Nuclear power stations in Great Britain

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VI 1

Nuclear Power Stations in Great Britain

Les centrales nucléaires en Grande-Bretagne

Atomkraftwerke in Großbritannien

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Government Programme

The 1953 Government White Paper described plans for the construction of nuclear power stations to develop 1500—2000 MW of electricity by 1965. The White Paper suggested that the programme was provisional and would be altered in many ways in the course of time and that new technical developments might perhaps lead to a more rapid improvement in the performance of stations than had been assumed. That this condition was wise is shown by the changes in output and in the programme during the last few years.

The first important change has been in the output of individual nuclear power stations. The White Paper made a conservative forecast that the output of a two reactor power station might increase from the 70 MW of Calder Hall to between 100 and 200 MW. This forecast has been overtaken by the design outputs of 275, 300 and 500 MW from the Berkeley, Bradwell, Hunterston and Hinkley Point power station. Aided by this, the overall programme has been increased and 5,000—6,000 MW are now to be installed by 1966.

The increase in output over Calder Hall has been achieved by straightforward engineering development. First by an increase in the size of the reactor and a corresponding increase in the amount of uranium fuel. Second by an approximate doubling of the amount of heat extracted from each ton of uranium. This increase in rating has been achieved by increasing the fuel element surface temperature from 410° C to about 425° C; by a 50 percent increase of the pressure of the carbon dioxide heat transfer gas and by improvements to the heat transfer surface. The overall result of this has been progressively to decrease capital costs per kilowatt.

Table 1. Industrial Power Stations in Great Britain
(Natural Uranium, Graphite-Moderated, CO_2-Cooled)

A. General Data						
1. Location		Calder Hall Cumberland Chapel Cross Scotland	Berkeley Gloucestershire	Hunterston South Scotland	Bradwell Essex	Hinkley Point Somerset
2. Authority or Consortium responsible for design and construction		U.K. Atomic Energy Authority	Assoc. Electr. Indust. John Thompson	General Electric Simon Carves	Nuclear Power Plant Co.	English Electric Co., Babcock & Wilcox Taylor Woodrow
3. Completion of first reactor		May 1956	Mid 1960	Early 1961	Mid 1960	Mid 1961
4. Electrical output (total from 2 reactors)	MW	184 (4 reactors)	275	300	300	500
5. Heat output per reactor	MW	200	550	535	530	980
B. Fuel						
6. Diameter of element	in.	1.15	1.10	1.15	1.15	1.10—1.15
7. Length of element	in.	40	19.2	24	36	36
8. Number of elements per channel	—	6	13	10	8	8
9. Diameter of channels	in.	3.61—4.16		4.0		3.85
10. Number of channels	—	1696	3275	3288	2575	4500
11. Weight per reactor	tonnes	130	250	251	240	370
C. Canning						
12. Material	—	Magnox C	*Magnesium alloy Magnox A 12*			

13. Construction	—	extended surface, single-start helical		straight extruded fins	machined or extruded surfaces	30-start helical extruded fins
14. Wall thickness	in.	0.072		0.08		0.075
15. Maximum can temperature	deg. C.	408	425	454	450	430
16. Support of fuel elements	—	stacked	graphite struts with zirconium end brackets	graphite sleeves loaded with cartridge	stacked	stacked
D. Moderator						
17. Net size of moderator	ft. dia. × height	31 × 21	42 × 24	44.5 × 23	40 × 25.67	49 × 25
18. Overall size, including reflector	ft. dia. × height	36 × 27	48 × 30	50.5 × 28	45 × 31	53 × 29
19. Total weight	tonnes	1146	2134	2180	1910	2032
E. Nuclear Data						
20. Lattice, square pitch	in.	8.0	8.16	8.25	8.0	7.75
21. Maximum thermal neutron flux	$n/cm^2/sec$			2×10^{13}	2.76×10^{13}	2.5×10^{13}
22. Conversion factor	—			0.80	0.85	0.85
23. Excess reactivity in cold, unpoisoned state	percent	4.5	4.0	4.5	4.9	4.2
24. Specified minimum burn-up of fuel	MWD/tonne	3000	3000	3000	3000	3000
25. Mean fuel rating	MW/tonne	1.4		2.16		2.60
26. Central channel rating	kW	100	214	201	236	258
27. Number of control channels per reactor	—	112	150	208	120	132
28. Diameter of control channels	in.	3.25		3.5		3.2

Table I (cont.)

