DUNGENESS

"Spindrift" Cottage. The site before construction began.

CENTRAL ELECTRICITY
GENERATING BOARD

DUNGENESS 'A'

NUCLEAR POWER STATION

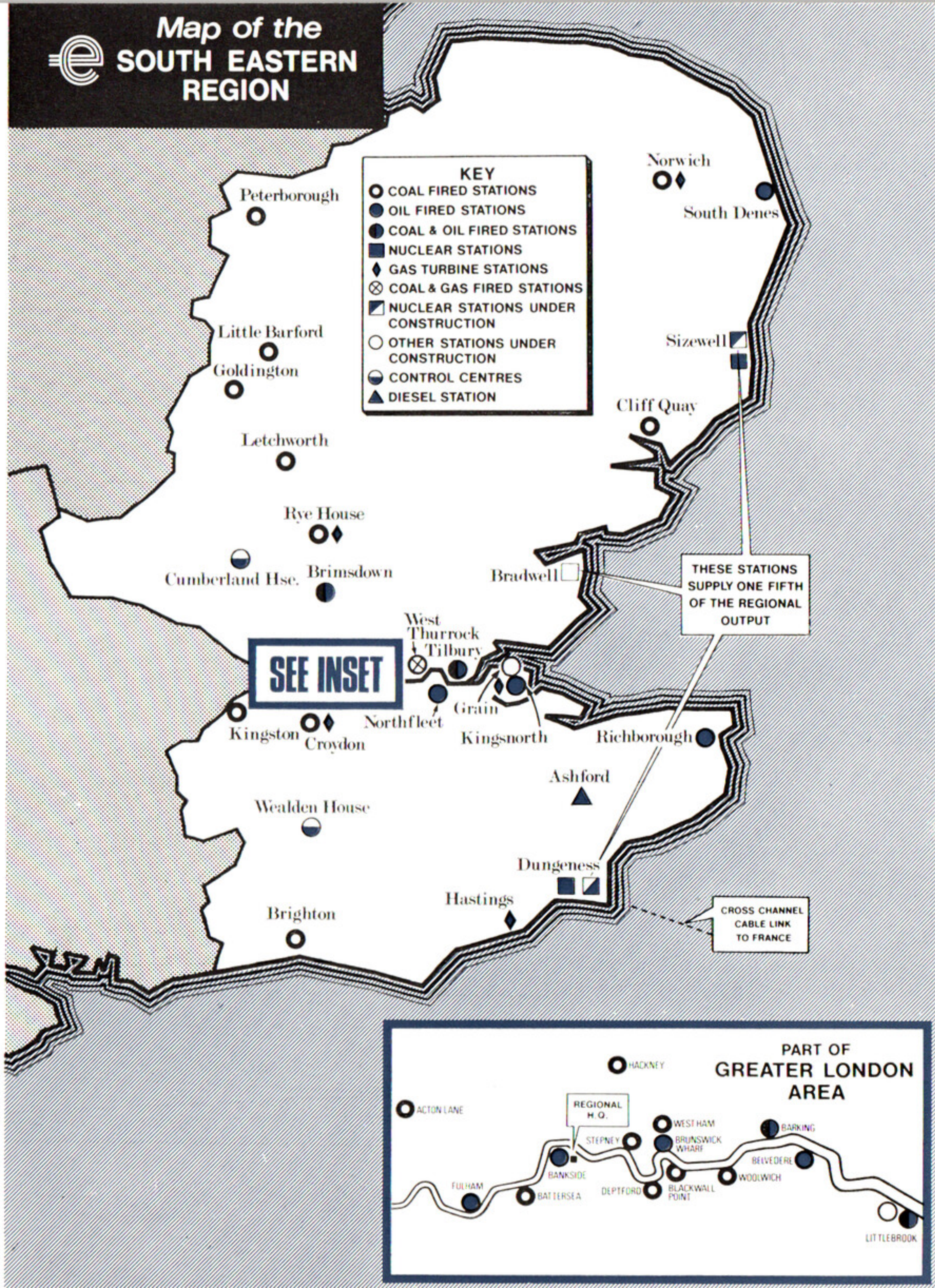
Reactor Buildings from the South East

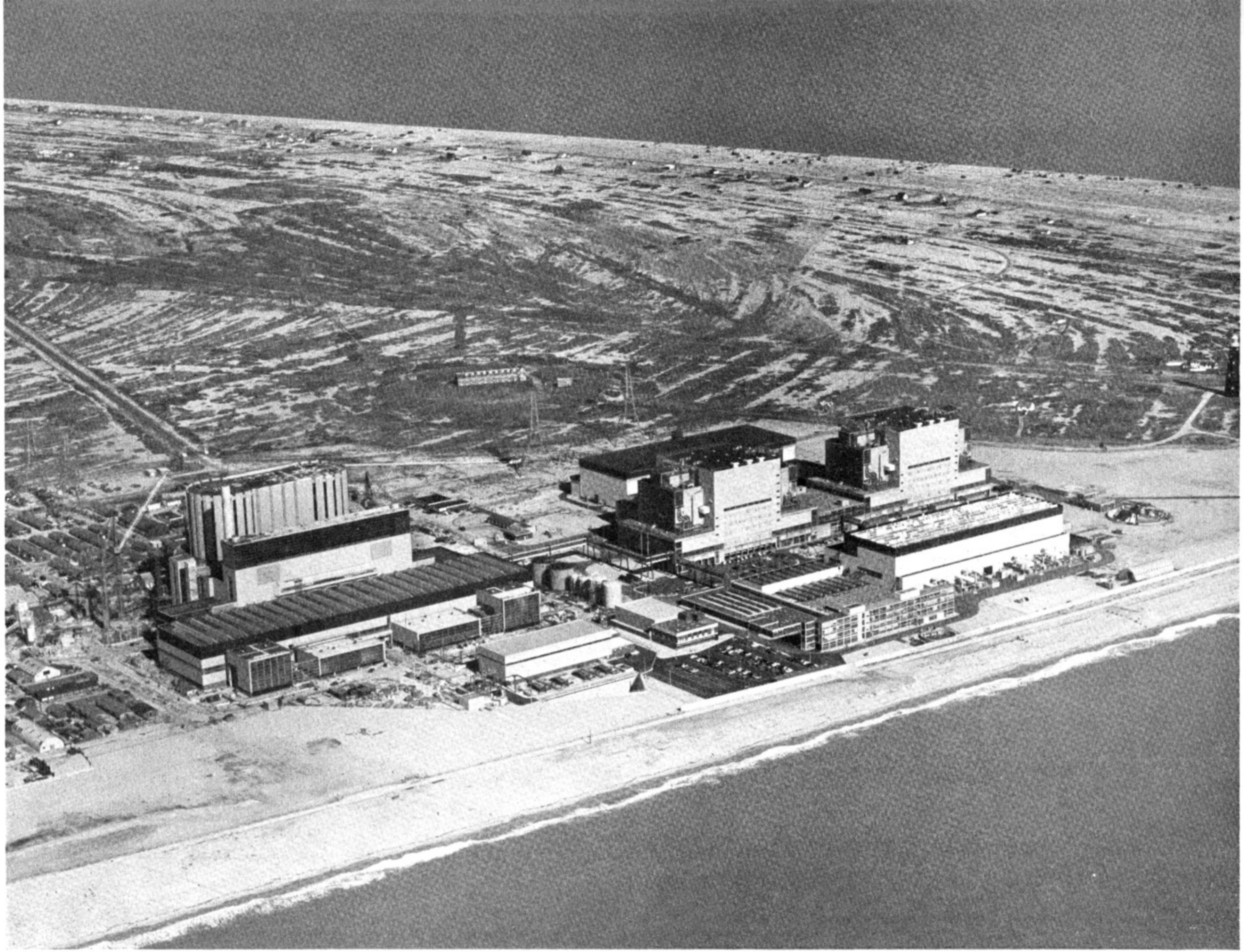
Organisation

The organisation of the Central Electricity Generating Board consists of a central headquarters in London and five regions responsible for the operation of the power stations and transmission lines within their areas. The construction, design and development functions associated with power stations and the transmission system are the responsibility of two divisions—the Generation Development and Construction Division and the Transmission Development and Construction Division.

The power generated in the Board's power stations is sent out at 275,000 volts or 400,000 volts over the Grid network to distribution points where it is sold to the Area Electricity Boards and other bulk supply customers.

Dungeness power station is one of three nuclear fuelled stations within the South Eastern Region of the C.E.G.B., the others are at Sizewell in Suffolk and Bradwell in Essex.

