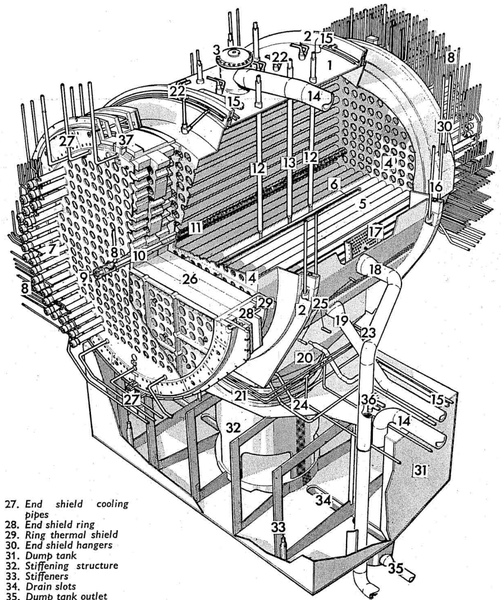
The World's Reactors

No. 37 CANDU (Douglas Point)

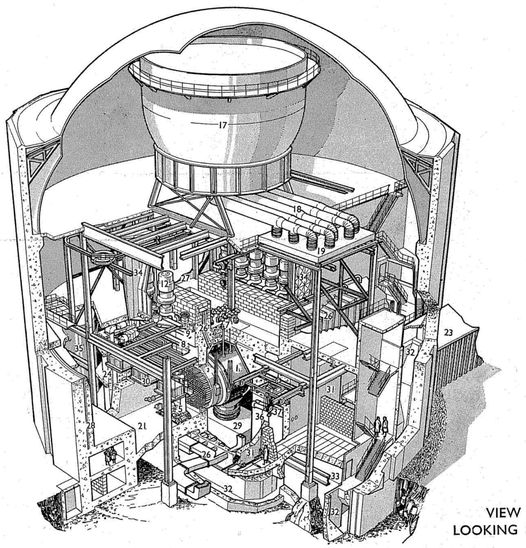
LOCATION	Douglas Point, Lake Huron (near Kincardine), Ontario
OWNER	Atomic Energy of Canada Limited
OPERATOR	Hydro-Electric Power Commission of Ontario.
OUTPUT	
Thermal	655 MW
Electrical	220 MW (gross) 203 MW (net)
EFFICIENCY	29·1% overall
FUEL	Natural UO_2
MODERATOR	Heavy Water
COOLANT	Heavy Water
TYPE	Horizontal pressure-tube
CALANDRIA	
Shell	Austenitic stainless steel, 19 ft 8 in (5·994 m) i.d.×16 ft 5 in (5·004 m) long
Tubes	Nickel-free zircaloy-2, 4·24 in (107·7 mm) i.d.×0·049 in (1·24 mm) wall thickness
Pressure Tubes	Zircaloy-2 3·25 in (82·6 mm) i.d.×0·155 in (3·99 mm) wall thickness. Total length over end fittings (type 403 stainless steel) 30 ft 3 in (9·22 m)
CORE	
No. of cells	306
Array	Approximately octagonal (20×19) on square lattice 9 in (228·6 mm) pitch
Max. thermal flux (average across hottest section)	10^{14} n/cm² s
Av./max flux ratio	
Radial	0·7885
Axial	0·649
Equivalent core diameter	177·8 in (4512 mm)
Temperature Coefficients (equilibrium fuel and effective neutron temperature of 100°C)	
Reactivity changes in	milli-k/°C
Fuel	
Neutron temp.	+0·0048
Doppler	−0·014
Coolant	
Neutron temp.	+0·013
Density	+0·011
Moderator	
Neutron temp.	+0·029
Density	−0·069
Average neutron temperature	
In moderator	53°C
In fuel	151°C
Average fuel temperature	595°C
Average moderator temperature	43·3°C
Power developed in hottest channel	2·74 MW
Reactivity decrease without refuelling	−0·4 mk/day
Additional reactivity by normal refuelling:	
Centre channel	0·24 mk
Outer channel	0·05 mk
Total weight of fuel (as natural U)	92 000 lb (41 600 kg)
Average burn-up (±10%)	9 750 MWd/t U
Average fuel life in reactor	2·3 years
Maximum fuel life in reactor (nominal)	3·1 years
CONTROL	
Start-up, shutdown	Moderator level
Start-up after short shut-down (xenon over-ride)	Booster rods
Cold start-up	B_2O_3 in moderator
Normal running	Absorber rods and refuelling
No. of absorbers	4
Reactivity worth, each	0·75 mk
Maximum change of reactivity per rod	0·015 mk/s
No. of booster rods	8
Reactivity worth, each	1·125 mk
Maximum change of reactivity, per rod	0·008 mk/s
FUEL ELEMENT	
Type	19-rod bundles 19·5 in (495 mm) long
Number per channel	12 (10·1 in active zone)
Diameter of rods	0·6 in (15·22 mm) over zircaloy sheath
UO_2 pellet size	14·24 mm diameter×20 mm long
Number of pellets per rod	24