		Calder Hall	Berkeley	Hunterston	Bradwell	Hinkley Point
F. Pressure Vessel						
29. Type of steel	—	Lowtem. Al-kill. mild steel	Si-killed mild steel	Coltuf 28	Low alloy steel	28/32 Si-killed boiler quality mild steel
30. Shape	—	Cylinder	Cylinder	Sphere	Sphere	Sphere
31. Dimensions	ft. dia. (× height)	37 × 70	50 × 80	70	66.75	67
32. Wall thickness	in.	2	3	2.88—3	3	3
33. Charged from	—	top	top	bottom	top	top
34. Supported by		A-frames	18 A-frames	Continuous skirt	24 rocking columns	Continuous skirt 30 ft. dia.
G. Coolant						
36. Mass flow	lb./sec	1964	6200	5640	5260	10,300
37. Gas pressure	p. s. i. g.	100	125	150	132	185
38. Inlet temperature	deg. C	140	160	204	180	180
39. Outlet temperature	deg. C	336	345	391	390	375
40. Number of inlet and outlet ducts	—	4	8	8	6	6
41. Diameter of ducts	ft.	4.5	5	5	5	6.5
H. Circulators						
42. Type	—	Centrifugal variable frequency induction motors	Single-stage axial a.c. induction motors	Vertical shaft centrifugal d.c. motors fed by	Single-stage axial variable-frequency induc-	Single-stage axial squirrel-cage motors from
43. Control	—	Ward-Leonard type speed control	Scoop-control fluid coupling	grid-controlled rectifiers	tion motors fed from turbo-generator	turbo-alternator
44. Speed	r. p. m.		580/2900	200/1000	600/3300	750/3000

45. Control-rod drive	—	Synchronous motor and winch, 20 : 1 gearing	Variable-frequency induction motors	Variable-frequency induction motors	Variable-frequency induction motors	Variable-frequency synchronous motors
46. Power	MW	5.44	19.04	14.08	15.18	31.26
I. Heat Exchangers						
47. Number per reactor		4	8	8	6	6
48. Dimensions	ft. dia. × height	17.25 × 77.33	17.5 × 70	20 × 73.5	19 × 82	21.5 × 90
49. H. P. steam temperature	deg. F	637	612	700	700	685
50. H. P. steam pressure	p. s. i. a.	210	320	590	765	650
51. L. P. steam temperature	deg. F	350	612	570	700	660
52. L. P. steam pressure	p. s. i. a.	63	77	160	210	180
J. Turbo-Alternators						
53. Number per reactor	—	4	4	6	6 + 3 auxiliaries	6 + 3 auxiliaries
54. Individual rating	MW	23	85	60	52 and 20.5	93.5 and 33
K. Shielding						
55. Biological concrete shield, thickness	ft.	7—8	8.5—10.5	9—10.5	9—10	7—9
56. Thermal steel shield, thickness	in.	6	Two 1/2″ plates and 1 1/2″ air gap	None	1/4″ sheeting and air gap	9″ concrete
57. Total weight on foundations, per reactor	ton	33,000	55,000	44,700	76,600	88,000

Whilst these designs have been proceeding there has been a substantial development of our technological knowledge although in a rapidly developing field such as this, design has inevitably anticipated technology.

The First Series of Civil Power Stations

Table 1 gives a summary survey of the main technical data of the Calder Hall prototype and the four civil power stations forming the first series of the U.K. programme: Berkeley, Bradwell, Hunterston and Hinkley Point.

All these stations use natural uranium for fuel, graphite as moderator, and CO_2 as coolant. Each station has two reactors of equal power. The fuel rods are of $1^1/_2$ in. dia. positioned at a square lattice of 8 in. on an average. The canning material is a magnesium alloy, Magnox A 12; its wall thickness is approximately 2 mm. The maximum thermal neutron flux is about 2.5×10^{13} n/cm²/sec. The minimum burn-up of fuel is specified as 3000 MW-days/tonne. The steel used for the pressure vessel is of mild or low alloy steel quality; the maximum thickness of plate used is 3 in. and all plates are welded. The supports of the pressure vessel allow for slight movements in order to minimise thermal stresses. The number of heat exchangers per reactor is six or eight; and that of the turbo-alternators six or four. The thickness of the concrete biological shield varies between 7 and 10 ft. according to location. Thermal shields are of various types.

