another, losing speed at each collision and eventually slanting back to the fuel rod at greatly reduced momentum.

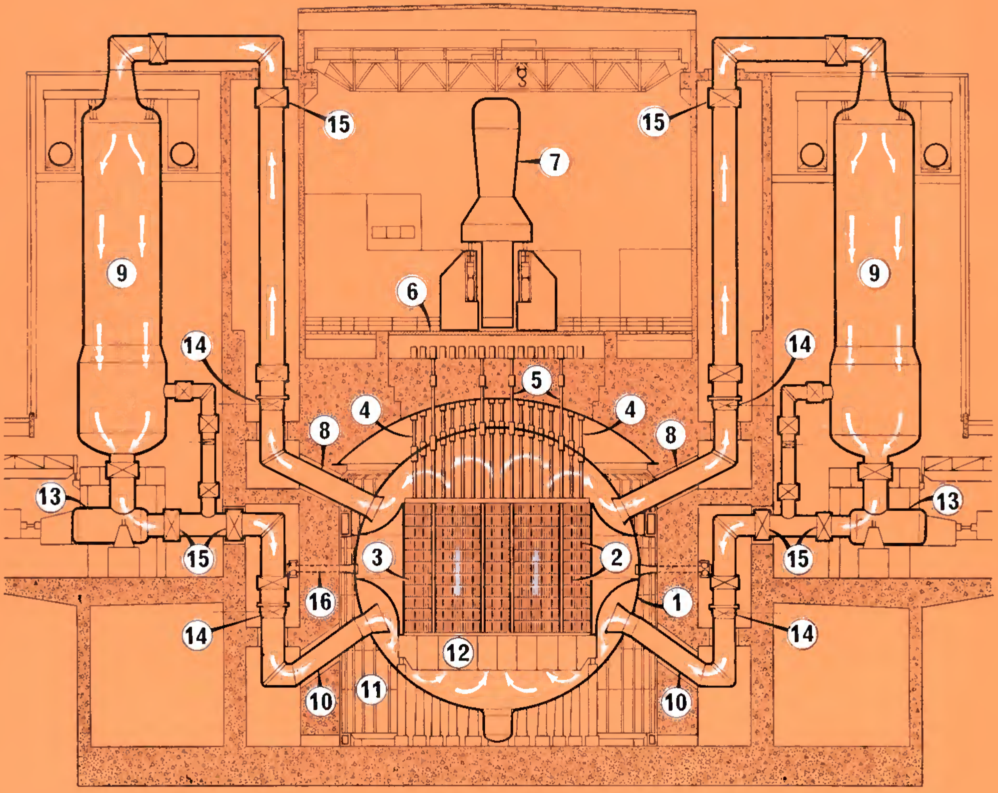
This is a material which slows down neutrons without capturing them. Graphite is such a material. Uranium fuel is prepared in the form of rods about one inch in diameter. These are encased in thin metal cans, and they are inserted into holes in the graphite about eight inches apart.

It is no good being able to start nuclear reaction and to obtain great heat output unless the process can be controlled. A chain reaction can be started by bringing together a "critical" amount of uranium fuel in a graphite moderator, but there must be at hand a means to reduce the speed of reaction when necessary, and this is done by installing, as part of the reactor, rods of boron steel. Boron has a remarkable capacity to absorb neutrons. When instruments indicate that nuclear fission is proceeding too fast, the boron rods can be dropped into the reactor. They quickly soak up free neutrons, so that the frequency of fission is immediately reduced and a steady rate of operation can be resumed.

The reason for using natural uranium as a fuel is that it is the only naturally occurring material which can produce a controlled chain reaction. Because of the escape of neutrons from the moderator, this process can only take place in a reactor of a certain minimum size. This is known as the critical size. If, in a reactor, the control rods are positioned so that power is neither increasing nor decreasing, the reactor is said to be critical.

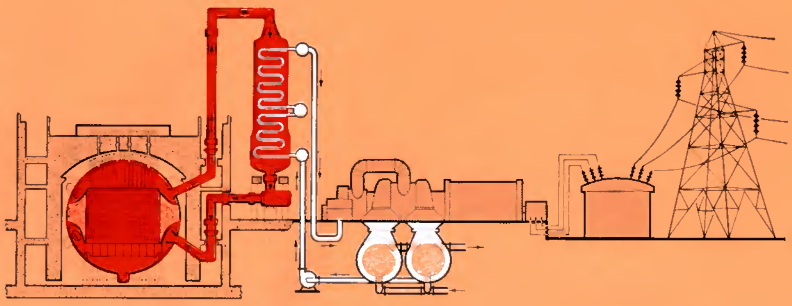
KEY

1. REACTOR PRESSURE VESSEL
2. FUEL ELEMENTS
3. GRAPHITE—MODERATOR
4. CHARGE TUBES
5. CONTROL ROD STANDPIPES
6. CHARGE FLOOR
7. CHARGE/DISCHARGE MACHINE
8. HOT GAS OUTLETS FROM REACTOR
9. BOILERS (SIX PER REACTOR)
10. COOL GAS INLETS TO REACTOR
11. THERMAL SHIELD
12. DIAGRID
13. MAIN CIRCULATORS
14. GAS ISOLATING VALVES
15. HINGED EXPANSION BELLOWS
16. CAN-FAILURE DETECTION STANDPIPES



ARROWS SHOW THE FLOW OF CARBON DIOXIDE THROUGH REACTOR AND BOILERS
(Diagram based on Bradwell nuclear power station)

During operation, carbon dioxide gas is blown through the channels in the moderator at high pressure. This transfers the heat of fission from the uranium, through the can into the gas. The hot gas is then blown over thousands of tubes containing water in boilers, where the water is turned into superheated steam for driving ordinary turbine-generators.



Oldbury Nuclear Power Station

OLDBURY is the seventh nuclear power station to be built by the Generating Board and is located near the village of Oldbury-on-Severn, Gloucestershire, about five miles south-west of Berkeley nuclear power station.

The Minister of Power gave his consent to the construction of the station in October, 1960, and it is expected to become operational in 1967.

The plant consists of two natural uranium carbon dioxide gas-cooled graphite-moderated reactors, each combined with four boiler units supplying steam to a 312 MW turbine-generator set. The station will have a net output of 600 MW.

The main power station buildings and equipment were designed, constructed and supplied by The Nuclear Power Group. Additional contracts being placed with Sir Lindsay Parkinson & Co. Ltd. for the construction of the circulating water reservoir, outfall culverts and site filling, the cooling water pump house, the cooling water seal pit and the 132 kV switchhouse. A. Reyrolle & Co. Ltd. provided the main 132 kV switchgear. The Central Electricity Generating Board Southern Project Group was responsible for overall supervision of the project and for the design of the switching station. Messrs. Rendel, Palmer & Tritton, Consulting Engineers, were responsible for design, site supervision of the separate cooling water works contracts and for technical advice, in conjunction with Professor Ross of Kings College, London, on design and site supervision of the concrete structure of the pressure vessel. The design and construction of reactor pressure parts, including the vessel liner and penetrations, was supervised by the Associated Engineering Insurers Ltd. Landscape treatment of the site and surroundings was the responsibility of Messrs. Jellicoe, Ballantyne & Coleridge, Chartered Architects, in association with J. R. Ingleby, Esq., B.Sc., D.I.P.L.D., A.I.L.A.