Minimum cladding thickness	0·015 in (0·38 mm)
Density of UO_2	10·4–10·7 g/cm³
Total weight of zircaloy per element	3·33 lb (1·51 kg)
Total weight of UO_2 (average density 10·55 g/cm³)	33·5 lb (15·2 kg)
Heat transfer area per bundle	698 in² (4 500 cm²)
Heat flux (average)	133 000 Btu/ft²h (10 cal/cm²s)
Heat flux (max.)	333 000 Btu/ft²h (25 cal/cm² s)
MODERATOR	
Type	D_2O
Total quantity	155 tons (140 000 kg)
Quantity normally in calandria	142 tons (128 600 kg)
Heat produced in moderator (approx.)	40 MW
Outlet temperature from reactor (max)	145°F (63°C)
Inlet temp. to reactor (minimum)	70°F (21°C)
Helium pressure in dump tank	24 psia (1·69 kg/cm²)
Flow through moderator coolers; from calandria	5 500 gal/min (25 000 l/min)
Flow through moderator coolers; from dump tank	500 gal/min (2 272 l/min)
Total flow to heat exchangers	6 000 gal/min (27 300 l/min)
Total returned to calandria direct (remaining flow returns through side circuits)	3 600 gal/min (16 400 l/min)
Head of D_2O above dump port with calandria full	18·6 ft (5·67 m)
PRIMARY COOLANT	
Type	D_2O
Quantity	87 100 lb (39 600 kg)
Total flow	24·1×10⁶ lb/h (10·9×10⁶ kg/h) i.e., 45 400 gal/min (3 450 l/s)
Pressure (inlet header)	1 480 psi (104 kg/cm²)
Pressure (outlet header)	1 310 psi (92·1 kg/cm²)
Inlet temperature	480°F (249°C)
Outlet temperature	560°F (293°C)
Inlet velocity	22·4 ft/s (7·77 m/s)
Pumps	Centrifugal
No. of pumps	10 (8 active) in two groups of 5
Rated flow, per pump	5 670 gal/min (25 800 l/min)
Operating head	203 psi (14 kg/cm²)
BOILERS	
Total number	8 (in two groups of 4)
Type	U-shell and tube, each boiler consisting of 10 sections and one steam drum. Heavy water: tube side.
Total heat exchange surface (boiling area)	74 500 ft² (6 920 m²)
Total heat exchange surface (preheating area)	11 050 ft² (1 027 m²)
Total evaporation rate	2·562×10⁶ lb/h (1·16×10⁶ kg/h)
Steam pressure at drum	583·7 psia (41 kg/cm² abs.)
Steam temperature	483·7°F (250·7°C)
Minimum approach temperature (H_2O–D_2O)	9·4°F (5·2°C)
Feed temperature	340°F (171°C)
Max. moisture in steam at drum	0·25%
TURBINE	
Type	Tandem compound (1 h.p. stage, 3 l.p. stages)
Speed	1 800 rev/min
Throttle pressure	579·7 psia (40·76 kg/cm² abs.)
Throttle temperature	482°F (250°C)
Steam conditions at l.p. stage inlet (after reheat)	67·9 psia (4·77 kg/cm² abs.) 430°F (221°C)
Condenser back pressure	1 in (25·4 mm Hg)
Type of condenser	Single pass with divided water box
Area	158 000 ft² (14 700 m²)
Cooling water flow	175 000 gal/min