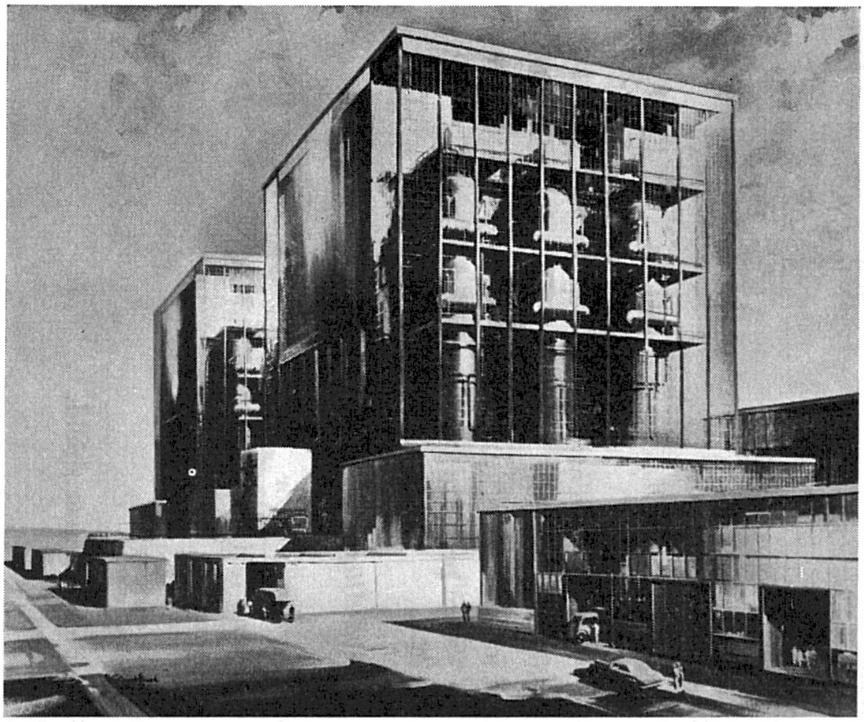

Fig. 1.

As a representative example of this type of nuclear power station, the 500 MW Hinkley Point Plant is illustrated here by a view of the plant when completed (fig. 1) and by a typical plan of the reactor building and its cross section (figs. 2 and 3). Fig. 4 shows one of the reactor buildings during construction at the beginning of 1959. At the time of writing the present report,

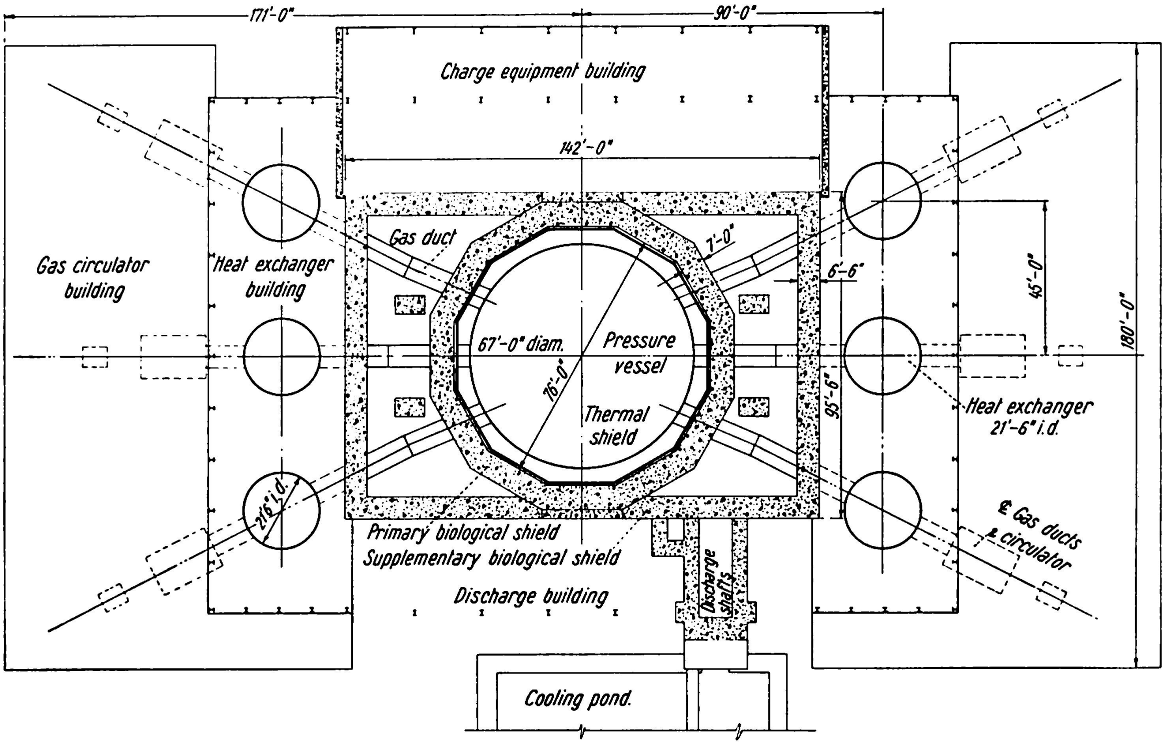

Fig. 2.