Oldbury is the first nuclear power station to enclose the reactor core and boilers within a pre-stressed concrete pressure vessel. Although the essential core characteristics of the Oldbury reactors bear a strong resemblance to those at Dungeness, the mechanical engineering is something quite new, even taking into account the early French use of concrete in the G2 and G3 reactors at Marcoule.

This use of concrete has been a major development, not only in nuclear power plant design in the United Kingdom, but in gas-cooled graphite-moderated reactor technology as a whole; the enclosure of the reactor with the boilers and gas circulators in an annular ring around the core, all within a single pressure vessel which serves also as the biological shield, being an important departure from previous designs.

The Site

The site consists of 175 acres of land on the east bank of the River Severn and 380 acres of the river bed.

The site provides strata at an easily accessible depth capable of sustaining the high loads necessary for the civil works of up to 12 tons per square foot, and has available ample supplies of cooling water from the River Severn which is three miles wide at this point. A 380 acre reservoir has been excavated in the river bed to ensure that cooling water is available at all phases of the tide cycle. The reservoir is surrounded by a concrete wall to give a depth of water of five feet providing 416 million gallons of cooling water during low tide conditions.

The spoil excavated from the reservoir was used to raise the power station construction area to an average height of 33·5 feet above O.D., 12 feet above the original ground level. This was necessary to ensure freedom from flooding as the original ground was well below the high water level of the river.

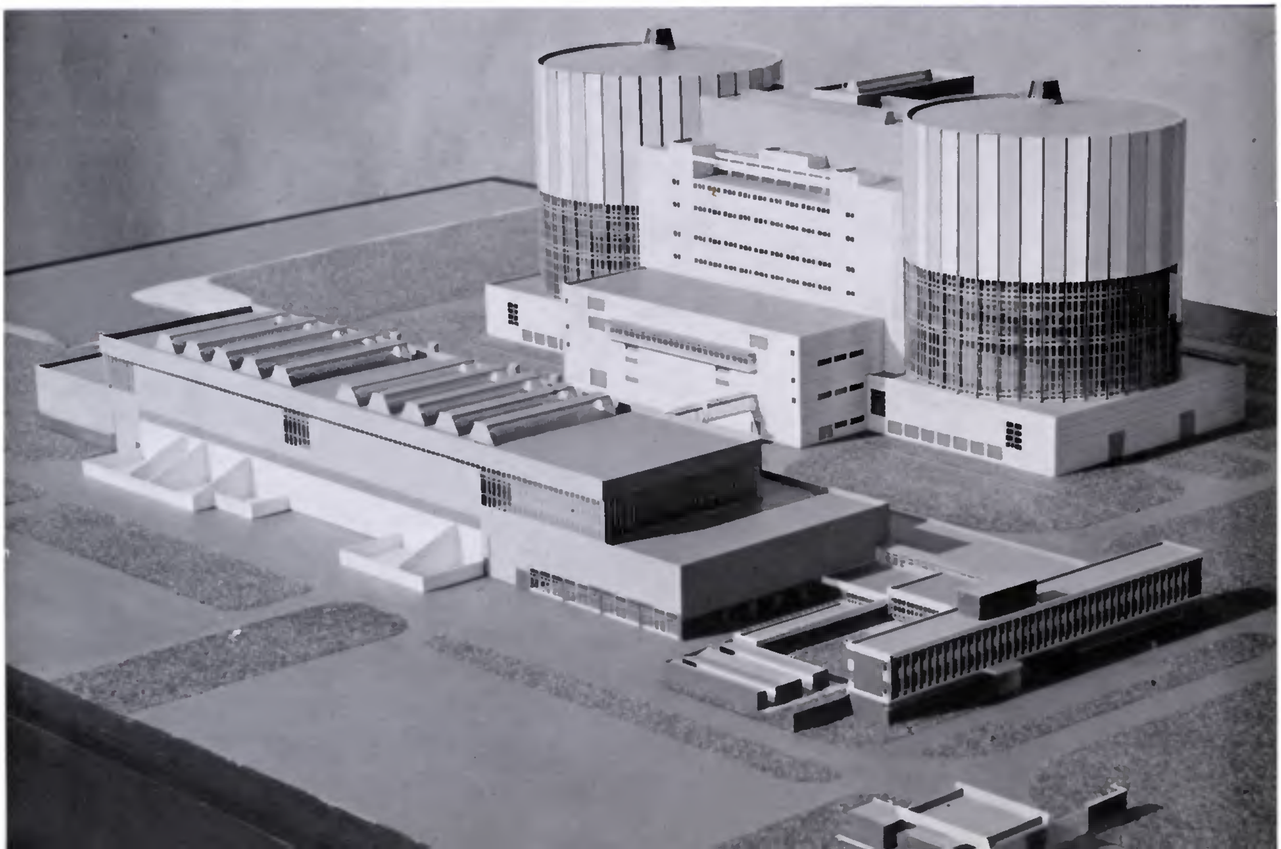
Access to the site was provided by the improvement of two miles of existing roads and the construction of one and a quarter miles of new road, all this work being executed by Gloucestershire County Council as agents of the Generating Board.

The station buildings comprise three major blocks. The reactor block contains the two reactors linked by a common central services building, which contains the majority of the equipment and instrumentation for the control and servicing of both reactors. The central control room for the whole station occupies an elevated position at the south side of this block and all the active areas are on the north side. The charge halls of the two reactors are connected through the central building.

The turbine house block runs in an east-west direction on the south side of the reactor block and pipe and cable connections between the two blocks run through tunnels. The administration building, workshops, stores and welfare building are at the east end of the turbine house and the water treatment plant, essential supplies and emergency generators at the west end.

The main 132 kV switchgear is housed in a separate building on the south side of the turbine house with overhead connections to the generator and station transformers which are outside the south wall of the turbine house.

A model of Oldbury nuclear power station



All the buildings are steel-framed with sheeting and patent glazing, except for the reactor central services building which is of reinforced concrete construction. Because of the open nature of the site the reactor block, which dominates the others, has been treated architecturally to minimise its bulk. The individual reactor buildings are in the form of cylinders rising from a low rectangular portion which houses the gas circulators. The lower half of the cylinder is of clear glass and the upper half is clad in alternate vertical strips of pale blue and light grey sheeting. Separate small buildings have been avoided except where they are essential for safety or operational reasons.

Particular care has been taken with the architectural treatment to provide an appearance which will blend with the surrounding open countryside. This has been supplemented by landscape treatment of the site outside the station boundary, including extensive tree planting both on the site and beyond it in conjunction with the Gloucestershire County Council and local landowners. Experimental planting of semi-mature trees has been used with a view to accelerating the production of a final vista.