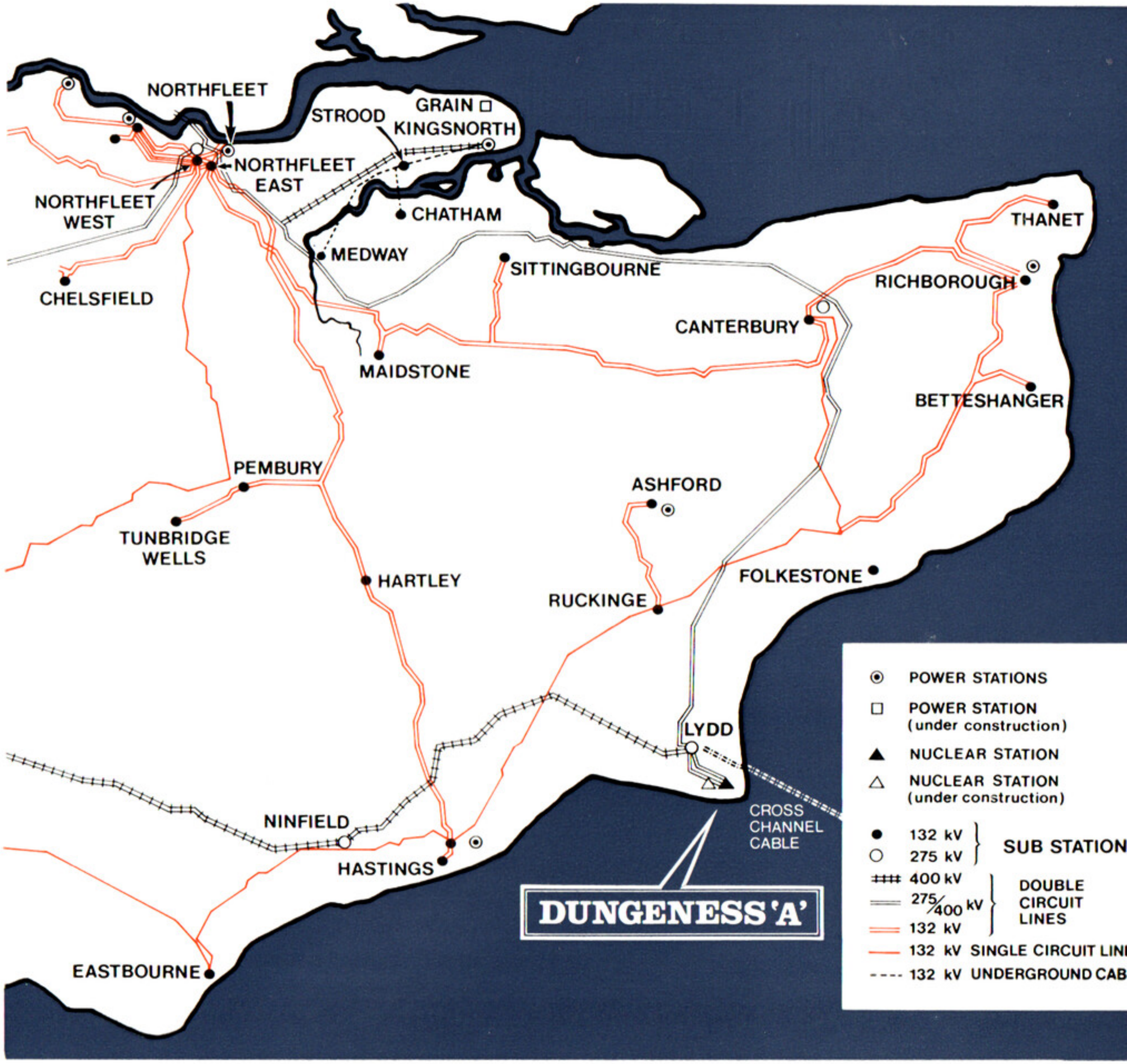


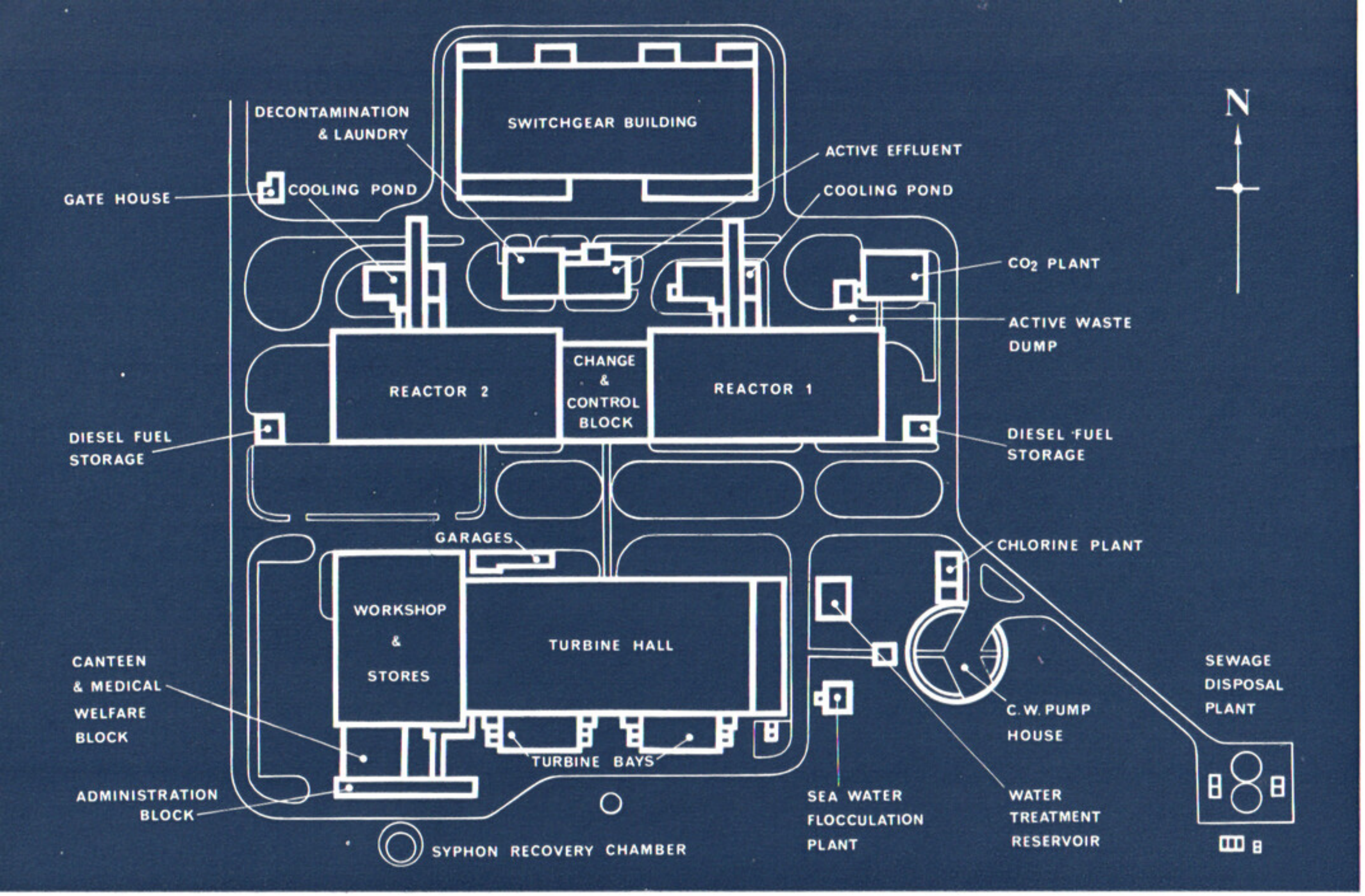


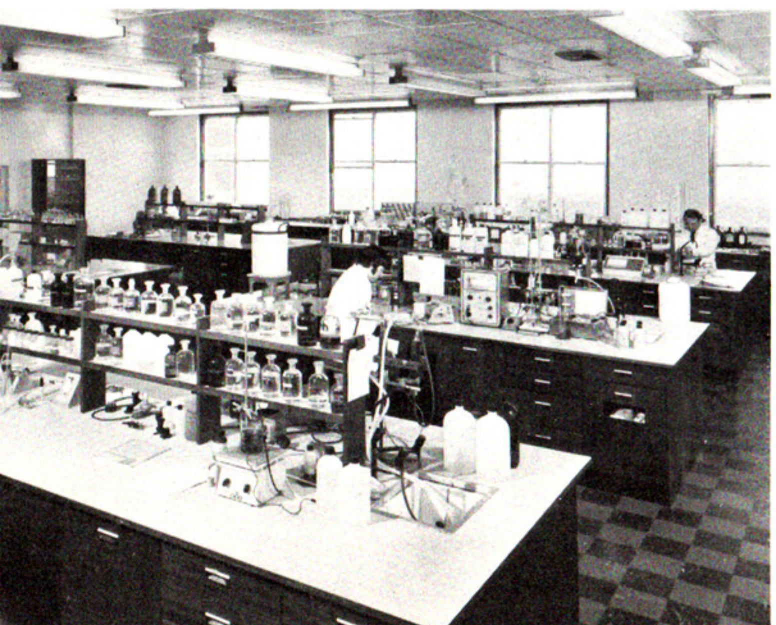
Dungeness Point and the Power Station.

siting

Dungeness 'A' Nuclear Power Station is the fifth station in the first nuclear power programme and already it has been possible to improve the design and efficiency of the plant. Dungeness has a capacity of 550 megawatts linked to the National Grid by 400,000 volt and 275,000 volt lines supplying the South Coast and London. The station is sited at Dungeness on the western side of the point approximately 3 miles from Lydd in Kent. Extensive investigations showed this site to be the best in south-eastern England particularly as it was close to deep water for cooling purposes and utilized land which was of minimal value to agriculture.







ayout

Each of the two reactor buildings at Dungeness houses one reactor, four boilers, gas blowers and associated plant. The main station control room is between the reactors, and is connected to the turbine house by an access bridge. Steam and feed mains, power and control cables, and other services pass through tunnels from the reactor buildings to the turbine house. The four turbo-generators are arranged transversely in the turbine hall.

The longitudinal axis of the turbine house runs in an east/west direction. The cooling water pump house is due east of the turbine house, with a straight run of cooling water culverts between them. The cooling water outlet culverts leave the west end of the turbine

above:—Interior of Administration office.

left:—Chemistry Laboratory.

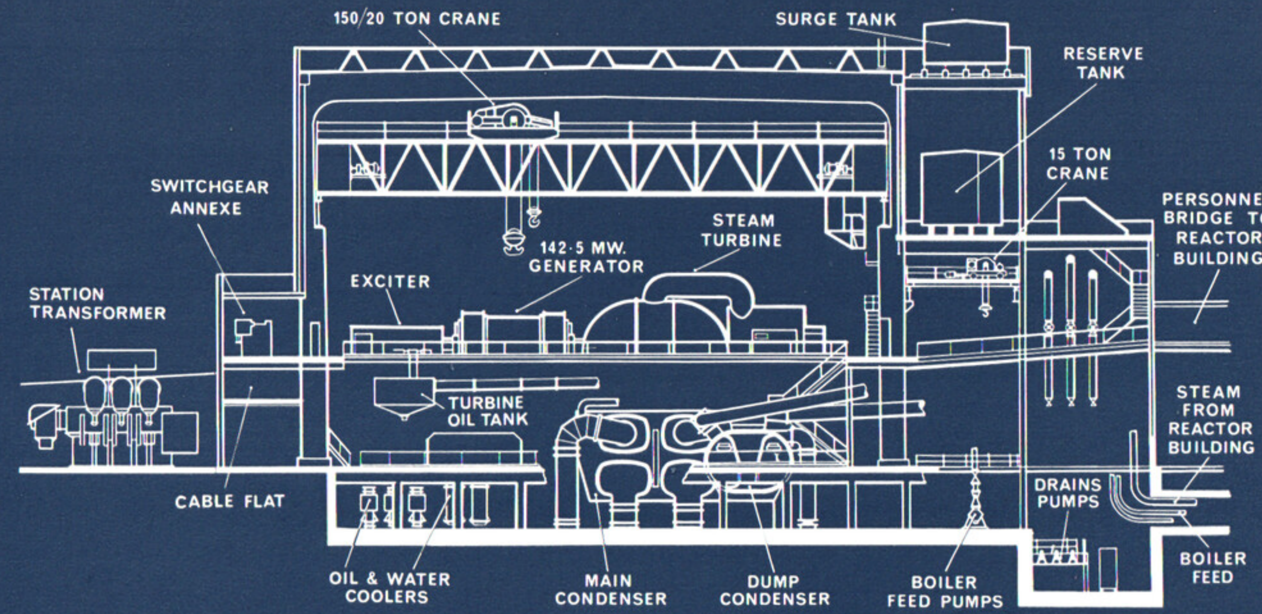
left middle:—Medical Centre.

house and turn seaward to the syphon recovery chamber.

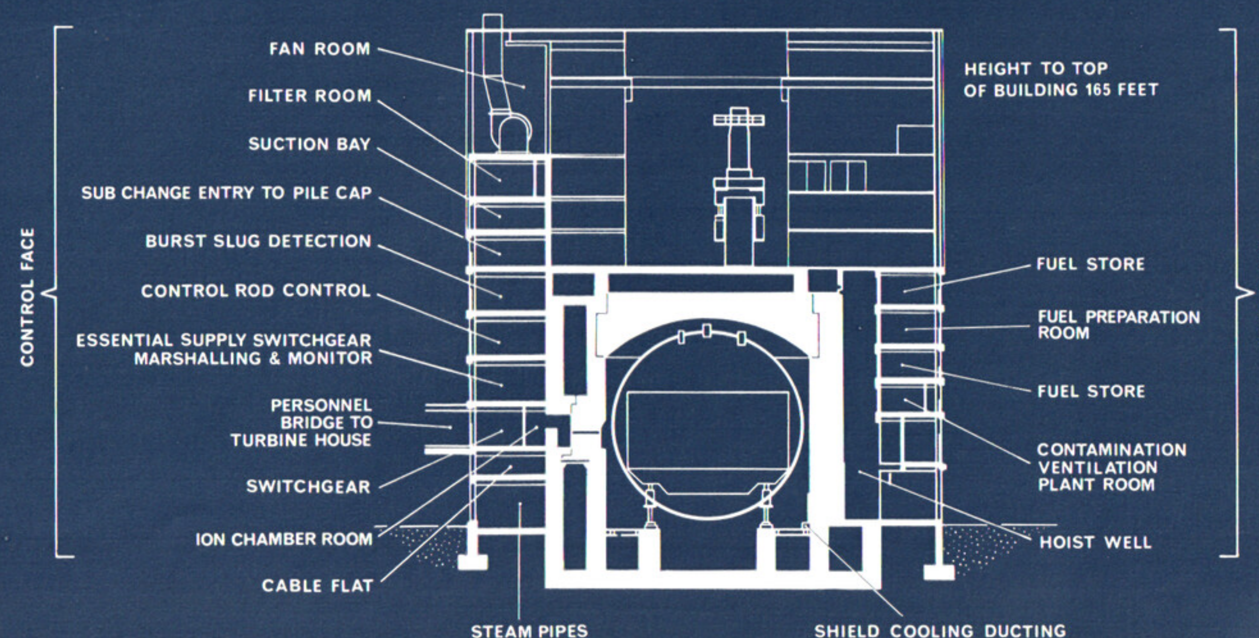
The administration block, workshops, stores and the welfare block are adjacent to the west end of the turbine house. This arrangement provides good facilities for direct movement of personnel. The reservoir settlement tanks, and filtered water storage tanks are grouped around the east end of the turbine house.

The buildings associated with the reactors are grouped on the north side remote from the turbine house. They are the carbon dioxide store, irradiated fuel cooling ponds, decontamination centre, laundries, etc. The switch house lies immediately to the north of these buildings.

