

APPENDIX

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APPENDIX

A.1. TABLE OF ARIES-I REACTOR PARAMETERS

1. CHARACTERISTIC MACHINE DIMENSIONS

1.1. Reactor Envelope^(a)

1.1.1. Height	14 m
1.1.2. Outside diameter	24 m
1.1.3. Circumference	74 m
1.1.4. Volume	6,114 m ³

1.2. Plasma Chamber

1.2.1. Major toroidal radius	6.75 m
1.2.2. Plasma half width	1.50 m
1.2.3. First-wall half width	1.60 m
1.2.4. Plasma volume	489 m ³
1.2.5. Plasma chamber volume	554 m ³
1.2.6. Wall surface area	619 m ²
1.2.7. Number of sectors ^(b)	16

2. PLASMA PARAMETERS^(c)

2.1. Fuel Cycle	DT/Li
2.2. Plasma Dimensions	
2.2.1. Plasma aspect ratio	4.50
2.2.2. Major toroidal radius	6.75 m
2.2.3. Plasma half width	
2.2.3.1. 95% flux surface	1.45 m
2.2.3.2. Separatrix	1.50 m
2.2.4. Plasma vertical elongation, κ	
2.2.4.1. 95% flux surface	1.60
2.2.4.2. Separatrix	1.80
2.2.5. Plasma triangularity, δ	
2.2.5.1. 95% flux surface	0.47
2.2.5.2. Separatrix	0.70
2.2.6. Plasma volume	
2.2.6.1. 95% flux surface	426 m ³
2.2.6.2. Separatrix	489 m ³
2.3. Electron Density ^(d)	
2.3.1. Average	1.45×10^{20} m ⁻³
2.3.2. Peak	1.89×10^{20} m ⁻³
2.3.3. At separatrix	1.00×10^{20} m ⁻³
2.4. Total Ion Density ^(d)	
2.4.1. Average	1.24×10^{20} m ⁻³
2.4.2. Peak	1.61×10^{20} m ⁻³
2.4.3. At separatrix	0.87×10^{20} m ⁻³
2.4.4. Ion fractions	
2.4.4.1. Proton	0.0004
2.4.4.2. Deuterium	0.4435
2.4.4.3. Tritium	0.4435
2.4.4.4. ³ He	0.0026
2.4.4.5. ⁴ He	0.1000
2.4.4.6. Oxygen (impurity)	0.0100

2.5. Electron Temperature ^(d)	
2.5.1. Average (density weighted)	19.3 keV
2.5.2. Average	17.4 keV
2.5.3. Peak	36.6 keV
2.5.4. Separatrix	0.22 keV
2.6. Ion Temperature ^(d)	
2.6.1. Average (density weighted)	20.0 keV
2.6.2. Average	18.1 keV
2.6.3. Peak	38.0 keV
2.6.4. Separatrix	0.30 keV
2.7. Effective Plasma Ion Charge	1.65
2.8. Core-Plasma Confinement	
2.8.1. Particle confinement time ^(e)	10.0 s
2.8.2. Lawson parameter	$2.94 \times 10^{20} \text{ s m}^{-3}$
2.8.3. Energy confinement time	2.5 s
2.8.4. Confinement enhancement multiplier	
2.8.4.1. ITER89-P	2.6
2.8.4.2. Kaye-Goldston	2.2
2.8.5. Core-plasma radiation fraction	
2.8.5.1. Synchrotron	0.402
2.8.5.2. Bremsstrahlung	0.093
2.8.5.3. Impurity radiation	0.005
2.8.5.4. Total	0.500
2.8.6. Particle flux at separatrix	$1 \times 10^{19} \text{ m}^{-2}\text{s}^{-1}$
2.8.7. Heat flux at separatrix	0.4 MW/m ²
2.9. Plasma Toroidal Current	10.20 MA
2.10. Plasma Toroidal Current Density ^(d)	
2.10.1. Average	0.85 MA/m ²
2.10.2. Peak	2.56 MA/m ²
2.11. Poloidal Field at Plasma Edge	0.94 T

2.12. Toroidal Field			
2.12.1. At plasma axis		11.3	T
2.12.2. Peak field on the coil		21.0	T
2.13. Vertical Field			
2.13.1. At plasma axis		0.79	T
2.14. Poloidal Beta			
2.14.1. Total		2.813	
2.14.2. Fuel ions and electrons		2.295	
2.14.3. Peak Shafranov		6.939	
2.14.4. $\epsilon\beta_p$		0.625	
2.15. Toroidal Beta			
2.15.1. Total		0.019	
2.15.2. Fuel ions and electrons		0.016	
2.15.3. Fast particles		0.003	
2.15.4. Troyon coefficient		0.032	T/A-m
2.15.5. Engineering beta ^(f)		0.006	
2.16. Safety Factor			
2.16.1. On axis, q_o		1.30	
2.16.2. At edge, q_ψ		4.75	
2.16.3. At edge, q_*		3.91	
2.17. Bootstrap-Current Fraction		0.68	
2.18. Current Drive			
2.18.1. Method	<u>FWCD</u>	<u>LHCD</u>	
2.18.2. Frequency	141	8,000	MHz
2.18.3. Input electric power	134	7	MW
2.18.4. Power to the plasma	97	5	MW
2.18.5. Driven current		3.26	MA
2.18.6. Efficiency		0.032	A/W
2.18.7. Efficiency factor, γ		0.33×10^{20}	A/m ² -W
2.19. Plasma Heating-to-Ignition Method ^(g)			ICRF

2.20. Plasma Ohmic Dissipation	0.85 MW
2.20.1. Plasma loop voltage	0.084 V
2.21. Plasma Disruption	
2.21.1. Stored plasma thermal energy	618 MJ
2.21.2. Most affected component	Divertor
2.21.3. Thermal energy on the divertor	420 MJ
2.21.4. Quench time	0.3 ms
2.21.5. Average heat flux	36.7 MW/m ²
2.21.6. Local peaking factor	5
2.21.7. Divertor armor disruption-allowance layer	1 mm
2.21.8. Divertor armor ablation thickness per disruption	100 μm

3. POWER FLOW

3.1. Total Nuclear Power ($M_N P_N + P_\alpha$)	2,387 MW
3.1.1. Fusion power	1,925 MW
3.1.1.1. Charged-particle power, P_α	386 MW
3.1.1.2. Neutron power, P_N	1,539 MW
3.1.2. Blanket energy multiplication, M_N	1.30
3.2. Total Plasma Power	
3.2.1. Charged-particle power, P_α	386 MW
3.2.2. Current-drive power	102 MW
3.2.3. Bremsstrahlung	49 MW
3.2.3.1. To first wall	39 MW
3.2.3.2. To divertor	10 MW
3.2.4. Synchrotron	195 MW
3.2.4.1. To first wall	173 MW
3.2.4.2. To divertor	5 MW
3.2.4.3. To "holes" ^(h)	17 MW
3.2.5. Transport into scrape-off layer	244 MW
3.2.5.1. Radiation in scrape-off layer	0 MW
3.2.5.2. Radiation in divertor	0 MW
3.2.5.3. Transport to first wall	2 MW
3.2.5.4. Transport to divertor	242 MW
3.3. First-Wall Thermal Power	305 MW
3.3.1. Surface heating	
3.3.1.1. Radiation	229 MW
3.3.1.2. Plasma	2 MW
3.3.2. Nuclear heating	
3.3.2.1. Structure	73 MW
3.3.2.2. Coolant	0 MW
3.3.3. Coolant-pumping power	1 MW

3.4. Breeder/Multiplier-Zone Thermal Power	1,458 MW
3.4.1. Nuclear heating	
3.4.1.1. Structure	235 MW
3.4.1.2. Coolant	0 MW
3.4.1.3. Beryllium	422 MW
3.4.1.4. Breeder	789 MW
3.4.2. Coolant-pumping power	12 MW
3.5. Reflector-Zone Thermal Power	459 MW
3.5.1. Nuclear heating	
3.5.1.1. Structure	453 MW
3.5.1.2. Coolant	0 MW
3.5.2. Coolant-pumping power	6 MW
3.6. Shield Thermal Power	11 MW
3.6.1. Nuclear heating	
3.6.1.1. Structure	11 MW
3.6.1.2. Coolant	0 MW
3.6.2. Coolant-pumping power	<1 MW
3.7. Divertor-Plate Thermal Power	311 MW
3.7.1. Surface heating	
3.7.1.1. Radiation	15 MW
3.7.1.2. Plasma	242 MW
3.7.2. Nuclear heating	
3.7.2.1. Structure	19 MW
3.7.2.2. Coolant	0 MW
3.7.3. Coolant-pumping power	35 MW
3.8. Total Reactor Thermal Power, P_{th}	2,544 MW
3.8.1. First-wall thermal power	305 MW
3.8.2. Breeder/multiplier-zone thermal power	1,458 MW
3.8.3. Reflector-zone thermal power	459 MW
3.8.4. Shield thermal power	11 MW
3.8.5. Divertor-plate thermal power	311 MW
3.9. Thermal-Cycle Efficiency, η_{TH}	0.49

3.10. Gross Electric Power, P_{ET}	1,247 MW
3.11. Recirculating Power	247 MW
3.11.1. Current-drive system	141 MW
3.11.2. Coolant-pumping power	54 MW
3.11.3. Auxiliary power	52 MW
3.12. Net Electric Power	1,000 MW
3.13. Recirculating-Power Fraction, ϵ	0.198
3.14. Engineering, $Q_E (= 1/\epsilon)$	5.058
3.15. Plasma, $Q_p (= P_F/P_{CD})$	19.91
3.16. Net Plant Efficiency, $\eta_p = \eta_{TH}(1 - \epsilon)$	0.393
3.17. Mass Power Density (MPD)	99 kWe/tonne
3.18. Plasma Power Density, P_F/V_p	3.94 MW/m ³

4. REACTOR COOLANT SYSTEM

4.1. First-Wall System

SiC-composite⁽ⁱ⁾ shell with
circular coolant channels^(j)
forming the front and sides
of the blanket module.

