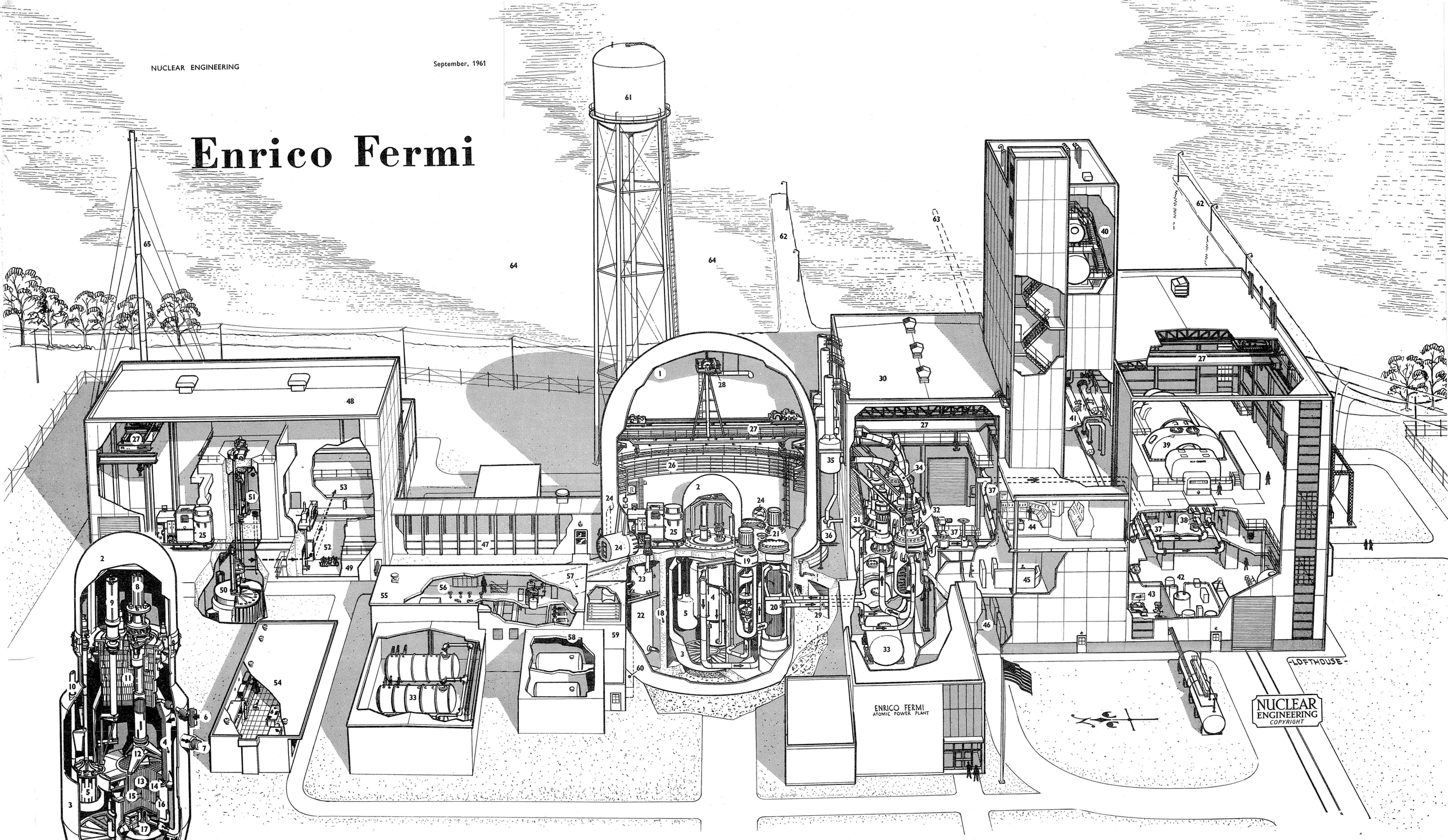
Enrico Fermi



KEY

1. Gastight building
2. Machinery dome
3. Primary shield tank
4. Reactor vessel
5. Transfer rotor
6. Coolant inlet
7. Coolant outlet
8. Control rod mechanism
9. Offset handling mechanism
10. Transfer tube
11. Rotating shield plug
12. Hold-down assembly
13. Core
14. Radial blanket
15. Axial blanket
16. Thermal shield
17. Melt-down pan
18. Secondary shield wall
19. Primary sodium pumps
20. Intermediate heat exchangers
21. Throttle valves
22. Primary sodium overflow tank
23. Overflow pumps
24. Airlocks
25. Cask car (in two positions)
26. Cable galleries
27. Overhead cranes
28. Atmosphere conditioning unit
29. Secondary sodium piping
30. Steam generating building
31. Secondary sodium pumps
32. Steam generators
33. Sodium storage tanks
34. Sodium-water reaction vents
35. Sodium separator units
36. Feedwater dump tank
37. Main steam line
38. Main steam stop valves
39. Turbo-generator
40. Storage and de-aerators
41. L.P. heaters
42. Water treatment plant
43. Workshop
44. Main control room
45. Reactor simulator
46. Switch room
47. Covered car track
48. Fuel handling building
49. Repair pit
50. Transfer tank rotor
51. Cleaning chamber and equipment
52. Cut-up pool
53. Decay pool
54. Health physics laboratory
55. Sodium service building
56. Sodium control room
57. Sodium tunnel
58. Waste gas building and decay tanks
59. Inert gas building
60. Inert gas tunnel
61. Potable water storage tank
62. Piers
63. Water intake channel
64. Lake Erie
65. Stack