TRANSVERSE SECTION THROUGH THE TURBINE HOUSE



SECTION THROUGH A REACTOR BUILDING

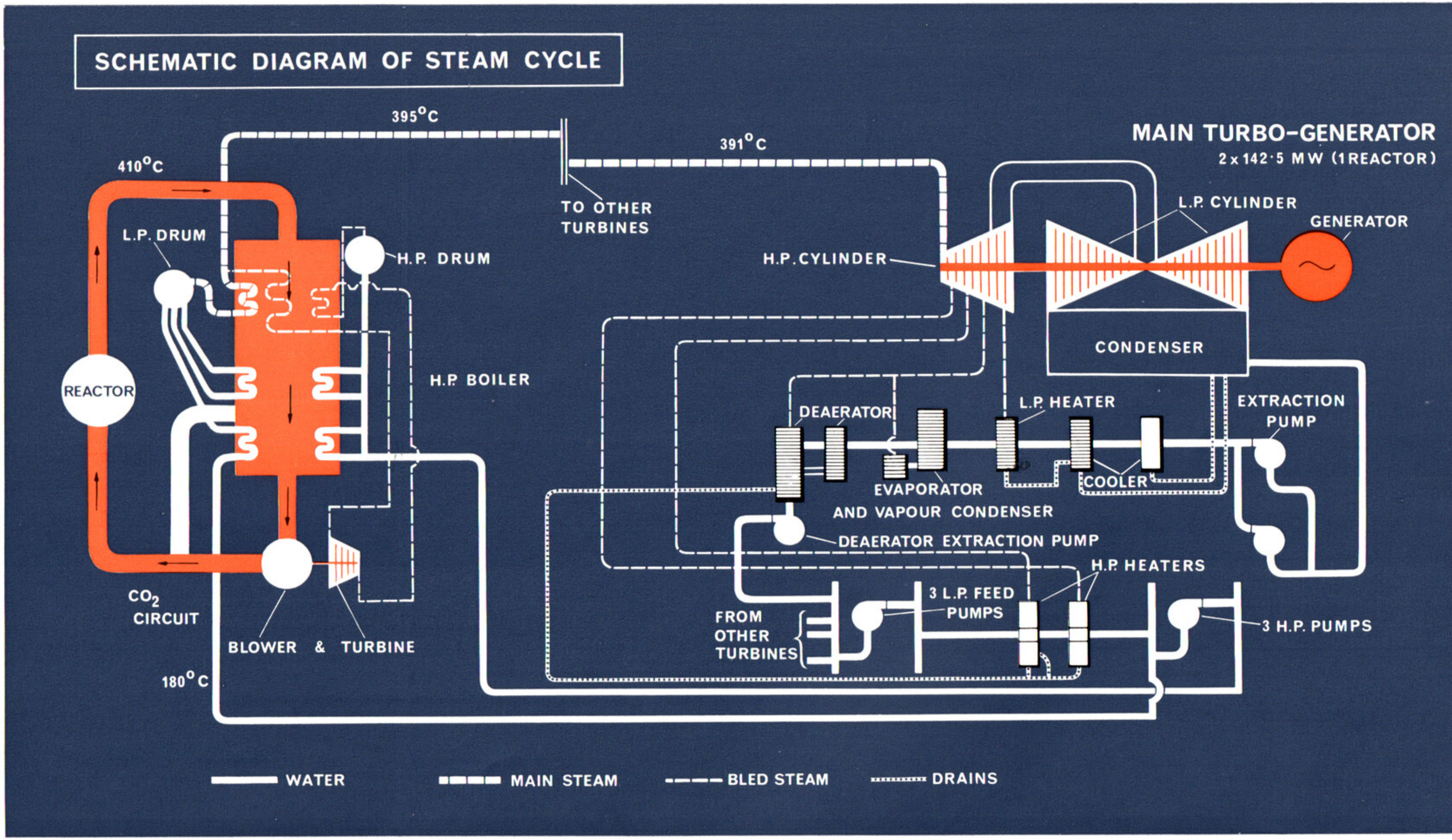


design

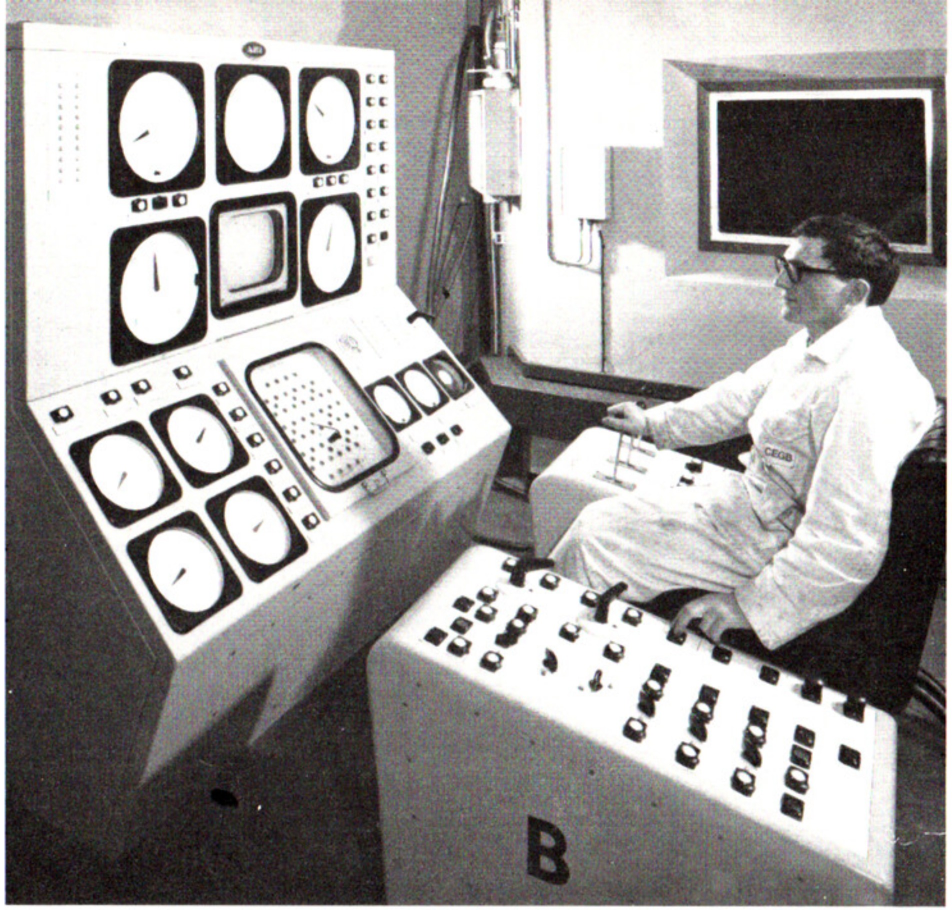
The design of Dungeness Nuclear Power Station follows logically from the experience of building earlier stations at Berkeley and Bradwell and Latina, Italy. It takes into account improvements in technology and an increasing understanding of the particular problems involved. A survey of the cost structure of the early stations indicated most strongly the advantages of an increase in the thermodynamic efficiency to reduce capital costs and running costs, and some increase in reactor gas outlet temperature is available with improved designs of the casings or "cans" which enclose the fuel elements. Further, the revised requirements for limiting the building-up of Wigner energy in the moderator implied a substantial increase in the graphite operating temperature, and the most certain way of meeting these requirements was to increase the gas temperature at the inlet to the reactor. The way was clear therefore to a significant improvement in the thermodynamic cycle by increasing the general temperature level of the source of heat. However, the reduced gas temperature rise over the reactor would have led to a large gas mass flow, and in turn to excessive blower power unless the density of the gas had been correspondingly increased.

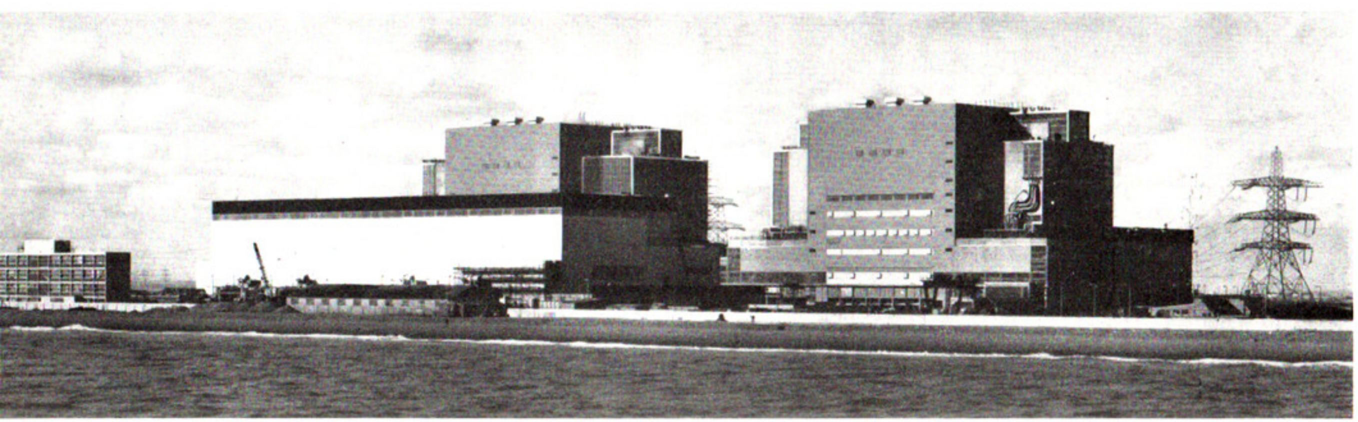
The increase in gas pressure was made possible by the use of four inch plate (4.5 inch thick support course) for the pressure vessel and a reduction in the vessel diameter by better utilisation of the space within it. The full potential of the heat source is utilised by the introduction of blowers incorporating back pressure turbine drive and reheat of the exhaust pressure steam. In this cycle 60 per cent of the steam is generated at high pressure (1418 pounds per square inch) also and used to drive the blowers; it is then returned to the boilers at 615 pounds per square inch for reheating to 392 degrees centigrade, mixing with the low pressure steam, and transmission to the main turbines. By this means the full advantages of the two pressure cycles are retained, the steam conditions at the main turbine stop-valve being as favourable as possible within the limitations of the Magnox (magnesium alloy) clad fuel element, and the thermodynamic benefits of reheat being obtained without the disadvantage of transporting the steam to and from the main turbines and the boilers.

The estimated design efficiency of 32.7 per cent indicates how significant the benefits are, both in reducing the running costs of the station, and also in reducing the capital cost by decreasing the reactor heat required, and thus the size of the reactor.


SCHEMATIC DIAGRAM OF STEAM CYCLE
395°C
391°C
410°C
MAIN TURBO-GENERATOR
2 x 142·5 MW (1 REACTOR)
TO OTHER TURBINES
L.P. DRUM
H.P. DRUM
H.P. CYLINDER
L.P. CYLINDER
GENERATOR
REACTOR
H.P. BOILER
CONDENSER
DEAERATOR
L.P. HEATER
EXTRACTION PUMP
COOLER
EVAPORATOR AND VAPOUR CONDENSER
DEAERATOR EXTRACTION PUMP
H.P. HEATERS
CO_2 CIRCUIT
3 L.P. FEED PUMPS
FROM OTHER TURBINES
3 H.P. PUMPS
BLOWER & TURBINE
180°C
WATER
MAIN STEAM
BLED STEAM
DRAINS

Refuelling machine remote control desk.



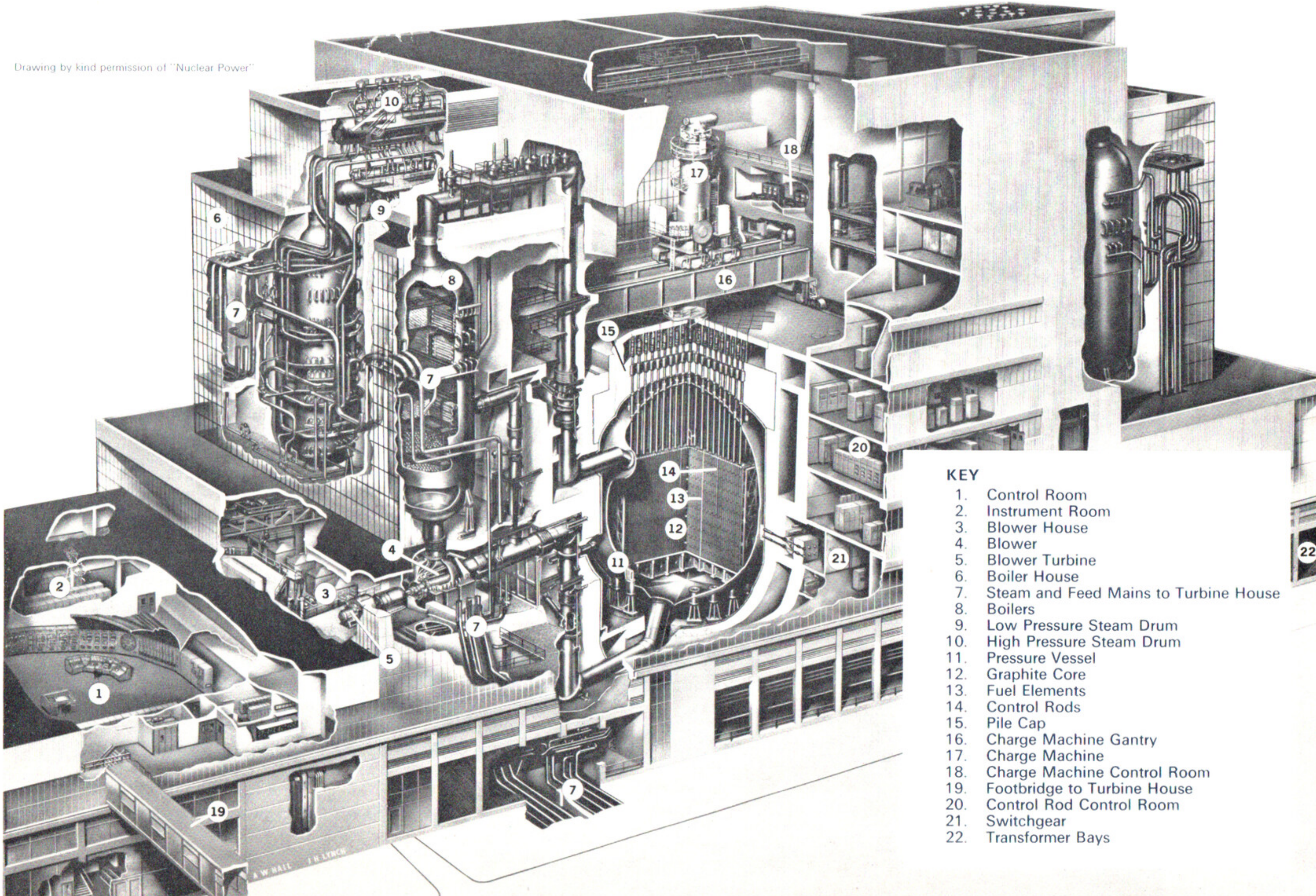


reactor buildings

The graphite core is contained in a spherical steel pressure vessel, supported on columns from the floor and surrounded by the biological shield wall which is circular in plan. The four gas circuits of each reactor are in pairs on opposite sides of the reactor, each pair leading to a boiler house outside the main biological shield. The blower houses are located beneath the boilers. The control face housing the control, monitoring and switchgear equipment is on the south side of the shield, and the fuel handling and storage face is on the north side.
From the reactor the vertical portions of the gas ducts pass into narrow vertical chambers, the walls of which provide secondary shielding. The boilers rest on slabs above the blowers and are fully shielded. For convenience in boiler operation all the main feed and steam valves are located beyond the boiler shielding walls. These walls not only provide shielding for local operation but also reduce the