4.1.1. Coolant	Helium
4.1.2. Structural material	SiC composite
4.1.3. Shell thickness ^(k)	12 mm
4.1.4. Coolant-channel inner diameter	8 mm
4.1.5. Erosion allowance	2 mm
4.1.6. Structure volume fraction	0.67
4.1.7. Coolant volume fraction	0.33
4.1.8. Void volume fraction	N/A
4.1.9. Structure volumetric heating	27.1 MW/m ³
4.1.10. Coolant volumetric heating	0.0 MW/m ³
4.1.11. Outlet temperature	923 K
4.1.12. Inlet temperature	623 K
4.1.13. Outlet pressure	9.98 MPa
4.1.14. Inlet pressure	10 MPa
4.1.15. Pressure drop	0.02 MPa
4.1.16. Maximum primary stress	33 MPa
4.1.17. Maximum secondary stress	44 MPa
4.1.18. Maximum wall temperature	
4.1.18.1. SiC composite ^(j)	1,233 K
4.1.18.2. SiC coating ^(k)	1,311 K
4.1.19. Total coolant flow rate	171 kg/s
4.1.20. Maximum coolant flow velocity	39 m/s
4.1.21. Reynolds number, Re	7×10^4
4.1.22. Nusselt number, Nu	130
4.1.23. Prandtl number, Pr	0.667
4.1.24. Critical heat flux	N/A
4.1.25. Subcooling at exit	N/A

4.2. Breeder/Multiplier-Zone System

Alternating layers of
He-cooled SiC-composite
shells^(i,j) and sphere-packed
breeder/multiplier mixture.^(l)

4.2.1. Coolant	Helium
4.2.2. Structural material	SiC composite
4.2.3. Multiplier material	Beryllium
4.2.4. Breeder material	Lithium zirconate
4.2.5. Outboard module width at the first wall	1.64 m
4.2.6. Zone radial dimension	0.2 m
4.2.7. Coolant shell thickness	7 mm
4.2.8. Coolant-channel inner diameter	5 mm
4.2.9. Number of coolant shells	10
4.2.10. Minimum sphere-pack-zone thickness	11 mm
4.2.11. Structure volume fraction	0.25
4.2.12. Coolant volume fraction	0.05
4.2.13. Multiplier volume fraction ^(l)	0.56
4.2.14. Breeder volume fraction ^(l)	0.14
4.2.15. Maximum structure volumetric heating	25 MW/m ³
4.2.16. Coolant volumetric heating	0.0 MW/m ³
4.2.17. Maximum breeder/Be volumetric heating	29 MW/m ³
4.2.18. Outlet temperature	923 K
4.2.19. Inlet temperature	623 K
4.2.20. Outlet pressure	9.97 MPa
4.2.21. Inlet pressure	10 MPa
4.2.22. Maximum pressure drop	0.03 MPa
4.2.23. Maximum breeder/Be temperature	938 K
4.2.24. Total coolant flow rate	964 kg/s
4.2.25. Maximum coolant flow velocity	20 m/s
4.2.26. Reynolds number, Re	1.26×10^4
4.2.27. Nusselt number, Nu	33
4.2.28. Tritium purge-stream gas	Helium
4.2.29. Tritium purge-stream gas pressure	0.1 MPa

4.3. Reflector-Zone System

Alternating layers of
He-cooled SiC-composite
shells^(i,j) and sphere-packed^(l)
reflector material.^(m)

4.3.1. Coolant	Helium
4.3.2. Structural material	SiC composite
4.3.3. Reflector material	
4.3.3.1. First zone	Beryllium
4.3.3.2. Second zone	SiC
4.3.4. Module width at the first wall	1.64 m
4.3.5. Outboard radial-zone dimension	
4.3.5.1. First zone	0.10 m
4.3.5.2. Second zone	0.37 m
4.3.6. Inboard radial-zone dimension	
4.3.6.1. First zone	0.10 m
4.3.6.2. Second zone	0.07 m
4.3.7. Coolant shell thickness	7 mm
4.3.8. Coolant-channel inner diameter	5 mm
4.3.9. Number of coolant shells	2
4.3.10. Minimum sphere-pack-zone thickness	11 mm
4.3.11. Structure volume fraction	0.25
4.3.12. Coolant volume fraction ^(m)	
4.3.12.1. First zone	0.05
4.3.12.2. Second zone	0.25
4.3.13. Reflector volume fraction	
4.3.13.1. First zone (Be)	0.70
4.3.13.2. Second zone (SiC)	0.50
4.3.14. Structure volumetric heating	5.4 MW/m ³
4.3.15. Coolant volumetric heating	0.0 MW/m ³
4.3.16. Maximum Be volumetric heating	24 MW/m ³
4.3.17. Outlet temperature	923 K
4.3.18. Inlet temperature	623 K
4.3.19. Outlet pressure	10 MPa
4.3.20. Inlet pressure	10 MPa
4.3.21. Pressure drop	0.005 MPa

4.3.22. Maximum Be temperature	1,073 K
4.3.23. Total coolant flow rate	290 kg/s
4.3.24. Maximum coolant flow velocity	8 m/s
4.3.25. Reynolds number, Re	5×10^3
4.3.26. Nusselt number, Nu	16

4.4. Shield System

Alternating layers of
He-cooled SiC-composite
shells^(i,j) and
shield material.⁽ⁿ⁾

4.4.1. Coolant	Helium
4.4.2. Structural material	SiC composite
4.4.3. Shield material	SiC/B ₄ C
4.4.4. Radial thickness	
4.4.4.1. Inboard	0.7 m
4.4.4.2. Outboard	0.8 m
4.4.5. Shield coolant-shell thickness	7 mm
4.4.6. Coolant-channel inner diameter	5 mm
4.4.7. Number of reflector coolant shells	4
4.4.8. Structure volume fraction	0.05
4.4.9. Shield-material volume fraction	0.90
4.4.10. Coolant volume fraction	0.05
4.4.11. Structure volumetric heating	3.1 MW/m ³
4.4.12. Coolant volumetric heating	0.0 MW/m ³
4.4.13. Outlet temperature	923 K
4.4.14. Inlet temperature	623 K
4.4.15. Outlet pressure	10 MPa
4.4.16. Inlet pressure	10 MPa
4.4.17. Pressure drop	0.006 MPa
4.4.18. Maximum temperature	1,000 K
4.4.19. Total coolant flow rate	7 kg/s
4.4.20. Maximum coolant flow velocity	9 m/s
4.4.21. Reynolds number, Re	6×10^3
4.4.22. Nusselt number, Nu	16

4.5. Divertor Plate System

He-cooled SiC-composite
shell^(i,j) with plasma-sprayed
tungsten armor.

4.5.1. Coolant	Helium
4.5.2. Structural material	SiC composite
4.5.3. Armor material	Tungsten
4.5.4. Coolant-tube outer diameter	3.5 mm
4.5.5. Coolant-tube inner diameter	2.5 mm
4.5.6. Armor thickness	2 mm
4.5.7. Outlet temperature	923 K
4.5.8. Inlet temperature	623 K
4.5.9. Outlet pressure	9 MPa
4.5.10. Inlet pressure	10 MPa
4.5.11. Maximum primary stress	35 MPa
4.5.12. Maximum secondary stress	86 MPa
4.5.13. Maximum structure temperature	902 K
4.5.14. Maximum armor temperature	1,094 K
4.5.15. Total coolant flow rate	198 kg/s
4.5.16. Maximum coolant flow velocity	195 m/s

4.6. Coolant-Circulator Type

4.6.1. First wall, blanket, and shield	Centrifugal pump
4.6.2. Divertor plate	Centrifugal pump

4.7. Power Input to Each Circulator

4.7.1. First wall, blanket, and shield	19 MW
4.7.2. Divertor plate	35 MW

5. SHIELD COOLANT SYSTEM

5.1. Hot-Shield Coolant^(o) Helium

6. INTERMEDIATE COOLANT SYSTEM

6.1. Secondary Coolant None

7. POWER CONVERSION SYSTEM

7.1. Cycle Type Advanced Rankine

7.2. Number of Turbine/Generator Sets 2

7.3. Turbine Arrangement Tandem

7.4. Number of Re-Heats 2

7.5. Number of Regenerative Feedwater Heaters 9

7.6. Throttle Steam Pressure 31 MPa

7.7. Condenser Back Pressure 6.7×10^{-3} MPa

7.8. Total Steam Flow Rate 892 kg/s

7.9. Throttle Steam Temperature 873 K

7.10. Steam Temperature After Each Reheat 873 K

7.11. Feedwater Inlet Temperature 574 K

7.12. Gross Cycle Efficiency 0.49

7.13. Gross Electric Output 1,247 MW

8. REACTOR AUXILIARY SYSTEM**8.1. Magnet Cooling System****8.1.1. Toroidal-field coils**

8.1.1.1. Coolant	Helium
8.1.1.2. Total cooling load during start-up	0.5 MJ
8.1.1.3. Total cooling load during disruption	2.0 MJ