Civil Works

The surface of the site consists of 13 feet of alluvium overlaying Keuper Marl which contains below a depth of 20 to 24 feet below ground level, a series of sandstone layers which hold a considerable quantity of water. The heavy structures are founded in the unweathered marl at a depth of between 37 and 44 feet below the finished site level of 33·5 feet above O.D. Lighter structures of importance are carried on piles. To allow excavation to proceed unhindered by ground water the water-bearing strata had to be sealed. This was done by surrounding each of the three main building areas, the two reactors and the turbine house, with a triple ring of holes two inches in diameter down to a depth of 50 feet below ground level.

A cement/water mix was pumped under pressure down these holes to form a grout curtain. Any water which continued to leak through the grout curtain was pumped out from bore holes three feet in diameter.

Work on the construction of the reservoir and cooling water outlet culverts began in January 1961 and by March 1962 sufficient filling of the site had been done to allow The Nuclear Power Group to start work on the main station site.

Work on the cooling water pumphouse commenced in December 1962, on the switchhouse in January 1963 and on the seal pit in July 1963. All these structures were completed to meet the plant installation requirements of the main station contract.

Transfer equipment and the first charge machine

Reactors and Boilers

Concrete Vessel

Each reactor at Oldbury is enclosed in a cylindrical pressure vessel of pre-stressed high-strength concrete 77 feet in diameter and 60 feet high internally. The vertical walls are 15 feet thick and the ends are 22 feet thick. The concrete is made from sulphate-resisting cement and limestone aggregates and is pre-stressed by layers of cable carried in steel tubes laid to a helical pattern in the wall, with alternate layers twisting in opposite directions, and horizontally in the end slabs. The cable positions in the top slab are determined by the charge and control tube entries. The cables must also pass round the boiler access openings before emerging on the side surfaces of the slab. The vertical wall of the vessel is penetrated near the bottom by four holes 8·5 feet in diameter for installation of the gas circulators. Many small penetrations are necessary to accommodate the steam and feed pipes to the boilers and instrumentation facilities. The top slab is penetrated by standpipes for fuelling, control and instrumentation and access openings into the boiler annulus.

Each stressing cable is made up from 12 high-tensile seven-wire steel strands 0·60 inches in diameter and terminated in Freyssinet-type anchorages located in four annular galleries. Access to the galleries is provided not only for the initial threading and stressing operations but also for subsequent inspection, re-stressing and, if necessary, replacement. The galleries are located below the bottom slab, above the top slab, under the charge hall operating floor and round the wall at the bottom.

The concrete vessel is sealed internally by a mild steel liner 0·5 inches thick which is attached by hook bolts at frequent intervals to the concrete, and welded to the steel tubes lining all the penetrations. To prevent overheating and to maintain the concrete temperature below 55 degrees centigrade, the vessel is water-cooled and the liner protected internally by stainless steel foil insulation which will limit the liner temperature to 65 degrees centigrade. The water cooling system consists of two parallel independent systems of 0·75 inch bore pipes welded to stiffening ribs which are welded to the outer face of the liner on a 12 inch pitch and embedded in the concrete, terminating in a series of headers where flow control can be carried out. Round the penetrations there are additional spirally wound cooling pipes to increase the heat dissipation.

Reactor Core

The reactor core uses a lattice arrangement with a square pitch of 7·75 inches and fuel elements with a uranium rod 38·3 inches long and 1·10 inches in diameter. Each fuel element is clad in Magnox A12 cans which each have 60 fins with four radial splitters. Of the 3,320 fuel channels in the core, 3,308 each contain eight fuel elements. The remainder contain seven elements. The fuel is natural uranium and each reactor contains a total of 293 tonnes. There are also 303 other channels for control rods, instrumentation, etc.

The graphite core is built up from a system of interlocking blocks of square and octagonal sections. Channel continuity and lattice pitch is maintained by a vertical and horizontal graphite keying system. The columns are fixed to a steel base support plate and each layer is positioned by a peripheral steel band. The complete core is designed to expand with the base as if it were steel and is carried on a steel grid which in turn is supported on rolling columns. Above the core, steel charge pans are suspended from the Burst Cartridge Detector bundles and fixed with steel sleeves to the core.

Boilers

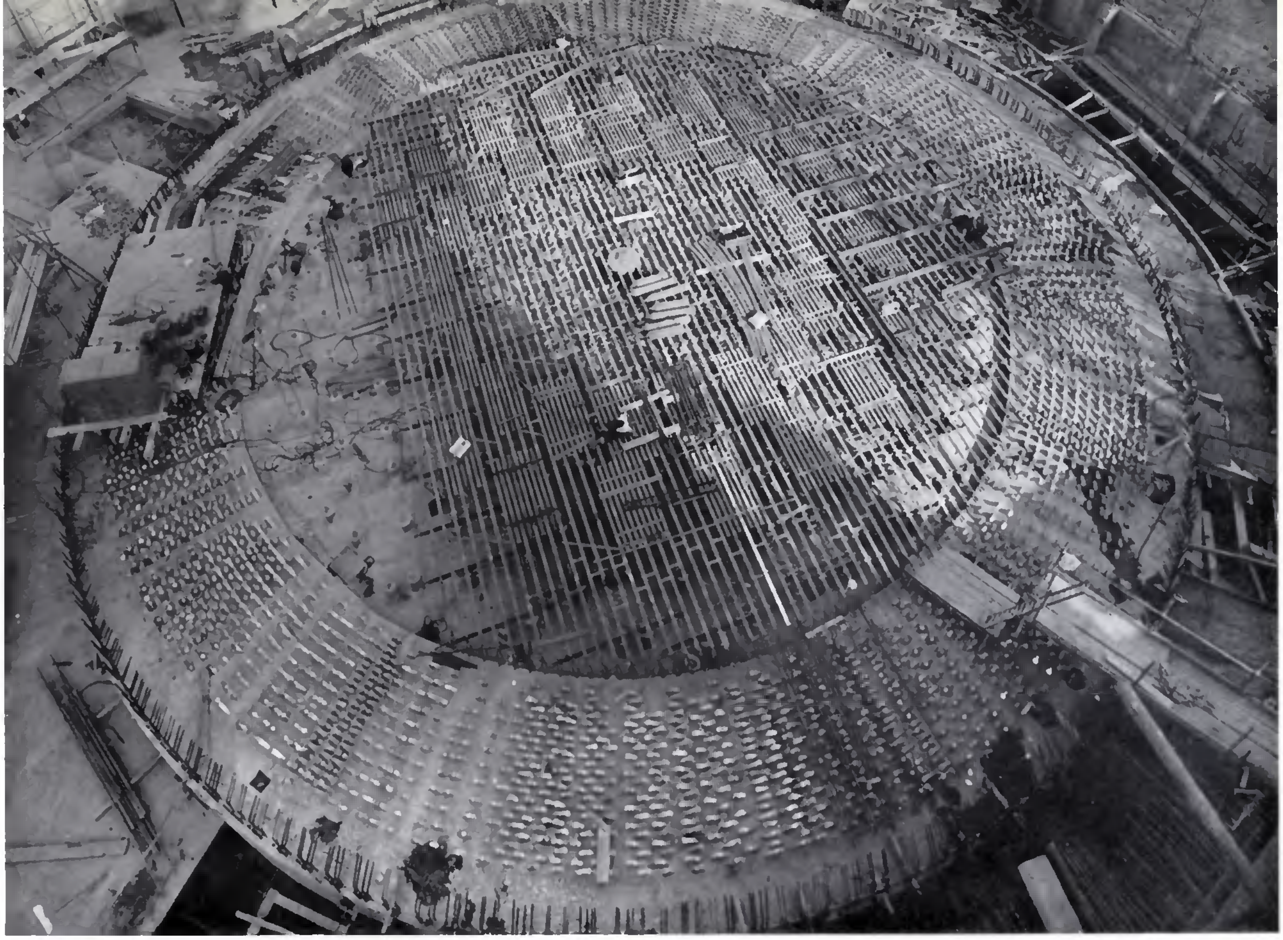
The boiler banks are arranged in an annular ring around the core and separated from the core by a shield wall 3·5 feet thick made of carbon and steel and supported on roller bearings. The wall will cut down radiation to a sufficiently low level for access to be possible to the boiler tube banks with the reactor shut down.