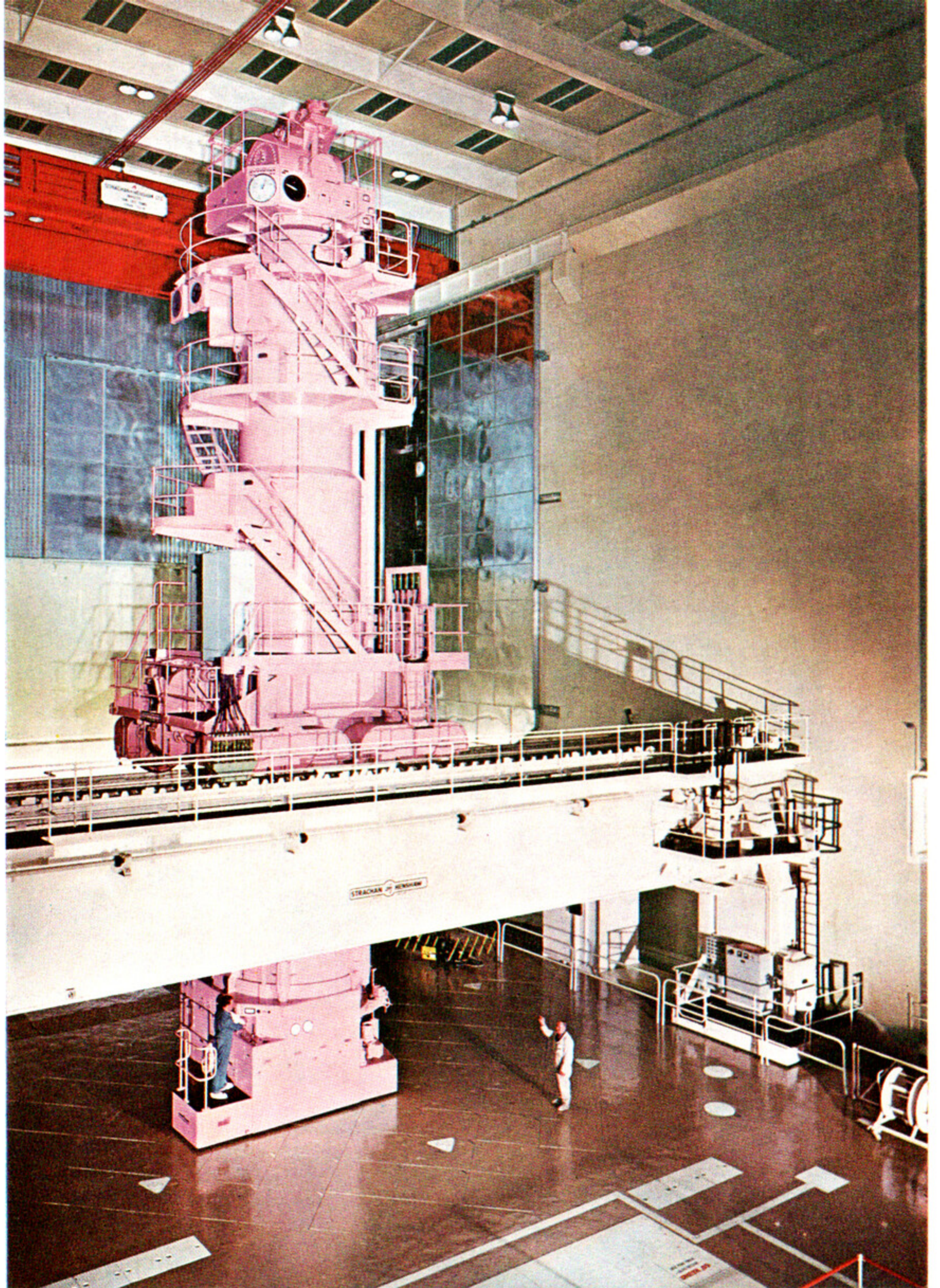
The station from the C.W. intake structure.

Drawing by kind permission of "Nuclear Power"



KEY

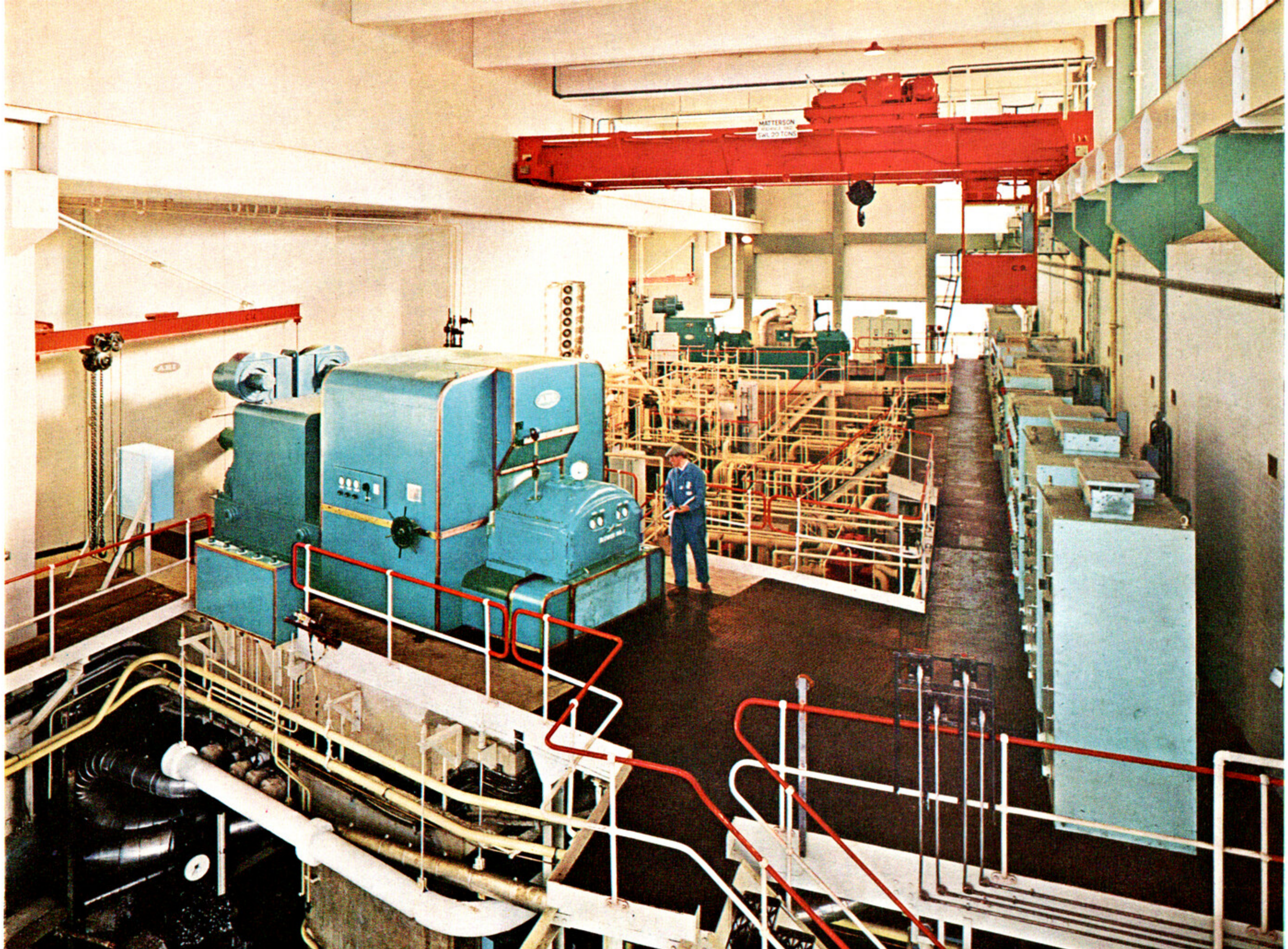
1. Control Room
2. Instrument Room
3. Blower House
4. Blower
5. Blower Turbine
6. Boiler House
7. Steam and Feed Mains to Turbine House
8. Boilers
9. Low Pressure Steam Drum
10. High Pressure Steam Drum
11. Pressure Vessel
12. Graphite Core
13. Fuel Elements
14. Control Rods
15. Pile Cap
16. Charge Machine Gantry
17. Charge Machine
18. Charge Machine Control Room
19. Footbridge to Turbine House
20. Control Rod Control Room
21. Switchgear
22. Transformer Bays



radiation level on the site, and in particular near the control room to a very low level. The boiler drums are mounted in a chamber above and between the boiler shells, shielded from them and from the gas ducts so that access is possible during normal operation.

The biological shield above the reactor is a concrete slab, flat on top and domed beneath. The slab is pierced for the reactor vessel standpipes and carries the pile cap services, and a secondary floor of removable concrete slabs forms the principal working area in the charge hall. The charge hall is straddled by a gantry which carries one of the two fuel charge machines, which change the irradiated fuel for the new fuel whlist the reactor continues to operate at power.

Refuelling machine on gantry over reactor.



Blower Hall.

left:—Reactor core. Assembling graphite blocks.

below:—Stacking fuel boxes in the fuel store.

reactor core

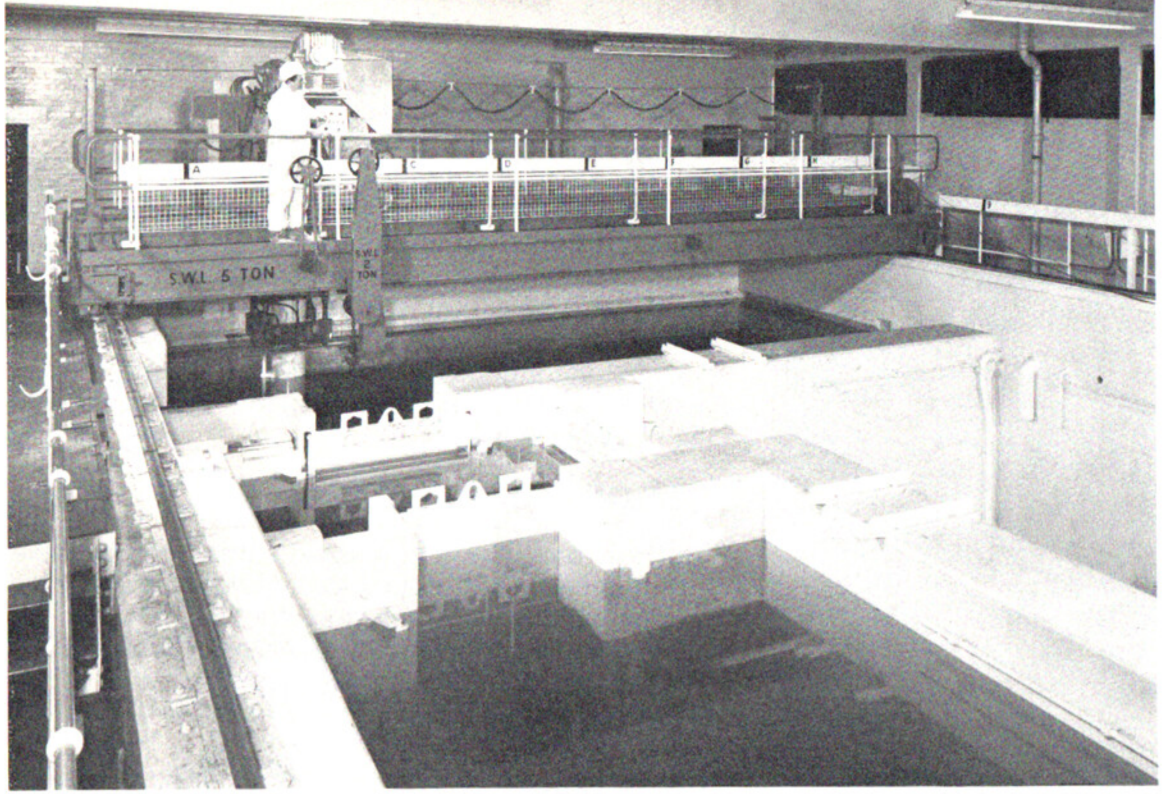
The reactor core is a 24 sided prism built up with graphite bricks of two types, one square in section and the other octagonal. Keys in keyways running the length of the bricks maintain the pattern while permitting thermal expansion growth and shrinkage of the graphite.

The core is pierced by 3,932 channels in each of which are stacked seven fuel elements. Intersitial channels are provided for absorbers, control rods, flux scanning facilities, graphite samples, and neutron sources. The fuel element is a solid natural uranium rod, encased as previously mentioned in a Magnox (magnesium alloy) can with a heat transfer surface of herringbone pattern fins.

pressure circuit

The reactor vessel is a sphere of 62.5 feet (19.06m) mean diameter constructed of steel plates having a general thickness of four inches (101.6mm). The vessel is supported on external rocking columns which transmit the weight of the core and the vessel to the ground through steel grillages embedded in the concrete. The plate thickness of this support course is 4.5 inches. Inside the vessel a cantilevered diagrid has been used with rocking supports which are contained within its own depth in order that the maximum possible size of core can be accommodated in the sphere.