REACTOR CORE

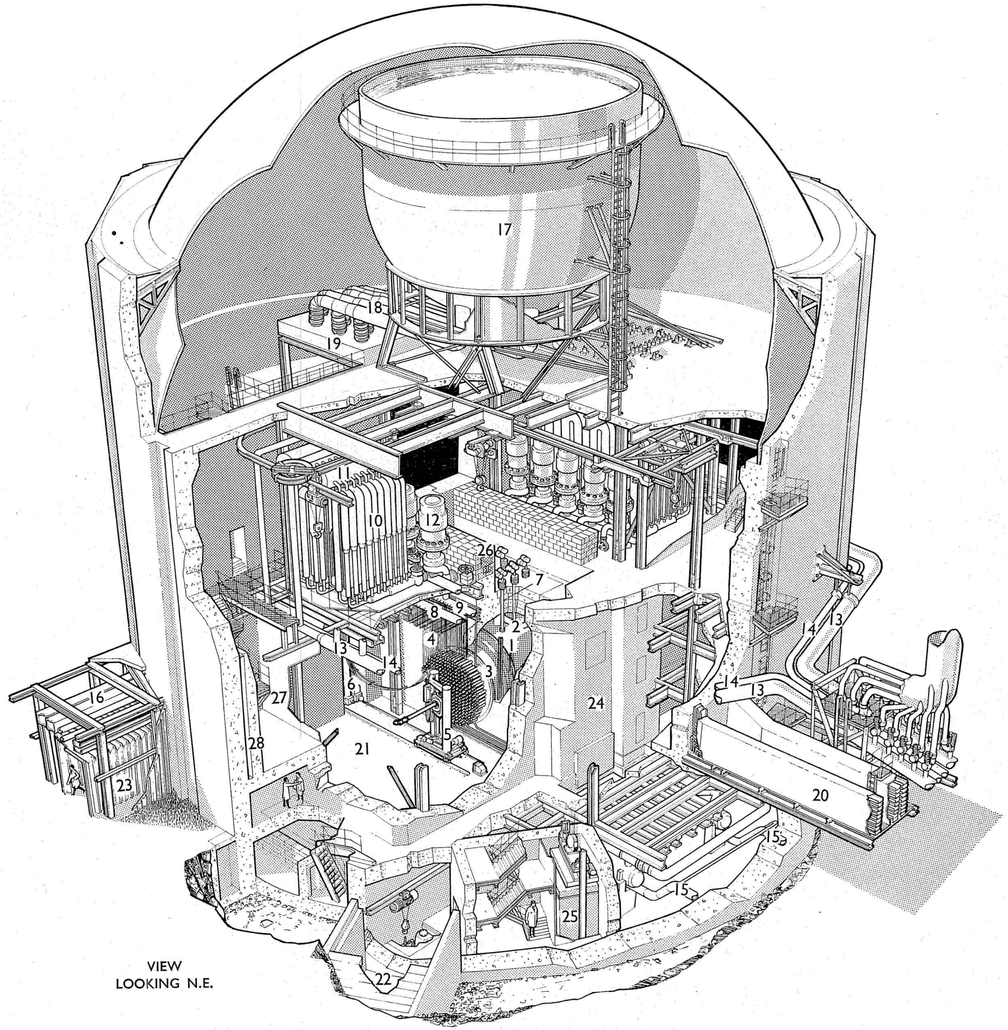


KEY

1. *Calandria*
2. *Stiffening ring*
3. *Pressure relief device*
4. *Tube plate*
5. *Calandria tubes*
6. *Coolant tubes*
7. *End fittings*
8. *Feeder pipes*
9. *Sealing plug*
10. *Shielding plug*
11. *Fuel*
12. *Booster rod cooling*
13. *Absorber rod cooling*
14. *Helium balance line*
15. *Helium purge line*
16. *Calandria hangers*
17. *Outlet manifold*
18. *Moderator outlet*
19. *Moderator inlet*
20. *Transition section*
21. *Expansion joint*
22. *Calandria spray cooling*
23. *Dump box spray cooling*
24. *Transition section spray cooling*
25. *Level indicating inlets*
26. *End shield*
27. *End shield cooling pipes*
28. *End shield ring*
29. *Ring thermal shield*
30. *End shield hangers*
31. *Dump tank*
32. *Stiffening structure*
33. *Stiffeners*
34. *Drain slots*
35. *Dump tank outlet*
36. *Dump tank and expansion joint spray cooling*
37. *End shield key block*