8.1.2. Poloidal-field coils

8.1.2.1. Coolant	Helium
8.1.2.2. Total cooling load during start-up	0.8 MJ
8.1.2.3. Total cooling load during disruption	1.0 MJ

8.2. Vacuum-Pumping System**8.2.1. Vacuum and plasma-chamber pressures**

8.2.1.1. Base plasma-chamber pressure	10^{-5} mtorr
8.2.1.2. Divertor duct pressure	20 mtorr

8.2.2. Temperature of neutral gas 1,300 K**8.2.3. Plasma chamber volume** 554 m³**8.2.4. Vacuum chamber volume** 650 m³**8.2.5. Particle throughput**8.2.5.1. DT 6.3×10^{21} s⁻¹8.2.5.2. Helium 6.8×10^{20} s⁻¹**8.2.6. Conductance of the divertor duct** 250 m³/s**8.2.7. Type of pumps** Turbo-molecular**8.2.8. Number of vacuum pumps** 16**8.2.9. Helium-pumping speed (per pump)** 25 m³/s**8.3. Plasma-Fueling System****8.3.1. Type** Pellet**8.3.2. Fuel composition** H, D, T, DT**8.3.3. Fueling rates** 2,645 kg/d**8.3.4. Pellet diameter** 4 - 6 mm**8.3.5. Pellet speed** 1 - 5 km/s**8.3.6. Pellet injection frequency** 3 s⁻¹

8.4. Blanket Tritium-Processing and Recovery System

8.4.1. Type	Purge gas recovery
8.4.2. Total tritium inventory	0.015 kg
8.4.3. Tritium handling rate	0.354 kg/d
8.4.4. Water processing rate	N/A
8.4.5. Primary-coolant tritium concentration	Negligible
8.4.6. Blanket detritiation factor	N/A

8.5. Fast-Wave Current-Drive System

8.5.1. Type	Folded waveguide
8.5.1.1. Structural material ^(i,j)	Cu-coated SiC composite
8.5.1.2. Number of modules	2
8.5.1.3. Dimensions ($w \times h \times d$)	$3.8 \times 0.6 \times 0.8$ m
8.5.1.4. First-wall perforation	0.65 %
8.5.1.5. Power	22.0 MW/m ²
8.5.2. Transmission system	Coax
8.5.2.1. Power (per coax)	4.2 MW
8.5.2.2. Efficiency	90 %
8.5.3. Radio-frequency transmitter	Klystrode
8.5.3.1. Power (per unit)	5 MW
8.5.3.2. Efficiency	90 %

8.6. Auxiliary Plasma Heating^(g)

8.6.1. Type	ICRF
9.4.2. Frequency	140 – 170 MHz

8.7. Energy Transfer and Storage System

Not required

9. REACTOR COMPONENTS

9.1. First Wall, Blanket, and Shield

9.1.1. Structural material	SiC composite	
9.1.2. Breeding material	Lithium zirconate	
9.1.3. Neutron multiplier material	Beryllium	
9.1.4. Tritium breeding ratio (TBR)		
9.1.4.1. Beginning of life	1.20	
9.1.4.2. End of life	1.17	
9.1.5. Blanket energy multiplication	1.3	
9.1.6. Number of modules	16	
9.1.7. Weight of module	181.6	tonne
9.1.7.1. First wall	0.8	tonne
9.1.7.2. Inboard blanket	15.3	tonne
9.1.7.3. Outboard blanket	67.1	tonne
9.1.7.4. Inboard shield	15.2	tonne
9.1.7.5. Outboard shield	82.7	tonne
9.1.7.6. Divertor	0.5	tonne
9.1.8. Largest single component	Outboard shield sub-module	
9.1.8.1. Weight	41.4	tonne
9.1.8.2. Dimensions ($w \times h \times d$)	$4.3 \times 4 \times 0.8$	m
9.1.9. Lifetime ^(p)	6	y

9.2. Divertor

9.2.1. Type	Double-null, high recycle	
9.2.2. Neutralizer plate		
9.2.2.1. Armor	Tungsten	
9.2.2.2. Coolant tube	SiC composite	
9.2.2.3. Coolant	Helium	
9.2.3. Weight of divertor (per module)	119	kg
9.2.4. Dimensions		
9.2.4.1. Inboard toroidal length	1.05	m
9.2.4.2. Outboard toroidal length	1.31	m
9.2.4.3. Radial length	2.17	m
9.2.5. Lifetime ^(a)	2	y

9.3. Magnets

9.3.1. Poloidal-field coils

9.3.1.1. Type	Superconducting
9.3.1.2. Number	12
9.3.1.3. Conductor	Nb ₃ (Sn-Ti)
9.3.1.4. Structure	Incoloy 908
9.3.1.5. Insulator	Organic
9.3.1.6. Coolant	Helium
9.3.1.7. Operating temperature	4.4 K
9.3.1.8. Maximum stress in coil	700 MPa

9.3.2. Toroidal-field coils

9.3.2.1. Type	Superconducting
9.3.2.2. Number	16
9.3.2.3. Conductor	Nb ₃ (Sn-Ti), NbTi
9.3.2.4. Structure	Incoloy 908
9.3.2.5. Insulator	Organic
9.3.2.6. Coolant	Helium
9.3.2.7. Operating temperature	3 – 8 K
9.3.2.8. Peak stress in coil	800 MPa
9.3.2.9. Mean coil radius	7.15 m

9.3.3. Maximum toroidal field

9.3.3.1. At plasma axis	11.3 T
9.3.3.2. At toroidal-field coil	21.0 T

9.3.4. Total stored energy

9.3.4.1. Poloidal-field system	13 GJ
9.3.4.2. Toroidal-field system	125 GJ

9.3.5. Largest single component

9.3.5.1. Weight	TF coil 190 tonne
9.3.5.2. Dimensions ($h \times d$)	1 × 8 m

10. ELECTRICAL POWER REQUIREMENTS

10.1. Maximum Power from Grid for Cold-Plasma Start-up	200 MW
10.2. Auxiliary-Power Requirements (Normal Operation)	
10.2.1. Electrical energy storage	
10.2.2. Toroidal-field coils	~ 0 MW
10.2.3. Divertor-field coils	~ 0 MW
10.2.4. Current drive	141 MW
10.2.5. First-wall, blanket, shield, and divertor-plate coolant circulators	54 MW
10.2.6. Other auxiliary systems	52 MW
10.2.7. Total	247 MW

11. BUILDINGS**11.1. Reactor Hall**

11.1.1. Characteristic dimensions ^(r)	
11.1.1.1. Outside diameter	52 m
11.1.1.2. Height	35 m
11.1.2. Enclosed volume	$7.4 \times 10^4 \text{ m}^3$
11.1.3. Minimum wall thickness	1 m
11.1.4. Internal pressure	1 atm
11.1.5. Containment atmosphere	Air

11.2. Turbine Building

11.2.1. Characteristic dimensions	
11.2.1.1. Length	100 m
11.2.1.2. Width	40 m
11.2.1.3. Height	33 m
11.2.2. Total enclosed volume	$2.6 \times 10^5 \text{ m}^3$

11.3. Reactor Service Building

11.3.1. Characteristic dimensions ^(s) ($w \times h \times d$)	$15 \times 30 \times 25 \text{ m}$
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12. REACTOR SAFETY AND WASTE DISPOSAL**12.1. Radioactive Material Storage for Life of Plant****12.1.1. Total Class C**

12.1.1.1. Weight

4,924 tonne

12.1.1.2. Volume

1,357 m³**12.2. Tritium Inventory**

12.2.1. First wall

6 g

12.2.2. Blanket

12.2.1.1 Beryllium

640 g

12.2.1.2 Multiplier

1 g

12.2.3. Divertor

10 g

12.3. Peak Temperature During a Loss-of-Coolant Accident (LOCA)^(t)

12.3.1. First wall

1,053 K

12.3.2. Divertor

1,293 K

12.4. Off-Site Doses^(u) at 1 km12.4.1. Zirconium^(v)

91 rem

12.4.2. Tungsten^(w)

11.2 rem

12.4.3. Tritium^(x)

6.4 rem

12.4.4. First wall and reflector

21 rem

12.4.5. Total

130 rem

FOOTNOTES TO TABLE A.1

- (a) The reactor envelope is the cylinder that includes all of the poloidal-field coils.
- (b) The ARIES-I fusion power core comprises 16 self-supporting, identical modules. Each module includes portions of the first wall, blanket, shield, and vacuum vessel, and one TF coil. Reactor maintenance is based on replacing an entire module.
- (c) All plasma parameters are at steady-state burn except as noted.
- (d) Self-consistent plasma profiles are used for all plasma engineering analyses. The plasma profiles are:

$$\begin{aligned}
 n(r) &= n(edge) + n(0) \left[1 - (r/r_p)^2\right]^{\alpha_n}, \\
 T(r) &= T(0) \left[1 - (r/r_p)^2\right]^{\alpha_T}, \\
 j(r) &= j(0) \left[1 - (r/r_p)^2\right]^{\alpha_j},
 \end{aligned}$$

with $n(edge)/n = 0.7$, $\alpha_n = 1.0$, $\alpha_T = 1.1$, and $\alpha_j = 2$. The density profile resembles a parabolic profile with $\alpha_n = 0.3$ if the edge density is zero.