The gas ducts linking the reactor, boiler and blowers are 6.5 feet (2.01m) in diameter, thermal expansion linking the reactor, boiler and blowers being taken up by restrained flexible bellows. Quick-acting butterfly valves are used to isolate each circuit from the reactor, and to bring a boiler gradually on to load. The duct circuits are stepped through the biological



COLOUR

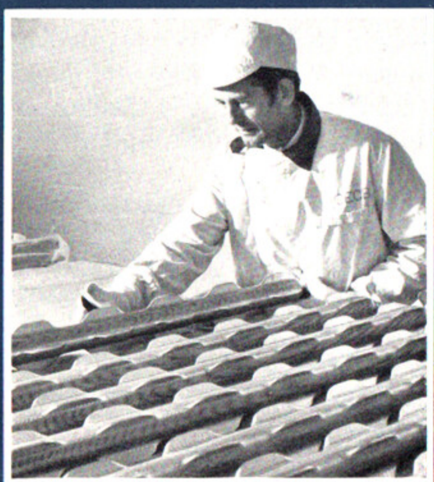
below:—Railhead. Flask handling crane.

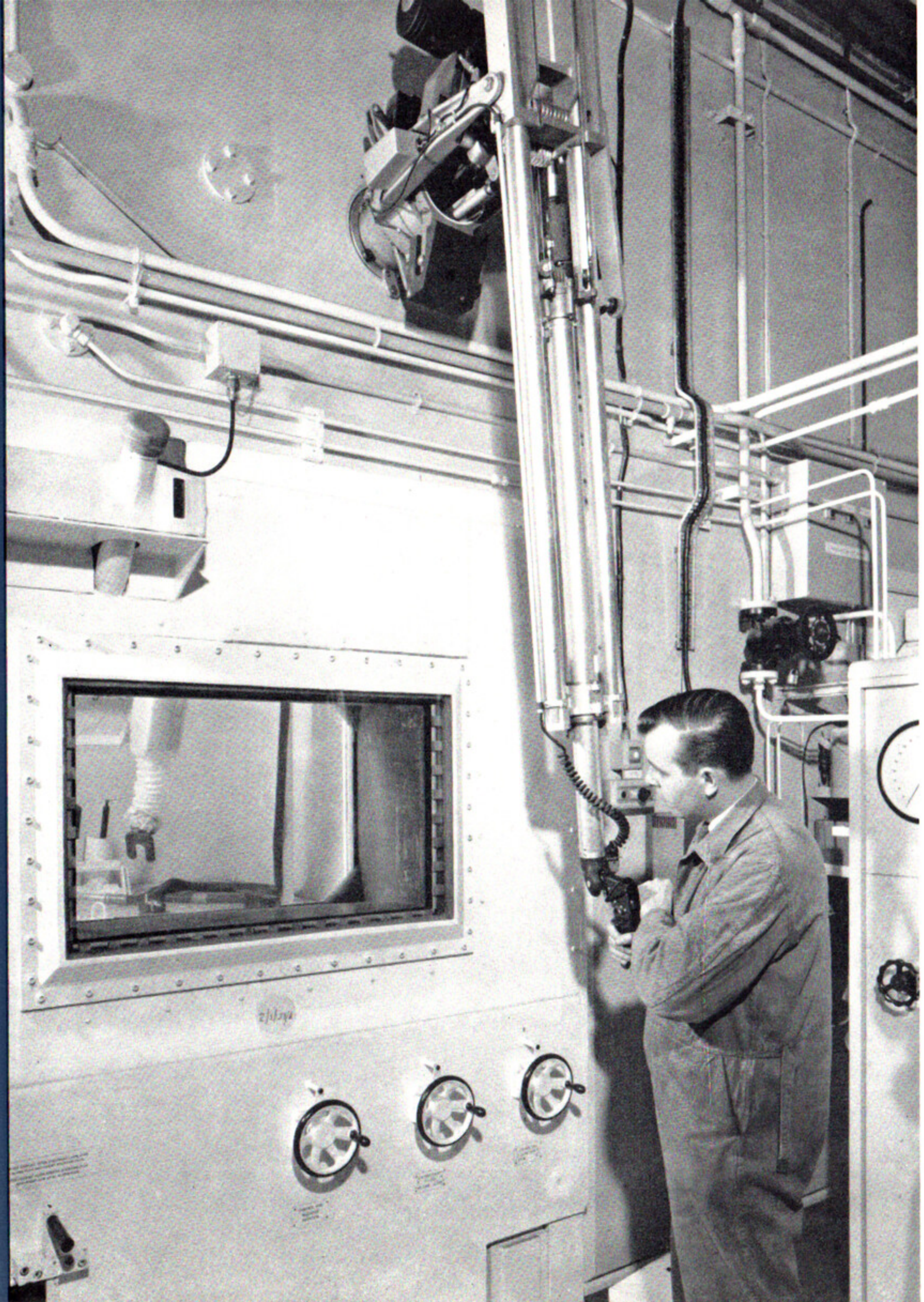
BLACK & WHITE

left:—Irradiated fuel cooling pond.

below left:—Inspection of fuel elements.

centre:—Loading new fuel magazine.





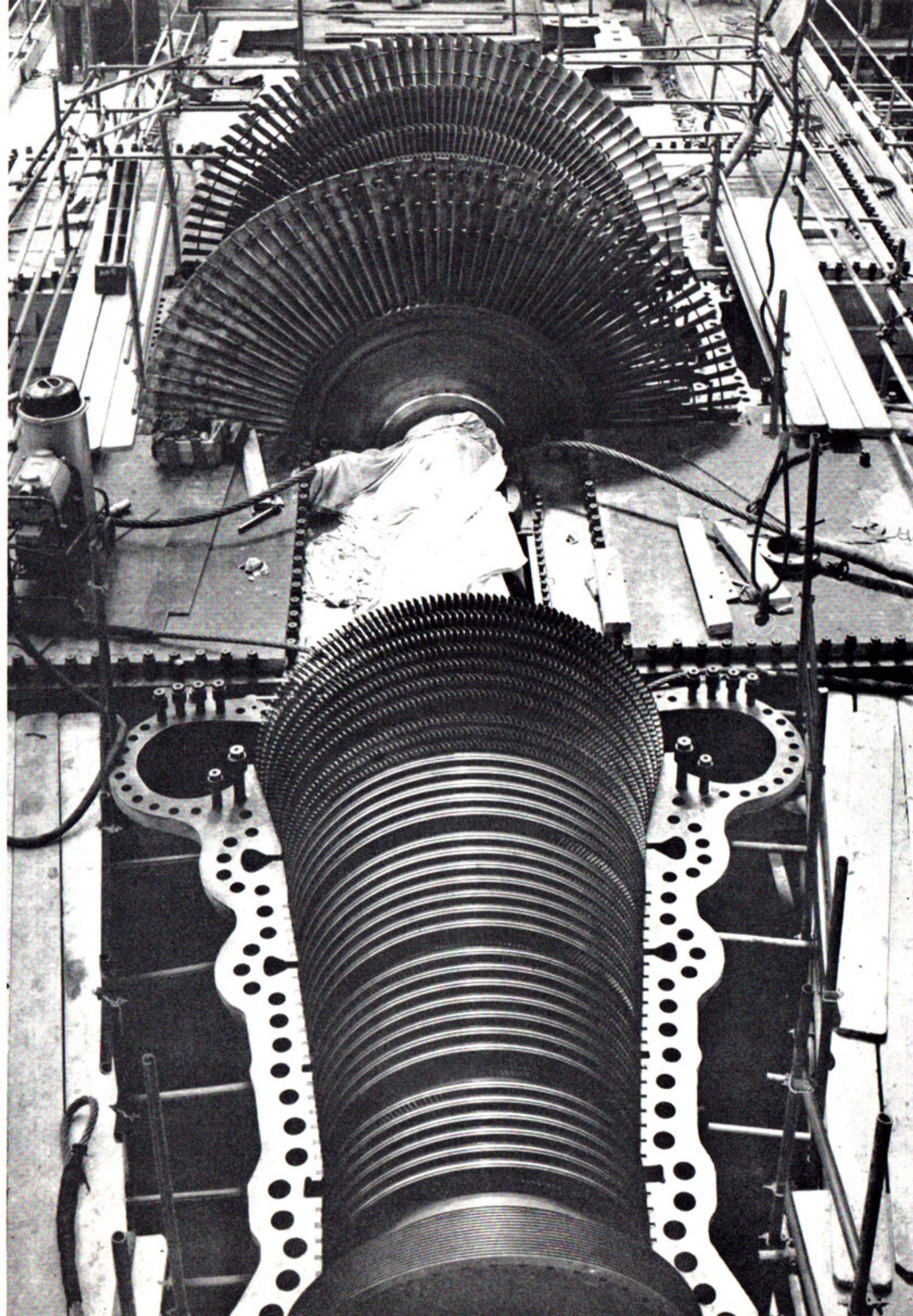
shield to reduce the effects of radiation streaming through the apertures.
Each boiler is a vertical pressure vessel forming part of the CO_2 gas circuit and fitted with horizontal banks of finned tubing to provide good gas to tube heat transfer. The banks are arranged in the conventional pattern of economiser, evaporator and superheater, the natural circulation steam-water flow being induced by the steam drums located high above the boiler and offers greater reliability and simplicity of operation.

steam pressures

Steam is raised at two pressures, the high pressure steam being used to drive the blower back pressure turbine before being returned to the boiler for reheating and mixing with the low pressure steam flow. The reheater bank is in parallel with the low and high pressure steam superheater banks at the top of the boiler.
The blowers are located beneath the boilers and are of single stage axial-flow design with an overhung impeller. Each blower has a spherical fabricated pressure casing and is connected to the underside of the boiler by a short length of duct and an unrestrained bellows unit. Unbalanced gas loads on the blower casing are avoided by using a closed duct and bellows unit connected to the underside of the casing, and bearing on the blower house foundations.
While turbine drive has been adopted primarily to suit the steam cycle it also reduces costs with the very large unit blowing power which could not be handled economically by electric motor drives. An electrically driven pony motor is solidly connected to each blower shaft to provide a drive of 20 per cent speed at full circuit pressure and 40 per cent speed at atmospheric pressure.

No. 1 maintenance cell on No. 1 reactor.

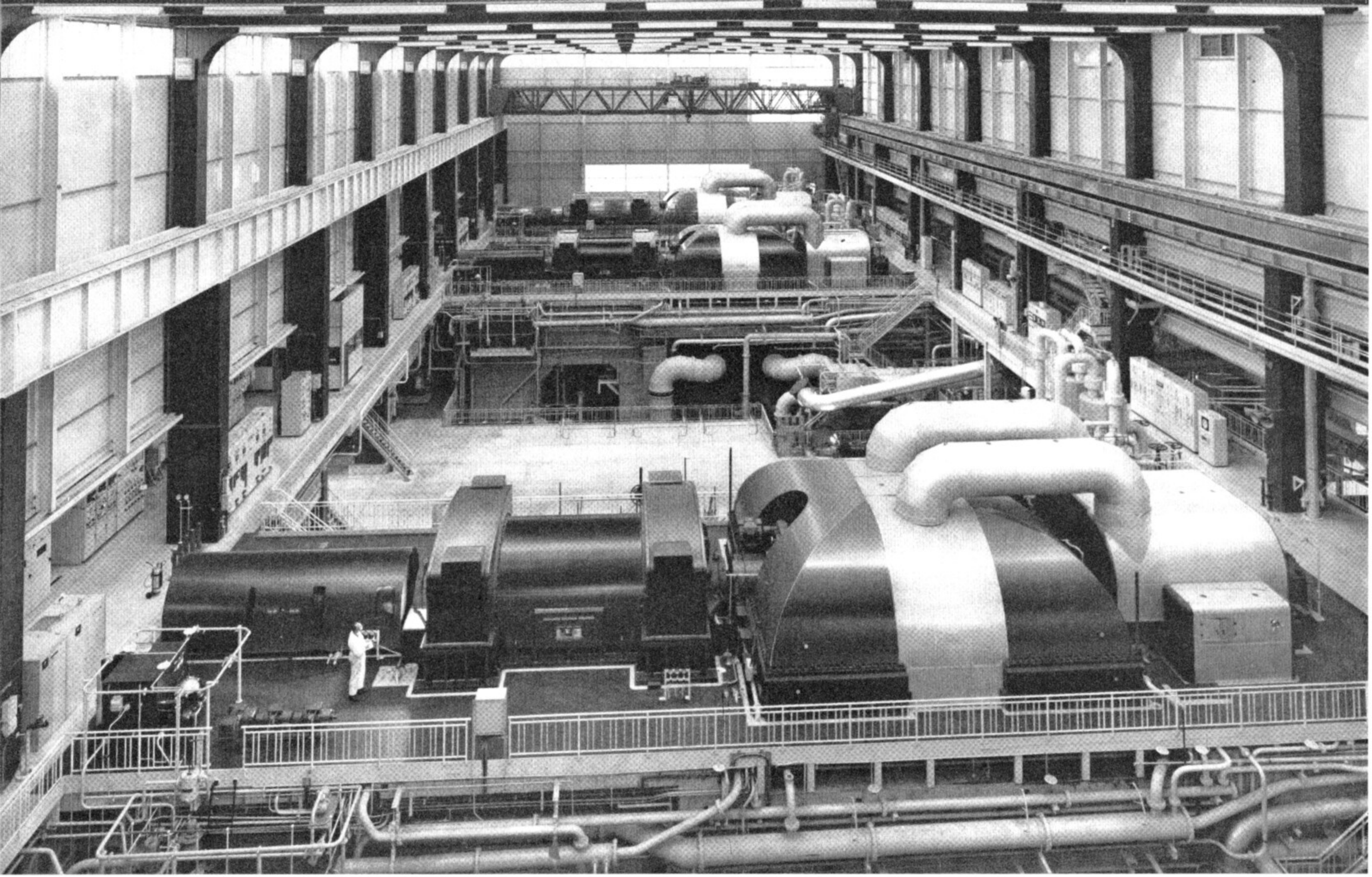
No. 1 turbo-generator set under construction.