Steam is generated at two pressures, the entire flow of high pressure steam passing first to the turbines driving the gas circulators then returning to the boilers for reheating before joining the low pressure steam and passing to the main turbines.

The boiler annulus is divided by steel plate partitions extending almost the full height of the vessel into four quadrants which communicate with each other only through a narrow space at the top of the partitions.

Each boiler bank occupies one quadrant and consists of two groups of 15 identical shop-fabricated units 36 feet high, 8·16 feet long and 1·33 feet wide, the casings of which are bolted together.

Each unit consists of a group of eight elements and contains a proportion of high pressure, low pressure and reheat circuits. The boiler tubing is of finned steel. Steam and water connections between individual units and external headers are made through insulated



Number 2 reactor during construction as seen from the central block

penetrations in the concrete vessel wall, there being two penetrations per unit, each carrying four tubes. The boilers use a once-through flow to minimise the number of penetrations and to give better operational flexibility. Variations in steam requirements on part-load will be met in the dual pressure reheat cycle by operation at varying water level, without recourse to bypass arrangements. No steam drums are used and the absence of continuous "blow-down" makes the solid content of the feed water critical. This is kept low by using double tube plates in the main condensers and by diverting 25 per cent of the feed to the boilers through a polishing section of the feed water treatment plant.

Gas Circulators

A gas circulator is located within the pressure vessel below each boiler and comprises a single stage axial flow unit. Gas is drawn from the boiler quadrants through inlet fairings and discharged into an annular duct at the bottom of the shield wall. The gas circulator impeller is overhung from a two bearing assembly bolted to the pressure casing which is in the form of a flanged truncated cone closing the aperture in the vessel through which the drive shaft passes. Each circulator is driven at a speed variable between 450—2,100 revolutions per minute by a back-pressure turbine, the full power speed being 2,000 revolutions per minute when power consumption is 5·25 MW. A pony motor mounted on the same shaft can drive the circulator at 454 revolutions per minute at design pressure or at 922 revolutions per minute at atmospheric pressure. Reverse flow through a boiler section in the event of one circulator being shut down is prevented by a sleeve valve mounted on the inlet fairings to the blower. This valve can be operated remotely from outside the vessel.

Fuel Handling

Charge and discharge of the fuel are from above as in previous designs but with the cylindrical vessel maximum head room can be maintained to the periphery and access is not limited by the curvature as has been the case with the previous spherical or domed vessels.

This has permitted the provision of a handling chute which can serve 60 channels with no greater angular deflection than previously necessary for only 32. This reduction in the number of charging tubes necessary for serving the whole core means that the majority of refuelling can be carried out without disturbing the access tubes used for flux scanning and axial string thermocouple elements.

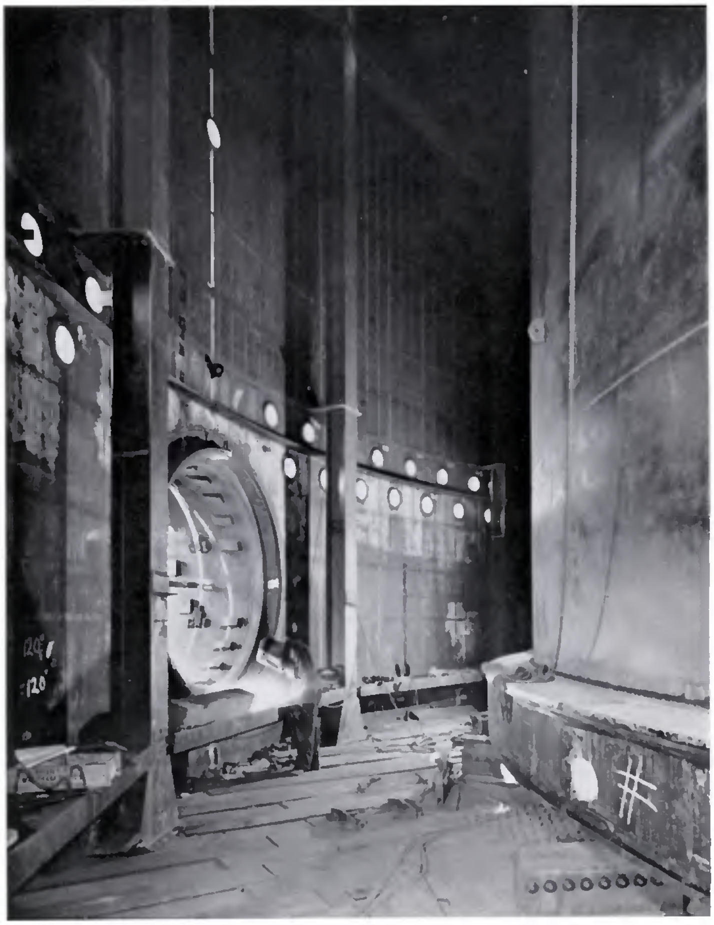
The charging machine is similar to that at Dungeness and carries out all operations involved in inserting or withdrawing fuel including handling standpipe shield plugs and charge chutes. It also handles all auxiliary components into and out of the reactor and can be fitted with attachments for inserting a television camera or temperature probes.

The charging machine runs in an east-west direction upon rails mounted on a gantry, which itself runs in a north-south direction on rails in the charge hall above the reactor thus enabling the machine to be located over any one of the 205 standpipes. It can also be run off the gantry on to any one of three sets of rails linking the two reactors on the top floor of the central services building. Two machines are provided and normally one works on each reactor but the central link enables one machine to service both reactors whilst the other is being overhauled or both machines to operate a shuttle service on one reactor should it be necessary to speed up the discharge of fuel.

The whole of the facilities for handling new and irradiated fuel and for maintaining the charging machines and active components are contained in the central services building. New fuel arriving at the station is unloaded and distributed to common fuel stores whence it is withdrawn as required, examined, prepared and loaded into magazines beneath the top floor. The charging machine picks up five channels of fuel from the magazine and conveys them to the reactor for charging. After exchanging the fuel in five channels the machine returns with the irradiated fuel elements to another position in the central building and discharges them into a water-filled tube leading directly to the common cooling pond in the basement of the building where they are stripped of their splitters and stored in skips for the necessary decay periods. Ultimately the skips are loaded under water into a shielded flask for transport away from the station.