- (e) It is assumed that $\tau_p \simeq 4\tau_E$.
- (f) The engineering beta is defined as the ratio of the average plasma pressure to the maximum field strength on the TF coils.
- (g) The current-drive system is used for auxiliary heating during start-up.
- (h) A 6% "hole" fraction is assumed. The power into the "hole" (pumping ducts, waveguides) are assumed to be absorbed by the first-wall system.
- (i) The term "SiC composite" denotes an SiC-fiber-reinforced SiC-matrix material. The fabrication method consists of two major steps: (1) A preform of the component is woven or braided from continuous SiC fibers using numerically controlled weaving machines. (2) The fiber preform is chemical-vapor infiltrated (CVI) with SiC matrix material. A major advantage of these ceramic-composite manufacturing techniques is that the result is a near-net-shape component that requires only minimal finishing touches. Furthermore, external features such as attachment holes and flanges can be integrated into the preform weaving process.

- (j) The first-wall and blanket shells are in the form of tube-sheets. Each shell is woven as a complete unit by programming the weaving machine to serpentine SiC fibers from tube to tube. It should be noted that such a tube-sheet is structurally quite different from conventional metallic tube-sheets (during welding of metallic tube-sheets, the microstructure of the tube wall in the vicinity of the weld changes, which may result in weak spots).
- (k) A 2-mm thick, 100%-dense SiC layer is chemical-vapor deposited (CVD) on the first-wall shell facing the plasma. This layer serves a double purpose: (1) It constitutes a sacrificial layer for erosion over the first-wall lifetime, and (2) it serves as a coolant leak barrier into the vacuum chamber. Among SiC ceramics, CVD SiC has one of the lowest hydrogen-diffusion coefficients at elevated temperatures (in the fission industry, a CVD layer of SiC is used to contain gaseous fission products inside spherical fission-reactor fuel elements).
- (l) The breeder/multiplier mixture is 20% breeder (lithium zirconate) and 80% Be with a theoretical density of 90%. The sphere-pack pebbles have a binary mixture of spheres with diameters of 1 and 0.1 mm (a packing fraction of 80%).
- (m) The reflector material is Be in the front zone and SiC in the rear zone, both with a theoretical density of 90%. The sphere-pack pebbles have a binary mixture of spheres with diameters of 1 and 0.1 mm (a packing fraction of 80%). The rear zone of the reflector includes the coolant plena for the first wall and blanket.
- (n) The shield materials are high-density SiC and B₄C. The shield also incorporates multiple layers of aluminum sheets sandwiched between He-cooled SiC shells to provide passive stabilization against vertical motion of the plasma. There are 40 layers of 1-mm-thick aluminum sheets and 40 layers of 19-mm-thick SiC shells for an overall shield thickness of 0.8 m. All of the aluminum sheets within a module are electrically connected together at the back of the shield. Neighboring shield modules are also electrically connected together with a detachable jumper to provide a complete toroidal circuit. Analysis shows that most of the electromagnetic forces generated by a plasma disruption appear on the aluminum sheets (since SiC composite is not electrically conducting) and, in effect, the aluminum shells shield the vacuum vessel from disruption forces. The disruption-induced electromagnetic forces generated in each of the aluminum sheets are restrained by the neighboring SiC shells.
- (o) Thermal power is recovered from the hot shield (see no. 4.4).

- (p) The SiC displacement-damage energy was estimated to be 25 eV. Based on this displacement damage energy, a displacement-per-atom (dpa) rate of 11 per MWy/m² was calculated. It has been suggested that radiation-damage-resistant metallic alloys may survive a total of 200 dpa. Because there are no data for SiC composite, the same maximum dpa value of 200 is adopted for the ARIES-I first wall, resulting in a lifetime of ~ 18 MWy/m². Then, in ARIES-I with a peak neutron wall loading of 4 MW/m², the lifetime of the first wall would be 4.5 full power years (FPY) or 6 calendar years. More recent analytical damage calculations suggest that the damage energy for SiC could be as high as 4 times the value used for ARIES-I. This would mean that the dpa rate would be lower by a factor of ~ 4 and the first-wall lifetime would be ~ 4 times longer. However, the predicted high resistance of SiC composite to displacement damage should be verified experimentally.
- (q) Because of extreme heat and particle fluxes on the divertor plate, its lifetime is assumed to be 2 FPY, considerably lower than its radiation-damage lifetime.
- (r) The reactor-hall building diameter is estimated at twice the reactor envelope diameter and its height is based on the vertical-lift maintenance scheme, which requires a clearance of at least 12 m.
- (s) Because the fusion power core is modular, the service building for the reactor can be small.
- (t) At the onset of a LOCA, the plasma is assumed to be quenched with a 10-s power ramp-down.
- (u) Off-site dose is calculated based on the radioactive inventory at the end of life for all components and using the following conditions: distance from release point is 1 km, CLASS-F stability, wind speed is 1 m/s, release duration is 3 m, Gaussian plume dimensions are $\sigma_y = 100$ m and $\sigma_z = 50$ m.
- (v) The zirconium is tailored to the following isotopic mixture: ⁹⁰Zr (0.057%), ⁹¹Zr (0.013%), ⁹²Zr (99.908%), ⁹⁴Zr (0.019%), ⁹⁶Zr (0.003%). The cost of tailoring Zr is \$2097/kg using the ALVIS (atomic-vapor laser-isotope separation) technique at \$50/swu (standard weight units).
- (w) The 2-mm-thick tungsten layer of the divertor plate is tailored to the following isotopic mixture: ¹⁸⁰W (0.02%), ¹⁸²W (3.23%), ¹⁸³W (90.00%), ¹⁸⁴W (3.76%), ¹⁸⁶W (3.51%).
- (x) Assuming release of all of tritium inventory in the FPC.

A.2. SYSTEMS-CODE PARAMETERS OF ARIES-I

plasma E/S parameters

plasma aspect ratio, A	4.500
minor plasma radius, ap(xp) (m)	1.500
minor plasma radius, ap(95) (m)	1.450
plasma vertical elongation, b/a(95)	1.600
plasma vertical elongation, b/a(xp)	1.800
plasma triangularity, d(95)	0.468
plasma triangularity, d(xp)	0.702
(plasma perimeter)/(circular perimeter at ap)=S(95)	1.334
(plasma perimeter)/(circular perimeter at ap)=S(xp)	1.453
scaling coefficient in q-I equation, Cq	1.099
Troyon beta scaling coefficient	0.032
poloidal beta (incl. fus. prods. andimps. , Zeff>1.0)	2.813
poloidal beta (only fuel ions and electrons, Zeff=1.0)	2.295
Shafranov peak poloidal beta	6.939
poloidal-beta/aspect	0.625
toroidal beta	0.019
pinch parameter, theta	0.114
reversal parameter, F	1.012
major toroidal radius, Rt (m)	6.750
circularized plasma radius, rp (m)	1.951
major toroidal radius of plasma centroid(95) (m)	6.586
major toroidal radius of plasma centroid(xp) (m)	6.505
plasma volume(95) (m ³)	425.846
plasma volume(xp) (m ³)	488.627
radial profile exponent for density , alpha(n)	1.000
radial profile exponent for temperature , alpha(T)	1.100
radial profile exponent for pressure, alpha(p)	2.100
radial profile exponent for current density, alpha(j)	2.005
peak/average ratio for current density	3.005
peak/average ratio for density	1.300
ratio of separatrix density to average plasma density	0.700
peak/average ratio for temp.[dens.-weight.-vol.-avg.]	1.898
peak/average ratio for temp.[vol. avg.]	2.100
plasma ion temperature [volume-averaged] (keV)	18.076
plasma electron temperature [volume-averaged] (keV)	17.443
on-axis safety factor, q(axis)	1.300
edge safety factor, q	4.750
edge safety factor, q(*)	3.906
edge safety factor, q(bar)	4.404
on-axis toroidal field (T)	11.325
plasma current, I (MA)	10.199
plasma bootstrap-current contribution (MA)	6.935
bootstrap-current fraction	0.680
bootstrap-current fraction from Harvey model	0.693
bootstrap-current fraction from ANL model	0.900
toroidal current density, j (MA/m ²)	0.853
plasma self inductance (H)	1.260e-05