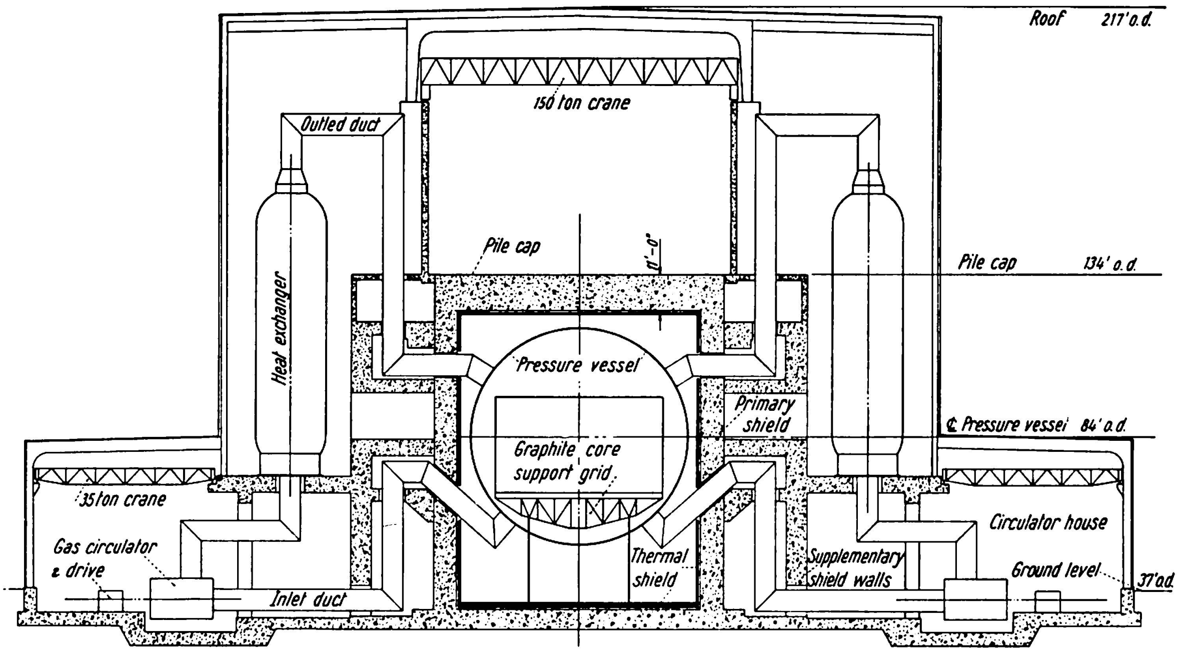

Fig. 3.

this nuclear power project is the largest in existence. It is designed and constructed by a Consortium comprising English Electric Co. Ltd., Babcock & Wilcox Ltd., and Taylor Woodrow Construction Ltd., with whom the author is associated.

The present type of gas-cooled reactor, though suitable for the generation of the base load component of the national power demand, will need further development to make it economically competitive for peak load operation. The development will be directed towards increasing the fuel element rating and thermal efficiency so as to bring down the size and cost of the larger units

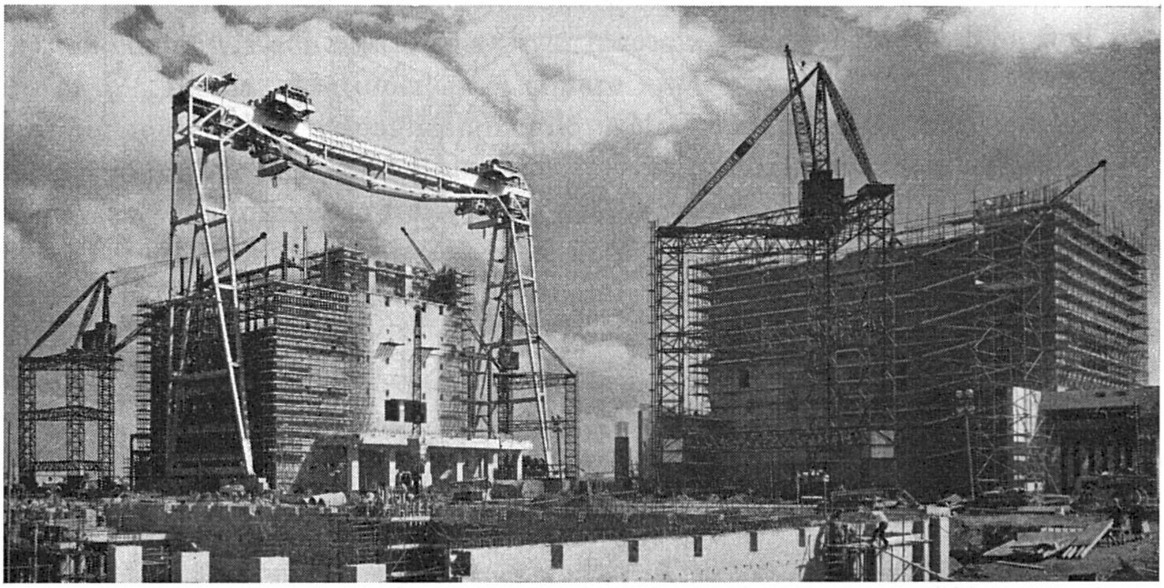

Fig. 4.

Table 2. Capital Costs of Nuclear Power Stations
(in £ per kW) and Cost of Power (in pence per kWh)

	Nuclear plant		Coal-fired
	275—300 MW	500 MW	plant
Capital costs in £ per KW	145	120[1])	45
Capital charges[2]), incl. charges on initial fuel, in pence per kWh	0.51—0.52	0.41—0.42	0.11
Fuel replacement costs do.	0.13—0.19	0.13—0.19	0.37—0.48
Works operating costs do.	0.06	0.05	0.05
Total generating costs do.	0.70—0.77	0.59—0.66	0.53—0.64

1) This cost is likely to fall to £ 100—110 as a result of expected reduction of capital costs.