The World's Reactors

No. 33 ENRICO FERMI

PLANT DESIGN AND PERFORMANCE DATA WITH INITIAL U-Mo ALLOY CORE

OWNER: Power Reactor Development Company.

DESIGN: Atomic Power Development Associates, Inc.

LOCATION: Lagoona Beach, (near Monroe) Michigan, U.S.A.

TYPE: Sodium cooled fast breeder reactor.

PURPOSE: Power generation; breeding.

PROGRAMME: Site work commenced: April, 1956.

CAPACITY: Thermal output: 200 MW.
Electric output: 65·9 MW gross.
60·9 MW net.
Conversion ratio: 1·16.

FISSILE: Enriched U-10 w/o Mo alloy.
Enrichment: 25·6 w/o.
Total loading: 4 270 lb.
Critical mass (105 sub-assemblies): 496 kg U^{235}.
Core conversion factor: 0·29.

FERTILE: Depleted U-3 w/o Mo alloy.
U^{235} concentration: 0·35 w/o.
Total loading: 67 780 lb.
Blanket conversion factor: 0·87.

FUEL ELEMENTS: Fuel pins: 0·158 in o.d. × 32·78 in total length.
Uranium portion of pin: 0·148 in dia. × 30·5 in.
Cladding: 0·005 in Zr.
Pin pitch: 0·199 in, square.
No. of pins per sub-assembly: 140.
No. of sub-assemblies in core: 105.
Sub-assembly dimensions: 2·646 in square × 97·489 in long; wall thickness: 0·096 in; "active" length of sub-assembly = 17 in (blanket) + 1 31/64 in (space) + 32 25/32 in (core) + 2 55/64 in (space) + 17 in (blanket).

BLANKET ELEMENTS: Breeding rods: 0·443 in o.d. × 65 in (radial).
0·415 in dia. × 14 in (axial).
Cladding: 0·010 in in s.s. type 304.
Sodium bond: 0·014 in.
Rod pitch: 0·483 in (radial and axial), square.
No. of rods per sub-assembly: 25 (radial).
No. of rods per section: 16 (axial).
No. of sub-assemblies: 531 (radial).
No. of sections: 105 (in each axial region).

CORE: Dimensions: 32·7 in dia. × 30·5 in (active length).
Active volume: 13.4 ft³.
Power: 174 MW.
Heat transfer surface: 1 545 ft².
Maximum heat flux: 640 000 Btu/ft²h.
Power density: 13 MW/ft³.
Specific power: 0·35 MW/kg U^{235}.
Maximum local removal burn-up: 0·4 a/o.
Max. nom. U temp.: 1 115° F.
Max. nom. cladding surface temp.: 1 051° F.

BLANKET: Radial dim.: 30·5 in i.d. × 79·9 in o.d. × 65 in total length; length of U alloy: 61·75 in.
Axial dim.: 30·5 in dia. × 14 in active length (each region).
Active volume: radial: 138 ft³;
axial: 6·1 ft³ (per region).
Power: radial: 23·6 MW;
axial: 1·2 MW (per region).
Heat transfer surface: radial: 7 923 ft²;
axial: 227·5 ft² (each).
Maximum heat flux: radial 217 000 Btu/ft²h
axial 72 200 Btu/ft²h.

PRIMARY COOLANT: Sodium.
Inlet temp.: 550° F.
Exit temp.: 800° F.
Max. nominal coolant temp. in core: 1 014° F.
Flow through core: 7·10 × 10⁶ lb/h.
Flow through radial blanket: 1·47 × 10⁶ lb/h.
Velocity in core: 15·7 ft/s.
Total Na volume: 7 260 ft³ (421 000 lb at 58 lb/ft³).
No. of primary circuits: 3.
Pumps: 3 motor driven vertical shaft centrifugal sump type.
Pump capacity: each, 11 800 gal/min at 310 ft.
Drive: 1 000 h.p., 900 rev/min wound rotor with liquid rheostat control.
Piping: 30 in flow, 16 in and 14 in return, all ⅜ in wall, in type 304 s.s.