plasma power/transport/CD parameters

plasma ion temp. [dens.-weight.-vol.-avg.] (keV)	20.000
plasma electron temp. [dens.-weight.-vol.-avg.] (keV)	19.300
plasma fus. prod. temperature (keV)	89.043
plasma impurity temperature (keV)	20.000
plasma (total) ion density ($10^{20}/m^3$)	1.235
ion [p,D,T,He3,He4,Imp.(Z= 8.0)] density fractions:	
0.00040 0.44350 0.44350 0.00260 0.10000	0.01000
plasma electron density ($10^{20}/m^3$)	1.449
Murakami-Hugill electron density limit ($10^{20}/m^3$)	0.859
Greenwald electron density limit ($10^{20}/m^3$)	0.907
effective plasma charge, Zeff	1.653
ideal Lawson parameter (10^{20} s/ m^3)	2.900
KAW Lawson parameter (10^{20} s/ m^3)	2.943
energy confinement time (s)	2.347
energy confinement time (s)	2.531
ratio of particle-to-energy confinement times	4.000
thermal diffusivity (m^2/s)	0.180
Kaye-Goldston-confinement multiplier, H1	2.186
KG-confinement multiplier, H2 (quadratic with NA)	2.178
Goldston-confinement multiplier, H3	2.241
G-confinement multiplier, H4 (quadratic with NA)	2.233
Odajima-Shimomura-confinement multiplier, H5	2.603
Rebut-Lallia-confinement multiplier, H6	1.776
Kaye-(All)-confinement multiplier, H7	3.279
Kaye-(Big)-confinement multiplier, H8	3.333
Riedel-Kaye-confinement multiplier, H9	2.340
ITER-89P -confinement multiplier, Ha	2.588
ITER-89OL-confinement multiplier, Hb	2.592
fusion power density (MW/m^3)	3.940
fusion power, Pf (MW)	1925.425
alpha power (MW)	384.852
scrape-off thickness (m)	0.100
plasma/first-wall radius ratio, x	0.938
first-wall surface area (m^2)	619.436
first-wall hole fraction	0.060
diamagnetic electron cyclotron frequency (GHz)	1974.014
effective FW(2.50e-03) & dev.(f=0.20) resistivity (ohm-m)	1.97e-03
effective FW synchrotron reflectivity [MJS]	-0.100
effective FW synchrotron reflectivity [KAW]	0.463
synchrotron radiation power loss (FW holes) (MW)	16.784
synchrotron radiation power loss (FW surf.) (MW)	177.953
synchrotron radiation power loss (total)	194.737
bremsstrahlung power loss (MW)	45.190
transport (conduction) power, Pcond (MW)	244.354
plasma internal energy, Wp (MJ)	618.460
radiation fraction, frad (bremsstrahlung+synchrotron)	0.495
radiation fraction, frad (core)	0.500
plasma ohmic dissipation during burn (MW)	0.854
plasma loop voltage (V)	0.084
current-drive efficiency factor, gamma(NBI)	0.317
current-drive efficiency factor, gamma(NBI)	0.544
current-drive efficiency factor, gamma(ICRF)	0.328
current-drive efficiency factor, gamma(FW)	0.295
synchrotron current-drive efficiency factor, gamma(SYN)	0.145
neutral-beam energy (keV)	3506.773
NBI attenuation length (m) [edge/centerline (tangent)]	4.743

toroidal field quantities

number of TF coils	16
bucking cylinder thickness (m)	0.728
bucking cylinder stress (MPa)	1000.000
mass of bucking cylinder (tonne)	507.751
major radius of TF-coil inboard leg	3.390
major radius of TF-coil outboard leg	10.559
TF-coil circumference (m)	27.889
TF-coil enclosed volume (m ³)	2148.484
D-coil maximum half-height to centerline (m)	4.989
outboard/inboard TF coil thickness ratio, fcoil	1.000
outboard/inboard TF coil thickness ratio, fcoilt	2.271
major radius of TF-coil inboard-leg inside face (m)	3.637
width of TF-coil inside face (m)	1.447
coil stress (MPa)	1270.894
(input) yield stress in coil stabilizer (MPa)	800.000
(input) allowable stress in coil structure (MPa)	1000.000
coil thickness (m)	0.637
coil homogenized mass density (kg/m ³)	7500.000
mass of TF coil set (tonne)	2931.660
on-axis toroidal field (T)	11.325
magnetic field at the coil (T)	21.020
TF ripple [(Bmax-Bmin)/Bavg] (on-axis) (%)	0.122
TF ripple [(Bmax-Bmin)/Bavg] (outboard) (%)	1.111
TF ripple [(Bmax-Bmin)/Bavg] (inboard TF Coil) (%)	0.004
stored TF magnetic energy (GJ) [Soell]	132.061
stored TF magnetic energy (GJ) [Turner & Abdou]	87.287
TF-coil current (MA)	23.889
TF coil current density (MA/m ²)	28.411
inboard TF-coil ohmic dissipation (MW)	0.000
outboard TF-coil ohmic dissipation (MW)	0.000
ohmic dissipation during burn (MW)	0.000
volumetric heating during burn (MW/m ³)	0.000

poloidal field quantities

OH solenoid bore (m)	2.272
OH solenoid height (m)	5.400
coil thickness (m)	0.001
magnetic field at the OH solenoid (T)	0.410
coil stress (MPa)	241.293
average minor radius of coil (m)	2.272
OH coil current density (MA/m ²)	518.556
coil homogenized mass density (kg/m ³)	7500.000
mass of OH coil set (tonne)	0.364
mass of EF coil set (tonne)	1503.422
magnetic field at the plasma surface (T)	0.936
magnetic field at the coil (T)	8.536
vertical field (T)	0.785
EF coil current (MA)	9.750
EF coil current density (MA/m ²)	27.990
stored PF magnetic energy (GJ)	6.588
ohmic dissipation during burn (MW)	0.000
volumetric heating during burn (MW/m ³)	0.000

Ref,zef,delef (m) = 1.0581e+01 1.3858e+00 4.1734e-01
 (PF-coil mass)/(total coil mass) 0.383

divertor field quantities

DF-coil current (MA)	45.896
DF coil current density (MA/m ²)	27.990
mass of DF coil set (tonne)	312.950
ohmic dissipation during burn (MW)	0.000

impurity control

divertor option nodiv=1: poloidal magnetic divertor	
first-wall surface area (m ²)	619.436
total divertor plate surface area (m ²)	N= 2 123.887
FW/divertor ave. surface heat flux (MW/m ²)	0.391 1.955
radiation fraction, frad (bremsstrahlung+synchrotron)	0.495
radiation fraction, frad (core)	0.500
scrape-off thickness (m)	0.100
flux expansion factor, fx	2.000
scrape-off power-flow scale length (mm) (High-recycle)	25.137
scrape-off power-flow scale length (mm) (Low -recycle)	16.164
watershed-to-null-point connection length (m)	65.473
null-point-to-divertor-plate connection length (m)	11.250
divertor-plate-to-mag.-surface inclination angle (deg)	10.000
divertor/scrape-off area ratio for power flow, omega	1.600
sheath power-flow transmission coefficient, gamma	7.200
scrape-off cross-field thermal diffusivity (m ² /s)	4.000
divertor-plate peak surface heat flux (MW/m ²)	3.882
divertor-plate plasma temperature (eV)	23.857
ratio of separatrix density to average plasma density	0.700
upstream (separatrix) plasma density (1.0e20/m ³)	0.865
vacuum system pumping speed (m ³ /s)	52.038

plasma startup

plasma startup risetime (s)	30.000
inductive flux-swing startup requirement (Vs)	128.469
resistive flux-swing startup requirement (Vs)	4.325
total flux-swing startup requirement (Vs)	6.640
CD flux-swing startup contribution (Vs)	126.154
fraction of total Vs supplied by CD-assisted startup	0.950

power-balance summary

thermal conversion efficiency (blanket)	0.490
thermal conversion efficiency (divertor)	0.490
thermal conversion efficiency (composite)	0.490
auxiliary site power fraction of P_g , f_{aux}	0.040
primary loop pumping power fraction of P_g , f_{pmp}	0.050
engineering q-value, Q_E	5.058
recirculating power fraction, $\epsilon_{ps}=1/Q_E$	0.198
net plant efficiency	0.393
plasma q-value, Q_p	19.910
CD/heater system efficiency	0.725
CD/heater power [NB] (MW)	0.000
CD/heater power [rf] (MW)	96.707
CD/heater power (MW)	96.707
current-drive efficiency (A/W)	0.034
current-drive efficiency factor, γ (10^{20} A/m ² W)	0.330
fusion power, P_f (MW)	1925.425
neutron power (MW)	1538.704
fraction of fusion power in neutron channel	0.799
neutron source density (neutrons/s m ³)	1.402e+18
fusion power in charged particles, P_{cp} (MWt)	386.721
fraction of $P_{cp}+P_{cd}$ to direct conversion	0.000
direct-conversion system efficiency, ϵ_{tadec}	0.000
direct-conversion electric power, P_{dc} (MWe)	0.000
total useful thermal power, $P(TH)$ (MW)	2543.716
gross electrical output power, $P(ET)$	1246.421
net electrical output power, $P(E)$	1000.000

engineering summary

tritium burnup (kg/day)	0.295
fractional burnup	0.193
tritium thru-put (no recycle) (kg/day)	1.533
blanket breeder material ^6Li enrichment	0.800
first-wall surface area (m^2)	619.436
14.06-MeV neutron load, I_w (MW/m^2)	2.482
14.06-MeV neutron energy multiplication in blanket, M	1.300
2.45-MeV neutron load (MW/m^2)	0.002
2.45-MeV neutron energy multiplication in blanket, M	4.200
blanket volume (m^3)	508.070
reflector volume (m^3)	0.000
EF-coil shield volume (m^3)	0.000
inboard shield volume (m^3)	99.089
outboard shield volume (m^3)	468.346
divertor shield volume (m^3)	117.086
shield volume (m^3)	684.522
TF-coil volume (m^3)	390.888
OH-coil volume (m^3)	0.048
EF-coil volume (m^3)	200.456
DF-coil volume (m^3)	41.727
mass of FW/SW/blanket (tonne)	1130.422
mass of reflector (tonne)	0.000
mass of TFC shield (tonne)	1822.659
mass of EFC shield (tonne)	0.000
mass of TF coil set (tonne)	2931.660
mass of OH coil set (tonne)	0.364
mass of EF coil set (tonne)	1503.422
mass of DF coil set (tonne)	312.950
total coil-set mass (tonne)	4748.395
mass of FPC structure (tonne)	1899.358
FPC (FW/SW/B/R/S/C) mass (tonne)	10097.635
fusion-power-core mass utilization, M/Pth (tonne/MWt)	3.970
FPC mass power density, MPD (kWe/tonne)	99.033
system power density (MW/m^3)	0.998
blanket power density (MW/m^3)	5.007
magnetic energy recovery time (s)	54.506
intra-TF-coil outboard equat.-plane horiz. opening (m)	2.459
intra-TF-coil outboard equat.-plane transparency	0.614