2) Capital charges taken at 8%, representing 5% rate of interest and 20 years' life of power station.

and make the small unit economically attractive. Indeed these objectives are common to most other reactor systems now under development.

An analysis of the cost of power from present-day nuclear stations and a comparison with that from conventional thermal power is given in table 2.

A second series of civil power stations is now being planned. The estimated figures of their electrical output are as follows:

Trawsfynydd, Merioneth	550 MW
Dungeness, Kent	650 ,,
Sizewell, Suffolk	650 ,,
Oldbury-on-Severn, Glos.	1000 ,,

which will add another 2850 MW to the 1400 MW of the first series of the U.K. nuclear power programme.

Future Reactors

During the past years, detailed design studies and research have been carried out on several promising types of liquid cooled reactors, such as the pressurised and boiling water reactors, and the liquid-sodium-cooled graphite-moderated reactor. Some of the problems which had to be carefully investigated in these projects were: temperature and pressure regimes, thermodynamic efficiencies, neutron economies, types of fuel, compatibility and safety problems, maintenance, and economics.

For technological as well as for economic reasons these types of reactors are not regarded to be suitable for large scale power plants in this country. Development work has therefore been concentrated on the two following lines: a) the development of the gas-cooled graphite-moderated reactor to the maximum of its considerable potentialities; and b) the possible advantages of a change to heavy water as a moderator.

The Advanced Gas-Cooled Reactor

The project on which U.K.A.E.A. development work has been mainly concentrated during the past few years has been called the advanced gas-cooled reactor (A.G.R.). The objective of the A.G.R. is to decrease capital costs per KW by a substantial amount — of the order of 30 percent — by increasing the surface temperature of fuel elements to about 600° C. By this means and by using clusters of smaller diameter fuel elements, average ratings should be increased to the region of 8 MW thermal per ton. To enable this increase of fuel element temperature to be obtained a change is being made from uranium metal fuel to a sintered uranium oxide fuel element. Sintered

UO_2 has a melting point of about 2400° C. This type of fuel is already being used in the Westinghouse PWR reactor and has been shown to have very good irradiation stability and burnups of up to 8000 MW-days per ton have been achieved.

Table 3 gives a comparison of the main parameters for three reactors of natural-uranium, graphite-moderated, and CO_2-cooled type. The three reactors which form definite milestones in the development of this type are the Calder Hall prototype, the Hinkley Point Station as the most progressed plant of the present series, and the experimental A.G.R. as the next step in our development work.

Table 3. Comparison of Main Parameters for CO_2-Cooled Graphite-Moderated Reactors

Item		Proto-type Calder Hall	Industrial power reactor Hinkley Point	Experimental advanced gas-cooled reactor Windscale
1. Year of completion of first reactor	—	1956	1960	1961
2. Heat output per reactor	MW	100	980	100
3. Net electrical output per reactor	MW	35	250	28.5
4. Type of fuel	—	Natural uranium		U_2O
5. Distribution of fuel	—	8″ square lattice		Cluster of thin rods
6. Number of fuel channels	—	1696	4500	253
7. Total weight of fuel per reactor	tonnes	130	370	12.3
8. Average fuel rating	MW/tonne	1.4	2.6	7.75
9. Minimum burn-up of fuel	MWD/tonne	3000	3000	5000
10. Maximum fuel temperature	deg. C	530	580	
11. Maximum can surface temperature	deg. C	408	425	600
12. Canning material	—	Magnox C and A 12		Beryllium
13. Graphite core, height	ft.	27	29	14
14. Graphite core, nominal diameter	ft.	35	53	15
15. Graphite core, total weight	tons	1146	2000	200
16. Pressure vessel, shape	—	cylinder	sphere	cylinder
17. Pressure vessel, dimensions	ft. dia. × height	37 × 70	67	21 × 60
18. Pressure vessel, wall thickness	in.	2	3	3
19. Gas pressure	p. s. i. g.	100	180	275
20. Diameter of main ducts	ft.	4.5	6.5	
21. Gas inlet temperature	deg. C	140	180	250 → 325
22. Gas outlet temperature	deg. C	336	380	500 → 575
23. Circulators, number per reactor	—	4	6	4
24. Power per circulator	H.P.	1495	3000	1200
25. Heat exchangers, number per reactor	—	4	6	4
26. Number of control rods	—	50	132	25
27. Thickness of concrete biological shield	ft.	7—8	7—9	9

At present, the Authority is pursuing a research study on the *High-Temperature Gas-Cooled Reactor.* They are attempting to develop impervious ceramic sheaths for a fuel element which is a ceramic — a mixture of graphite, uranium and thorium. A zero energy experiment is being built at Winfrith Heath. This will enable the nuclear properties of the reactor at high temperature to be studied.

