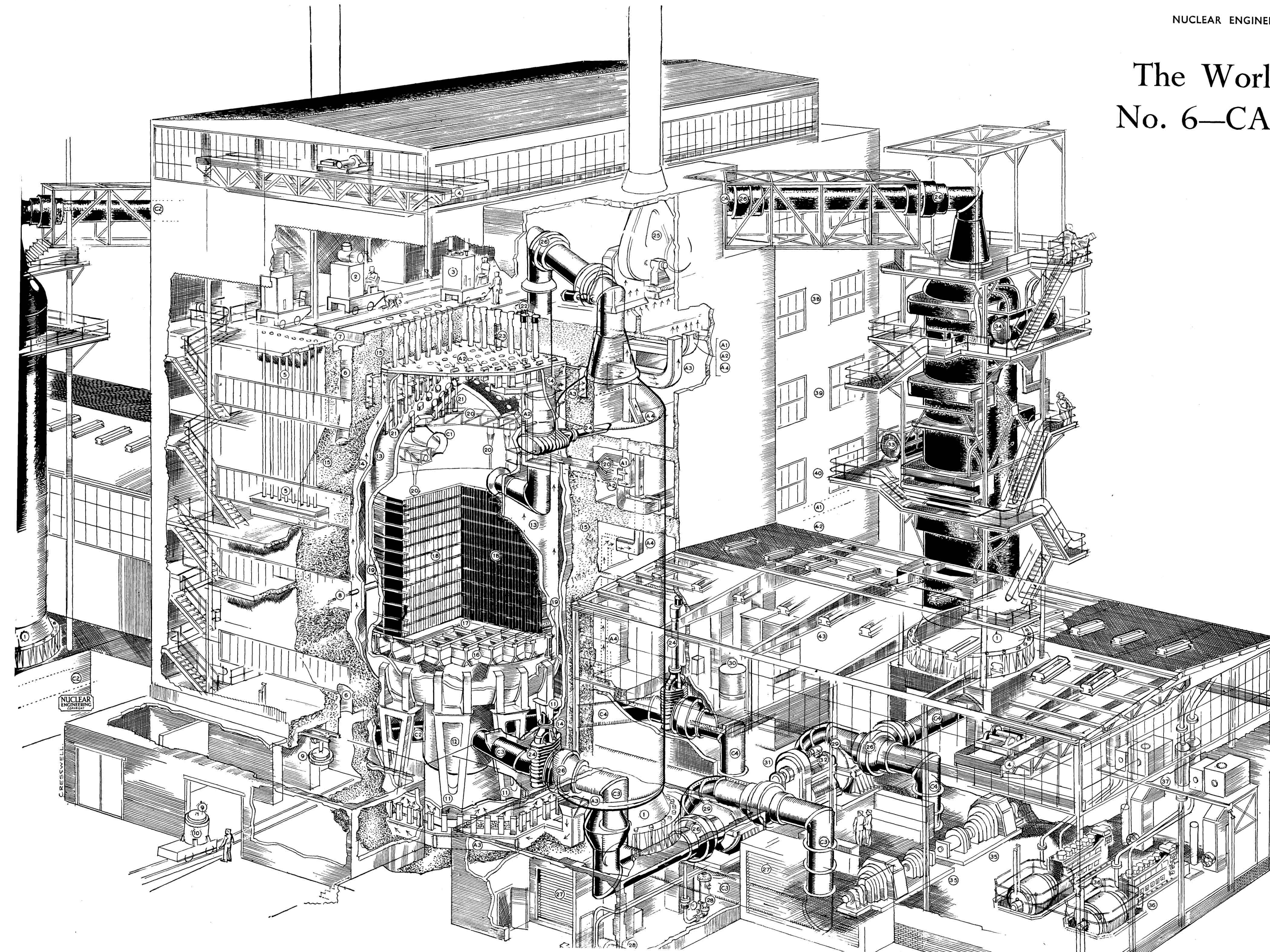


The World's Reactors

No. 6—CALDER HALL

KEY

- A. Biological and thermal shield cooling circuits
- C. Coolant circuits
- 1. Heat exchanger
- 2. Discharge machine
- 3. Charge machine
- 4. Travelling crane
- 5. Chute stowage tubes
- 6. Discharge well
- 7. Cross-traverse pit
- 8. Graphite probe
- 9. Flask lid
- 10. Transport flask
- 11. "A" frames
- 12. Inlet manifold
- 13. Pressure vessel
- 14. Thermal shield
- 15. Biological shield
- 16. Diagrid
- 17. Support plates
- 18. Graphite
- 19. Restraint rings
- 20. Burst-slug detection tubes
- 21. Charge tubes
- 22. Control actuating mechanisms
- 23. Shield plug
- 24. Motorized duct valves
- 25. Exhaust fans
- 26. Duct bellows
- 27. Cooling air filters
- 28. H.E. circulating pump
- 29. Main CO₂ blower
- 30. CO₂ purification plant
- 31. Blower motor
- 32. Pony motor
- 33. Low-pressure steam drum
- 34. High-pressure steam drum
- 35. Ward-Leonard set
- 36. Stand-by diesel generators
- 37. Diesel ancillaries
- 38. Fuel-preparation room
- 39. Burst-slug detection room
- 40. Control room
- 41. Cable gallery
- 42. Battery room
- 43. Switch room



The World's Reactors—No. 6

CALDER HALL: PIPPA—POWER AND PLUTONIUM PRODUCTION

INTERIM DATA

TYPE:	Thermal heterogeneous.
PURPOSE:	Plutonium production. Power production Prototype for central power stations.
LOCATION:	Sellafield, Cumberland, England.
CAPACITY:	42 MW from two turbines fed by four heat exchangers. Heat rating: 180 MW. Complete station includes four reactors. Maximum electrical output: 184 MW. Feed-back: 20%
OPERATION:	Diverged, May 1956. Opened by H.M. Queen Elizabeth, October 17, 1956.
FUEL:	Natural uranium. U as cast bars, 1.15-in. dia., 40 in. long. Elements in vertical channels, six per channel. Total number of channels: 1,696. Charge for criticality: over 20 tonnes. Total investment: 63 tonnes.
CANNING:	Magnesium alloy—Magnox. Wall thickness of core: 0.072 in. Extended surface: single-start helical fin, 0.125 in. pitch, 0.43 in. radial width, overall dia. 2.125 in. Manufacture: cans turned from solid, swaged on to U, He filled.