***** RADIAL BUILD (TETRA format) *****

	Thickness (m)	Radius (m)
Device Centerline	0.0	0.000
Bore	2.272	2.272
OH Solenoid	0.001	2.272
Gap	0.000	2.272
Bucking Cylinder	0.728	3.000
TF Coil	0.708	3.708
Cryostat	0.050	3.758
Gap	0.000	3.758
Shield - inboard	0.710	4.468
Gap	0.000	4.468
Inboard Blanket	0.670	5.138
Gap	0.000	5.138
First Wall - inboard	0.012	5.150
Scrape Off	0.100	5.250
Plasma C/L	1.500	6.750
Plasma Edge	1.500	8.250
Scrape Off	0.100	8.350
First Wall - outboard	0.012	8.362
Gap	0.000	8.362
Outboard Blanket	0.970	9.332
Gap	0.000	9.332
Shield - outboard	0.810	10.142
Lead	0.000	10.142
Gap	0.049	10.191
Cryostat	0.050	10.241
TF Coil	0.637	10.878
Cryostat	0.050	10.928

***** VERTICAL BUILD *****

	Increment (m)	Height (m)
elongated plasma, $b/a = 1.800$	2.700	2.700
impurity control/blanket	0.970	3.670
outboard-shield/gap	0.950	4.620
Cryostat	0.050	4.670
TF coil, $R = 6.172$	0.637	5.307
Cryostat	0.050	5.357

A.2. SYSTEMS-CODE PARAMETERS OF ARIES-I

A-31

FPC components:	volume frac.	density (kg/m ³)	frac. density	cost (1980) (\$/kg)	thick. (m)
SiC	0.667	3200.000	1.000	280.900	
Void	0.333	0.000	1.000	0.000	
Void	0.000	0.000	1.000	0.000	
Void	0.000	0.000	1.000	0.000	
Void	0.000	0.000	1.000	0.000	
Total FW		2134.400		280.900	0.012 0.012
SiC	0.190	3200.000	1.000	280.900	
Li2ZrO3	0.042	4150.000	0.720	106.333	
Be	0.272	1850.000	0.720	372.600	
SiC	0.336	3200.000	1.000	35.100	
Void	0.160	0.000	1.000	0.000	
Total BL(ib)		2171.000		164.378	0.670
SiC	0.363	3200.000	1.000	280.900	
Li2ZrO3	0.029	4150.000	0.720	106.333	
Be	0.188	1850.000	0.720	372.600	
SiC	0.232	3200.000	1.000	35.100	
Void	0.188	0.000	1.000	0.000	
Total BL(ob)		2241.068		202.970	0.970
SiC	0.596	3200.000	0.950	35.100	
B4C	0.256	2500.000	0.950	14.900	
Al	0.014	2700.000	1.000	10.000	
Void	0.134	0.000	1.000	0.000	
Void	0.000	0.000	1.000	0.000	
Total SH(ib)		2457.640		29.717	0.710
SiC	0.657	3200.000	0.950	35.100	
B4C	0.280	2500.000	0.950	14.900	
Al	0.013	2700.000	1.000	10.000	
Void	0.050	0.000	1.000	0.000	
Void	0.000	0.000	1.000	0.000	
Total SH(ob)		2697.380		29.793	0.810
Blanket breeder material 6Li enrichment				0.800	
TF-coil		7500.000		63.000	
OH-coil		7500.000		56.000	
EF-coil		7500.000		50.000	
DF-coil		7500.000		50.000	
rf current-drive unit cost (\$/W)				0.755	

NOTE: unit-cost(1980) x 1.4238 = unit-cost(1988)

A.3. COST SUMMARY OF ARIES-I REACTOR

acc. no.	account title	million dollars (1988)
20.	land & land rights	5.281
21.	structures & site facilities	339.280
22.	reactor plant equipment	1362.833
22. 1. 1.	FW/SW/blanket/reflector	260.333
22. 1. 2.	shield	77.323
22. 1. 3.	magnets	392.309
22. 1. 4.	supplemental-heating/CD systems	103.919
22. 1. 5.	primary structure & support	63.572
22. 1. 6.	reactor vacuum systems(unless integral elsewhere)	32.232
22. 1. 7.	power supply, switching & energy storage	51.257
22. 1. 8.	impurity control	7.850
22. 1. 9.	direct energy conversion system	0.000
22. 1. 10.	earth breakdown system	23.023
22. 1.	reactor equipment	1011.817
22. 2.	main heat transfer & transport systems	229.688
23.	turbine plant equipment	245.262
24.	electric plant equipment	137.051
25.	miscellaneous plant equipment	50.474
26.	special materials	0.566
90.	direct cost (not incl. spares and contingency)	2140.746
91.	construction services & equipment	214.075
92.	home office engineering & services	214.075
93.	field office engineering & services	214.075
94.	owner's cost	107.037
96.	project contingency	214.075
97.	interest during construction (IDC)	512.794
99.	total cost	3616.876

thermal power (MWth)	= 2543.72	unit direct cost (\$/kWe) [90]= 2140.75
gross electric power (MWe)	= 1246.42	unit base cost (\$/kWe) [94]= 3104.08
net electric power (MWe)	= 1000.00	unit total cost (\$/kWe) [99]= 3616.89
1/recirculating power fraction QE=	5.058	capital return (mill/kWeh) = 52.56
plant availability factor	= 0.759	O&M(1.43%) (mill/kWeh) [40-47,51]= 6.67
construction= 6 yr: constant	then-current	W/B/R replace. (mill/kWeh) [50]= 5.58
FCS=	0.0966	decommissioning allowance = 0.50
FIDC=	0.1652	D (D & 3He) fuel (mill/kWeh) [02]= 0.04
fEDC=	0.0000	COE (mill/kWeh) = 65.34
		131.91

A.3. COST SUMMARY OF ARIES-I REACTOR

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acc. no.	account title	million dollars (1988)
20. 1.	land & privilege acquisition	
4.753		
20. 2.	relocation of buildings, utilities, highways, etc.	0.528
20.	land & land rights	5.281
21. 1. 1.	general yard improvements	
21. 1. 2.	waterfront improvements	
21. 1. 3.	transportation access (off site)	
21. 1.	site improvements & facilities	16.060
21. 2. 1.	basic building structures	83.890
21. 2. 2.	building services	2.848
21. 2. 3.	containment structures	42.714
21. 2. 4.	architectural	10.678
21. 2.	reactor building	140.130
21. 3. 1.	basic building structures	42.714
21. 3. 2.	building services	2.848
21. 3. 3.	architectural	2.136
21. 3.	turbine building	47.697
21. 4. 1.	intake structures	
21. 4. 2.	discharge structures	
21. 4. 3.	unpressurized intake & discharge conduits	
21. 4. 4.	recirculating structures	
21. 4. 5.	cooling tower systems	
21. 4.	cooling system structures	10.852
21. 5. 1.	basic building structures	11.433
21. 5. 2.	building services	0.755
21. 5. 3.	architectural	0.854
21. 5.	power supply & energy storage building	13.042
21. 6. 1.	reactor auxiliaries building(incl. switchgear bay)	4.642
21. 6. 2.	hot cell building	76.828
21. 6. 3.	fuel storage building	12.287
21. 6. 4.	control room building	4.414
21. 6. 5.	diesel generator building	2.919
21. 6. 6.	administration building	1.239
21. 6. 7.	service building	2.677
21. 6. 8.	cryogenics building	1.296
21. 6. 9.	miscellaneous structures & building work	2.620
21. 6.	miscellaneous buildings	108.921
21. 7.	ventilation stack	2.577
21.98.	spare parts allowance	
21.99.	contingency allowance	
21.	structures & site facilities	339.280