Design of Reactor Structures

General Considerations

Many of the problems encountered in the structural design of nuclear power stations are similar to those which have been solved for the more usual thermal stations. Both involve heavy engineering and both present the designer with similar problems relating to turbine halls, cooling water systems and ancillary buildings. The essential difference involves the reactor unit, where new considerations call for a new approach to various aspects of design and construction. The principal components of the reactor unit are the pressure vessel, the biological shield and the steam-raising units.

The internal dimensions of the biological shield are decided by the size of the pressure vessel and the necessary clearances for erection, ducting and operation. The thickness of the concrete shield is carefully calculated to reduce all emergent radiations to a safe level. Openings occur in the biological shield for various charge and control tubes, inspection purposes and ducting. A thermal shield is introduced between the biological shield and the pressure vessel to protect the former from the full effect of radiations from the reactor. Cooling air passages, a few inches thick, are formed between the biological shield and the thermal shield to reduce temperatures to a reasonable design level.

Loading

In contrast to conventional industrial structures, the principal loads to be carried by reactor structures are those due to change in temperature, changes in moisture content, shrinkage and creep.

The usual type of gravity loads also play a considerable role but only in certain parts of the structure, such as the pile cap, the heat exchanger plinth, the equipment building and the reactor foundations.

The structure is designed to withstand the effects of self-weight of the structure, dead-weight of the plant and superimposed floor loads; loading due to heating from the reactor and ambient air; the effects of shrinkage and creep; wind loading and other lateral forces such as due to earthquakes.

Joints

From the point of view of thermal loads, buildings subjected to different ranges of temperature should be separated from each other to keep temperature stresses at a low level. For this reason, the charge and discharge buildings are usually separated from the central shield structure by full expansion joints while the buildings surrounding the heat exchangers are monolithically constructed with the secondary shields. Generally, there is also a complete joint between the primary and secondary shields from the foundation level upwards.

Preliminary Design

For practical reasons, a polygonal shape is usually adopted for the biological shield. Allowance may be made for this in the shield design, but where the polygon is 12-sided or more, the shape may be regarded as a cylindrical one for simplicity. The dimensions of the shield vary with the power of the reactor and the shape of the pressure vessel. However, for the type of industrial reactor described in this Paper, the height of the shield may be taken as, say, 100 ft. to pile cap level, the internal diameter as 70 ft., and the thickness of both the wall and roof as 8 ft.

In the preliminary design, the pile cap, the shield wall and the raft may be analysed quite separately. The pile cap is treated as a circular reinforced concrete slab. Fixed end moments are computed for both gravity and heating effects and the free radial deflection due to heating in the cap is estimated.

In the design of the shield walls, two separate aspects are considered: the shield expanding freely in the radial direction and the effect of restraints at the roof-wall and wall-raft junctions. The elastic equation governing the behaviour of the cylindrical shield wall due to these top and bottom restraints is first determined. The slope, moment and shear at any point up the height of the shield wall is then obtained in the usual way from the first, second and third derivatives of that equation. Finally, fixed end moments in the shield are computed for any required deflection at the top and bottom junctions.

The design of the raft, or individual foundations to the reactor, depends on gravity loads from the superstructure and on the nature of the subsoil. Effects of long-term settlement have sometimes to be considered. Allowance has to be made for stresses arising from heat soakage through the raft into the underlying ground, unless suitable protective measures are taken.

The relative stiffnesses of the pile cap, shield wall and raft are obtained by calculating the moments necessary to rotate through the same angle (a) the pile cap at its periphery; (b) the top or bottom of the shield wall; and (c) the raft at its junction with the wall. The ratios of these moments give the relative stiffnesses of the members. When the stiffness factors and fixed end moments are determined, it is then possible to obtain "balanced" moments for the connections and to complete the design.

Foundations

The loads of reactor structures to be carried on the subsoil are very substantial. In a typical example for a 250 MW unit, the total weight was of the order of 100,000 tons, and the major items were as follows:

Reactor	31,600 tons
Charge equipment building	9,800 ,,
Discharge building	10,000 ,,
Heat exchanger building	9,000 ,,
Foundation raft	35,600 ,,
Total live loads	6,200 ,,
Total	102,200 tons

Wherever possible nuclear power plants are therefore sited where good load-bearing rock strata is available within a reasonable depth. In such cases, the shield structure, pressure vessel, heat exchangers, blowers, and other equipment are usually carried on independent block or strip foundations, as the question of settlement does not arise.

However, under less favourable ground conditions it has been found necessary to carry the major items of the plant on a common raft foundation which, for a 250 MW reactor, may require a thickness of 12—15 ft. Although the full thickness may not be required at the outer portions of the reinforced concrete raft, the underside is usually kept level to facilitate construction and to allow for the provision of pits and ducts in the outer region of the foundation.

The raft is designed for gravity loads, temperature stresses and the most severe moments and shears transferred from the shield walls. Effects of immediate and long-term settlement and rotations should be checked.