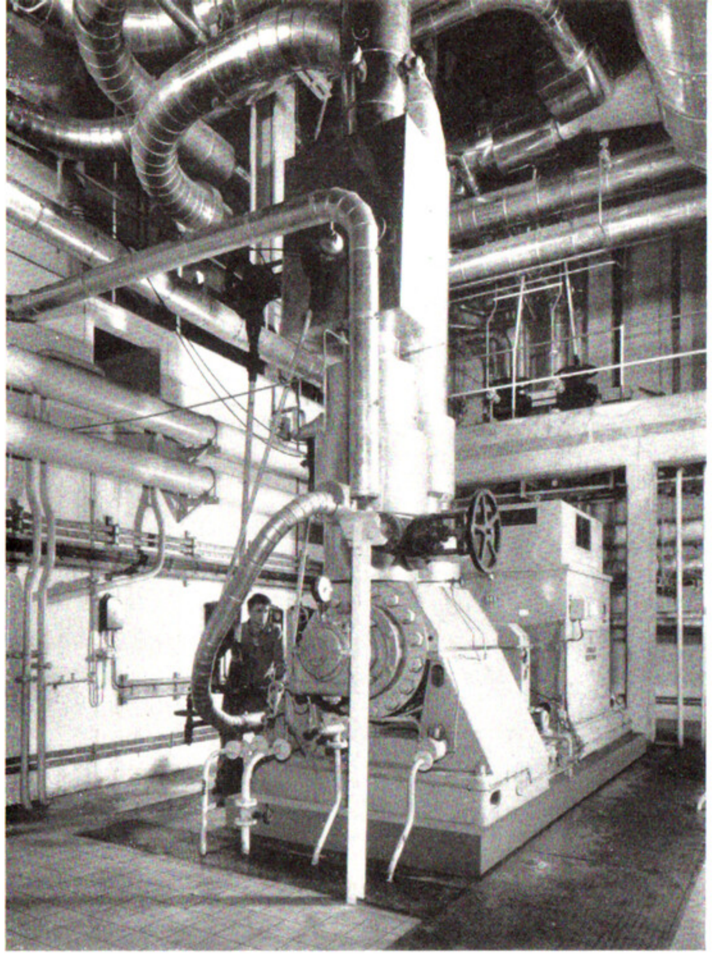
generating plant

The turbine hall has one main bay for the turbo-generators, a steam annexe on the side nearest the reactors, and an electrical annexe on the other side. The four turbo-generators are arranged at 70-feet (21.3m) centres across the main hall. In the steam annexe are the main steam and feed pipes and valves, and boiler feed pumps. The reserve feed and surge tanks are mounted on the annexe roof. The steam mains from each reactor pass through separate tunnels into the annexe where they are interconnected and linked by T joints to the turbines and feed pumps.

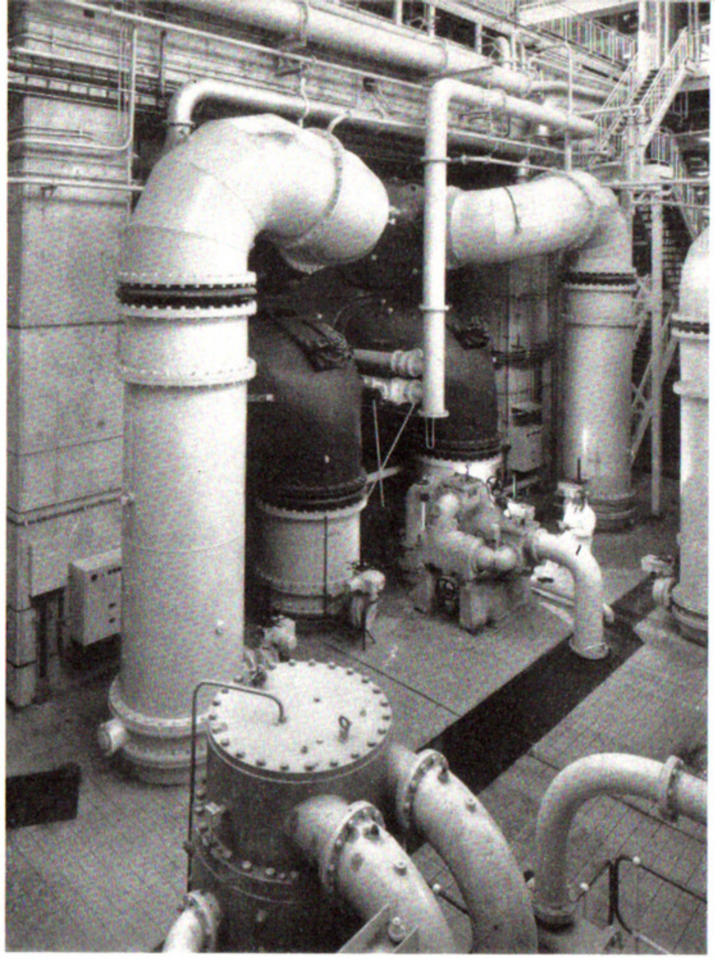
The turbo-generators are rated at 142.5 megawatts and run at 1,500 r.p.m. Each machine has two cylinders with double flow low pressure sections exhausting into a single condenser. The condensers are of the double pass type, two condensers being fed from one of the two inlet culverts, and discharging into one of the two outlet culverts, the other two condensers being served by the other inlet and outlet culverts. The high pressure, low pressure and



Turbine Hall.



Boiler Feed Pump annexe.

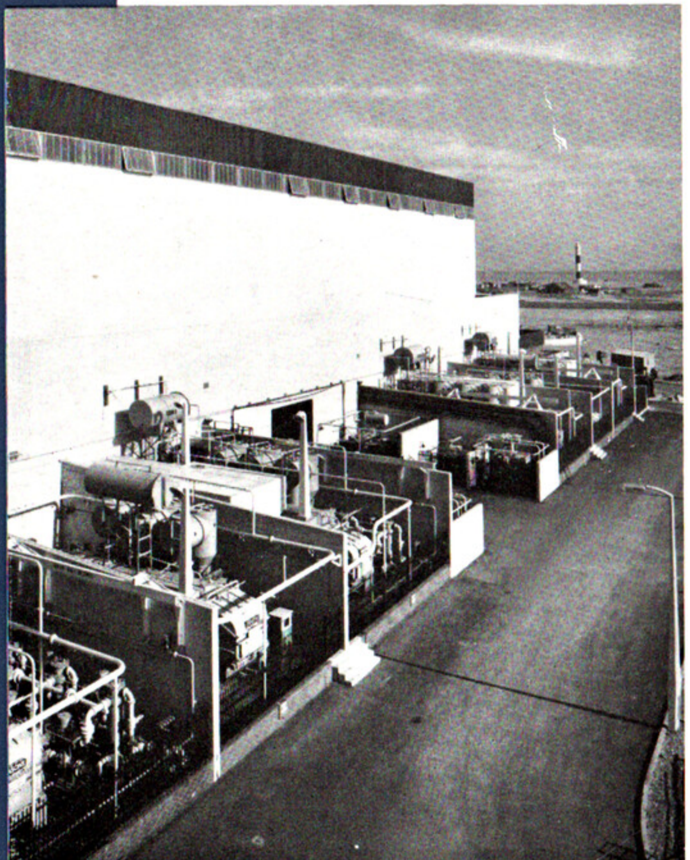


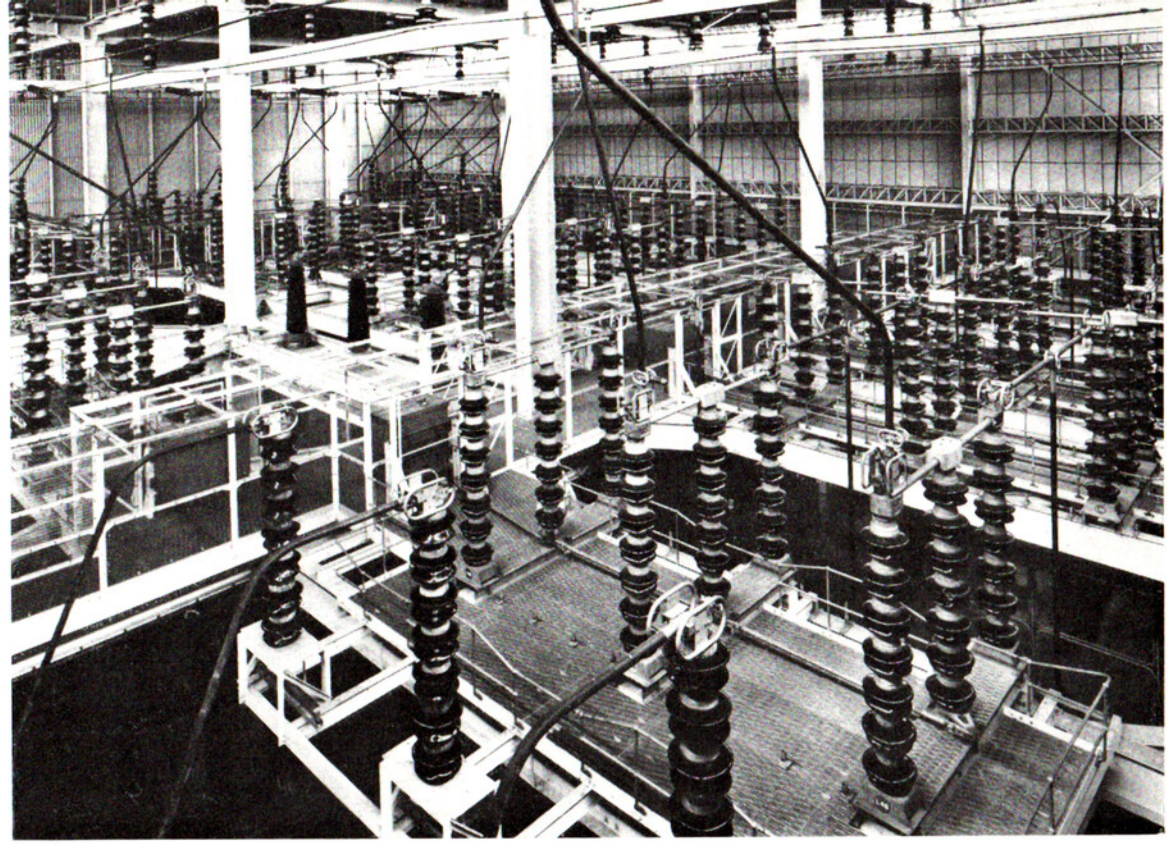
C.W. Pipe connections to a main condenser.

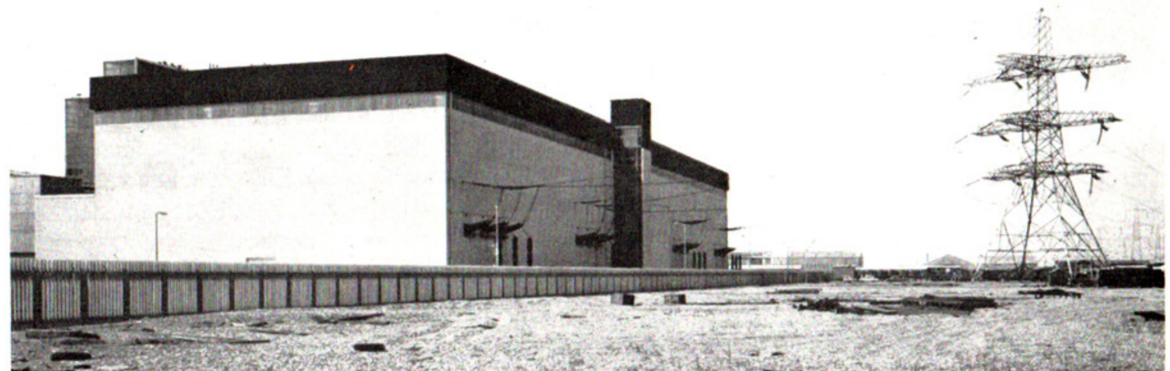
electrical rotors are solidly coupled and a single thrust bearing is located at the governor end of the high pressure cylinder. The high pressure cylinder is bolted solidly to the low pressure cylinder which is anchored about its H.P. end exhaust branch. The governor end of the high pressure cylinder is free to slide in order to take up expansion.

The generators are cooled by hydrogen at 30 pounds per square inch gauge (3.04 atm.abs). They generate at 13.8kV and are solidly connected to 165 MVA, 13.8/295kV transformers mounted in a generator transformer compound abutting the south wall of the turbine house. The exciters are directly coupled to the main generator shafts.

Electrical output from the generator transformers at 275,000 volts is taken via compression cables located inside nitrogen gas filled steel pipes through an underground tunnel to the main switch house, from which connections are made to grid lines, one to Bolney and one to Canterbury and Northfleet.