Generating Plant

The turbine house has one main bay for two turbine-generators placed in line with their steam ends together. Steam and electrical annexes are both on the reactor side of the turbine house with the deaerators and storage tanks mounted outdoors on the steam annexe roof.



Number 1 reactor—boiler annulus and gas circulator opening

The turbines are 312 MW, 1,500 revolutions per minute, three-cylinder (one H.P., one L.P. and one double L.P.) machines taking 2,657,000 pounds of steam per hour at 640 pounds per square inch gauge and 389 degrees centigrade exhausting through three exhausts to a single longitudinal condenser at a vacuum of 28·9 inches of mercury. The generators operate at 16,500V, 50 cycles, and are hydrogen-cooled with condensate-cooled stator windings and a static excitation system. Overall plant thermal efficiency will be 33·6 per cent.

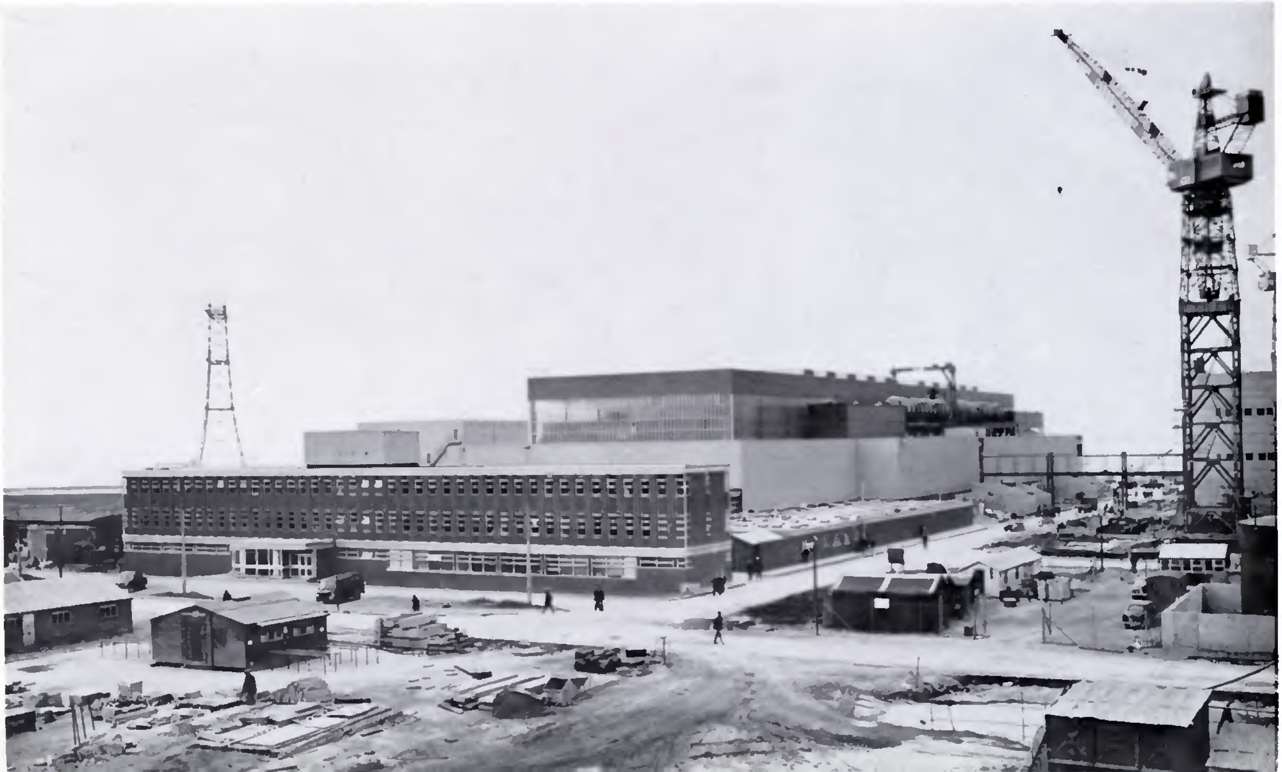
The main condensers can function as dump condensers at start-up and shut-down and, used in conjunction with de-superheating flash vessels and pressure reducing valves, can each accept 20 per cent of the full load steam production of one reactor.

The output of these sets is transformed to 132 kV and switched in an enclosed switching station on site. Two double circuit lines connect the switching station to a Grid substation at Iron Acton about eight miles away where electricity is either distributed to the South Western Electricity Board or transformed to 275 kV to feed the Supergrid.

Cooling Water System

Cooling water is drawn direct from the river reservoir into a pumphouse on the river bank through coarse screens and double-entry rotary-drum fine screens. The screens are outdoor and the cooling water pumphouse is entirely below ground with sliding roof units for access, the whole area being served by a Goliath crane. Four horizontal centrifugal cooling water pumps each deliver 87,500 gallons per minute at a head of 32 feet through automatic reflex-action butterfly valves into an R.C. bus main which is divided into two parts by a butterfly valve. Each section of the bus main supplies one condenser through a single culvert. The discharge from each condenser is carried by a separate culvert to a point on the river bank 1,000 feet north of the pumphouse, where a seal pit is installed for syphonic recovery. The two culverts are connected to a common chamber in the seal pit. From this common chamber, the water flows over four independent weirs of adjustable height into four culverts arranged in pairs in the river bed. One pair run to a point outside the north-west wall of the reservoir so that they discharge at all times direct to the river. The other pair run to a point just inside the reservoir wall where isolating arrangements are installed to permit them to discharge either into the reservoir or direct to the river.

The turbine house and administration block, looking west



Auxiliary Electric Supplies

Because the station contains only two generating sets, each connected by two 132 kV overhead lines to the Iron Acton switching station, it has been possible to achieve considerable economy in the method of obtaining auxiliary electric supplies without prejudicing their security. Each generator has a solidly-connected unit transformer of a capacity (25 MVA) sufficient to run its own reactor and turbine auxiliaries and the general station auxiliaries and in addition to start-up and run the auxiliaries of the other reactor-turbine unit. Only one station transformer, also of 25 MVA, is provided instead of the normal two and is arranged so that it can be connected to either of two of the outgoing 132 kV lines. The 132 kV switching station, therefore, contains only five switches instead of six, and it is from this that the bulk of the saving results. The switchgear is 2,000A, 3,500 MVA air-blast outdoor type, but following the Generating Board's current policy for coastal sites the complete switching station is enclosed in a building for protection against the salt- and spray-laden atmosphere.