MODERATOR:	Graphite. Built up from 8 in. sq. interlocking blocks and tiles. Drilled 4-in. (av.) holes for fuel channels. Overall size, including reflector 36 ft. dia., 27 ft. high. Supported by ball bearings on 4-in. plates resting on diagrid. Total weight: 1,150 tons.
CORE:	Size: 31 ft. dia., 21 ft. high. Lattice: regular square, 8-in. pitch.
COOLANT:	Carbon dioxide at 100 p.s.i. circulated upwards through reactor. Flow: 7.1 million tons/hour. Ducting: 4 ft. 6 in. dia. Inlet temperature: 140°C. Outlet temperature: 336°C. Shielding cooling: blown air.
PUMPING:	Four centrifugal blowers, one in each heat exchanger circuit. Total power absorbed: 5.44 MW. Speed Control: Ward-Leonard type, range 10/1.
CONTROL:	Coarse: up to 60 rods ganged together. Fine: up to four manually operated. Normal operation: total of 40 rods. Rod construction: boron steel in stainless steel tubes. Suspension: stainless steel cable. Travel: 21 ft. Maximum rod speed for shut-off: 4 ft./sec. Minimum automatic rod speed: 0.5 in./min.
SHIELDING:	6-in. thick steel plates. Concrete, on sides: 7 ft., on top: 8 ft. Minimum density: 150 lb./ft. ³ , mean: 160 lb./ft. ³ Overall: octagon 60 ft. across flats, 90 ft. high. Total weight on foundations: 33,000 tons.

A limited supply of separate copies is available of this series of data sheets on various reactors built or projected throughout the world. Copies may be obtained from the publishers, Temple Press Limited, Bowling Green Lane, London, E.C.1, at the cost of packing and postage only (4d. each).

Data sheets in this series already published in "Nuclear Engineering" are:

- No. 1. BEPO (April, 1956).*
- No. 2. CP5 (May, 1956).*
- No. 3. NRX (June, 1956).*
- No. 4. DIMPLE (August, 1956).*
- No. 5. ZEUS (September, 1956).*

December, 1956

NUCLEAR ENGINEERING

The World's Reactors

No. 6—CALDER HALL

he following parameters and performance data are compiled from papers given at the British Nuclear Energy Conference Symposium on the Calder Works Nuclear Power Station on November 22-23, 1956, and supersede the interim data given in “The World's Reactors—No. 6” published in the October, 1956, issue.

TYPE:

PURPOSE:

LOCATION:

CAPACITY:

OPERATION:

FUEL:

CANNING:

MODERATOR:

LATTICE:

Thermal heterogeneous.

Plutonium production.
Power production.
Prototype for central power stations.

Sellafield, Cumberland, England.