acc. no.	account title	million dollars (1988)
22. 1. 1. 1.	breeding material(incl. tritium breeding)	7.238
22. 1. 1. 2.	first wall & structural material	213.851
22. 1. 1. 3.	attenuators, reflectors, & multipliers	
22. 1. 1. 4.	wall modifiers(coatings, liners, limiters, etc.)	39.245
22. 1. 1. 5.	reflector	0.000
22. 1. 1. 6.	other	
22. 1. 1. 1.	FW/SW/blanket/reflector	260.333
22. 1. 1. 1.	primary	77.323
22. 1. 2. 1.	secondary	0.000
22. 1. 2. 2.	shield	
22. 1. 3. 1.	toroidal field coils	262.999
22. 1. 3. 2.	ohmic-heating coils	0.029
22. 1. 3. 3.	equilibrium field coils	106.999
22. 1. 3. 4.	divertor field coils	22.282
22. 1. 3. 5.	other coils	
22. 1. 3.	magnets	392.309
22. 1. 4. 1.	beam heating(neutral, ion or electron)	0.000
22. 1. 4. 1.	rf heating	103.919
22. 1. 4. 2.	laser heating	
22. 1. 4. 3.	other heating systems	
22. 1. 4. 4.	supplemental-heating/CD systems	103.919
22. 1. 4.	reactor structure	
22. 1. 5. 1.	equipment support structure	
22. 1. 5. 2.	primary structure & support	63.572
22. 1. 5.	plasma chamber vacuum(incl. pumps/comp./pipe)	
22. 1. 6. 1.	magnet dewar vacuum(incl. pumps/comp./pipe)	6.219
22. 1. 6. 2.	suppl. heating vacuum(incl. pumps/comp./pipe)	
22. 1. 6. 3.	direct converter vacuum(incl. pumps/comp./pipe)	
22. 1. 6. 4.	reactor vacuum system(low grade)	
22. 1. 6. 5.	reactor vacuum wall	
22. 1. 6. 6.	reactor vacuum tank/enclosure	26.013
22. 1. 6. 7.	reactor vacuum systems(unless integral elsewhere)	32.232
22. 1. 6.	EF-coil power supplies	0.000
22. 1. 7. 1.	OH-coil power supplies	
22. 1. 7. 2.	TF-coil power supplies	
22. 1. 7. 3.	DF-coil power supplies	
22. 1. 7. 4.	other power supplies	1.424
22. 1. 7. 5.	current drive power supplies	0.000
22. 1. 7. 6.	control system	
22. 1. 7. 7.	central energy storage	
22. 1. 7. 8.	other incl. busbars	49.833
22. 1. 7. 9.	power supply, switching & energy storage	51.257
22. 1. 7.	impurity control	7.850
22. 1. 8.	vacuum tank	
22. 1. 9. 1.	direct converter modules	
22. 1. 9. 2.	thermal panels	
22. 1. 9. 3.	power conditioning equipment	0.000
22. 1. 9. 4.	direct energy conversion system	23.023
22. 1. 9.	ecrh breakdown system	1011.817
22. 1. 10.	reactor equipment	
22. 1.		

acc. no.	account title	million dollars (1988)
22. 2. 1. 1.	pumps & motor drives(modular & nonmodular)	
22. 2. 1. 2.	piping	
22. 2. 1. 3.	heat exchangers	
22. 2. 1. 4.	tanks(dump,make-up,clean-up,trit.,hot storage)	
22. 2. 1. 5.	clean-up system	
22. 2. 1. 6.	thermal insulation, piping & equipment	
22. 2. 1. 7.	tritium extraction	
22. 2. 1. 8.	pressurizer	
22. 2. 1. 9.	other	
22. 2. 1. 1.	primary coolant system	151.949
22. 2. 2. 1.	pumps & motor drives(modular & nonmodular)	
22. 2. 2. 2.	piping	
22. 2. 2. 3.	heat exchangers	
22. 2. 2. 4.	tanks(dump,make-up,clean-up,trit.,hot storage)	
22. 2. 2. 5.	clean-up system	
22. 2. 2. 6.	thermal insulation, piping & equipment	
22. 2. 2. 7.	tritium extraction	
22. 2. 2. 8.	pressurizer	
22. 2. 2. 9.	other	
22. 2. 2. 1.	intermediate coolant system	77.731
22. 2. 3. 1.	pumps & motor drives(modular & nonmodular)	
22. 2. 3. 2.	piping	
22. 2. 3. 3.	heat exchangers	
22. 2. 3. 4.	tanks(dump,make-up,clean-up,trit.,hot storage)	
22. 2. 3. 5.	clean-up system	
22. 2. 3. 6.	thermal insulation, piping & equipment	
22. 2. 3. 7.	tritium extraction	
22. 2. 3. 8.	pressurizer	
22. 2. 3. 9.	other	
22. 2. 3. 1.	secondary coolant system	0.008
22. 2. 3. 2.	main heat transfer & transport systems	229.688
22. 2. 3. 3.		
22. 3. 1. 1.	refrigeration	0.000
22. 3. 1. 2.	piping	
22. 3. 1. 3.	fluid circulation driving system	
22. 3. 1. 4.	tanks	
22. 3. 1. 5.	purification	
22. 3. 1. 1.	magnet cooling system	0.000
22. 3. 2. 1.	refrigeration	
22. 3. 2. 2.	piping	
22. 3. 2. 3.	fluid circulation driving system	
22. 3. 2. 4.	tanks	
22. 3. 2. 5.	purification	
22. 3. 2. 2.	shield & structure cooling system	2.427
22. 3. 2. 3.		

acc. no.	account title	million dollars (1988)
22. 3. 3. 1.	refrigeration	
22. 3. 3. 2.	piping	
22. 3. 3. 3.	fluid circulation driving system	
22. 3. 3. 4.	tanks	
22. 3. 3. 5.	purification	
22. 3. 3.	supplemental heating system cooling system	
22. 3. 4. 1.	refrigeration	
22. 3. 4. 2.	piping	
22. 3. 4. 3.	fluid circulation driving system	
22. 3. 4. 4.	tanks	
22. 3. 4. 5.	purification	
22. 3. 4.	power supply cooling system	
22. 3. 5.	other cooling systems (ECCS)	2.427
22. 3.	auxiliary cooling systems	
22. 4. 1.	liquid waste processing & equipment	
22. 4. 2.	gaseous wastes & off-gas processing system	
22. 4. 3.	solid waste processing equipment	
22. 4.	radioactive waste treatment & disposal	4.347
22. 5. 1.	fuel injection systems	10.562
22. 5. 2.	fuel processing systems	12.759
22. 5. 3.	fuel storage	5.281
22. 5. 4.	atmospheric tritium recovery	2.434
22. 5. 5.	water tritium recovery systems	5.281
22. 5. 6.	blanket tritium recovery systems	5.281
22. 5. 7.	other	
22. 5.	fuel handling & storage systems	41.597
22. 6. 1. 1.	blanket & coil maintenance equipment	
22. 6. 1. 2.	components rotated into service to allow maint.	
22. 6. 1. 3.	other maintenance equipment	
22. 6. 1.	maintenance equipment	
22. 6. 2.	special heating systems(start-up,trace, etc.)	
22. 6. 3.	coolant receiving, storage & make-up systems	
22. 6. 4.	gas systems	
22. 6. 5.	building vacuum systems	
22. 6.	other reactor plant equipment	39.626
22. 7. 1.	reactor i&c equip.(burn control, diagnostics, etc.	
22. 7. 2.	radiation monitoring systems	
22. 7. 3.	isolated indicating & recording gauges, etc.	
22. 7.	instrumentation & control(i&c)	33.331
22.98.	spare parts allowance	
22.99.	contingency allowance	
22.	reactor plant equipment	1362.833

A.3. COST SUMMARY OF ARIES-I REACTOR

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acc. no.	account title	million dollars (1988)
23. 1. 1.	turbine-generators & accessories	
23. 1. 2.	foundations	
23. 1. 3.	standby exciters	
23. 1. 4.	lubricating system	
23. 1. 5.	gas systems	
23. 1. 6.	reheaters	
23. 1. 7.	shielding	
23. 1. 8.	weather-proof housing	99.517
23. 1.	turbine-generators	6.078
23. 2.	main steam (or other fluid) system	
23. 3. 1.	water intake common facilities	
23. 3. 2.	circulating water systems	
23. 3. 3.	cooling towers	
23. 3. 4.	other systems which reject heat to the atmosphere	
23. 3.	heat rejection systems	27.828
23. 4. 1.	condensers	
23. 4. 2.	condensate system	
23. 4. 3.	gas removal system	
23. 4. 4.	turbine by-pass systems(excl. piping)	
23. 4.	condensing systems	23.953
23. 5. 1.	regenerators & recuperators	
23. 5. 2.	pumps	
23. 5. 3.	tanks	
23. 5.	feed heating system	9.562
23. 6. 1.	turbine auxiliaries	
23. 6. 2.	auxiliaries cooling system(excl. piping)	
23. 6. 3.	make-up treat. system(excl. piping)	
23. 6. 4.	chemical treat. & condensate purification systems	
23. 6. 5.	central lubrication service system(excl. piping)	
23. 6.	other turbine plant equipment	66.459
23. 7.	instrumentation & control(i&c) equipment	11.865
23.98.	spare parts allowance	
23.99.	contingency allowance	
23.	turbine plant equipment	245.262

acc. no.	account title	million dollars (1988)
24. 1. 1.	generator circuits	
24. 1. 2.	station service	15.257
24. 1.	switchgear	
24. 2. 1.	station service & startup transformers	
24. 2. 2.	low voltage unit substation & lighting transformer	
24. 2. 3.	battery system	
24. 2. 4.	diesel engine generators	
24. 2. 5.	gas turbine generators	
24. 2. 6.	motor generator sets	25.192
24. 2.	station service equipment	
24. 3. 1.	main control board for electric system	
24. 3. 2.	auxiliary power & signal boards	
24. 3.	switchboards (incl. heat tracing)	9.580
24. 4. 1.	gen. station grounding sys. & cathodic protection	
24. 4.	protective equipment	3.004
24. 5. 1.	concrete cable tunnels, trenches & envelopes	
24. 5. 2.	cable trays & support	
24. 5. 3.	conduit	
24. 5. 4.	other structures	
24. 5.	electrical structures & wiring containers	23.578
24. 6. 1.	generator circuits wiring	
24. 6. 2.	station service power wiring	
24. 6. 3.	control wiring	
24. 6. 4.	instrument wiring	
24. 6. 5.	containment penetrations	
24. 6.	power & control wiring	48.765
24. 7. 1.	reactor building lighting	
24. 7. 2.	turbine building lighting	
24. 7. 3.	reactor auxiliaries building lighting	
24. 7. 4.	radioactive waste building lighting	
24. 7. 5.	fuel storage building lighting	
24. 7. 6.	miscellaneous buildings lighting	
24. 7. 7.	yard lighting	
24. 7.	electrical lighting	11.675
24. 98.	spare parts allowance	
24. 99.	contingency allowance	
24.	electric plant equipment	137.051