Each unit transformer feeds an 11 kV unit switchboard which is directly connected to half of the major auxiliaries (boiler feed, cooling water and extraction pumps), and through further transformers at 415V, to all the smaller auxiliaries of the corresponding reactor-turbine unit. The station transformer feeds an 11 kV station switchboard divided into two sections and interconnected with both unit boards. Each half of the station board supplies direct the other half of the major auxiliaries of the associated generating unit and the two halves jointly supply, through duplicate transformers, various station services at 415V and the essential supplies system at 3·3 kV. Interconnections between station and unit supplies are also provided at 415V arranged to switch automatically to the good supply in the event of a failure.

The essential supplies system provides an immediate source of power should the normal auxiliary supplies fail and ensures that in an emergency all the auxiliaries necessary for the safety of the reactor continue to run. The system is divided into two parts, no-break and short-break. The direct current no-break system, which supplies those auxiliaries such as safety circuit and instrument supplies for which even a short interruption cannot be tolerated, is based upon batteries which ensure 20 minutes independence of all other supplies. The system is normally supplied and the batteries kept charged from the short-break essential supplies 3·3 kV board through transformer/rectifier units. The short-break system to which the gas circulator pony motors are connected is supplied normally from the station supplies, but if these fail the supply is restored automatically by starting two out of three Bristol-Siddeley Proteus aircraft-type gas turbines driving 2·75 MW brushless generators. These replace the diesel engines installed in earlier nuclear stations for the same purpose. All the auxiliary switchgear is of the air-break type.

Control and Safety

All major reactor and turbine-generator plant and auxiliaries are controlled from the central control room under running, start-up and shut-down conditions. Most auxiliaries are controlled individually at start-up but automatic sequence operation is used in some cases. The control room is divided into two main areas, one for operation and the other for recording. The operation area contains the reactor and generator load control desks from which two seated operators have effective reactor start-up and station normal running control. Start-up controls for the turbines and ancillary plant are on vertical panels surrounding the desks. A computer is to be used to monitor the many thousands of alarms and this will, in addition to printing a record of every abnormal occurrence, display on cathode-ray screens on the control desks an analysis of the basic fault and the required remedial action. A second computer is to be employed, to scan at high speed, signals received from the Burst Cartridge Detection equipment. This computer will give print-out and punched-tape records and will compare current signals with earlier ones, to determine the rate of rise in radioactivity. If this is above a certain level, an alarm will be initiated to warn the unit operator. A 50V system has been adopted for transmitting control and indication signals, to achieve a compact arrangement of equipment on desks and panels. The recording area is an annexe outside the main suite of vertical panels and contains all the recorders and relay, safety circuit and auto-control equipment. In the centre of the operation area is the supervising engineer's desk which carries equipment for communications inside and outside the station and duplicates of the alarm display screens.

Reactor power is controlled by varying the speed of the gas circulators. This control may be exercised manually but will normally be automatically adjusted to maintain the L.P. steam pressure at the main turbines constant. Reactivity is controlled by the movement of 101 control rods, comprising nine safety, four groups of 16 bulk control, 18 fine control and 10 individual trim. All rod movements are manually controlled during start-up. During normal operation the bulk and fine control rods can be adjusted manually. The fine rod groups are disposed two in each of nine zones (one central and eight azimuthal sectors) and are normally automatically controlled to maintain a constant gas outlet temperature from the core. Reactor inlet gas temperature is automatically controlled at a constant level by adjustment of the low pressure boiler feed water flow and provision is made for manual increase of the controlled temperature to provide reactivity override on reduction of load.

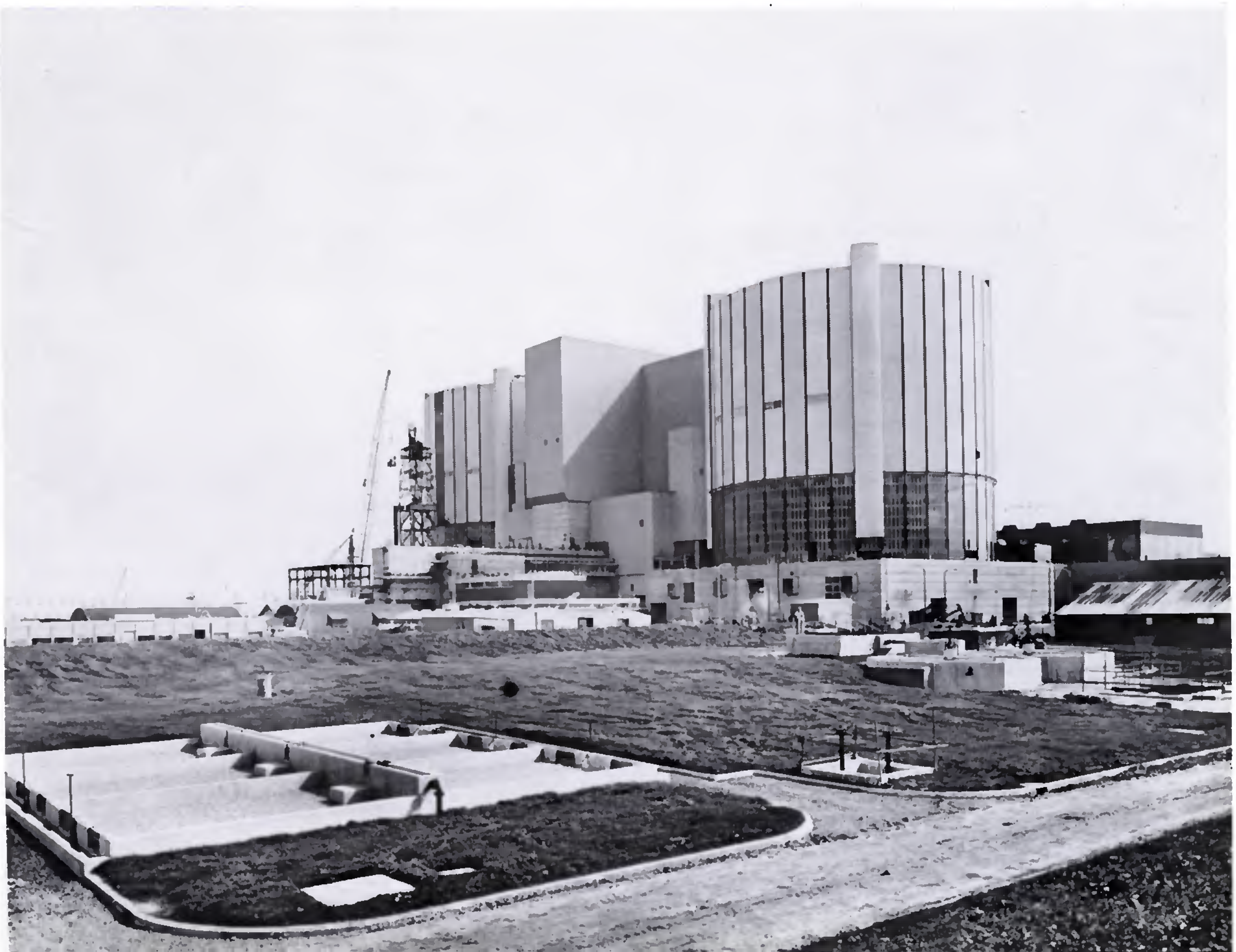
In the event of a reactor fault the safety system trips all 101 control rods into the core.