Maximum electrical rating: 184 MW from four reactors and eight turbo-alternator sets.
Electrical output: 21 MW per turbo-alternator set.
Feed-back: 7.5 MW per reactor.
Distribution to grid: 132 kV.
Internal distribution: 11 kV, 3.3 kV and 415 V.
Heat rating: 182 MW.

Diverged May, 1956.
Opened by H.M. Queen Elizabeth, October 17, 1956.

Natural uranium.
U as cast bars 1.15 in. dia., 40 in. long.
Density: 18.7 g/cm³.
Elements in vertical channels: six per channel.
Total weight of fissile material: 120 tonnes per reactor.
Number of fuel-element channels: 1,696.
Diameter of channels: 256 at 4.16 in.
576 at 3.95 in.
864 at 3.61 in.
Average temperature: 425°C.

Magnesium alloy—Magneox C, He filled.
Wall thickness: 0.072 in.
Diameter: 1.30 in.
Extended surface: single-start helical fin 0.125 in. pitch.
Overall diameter: 2.125 in.
Design maximum can surface temperature: 408° C.

Graphite.
Core size: 21 ft. high, 31 ft. dia.
Overall size including reflector: 24-sided regular prism, 27 ft. high, 36 ft. across corners.
Total weight: 1,146 tons.
Blocks 8 in. sq., 25 in. long.
Each column supported by ball bearings on 4-in. plates resting on diagrid.
Average temperature: 250°C.

Regular square, 8 in. pitch.

Zone A

Core Zone B

Zone C

Inner radius, ft.:

Outer radius, ft.:

Channel diameter, in.:

Number of channels:

Thermal utilization factor, *f*:

Resonance escape factor, *p*:

Fast fission factor, *ε*:

Thermal fission factor, *η*:

Multiplication constant, *k*_∞:

Radial diffusion area, cm²:

Axial diffusion area, cm²:

Radial slowing-down area, cm²:

Axial slowing-down area, cm²:

0

6.02

4.16

256

0.93186

0.87533

1.02972

1.26595

1.06330

406.6

464.6

628.9

709.5

6.02

10.85

3.95

576

0.93010

0.87861

1.02972

1.26595

1.06527

391.9

438.9

588.6

652.7

10.85

15.49

3.61

864

0.92672

0.88398

1.02972

1.26595

1.06789

371.1

403.6

528.1

570.6

PRESSURE VESSEL:

COOLANT:

PUMPING:

CONTROL:

REACTIVITY:

SHIELDING:

HEAT EXCHANGERS:

2-in.-thick Lowtem Al-kill mild steel, fusion welded.
37 ft. inside diameter, 70 ft. high.
Design stress at 400°C: 1,200 lb./in.²

Carbon dioxide circulated upwards through reactor.
Working pressure: 100 p.s.i.g.
Flow: 1,964 lb./sec. (2,160 lb./sec. maximum).
Inlet temperature: 140°C.
Outlet temperature: 336°C.
Number of ducts: four.
Diameter of ducts: 4 ft. 6 in.
Mean coolant velocity: (cool ducts) 49 ft./sec.; (hot ducts) 74 ft./sec.

Four centrifugal blowers, one in each heat-exchanger circuit.
Mass flow in each circulator: 500 lb./sec. (550 lb./sec. maximum).
Circuit pressure drop: 5.53 p.s.i. (6.69 p.s.i. maximum).
Isentropic efficiency at design point: 78%.
Compression power: 1,497 b.h.p.
Speed control: Ward-Leonard type, range 10:1.
Power required (four circulators): 5.44 MW.

Number of channels: 112.
Diameter of channels: 3.25 in.
Coarse: up to 60 rods ganged together.
Fine: up to four, manually operated.
Normal operation: total of 40 rods.
Rod construction: boron steel in 18/8/1 stainless steel sheath.
Length: 22 ft.
Suspension: stainless steel cable (seven strands, each of 19 wires 0.010 in. 18/8 stainless steel EN 58).
Drive: synchronous motor and winch, 20:1 gearing.
In speed: 5 in./min. and 50 in./min. Out speed: ½ in./min.
Shut-down speed: 4 ft./sec. (6 in./sec. for last 2 ft. 6in. of travel).

Total excess: 4%.
Central channel increment: 0.015%.
Increment per control rod: ~ 0.2%.

Thermal: 6-in. thick steel plates.
Biological: concrete, 7 ft. on sides, 8 ft. on top.
density, 150 lb./ft.³ minimum, 160 lb./ft.³ av.
octagon, 60 ft. across flats, 90 ft. high.
total weight on foundations, 33,000 tons.
Cooling: blown air.