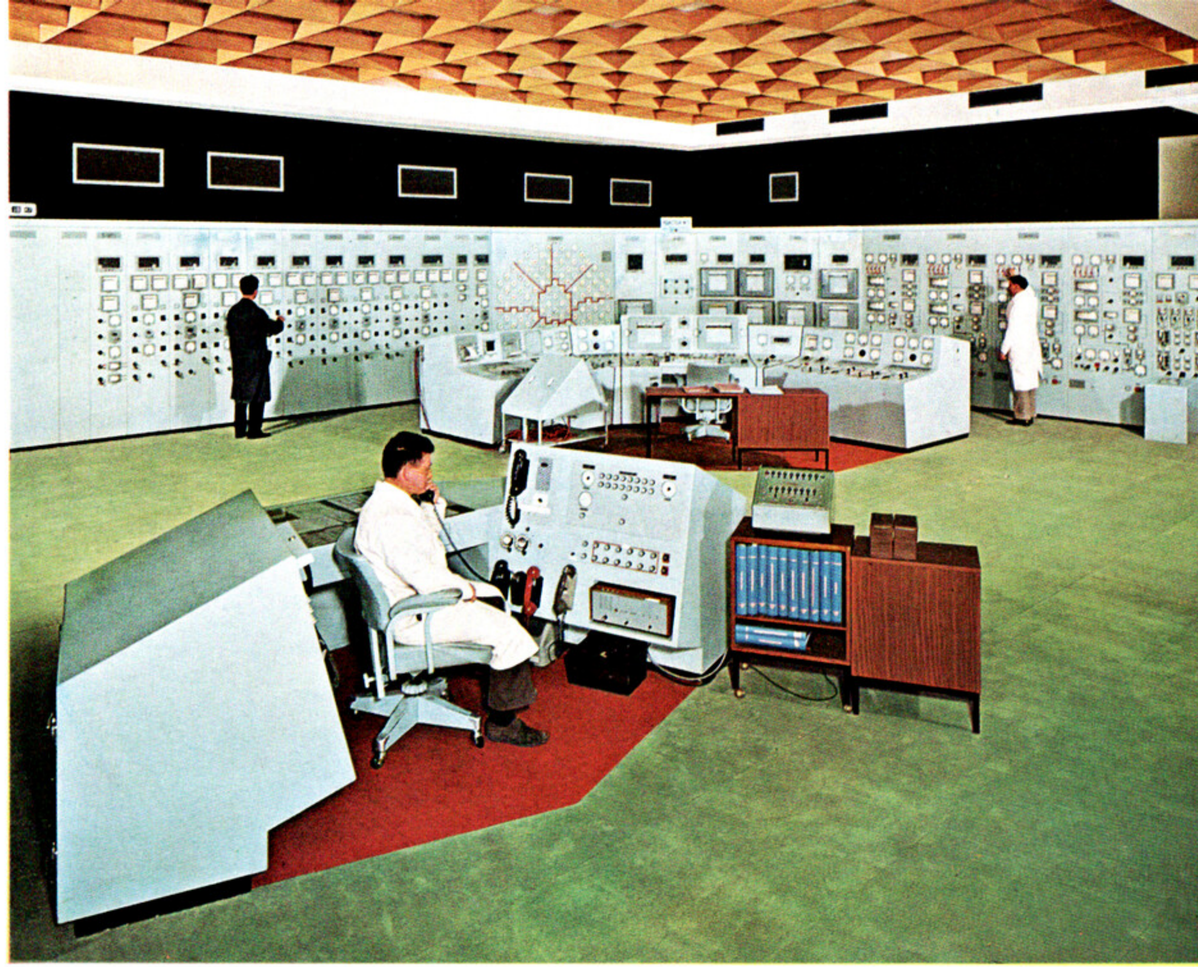
above:—Transformer Bays.

top right:—The Switchhouse interior.

right:—The Switchhouse and the Grid lines.

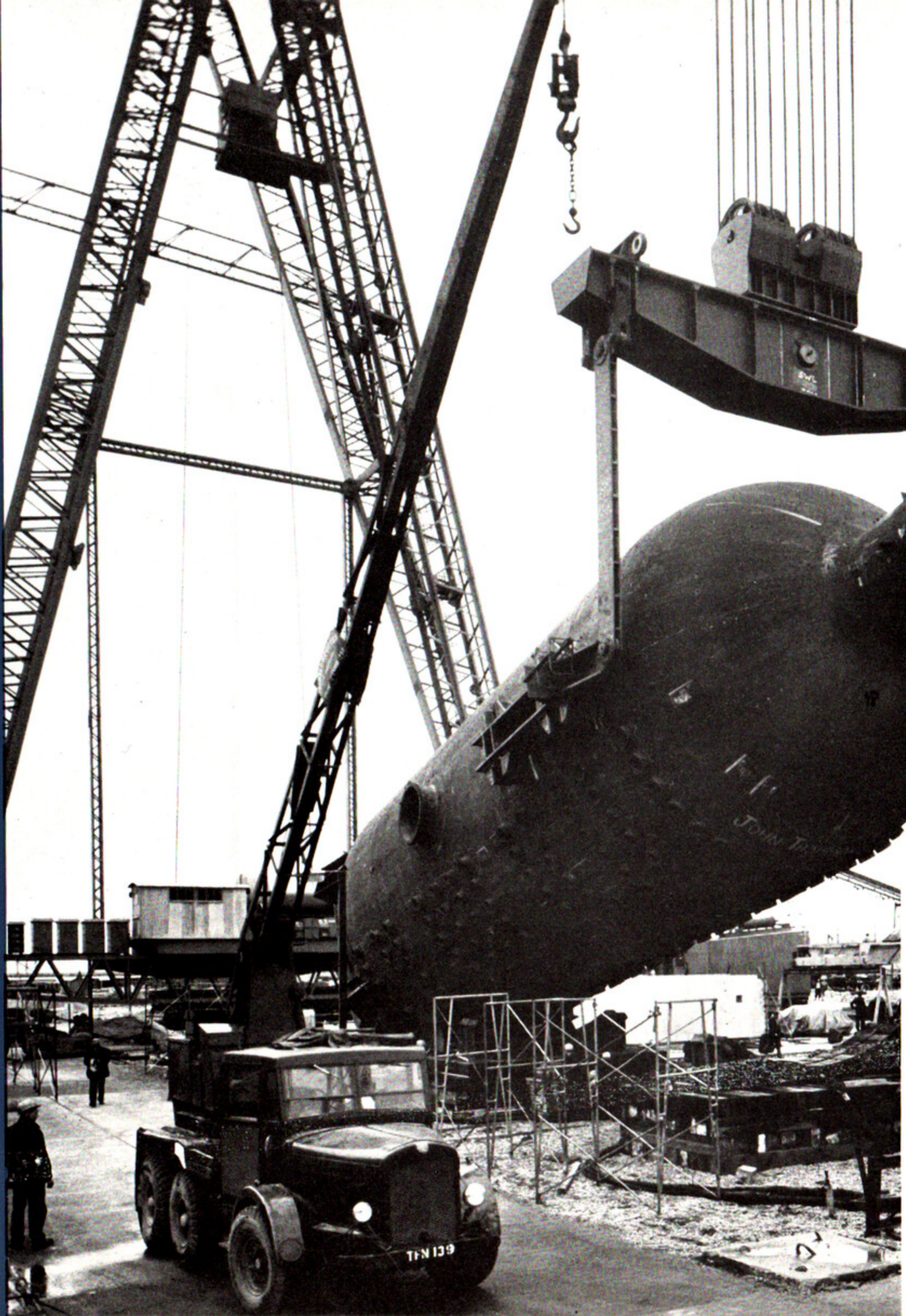
control

The control block—located between the two reactors—houses the control room proper, a cable flat below it, and below this the central change room.
The control room contains all indications and controls necessary for the normal and emergency control of both reactors and the turbo-generating plant. Adjacent to the main control room are rooms housing telecommunications, metering, data processing and automatic control equipment.
Under normal automatic control the reactor power is automatically adjusted to meet the demand of the turbo-generators. Thus deliberate power changes are made by adjustment of the turbo-generators as in conventional stations and changes due to frequency variations of the grid system are met automatically. Manual control is provided for starting and emergency use.
Core reactivity is controlled by the movement of 120 control rods. Certain rods can act independently of one another to maintain a uniform radial flux pattern or together to compensate for a change in load. For example an increased demand for power from the turbo-generator leads to a fall in steam pressure, and then, by operation of the automatic overall control system to an increase in blower speed. This in turn leads to an increase in coolant flow and a decrease in reactor gas outlet temperature. Selected rods then move out together to maintain gas outlet temperatures constant.



Reactor and Electrical Control Room.

Additional to the automatic control system is a comprehensive system of alarm and trip circuits. These circuits ensure that the operators are fully aware of the plant conditions. Should any major fault occur control rods are automatically inserted into the core to shut down the reactor.
The Dungeness station generates electricity economically and safely, with a very high plant availability and load factor and thus makes a substantial contribution to the security and economy of the electricity supply system of Britain and more particularly to that of south-eastern England.



Boiler shell being raised into position.

construction

The Dungeness 'A' Power Station was designed and constructed for the Central Electricity Generating Board by the Nuclear Power Group. The project was engineered by the Board's Southern Project Group, Sir William Halcrow and Partners acting as advisers on civil engineering works.

Consent for the construction of the power station was given by the Minister of Power in July 1959 after a Public Inquiry and work started on the site on 1st August, 1960.

The geological condition of the site consists of a 15-ft layer of coarse shingle which changes to a ballast with a high sand content and finally at about 60-ft. depth it is mostly fine sand.

Because the whole of the Lydd and Dungeness area forms a vast water catchment area with a standing water level of 10 feet below ground level, a de-watering system had to be adopted to allow excavation and foundation work to proceed in the dry. For this purpose a steel sheet piled girdle some 45 feet deep was driven round the perimeter of the main buildings within which 28 wells were sunk 60 feet deep, with 11 wells 135 feet deep in the area of the pumphouse and a further 11 wells 135 feet deep around the syphon recovery chamber. The foundation level was generally 25 feet below ground level. The high ground water level demanded special consideration in the design of structures for dealing with the storage of contaminated materials and this was effected by means of a double skin construction with provision made for the monitoring and treatment of drainage from the interspace.

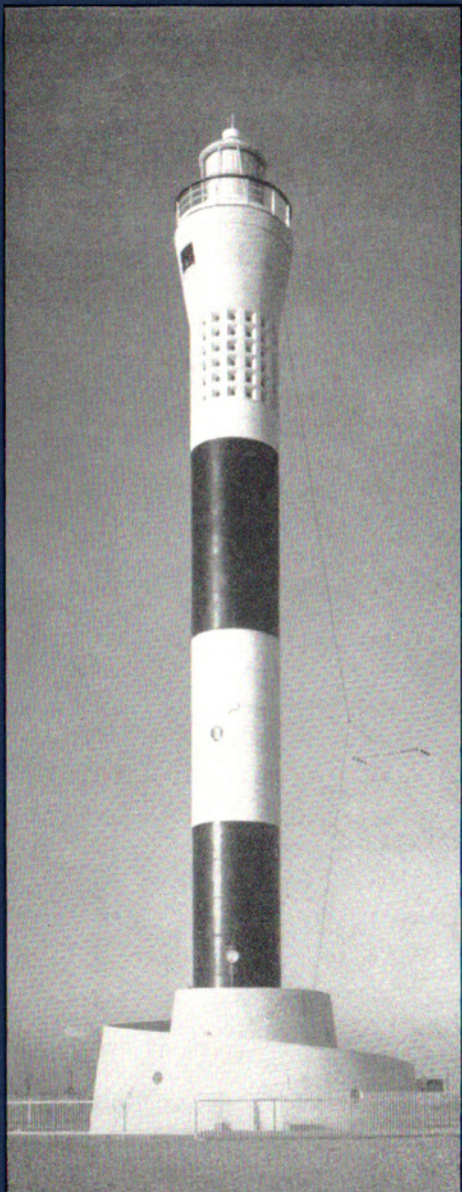
The intake structure for the 14-ft. diameter circulating water tunnel was built in Folkestone Harbour and towed by sea to its permanent position some 1,000 feet off-shore. Once in position, the circulating water tunnel was connected by means of two 10-ft. diameter vertical shafts driven up into the structure to form the intake.

A 400-ton goliath crane was erected to span the width of the reactor buildings and was used for the major lifts up to 370 tons. This enabled each spherical steel pressure vessel to be fabricated in six courses in the construction area west of the station, each course being lifted into the appropriate reactor by the goliath crane. Four of the boiler units were fabricated on site and lifted as complete shells by the goliath crane. The other four boiler shells were floated down from the manufacturer's works by sea and landed on the beach, being similarly lifted into position. At the completion of construction the goliath crane was demolished.

During the construction and commissioning period from August 1960 until December 1965 a large residential camp was provided by The Nuclear Power Group capable of housing some 700 people. All amenities were provided such as—camp shops, cinema and chapel. The maximum labour force during this period was 2,400 personnel.

The generation of power into the Grid in September, 1965 from Reactor 1 and in December, 1965 from Reactor 2 was achieved as a result of close co-operation between the appropriate departments of the Central Electricity Generating Board and The Nuclear Power Group on the design, programming, construction and commissioning of the Station. The responsibility for effecting this co-ordination rested largely with the Southern Project Group.

 The Goliath lifting the lower half of the pressure vessel.



above:—The Romney Hythe and Dymchurch railway still has its terminal near the power station.