The raft can be regarded as a flexible plate on a compressible sub-grade, and to arrive at an acceptable solution several designs based on different assumptions and methods were made:

a) *Grid of beams.* In the first approximation an analysis was carried out of a grid of beams, running in the directions of the two principal axes of the foundation. The design was based on the compatibility of the deflections of the two sets of beams where they cross each other. This lead to a series of simultaneous equations; the unknowns in these equations being the deflections. Various patterns of soil reactions were assumed and the design was carried out for three types of pressure distribution. The deflected form of the raft under the influence of the external loads on the top and the soil pressure on the bottom was then compared with the deflected form of the ground under the same soil pressure conditions. The actual soil pressure distribution adopted for the final design was that for which the deflections of the raft approached nearest the deformation of the ground.

b) *Grid of beams on an elastic foundation.* This method utilised the same grid as method a) but instead of assuming a bearing pressure distribution, the contact pressure at any point is assumed to be proportional to the deflection at that point. The coefficient of proportionality (i.e. the modulus of sub-grade reaction) was assumed, in this particular design, to have a constant value of 200 tons/sq. ft./ft. over the central area, falling off towards the edges to a value equal to half of the maximum.

c) *Rigid central plate with four cantilever wings.* A third method was evolved in order to take into account the considerable stiffening effect of the shield walls on the central part of the raft, which is assumed to be completely rigid and to remain flat. The four separate cantilever slabs carrying the heat exchangers, the equipment and discharge buildings, are then analysed on the basis of an elastic subgrade, using values similar to those under b). While this approach is of necessity approximate, it is thought to give a more realistic solution to the problem since it takes into account the rigidity of the central shield structure.

d) *Plate on elastic foundations.* A rather more complex solution, treating the raft as a continuous plate was carried out, also on the basis of the same grid as the previous solutions. This method has the advantage of taking into account the torsional rigidity of the individual beams in addition to the bending resistance which alone was considered in the three preceeding methods.

Thus a considerable effort was made to study the foundation problem, and the raft design in particular, because of the great importance attached to a satisfactory performance of the foundation. Uneven settlement must be prevented at all costs and displacement between the principal items of the plant must be minimised even under the most exacting loading conditions. The loads carried are extremely high: the weights are of the order of 100,000 tons, and the thermal loads are considerably greater than in normal industrial structures. By considering several different methods of design which lead to essentially similar results, sufficient assurance was obtained that our estimates of stresses, strains and deformations are reasonably correct. The results obtained by the various methods varied within ± 15 percent from the average.

Biological Shield

The biological shield is designed to withstand gravity loads due to the self-weight of the walls and roof and superimposed loads due to the maximum concentrations of machines and equipment on the pile cap. At the same time, severe temperature stresses have to be accommodated. During reactor operation heat is caused in the biological shield by the capture and slowing down of nuclear radiation and by the thermal radiation across the air space from the thermal shield. The intensity and distribution of temperatures through the shield vary from point to point up the wall and across the roof. They remain, however, reasonably constant at any given level around the walls. The effect of these temperature variations is to produce strains which, due to restraints imposed at the roof-wall and wall-raft junctions, are accompanied by stresses in the shield.

The flow of heat through the raft is more indeterminate. Special thermal shields and cooling precautions are taken to restrict the heat flow into the raft and to improve the temperature conditions in the concrete foundations and underlying ground. The actual temperatures in the structures are dependent also on ambient temperatures and the design must take into account their seasonal variation. Calculations also cover the effects of drying shrinkage and heat of hydration.

The analysis of the primary shield is based on the investigation of a long cylinder restrained at both ends. It may be assumed that the radial expansion of the walls is unrestrained at all levels, as an expansion joint separates the primary and the supplementary shields.

Full consideration is given to the various conditions to which the reactor may be subjected, namely from the one extreme of reactor heating and ambient temperature rise to the other extreme of ultimate shrinkage and minimum temperature during a shut-down of the plant.

Moments and shears in the biological shield are computed on the basis of homogeneity. Checks are applied, as necessary, to establish the validity of this assumption.

The design allows for a range of deflections of the connection between the roof and wall. Heating, shrinkage and imposed loadings are taken into account in determining the degree of fixity of the shield wall with the pile cap. The treatment of the lower wall junction depends on the type of foundation