The reactor safety system and associated indicating equipment is based on solid state techniques with laddic gates and transistors.

Construction

The incorporation of the reactor and boiler in a single vessel introduced problems of construction, due to the concentration of many activities in a very restricted area, which have not been met at earlier stations. Elaborate planning was required to dovetail all the operations so that mutual interference is avoided to the maximum extent. Initially work has proceeded on each reactor in two separate major areas. On the reactor sites the foundations of the concrete vessels and the reactor buildings and subsequently the vessel base slabs and the surrounding building structures were constructed up to the level of the internal floors of the vessels, and the floors of the steel liners were laid. At the same time, the vertical part of the steel liners were being fabricated on sites adjacent to the reactors on their common east-west centre line at the same level as the internal floor

General view of site from north-west



The reservoir outfall looking west across the River Severn

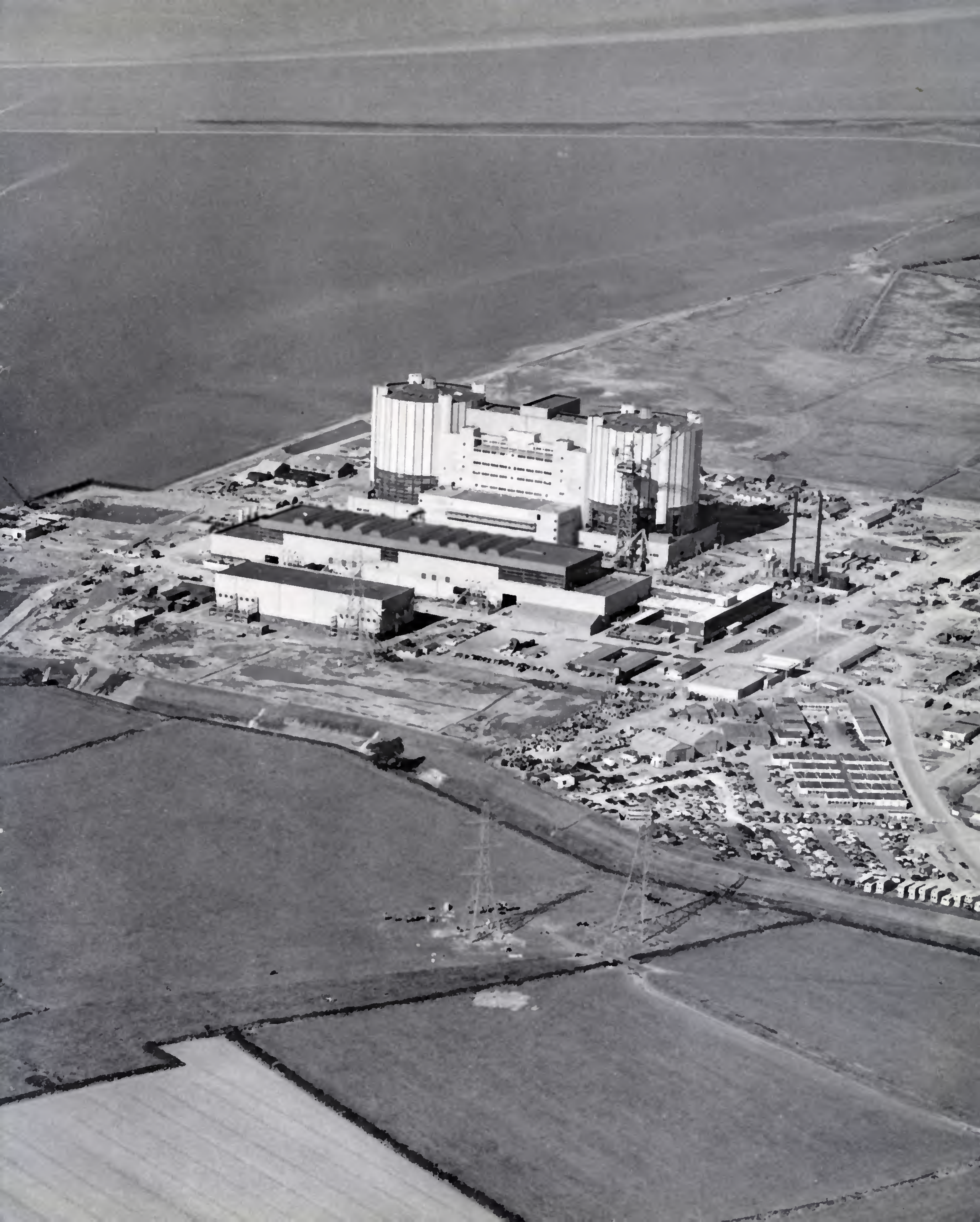
of the vessel. Inside the liners the base rings for the boiler shield walls and the steel membranes separating the carbon and steel portions of the shield wall were fabricated and the core support structures were built inside. All these structures were finally jacked-up and mounted on bogies running on rail tracks laid from the liner fabrication area, spanning the circulator house basement, on to the vessel floor which was by then completed. The whole assembly was then rolled into position on the vessel floor, the bogies removed and each structure lowered on to its prepared supports.

The shield wall membrane was constructed beyond its final height and the central portion of the liner roof was built upon it. When installed on the vessel floor, this latter structure, together with some temporary boarding-up of the small space between its support ring and the floor, provides complete physical segregation of the space inside the shield wall from the boiler annulus. This enabled work on building the carbon portion of the shield wall to proceed in the inner space at the same time as other work in the boiler annulus. After moving the liner, etc., into position work proceeded concurrently on concreting the vessel wall, completing the liner roof, fixing standpipes and concreting part of the vessel roof, which was supported by steelwork built up inside the shield wall and in the boiler annulus. At the same time erection of the steel portion of the shield wall in the annulus area, erection of the carbon portion of the shield wall in the central area, and construction of the circulator houses and reactor buildings enclosing the vessel was carried out. When the vessel walls were completed, concreting of the top slab continued until it was 12 feet thick at which stage it became self-supporting and the internal supporting steelwork could be removed leaving the central space clear for core erection and the annulus space for boiler erection.

This method of construction avoided the necessity of lifting very heavy loads and enabled the whole operation to be carried out using only a number of 15 ton and five ton monotower cranes suitably disposed around the reactor area.

The peak labour force employed on the main station contract was nearly 2,000 and living accommodation was provided in a camp on site for 690 men.

Right—An aerial view of the power station



Technical Data

Number of REACTORS	2
Number of TURBINE GENERATORS	2

The following figures apply to one reactor and one turbine.