REACTOR PHYSICS: Critical mass: (105 sub-assemblies) 496 kg U^{235}.
Median flux energy: 0·32 MeV.
Mean fission energy 0·25 MeV.
Average core flux: 3×10^{15} n/cm² s.
Average neutron generation time: 0·084 s.
Mean delay time of delayed neutrons: 12 s.
Prompt neutron lifetime: $1{\cdot}4 \times 10^{-7}$ s.
sothermal temp. reactivity coefficients, 10^{-6} $\Delta k/k$ °C :

	Core region	Axial blanket region	Radial blanket region
Sodium expansion	−4·4	−5·2	−1·7
Uranium alloy expansion	−6·2	−0·1	−0·2
Hold-down plate expansion	0·0	−0·4	−0·3
Doppler (at 550° F)	−2·6		
Sub-assembly can radial expansion	−11·3		−0·7
Lower support expansion	−1·5		
Power Coefficients, 10^{-2} ϕ/MW			
Sodium expansion	−2·1	−2·7	−0·9
Uranium alloy expansion	−6·8	−0·1	−0·2
Hold-down plate expansion	0·0	−0·2	−0·1
Bowing	+0·2		
Doppler (at 200 MW)	−1·9		
Sub-assembly can radial expansion	−9·4		−0·3

Reactivity requirements, weekly unloading	ϕ	% $\Delta k/k$
Temp. override	60·0	0·40
Total loss, per week	15·4	0·10
Control margin	16·6	0·11
	92·0	0·61

CONTROL: Effective delayed fraction (β): 0·662% $\Delta k/k$.
Safety rods: 8.
Total controlled: 0·061 $\Delta k/k$; each controlling at least 0·0166 $\Delta k/k$.
Rods comprise: 6 tubes of B_4C "doughnuts" enriched to 59 w/o in B^{10} clad in stainless steel type 316 tubes; inner cladding 0·01 in, outer 0·032 in.
Total B^{10} weight per rod: 535 g.
B_4C tube dimensions: 36·3 in long; inner 0·312 in o.d.; outer 0·625 in o.d.
Rod dimension 2⅛ in o.d. × 68⅛ in.
Scram shut down average rate of reactivity insertion on scram: 0·11 $\Delta k/k$ s.
Operating control rods: 2, each controlling 0·305% $\Delta k/k$.
Rods comprise: 19 cylinders of B_4C enriched to 34 w/o in B^{10} clad in 0·028 in of s.s. type 316.
B_4C cylinder dimensions: 0·254 in dia. × 10 in; tube length 30 in.
Rod dimensions: 2¼ o.d. × 42 17/64 in.

REACTOR VESSEL: S.s. type 304, 14·5 ft max. dia. × 36·3 ft high.
Wall: 2in max.
High pressure plenum, 110 psi, 750° F.
Radial blanket plenum, 50 psi, 1 000° F.
Upper vessel, 50 psi, 1 000° F.

INTERMEDIATE H.E.s: 3, counter flow shell and tube type in type 304 s.s.
No. of tubes per shell: 1 860.
Tube size: ⅜ in o.d. × 0·049 in wall.
Heat transfer per H.E.: 489 × 10⁶ Btu/h.
Heat transfer surface: 4 840 ft².

SECONDARY COOLANT: Secondary coolant: Na.
Secondary flow (in tubes):= primary flow= 2·95 × 10⁶ lb/h per H.E.
Temp. rise: 517° F–767° F.
Total secondary Na wt.: 256 300 lb; volume 4 418 ft³ (at 58 lb/ft³).
Piping: 18 and 12 in with ⅜ in wall in 2¼% Cr–1% Mo steel.
Secondary pumps, double-volute centrifugal, vertically mounted.
Capacity: 12 000 gal/min at 35 psi.
Drive: 350 h.p., 900 rev/min induction motors with eddy current couplings.

STEAM GENERATORS: 3 once through cross and counterflow.
Material: 2¼% Cr–1% Mo steel.
Steaming capacity per unit: 211 560 lb/h.
Steam conditions: 600 psia, 764°F.
Feedwater temp.: 340° F.
Heat transfer areas: economizer: 965 ft².
evaporator: 2 165 ft².
superheat: 7 670 ft².

SHIELDING: Primary radial: blanket, 12 in s.s., 6 in of 5% borated graphite, layer of insulation, 2½ ft graphite, 6 in of 1% borated graphite.
Secondary radial: 2½ ft concrete with ½ in steel liners + 2 in steel baffle opp. Na loops.
Biological shield: 7 ft concrete outside 1·03 in reactor building.
Top shield: s.s. shell containing from bottom to top: six 11-in layers of plain graphite, one 11-in layer of 1½% borated graphite, 12 in carbon steel, 1 ft s.s. insulating material, 11 in cover plate of solid carbon steel.
Operating floor: steel-and-concrete 5 ft thick.

REACTOR BUILDING: Cylindrical steel vessel 72 ft i.d. with hemispherical top, ellipsoidal bottom.
Height: 120 ft, 51 ft below grade.
Material: ASTM A–201 grade B.
Design pressure: 32 psig.
Design temp.: 450° F.

GENERATING PLANT: Tandem compound single flow machine.
1 800 rev/min.
Gross capability: 150 MW, 1 inHg back pressure.
Operating performance at reactor power of 200 MW (th):
Gross output: 65·9 MW; net output 60·9 MW.
Steam conditions (at turbine): 576 psia, 760° F.

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