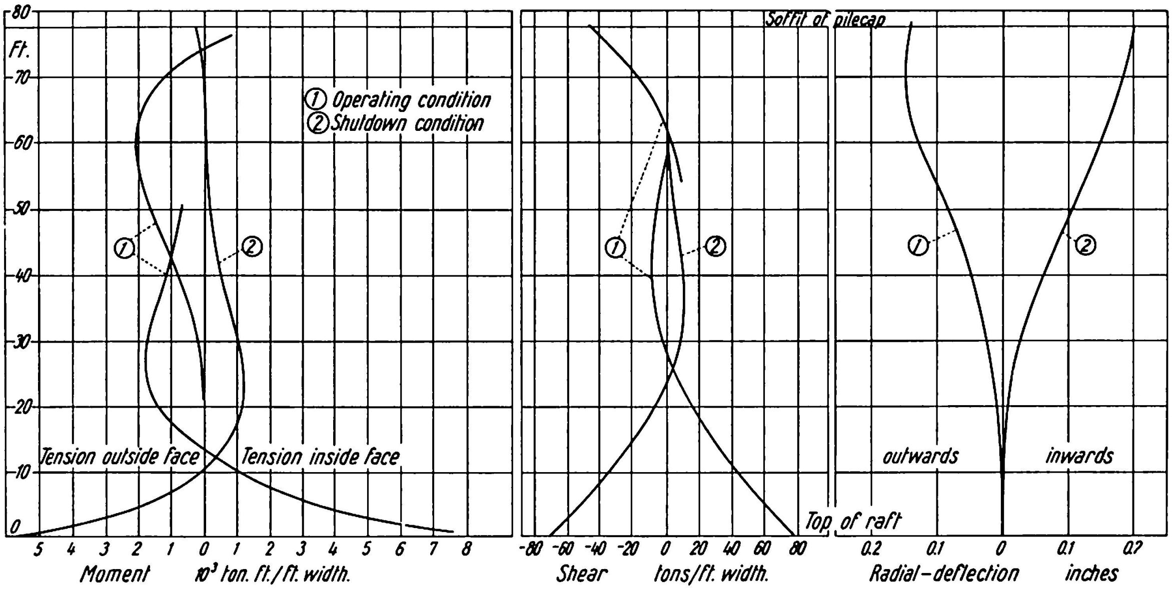

Fig. 5.

adopted. Limiting conditions are established and the design should permit the joint to take any intermediate position.

Bending moments and shear envelopes are next prepared for the shield wall. The wall is then designed for gravity loads and bending moments at the top, bottom and several intermediate positions, using concrete and steel stresses somewhat below the permissible values.

As soon as the quantitiy of steel reinforcement is known, it is possible to calculate the additional concrete and steel stresses due to the temperature gradient across the wall. These stresses are added to the main stresses determined previously and their total values should not exceed the maximum permissible values.

Fig. 5 shows a typical example of moment, shear and deflection curves for the design of a biological shield wall.

Acknowledgment

The author is indebted to U.K.A.E.A. for permission to use in this report extracts and summaries from the following publications:

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"Hinkley Point Nuclear Power Station." English Electric Co. Ltd., Babcock & Wilcox Ltd., Taylor Woodrow Construction Ltd.

Summary

The paper starts with giving the outlines of the U.K. nuclear power programme. A summary survey of the main technical data of the power stations at Calder Hall, Berkeley, Bradwell, Hunterston and Hinkley Point is given in form of a table, followed by a comparison of the cost of power from nuclear stations with that from conventional thermal plant. Development towards the advanced gas-cooled reactor and the high-temperature gas-cooled reactor is then described.

In the second part of the paper a typical design of a reactor structure is given in its outlines: general considerations, loading and joints. Several alternative design methods of the heavy raft foundations are discussed and the report closes with the structural analysis of the primary shield structure.

Résumé

L'auteur esquisse tout d'abord, dans ses grands traits, le programme de développement de l'énergie nucléaire en Grande-Bretagne. Il expose dans leur ensemble les caractéristiques techniques essentielles des centrales nucléaires de Calder Hall, Berkeley, Bradwell, Hunterston et Hinkley Point, sous forme de tableaux. Il compare ensuite les prix de revient de l'énergie produite par les centrales nucléaires avec ceux de l'énergie fournie par les centrales thermiques classiques. Il décrit l'évolution qui s'est manifestée dans le sens des réacteurs à refroidissement gazeux et des réacteurs à refroidissement gazeux sous hautes températures.

La deuxième partie de cette étude est consacrée à un projet de centrale à réacteurs: considérations générales, charges, exécution des joints entre les différentes parties de l'ouvrage. L'auteur examine enfin différentes variantes pour le calcul du radier lourd et continu, puis étudie la construction de l'écran principal.

Zusammenfassung

Die Arbeit erhellt zuerst die allgemeinen Umrisse des Atom-Energie-Programms von Großbritannien. Eine zusammenfassende Darstellung der wesentlichen technischen Daten der Kraftwerke von Calder Hall, Berkeley, Bradwell, Hunterston und Hinkley Point wird in Tabellenform gegeben. Anschließend werden die Kosten von aus Nuklear-Stationen gewonnener Energie mit der aus konventionellen thermischen Kraftwerken verglichen. Sodann wird die Entwicklung in Richtung gasgekühlter Reaktoren und unter hohen Temperaturen gasgekühlter Reaktoren beschrieben.

Der zweite Teil der Arbeit behandelt die Projektierung einer Reaktorstation: Allgemeine Betrachtungen, Belastungen, Ausführung der Stöße zwischen den verschiedenen Gebäudeteilen. Es werden mehrere Varianten für die Berechnung der schweren, durchgehenden Fundamentplatte diskutiert und schließlich wird noch die Konstruktion der Hauptabschirmung behandelt.

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