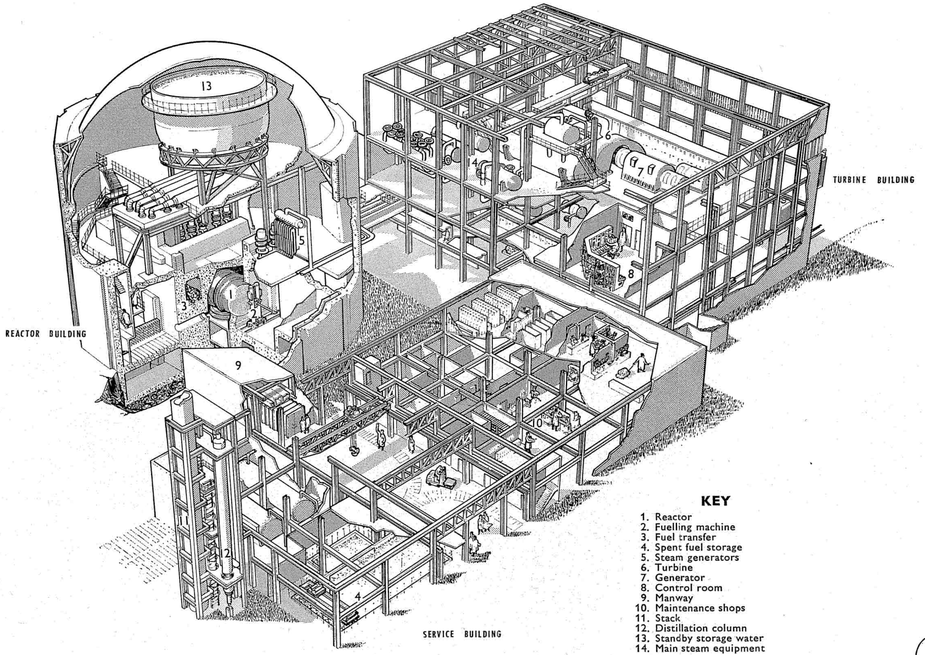
VIEW LOOKING S.W.



VIEW LOOKING N.E.

KEY TO REACTOR BUILDING

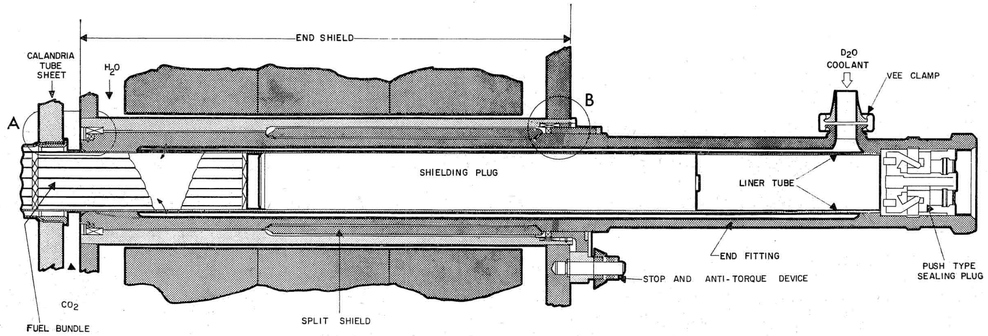
1. Calandria
2. Helium line
3. End shield
4. Coolant feeders
5. Fuelling machine
6. Cable cart
7. Booster and absorber rods
8. Hot primary header
9. Cold primary header
10. Boiler
11. Steam drum
12. Primary pumps
13. Steam header
14. Feedwater headers
15. Process water inlets
16. Ventilation ducts
17. Dousing tank
18. Dousing pipes
19. Spray tank
20. Cable trays
21. Fuelling machine vault
22. Spent resin storage
23. Manway
24. Labyrinth
25. Elevator
26. Thermal shield cooling ducts
27. Blow-out panel
28. Pressure wall
29. Dump tank
30. Building ventilation
31. Fuelling machine access duct
32. Dousing water passages
33. Decontamination tank
34. Boiler insulation
35. D_2O storage tank
36. Shield tank
37. Ion chambers