Number per reactor: four.
Main shell: 73 ft. 4 in. over flanges; 77 ft. 4 in. overall; 17 ft. 3 in. I.D.; thickness 1½ in.
Gas inlet: 6 ft. dia. Gas outlet: 4 ft. 6 in. dia.
Steam drums: length 19 ft. 7½ in.; 4 ft. I.D.; thickness ⅞ in.
Headers: 10½ in. O.D.; thickness 1 in.
Economizer tubes: 1½ in. O.D. × 8 S.W.G.
Boiler tubes: 2 in. O.D. × 7 S.W.G.
Superheater tubes: 2 in. O.D. × 6 S.W.G.
Gas volume: (live) 7,370 ft.³; (dead) 6,600 ft.³
Total gas volume: 13,970 ft.³
Heating surface areas per heat exchanger:—
Outside of tubes in live gas:
H.P. superheater 4,450 ft.²; L.P. superheater 785 ft.²
H.P. superheater 31,500 ft.²; L.P. superheater 31,500 ft.²

HEAT EXCHANGERS:

TURBO-ALTERNATORS:

COOLING TOWERS:

H.P. H.T. econ. 15,750 ft.²; L.P. H.P. econ. 15,750 ft.²
Total: 99,735 ft.²
Inside of tubes in live gas:
H.P. superheater 3,580 ft.²; L.P. superheater 632 ft.²
H.P. evaporator 5,886 ft.²; L.P. evaporator 5,886 ft.²
H.P. H.T. econ. 3,304 ft.²; L.P. H.P. econ. 3,304 ft.²
Total 22,592 ft.²
Length of tubes per heat exchanger:—
H.P. superheater 152 ft. 6 in. per element, 9,764 ft. per bank.
H.P. evaporator 253 ft. 9 in. per element, 16,143 ft. per bank.
H.P. H.T. econ. 286 ft. 9 in. per element, 12,044 ft. per bank.
L.P. superheater 59 ft. 3 in. per element, 1,898 ft. per bank.
L.P. H.P. econ. 292 ft. 6 in. per element, 12,333 ft. per bank.
Total length 1½ in. O.D. tubing in banks: 24,378 ft.
Total length 2 in. O.D. tubing in banks: 43,949 ft.
Gas and steam conditions for one heat exchanger at full load:—
CO₂ gas flow-rate: 491 lb./sec.
Gas temperature at H.E. inlet: 336°C (637°F).
Gas temperature at H.E. outlet: 135°C (275°F).
H.P. steam flow-rate (77% total): 99,000 lb./h.
H.P. steam exit temperature: 595°F (313°C).
H.P. steam exit pressure: 210 p.s.i.a.
H.P. steam exit enthalpy: 1,318.3 B.t.u./lb.
Power of H.P. circulating pump: 40 h.p.
L.P. steam flow-rate (23% total): 29,650 lb./hr.
L.P. steam exit temperature: 350°F (171°C).
L.P. steam exit pressure: 62.7 p.s.i.a.
L.P. steam exit enthalpy: 1,207.4 B.t.u./lb.
Power of L.P. circulating pump: 12.5 h.p.
Feed-water pressure at H.E. inlet: 340 p.s.i.a
Feed-water temperature at H.E. inlet: 100°F (37.8°C).
Feed-water enthalpy at H.E. inlet: 68.9 B.t.u./lb.
Feed-water flow-rate: 128,650 lb./hr. (plus losses).
Heat taken up by water and steam: 46.15 MW.

Number of sets per reactor: two.
Maximum continuous rating: 23 MW at a power factor of 0.8 lagging.
Speed: 3,000 r.p.m.
Generator voltage: 11.5 kV, three-phase, 50 c/s.
High-pressure steam pressure at turbine stop-valve: 200 p.s.i.a.
High-pressure steam temperature at T.S.V.: 310°C.
High-pressure steam per set (77% total): 198,000 lb./hr.
Low-pressure steam pressure at T.S.V.: 53 p.s.i.a.
Low-pressure steam per set (23% total): 59,300 lb./hr.
Output: 21 MW.
Flow-rate to condenser per set: 257,300 lb./hr.
Maximum cooling water temperature: 29.4°C.

Two, serving two reactors.
Half-basin capacity: 687,500 gal.
Cooling range: 30.5°C to 21.1°C.
Wet-bulb temperature: 8.3°C.
Dry-bulb temperature (humidity 60%): 11.1°C.
Tower height above sill: 290 ft.
Tower diameter at ring beam: 200 ft.
Throat diameter: 104 ft.

A limited supply of separate copies is available of this series of data sheets on various reactors built or projected throughout the world. Copies may be obtained from the publishers, Temple Press Limited, Bowling Green Lane, London, E.C.1, at the cost of packing and postage only (4d. each).