REACTOR

Type	Graphite-moderated CO_2 gas-cooled
Pressure Vessel Shape	Upright cylinder
Internal dimensions	Diameter 77 feet Height 60 feet
Construction	Pre-stressed concrete
Thickness	Walls 15 feet Top and bottom 22 feet
Lining	0·5 inch steel
Boiler shield wall	Thickness 3·58 feet Diameter 48 feet (internal)
Gas inlet temperature to reactor	245°C
Gas outlet temperature	412°C
Gas pressure at reactor inlet	364·2 lb/sq in absolute
Gas circuit pressure drop	11·7 lb/sq in
Total gas flow through reactor	10,800 lb/sec
Systematic peak can temperature	480°C
Reactor heat rating	892 MW

GRAPHITE CORE

Active core dimensions	Height 28 feet Diameter 42 feet
Number of fuel element channels	3,320
Number of control rod and other channels	303
Lattice pitch (square)	7·75 inches

FUEL	Natural uranium
Dimensions of fuel rods	Diameter 1·10 inches Length 3 feet 2¼ inches
Fuel elements per channel	8 (3308) 7 (12)
Weight of uranium	293 tonnes
Canning material	Magnox A.12

CONTROL RODS

Number	101
Material	Boron steel
Length	27 feet
Diameter	3·2 inches
Weight per rod	290 lbs

GAS CIRCULATORS

Number of circulators	4
Type of circulator	Single stage axial flow
Drive	H.P. back-pressure turbines
Standby drive	3·3 kV motors
Gas flow/circulator	2,751 lb/sec
Power input/circulator	5·25 MW
Running speed (rated output)	2,000 r.p.m.
Speed range	450-2,100 r.p.m.

CIRCULATOR TURBINES

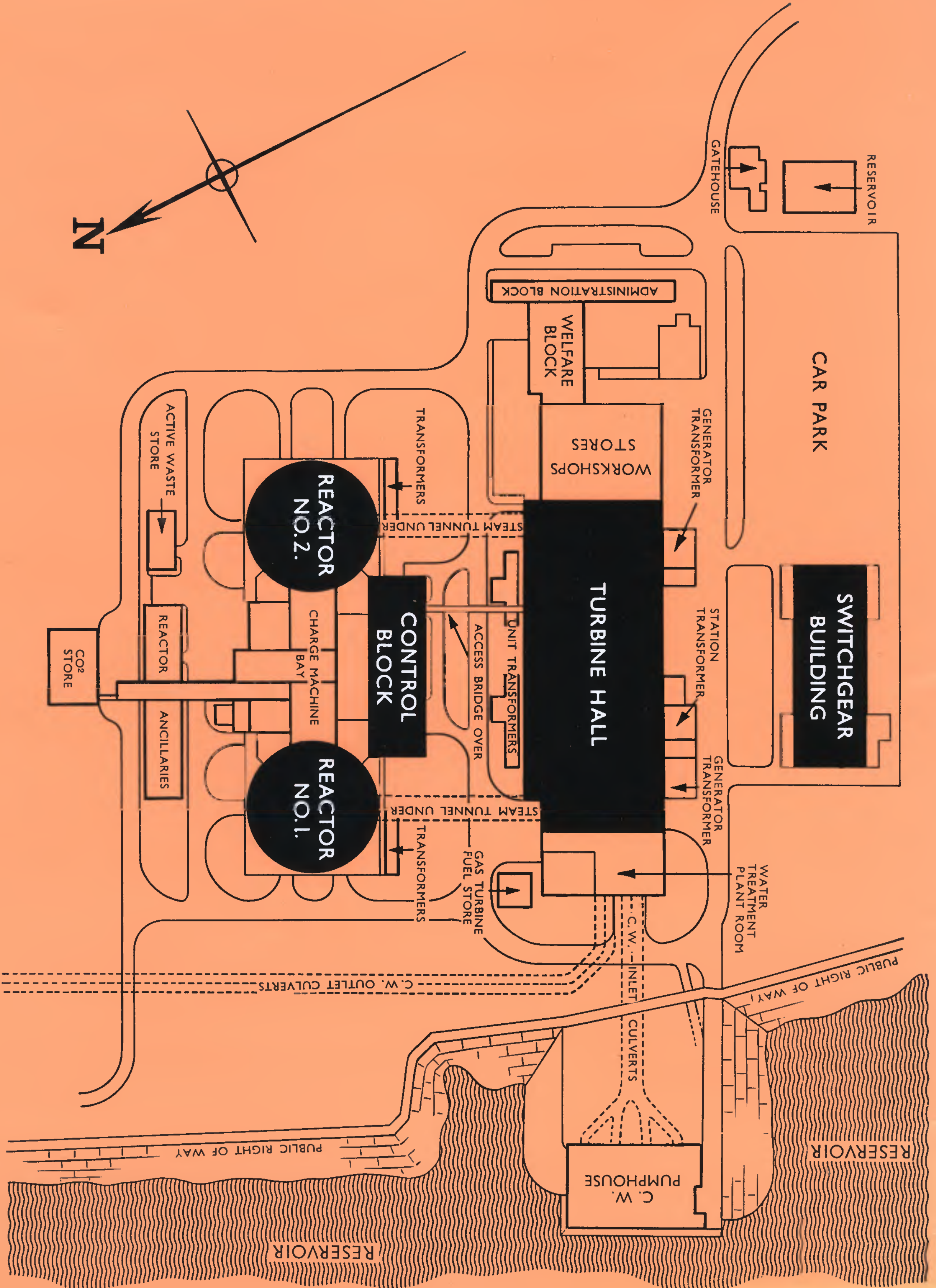
Number of turbines	4
Steam conditions at T.S.V.	1,377 lb/sq in absolute 399°C
Steam conditions at exhaust	750 lb/sq in absolute 328°C
Steam flow per turbine	394,000 lb/hr

BOILERS

Location	Inside pressure vessel quadrature with interconnection outside pressure vessel
Number of boilers per reactor	4
Feed water temperature	138°C
H.P. steam conditions	1,402 lb/sq in absolute 399°C
H.P. steam flow/reactor	1,576,000 lb/hr
L.P. steam conditions	705 lb/sq in absolute 392°C
L.P. steam flow/reactor	1,124,000 lb/hr
Reheater steam flow/reactor	1,537,000 lb/hr

TURBINE GENERATORS

Capacity	312 MW
Speed	1,500 r.p.m.
Steam conditions at T.S.V.	640 lb/sq in absolute 389·4°C
Number of cylinders	3
Vacuum	28·9 inches, Hg
Generating voltage	16·5 kV


N
RESERVOIR
GATEHOUSE
ADMINISTRATION BLOCK
WELFARE BLOCK
CAR PARK
WORKSHOPS
STORES
GENERATOR TRANSFORMER
SWITCHGEAR BUILDING
TURBINE HALL
STATION TRANSFORMER
GENERATOR TRANSFORMER
WATER TREATMENT PLANT ROOM
TRANSFORMERS
STEAM TUNNEL UNDER
REACTOR NO.2.
CONTROL BLOCK
ACCESS BRIDGE OVER
UNIT TRANSFORMERS
CHARGE MACHINE BAY
ACTIVE WASTE STORE
REACTOR ANCILLARIES
CO² STORE
STEAM TUNNEL UNDER
REACTOR NO.1.
TRANSFORMERS
GAS TURBINE FUEL STORE
C.W. OUTLET CULVERTS
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CENTRAL ELECTRICITY GENERATING BOARD

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Printed in England by Southern Press (Printers) Ltd., Purley, Surrey.
G.446 August 1966