General Arrangement of Station

KEY

1. Reactor
2. Fuelling machine
3. Fuel transfer
4. Spent fuel storage
5. Steam generators
6. Turbine
7. Generator
8. Control room
9. Manway
10. Maintenance shops
11. Stack
12. Distillation column
13. Standby storage water
14. Main steam equipment



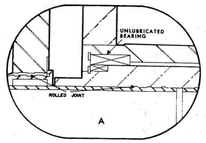
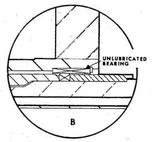


Fig.: 4 (in text)
Details of pressure tube end fitting



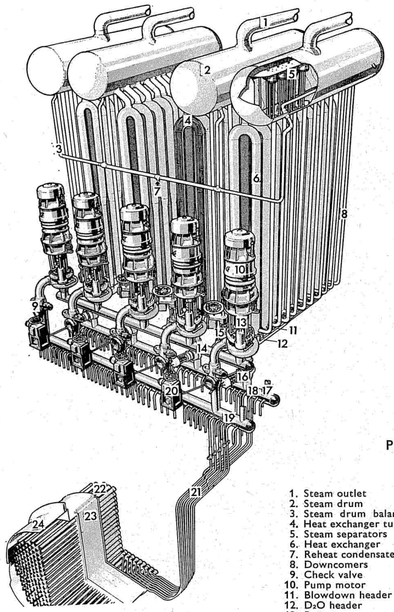


Fig.: 5 (in text)
Primary coolant system

KEY

1. Steam outlet
2. Steam drum
3. Steam drum balance pipe
4. Heat exchanger tubes
5. Steam separators
6. Heat exchanger
7. Reheat condensate return
8. Downcomers
9. Check valve
10. Pump motor
11. Blowdown header
12. D_2O header
13. Pump
14. Pump header
15. and 16. Heat exchanger and isolating valves
17. Standby cooling inlet
18. Reactor outlet header
19. Reactor inlet header
20. Isolating valve operator
21. Feeder bank
22. End fittings
23. End shield
24. Calandria

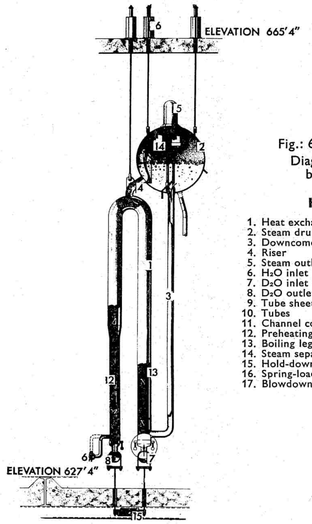
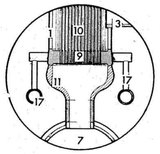


Fig.: 6 (in text)
Diagram of boiler

KEY

1. Heat exchanger
2. Steam drum
3. Downcomer
4. Riser
5. Steam outlet
6. H_2O inlet manifold
7. D_2O inlet manifold
8. D_2O outlet manifold
9. Tube sheet
10. Tubes
11. Channel cover
12. Preheating leg baffles
13. Boiling leg baffles
14. Steam separators
15. Hold-down arrangement
16. Spring-loaded supports
17. Blowdown headers



Detail at D_2O inlet

Pull-outs already published in this series in " Nuclear Engineering " are:

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No. 2. *CP5 (May, 1956)*
No. 3. *NRX (June, 1956)*
No. 4. *DIMPLE (August, 1956)*
No. 5. *ZEUS (September, 1956)*
No. 6. *CALDER HALL (October and December, 1956)*
No. 7. *RUSSIAN 5 MW (November, 1956)*
No. 8. *DIDO (January, 1957)*
No. 9. *THE SOUTH OF SCOTLAND ELECTRICITY BOARD STATION (February, 1957)*
No. 10. *BERKELEY POWER STATION (March, 1957)*
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