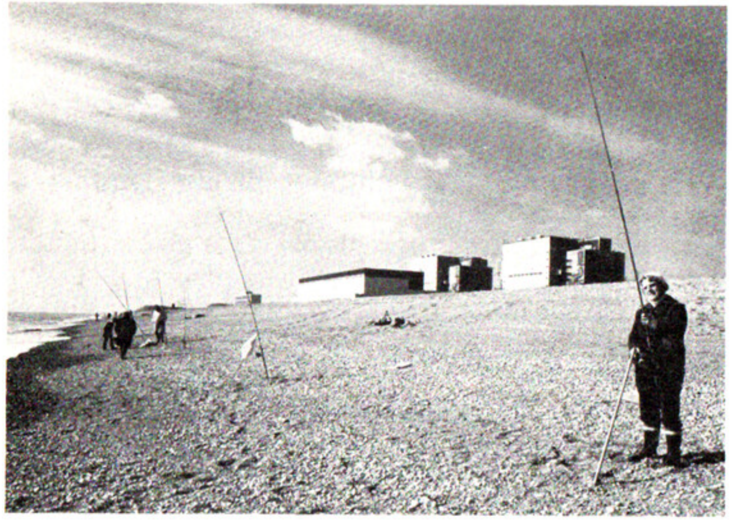
left:—The new Dungeness lighthouse.

right:—17th century silver spoon found during excavation and thought to have come from a ship wrecked on the point.

local interest and amenities

Dungeness is a unique shingle depositional feature and has many unusual mosses, lichens and other plants and also has several rare insect colonies, apart from which it is one of the major crossroads of bird migration routes. The area has considerable interest for naturalists and physiographists and special measures were taken by the Board to minimise any disturbance to the natural life and surface features. In conjunction with the Royal Society for the Protection of Birds, a local warden was appointed to protect these interests and close liaison with the Boards' resident engineer established even before any construction work started.

The existing lighthouse at the point would have been partially obscured by the power station building and as it was due to be automated, a new lighthouse was built by Trinity House, the first new one in England for some 60 years.



The beach in front of the station is popular with anglers.

Interesting insects, mainly moths, are found on the old posts of a fence on the site and many of these have been retained.

COLOUR

Three species of moths typical of the Dungeness environment.

top: Eyed hawk moth, a typical moth of the area.

bottom left:—The white spot moth, unique to Dungeness.

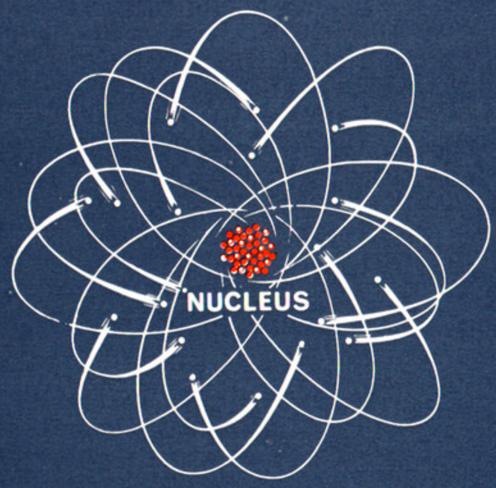
bottom right:—An immigrant species—the silver 'Y'.

Just two of the day-to-day jobs of the Warden at Dungeness.

left:—Storm driven guillemots are cared for until strong enough for release.

right:—Ringing in progress. Birds are trapped, ringed and released to aid the studies of bird migratory habits.

electricity from nuclear energy



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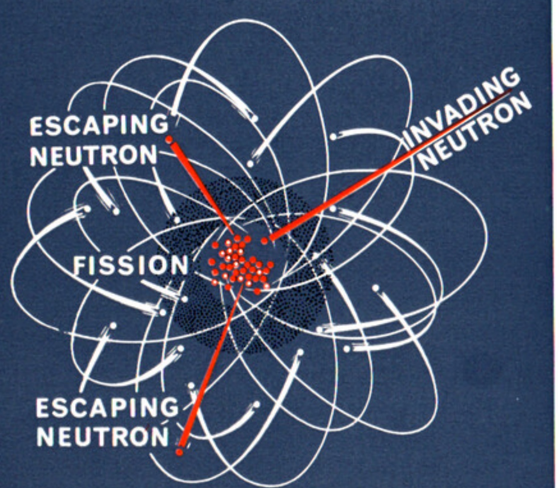
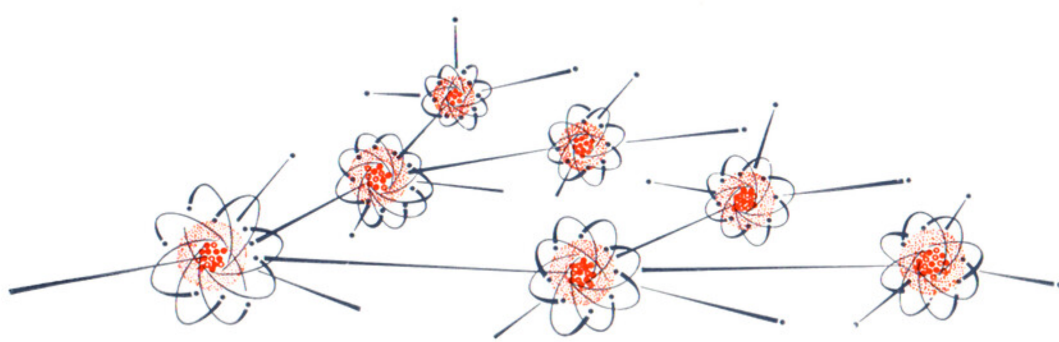


Nearly all of the electricity which the Generating Board produces is generated by turbo-alternators. For these steam is required to drive the turbines.
Nuclear power stations differ from the conventional installations in that, instead of burning coal or oil, the heat from nuclear energy is used to boil 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.
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.

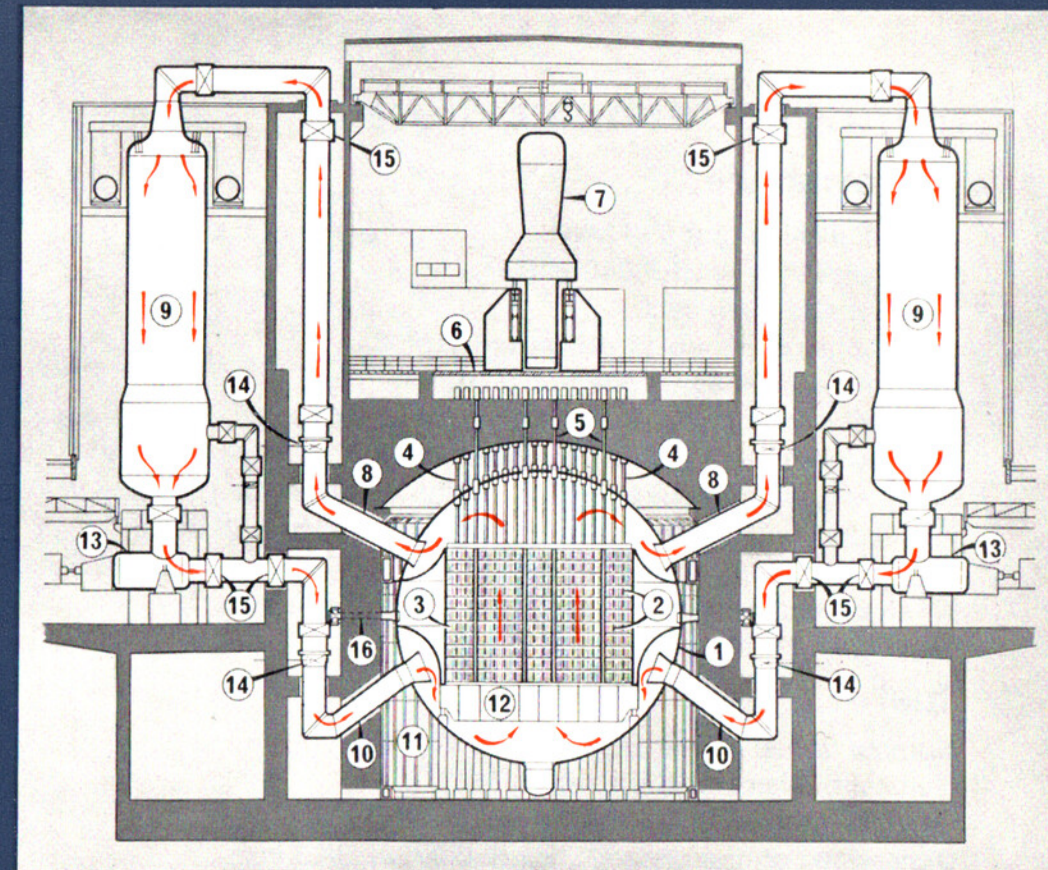
The reason for using natural uranium as a fuel is that it is the only naturally occurring material which can produce a controlled chain reaction. Because of the escape of neutrons from the moderator, this process can only take place in a reactor of a certain minimum size. This is known as the critical 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.

During operation carbon dioxide gas is blown through the moderator holes 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 turbo-alternators.

KEY TO CROSS SECTION THROUGH NUCLEAR REACTOR

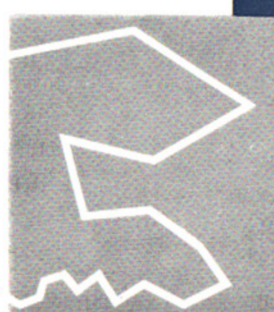
1. Reactor pressure vessel; **2.** Fuel elements; **3.** Graphite—moderator; **4.** Charge tubes; **5.** Control rod standpipes; **6.** Charge floor; **7.** Charge/discharge machine; **8.** Hot gas outlets from reactor; **9.** Boilers (six per reactor); **10.** Cool gas inlets to reactor; **11.** Thermal shield; **12.** Diagrid; **13.** Main circulators; **14.** Gas isolating valves; **15.** Hinged expansion bellows; **16.** Can-failure detection standpipes.

Note:—Arrows show the flow of Carbon dioxide through reactor and boilers.



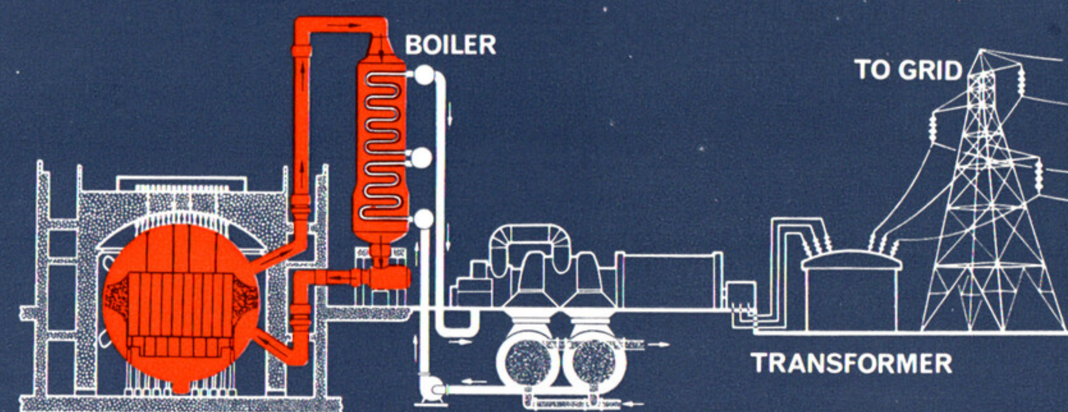
Neutrons emerge from fissioning uranium nuclei at a speed of 10,000 miles a second, at this rate their chances of hitting another nucleus are diminished, but if we can reduce the speed to about 1 mile a second the possibility is 10,000 times improved. When we imprison the uranium fuel rods in graphite, 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.

FAST NEUTRON



SLOW NEUTRON

CARBON ATOMS



abridged technical data

performance

Net electrical output 550 MW
Heat output per reactor 840 MW
Efficiency 32.8 per cent
Reactor gas bulk outlet temperature 410 °C.
Reactor gas inlet temperature 250 °C.
Nominal maximum can surface temperature 442 °C.
Nominal maximum uranium temperature 572 °C.
HP steam pressure at Blower Turbine Stop Valve 96 atm. 1410 p.s.i.a.
HP steam temperature at Blower Turbine Stop Valve 392 °C.
LP steam pressure at main Turbine Stop Valve 37.4 atm. 550 p.s.i.a.
LP steam temperature at main Turbine Stop Valve 391 °C.
Feedwater temperature 180 °C.

fuel

Number of fuel elements per reactor 27,515
Number of elements per channel 7
Overall length of fuel element 1.097m. 43.2 ins.
Dimensions of uranium rod: length 0.973m. 38.3 ins.
Dimensions of uranium rod: diameter 27.9mm. 1.1 ins.
Total weight of uranium per reactor 304×10^3 kg. 298.4 tons

gas circuit

Mean diameter of reactor vessel 19.05m. 62.5 ft.
Reactor vessel general thickness 101.6mm. in4 s.
Gas working pressure 19.25 atm. 283 p.s.i.a.
Number of gas circuits per reactor 4
Diameter of gas ducts 1.98m. 6.5 ft.
Power input per blower 7.00 MW
Overall height of boilers 22.86 m. 79 ft. 3 ins.
Internal diameter of boilers 7.16m. 23.5 ft.
Shell thickness (graded) 444.5 to 984.0 mm. 1.75 ins. to 3.875 ins.

turbo-alternators

Number of main turbo-alternators 4
Continuous maximum rating per set 142.5 MW
Speed 1500 r.p.m.
Generator voltage 13.8 kV
Vacuum 735 mm., Hg. 28.9 ins. Hg.
Exhaust wetness 14.3 per cent
Total circulating cooling water quantity 26.7×10^3 kg/sec. 21.3×10^6 gal/hour.

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