A.3. COST SUMMARY OF ARIES-I REACTOR

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acc. no.	account title	million dollars (1988)
25. 1. 1.	cranes, hoists, monorails, & conveyors	
25. 1. 2.	railway	
25. 1. 3.	roadway equipment	
25. 1. 4.	watercraft	
25. 1. 5.	vehicle maintenance equipment	22.325
25. 1.	transportation & lifting equipment	
25. 2. 1.	air systems(excl. piping)	
25. 2. 2.	water systems(excl. piping)	
25. 2. 3.	auxiliary heating boilers(excl. piping)	17.584
25. 2.	air & water service systems	
25. 3. 1.	local communications systems	
25. 3. 2.	signal systems	
25. 3.	communications equipment	8.856
25. 4. 1.	safety equipment	
25. 4. 2.	shop, laboratory, & test equipment	
25. 4. 3.	office equipment & furnishings	
25. 4. 4.	change room equipment	
25. 4. 5.	environmental monitoring equipment	
25. 4. 6.	dining facilities	1.709
25. 4.	furnishings & fixtures	
25.98.	spare parts allowance	
25.99.	contingency allowance	
25.	miscellaneous plant equipment	50.474
26. 1.	reactor coolant	0.000
26. 2.	intermediate coolant	
26. 3.	turbine cycle working fluids	
26. 4.	other materials	0.356
26. 5.	Ar reactor-building cover gas	0.210
26.98.	spare parts allowance	
26.99.	contingency allowance	
26.	special materials	0.566

acc. no.	account title	million dollars (1988)
20.	land & land rights	5.281
21.	structures & site facilities	339.280
22.	reactor plant equipment	1362.833
23.	turbine plant equipment	245.262
24.	electric plant equipment	137.051
25.	miscellaneous plant equipment	50.474
26.	special materials	0.566
90.	direct cost (not incl. spares and contingency)	2140.746
91.	construction services & equipment	214.075
92. 1.	systems engineering	
92. 2.	management	
92. 3.	quality assurance	
92. 4.	safety & environmental engineering	
92.	home office engineering & services	214.075
93. 1.	construction management	
93. 2.	inspection	
93. 3.	preoperational testing	
93.	field office engineering & services	214.075
94. 1.	project administration	
94. 2.	staff training & plant startup	
94. 3.	inventories & spares	
94.	owner's cost	107.037
95.	process contingency	
96.	project contingency	214.075
97.	interest during construction (IDC)	512.794
98.	escalation during construction (EDC)	
99.	total cost	3616.876

A.4. COST DATA BASE FOR ARIES-I REACTOR

acc. no.	account title	UC(1988) = 1.424 x UC(1980)	unit cost(1980)	no. of units	refs.
20. 1. 0. 0	land & privilege acquisition		3.338e+03 \$/acre	1.000e+03	10
20. 2. 0. 0	relocation of buildings, utilities, highways, etc.		3.710e+02 \$/acre	1.000e+03	10
20. 0. 0. 0	land & land rights		0.	1.000e+00	
21. 1. 1. 0	general yard improvements		0.	1.000e+00	
21. 1. 2. 0	waterfront improvements		0.	1.000e+00	
21. 1. 3. 0	transportation access (off site)		0.	1.000e+00	
21. 1. 0. 0	site improvements & facilities		1.128e+07 \$	1.000e+00	10
21. 2. 1. 0	basic building structures		3.000e+02 \$/m^3	1.964e+05	13,18
21. 2. 2. 0	building services		2.000e+06 \$	1.000e+00	13,14,+
21. 2. 3. 0	containment structures		3.000e+07 \$	1.000e+00	13,14,+
21. 2. 4. 0	architectural		7.500e+06 \$	1.000e+00	13,14,+
21. 2. 0. 0	reactor building		0.	1.000e+00	
21. 3. 1. 0	basic building structures		3.000e+07 \$	1.000e+00	13,14,18
21. 3. 2. 0	building services		2.000e+06 \$	1.000e+00	13,14,+
21. 3. 3. 0	architectural		1.500e+06 \$	1.000e+00	13
21. 3. 0. 0	turbine building		0.	1.000e+00	
21. 4. 1. 0	intake structures		0.	1.000e+00	
21. 4. 2. 0	discharge structures		0.	1.000e+00	
21. 4. 3. 0	unpressurized intake & discharge conduits		0.	1.000e+00	
21. 4. 4. 0	recirculating structures		0.	1.000e+00	
21. 4. 5. 0	cooling tower systems		0.	1.000e+00	
21. 4. 0. 0	cooling system structures		8.982e+05 \$/unit	8.486e+00	2,13,14
21. 5. 1. 0	basic building structures		8.030e+06 \$	1.000e+00	13,14
21. 5. 2. 0	building services		5.300e+05 \$	1.000e+00	13,14
21. 5. 3. 0	architectural		6.000e+05 \$	1.000e+00	13
21. 5. 0. 0	power supply & energy storage building		0.	1.000e+00	
21. 6. 1. 0	reactor auxiliaries building(incl. switchgear bay)		3.260e+06 \$	1.000e+00	13,14
21. 6. 2. 0	hot cell building		5.396e+07 \$	1.000e+00	13,14
21. 6. 3. 0	fuel storage building		8.630e+06 \$	1.000e+00	13,14
21. 6. 4. 0	control room building		3.100e+06 \$	1.000e+00	13,14
21. 6. 5. 0	diesel generator building		2.050e+06 \$	1.000e+00	13,14
21. 6. 6. 0	administration building		8.700e+05 \$	1.000e+00	13,14
21. 6. 7. 0	service building		1.880e+06 \$	1.000e+00	13,14
21. 6. 8. 0	cryogenics building		9.100e+05 \$	1.000e+00	13,14
21. 6. 9. 0	miscellaneous structures & building work		1.840e+06 \$	1.000e+00	13,14
21. 6. 0. 0	miscellaneous buildings		0.	1.000e+00	
21. 7. 0. 0	ventilation stack		1.810e+06 \$	1.000e+00	13,14
21. 98. 0. 0	spare parts allowance		0.	-1.000e+00	2,13,14
21. 99. 0. 0	contingency allowance		0.	-1.000e+00	2,13,14
21. 0. 0. 0	structures & site facilities		0.	1.000e+00	
22. 1. 1. 1	breeding material(incl. tritium breeding)		1.063e+02 \$/kg	4.782e+04	15,18
22. 1. 1. 2	first wall & structural material		2.809e+02 \$/kg	5.347e+05	10
22. 1. 1. 3	attenuators, reflectors, & multipliers		0.	1.000e+00	
22. 1. 1. 4	wall modifiers(coatings, liners, limiters, etc.)		4.450e+04 \$/m^2	6.194e+02	6
22. 1. 1. 5	reflector		1.855e+02 \$/kg	0.	
22. 1. 1. 6	other		0.	1.000e+00	
22. 1. 1. 0	FW/SW/blanket/reflector		0.	1.000e+00	
22. 1. 2. 1	primary		2.979e+01 \$/kg	1.823e+06	10
22. 1. 2. 2	secondary		2.979e+01 \$/kg	0.	10
22. 1. 2. 0	shield		0.	1.000e+00	

acc. no.	account title	UC(1988) = 1.424 x UC(1980)	unit cost(1980)	no. of units	refs.
22. 1. 3. 1	toroidal field coils		6.300e+01 \$/kg	2.932e+06 10	
22. 1. 3. 2	ohmic-heating coils		5.600e+01 \$/kg	3.635e+02 10	
22. 1. 3. 3	equilibrium field coils		5.000e+01 \$/kg	1.503e+06 10	
22. 1. 3. 4	divertor field coils		5.000e+01 \$/kg	3.130e+05 10	
22. 1. 3. 5	other coils		0.	1.000e+00	
22. 1. 3. 0	magnets		0.	1.000e+00	
22. 1. 4. 1	beam heating(neutral, ion or electron)		2.110e+00 \$/W	0.	28+
22. 1. 4. 2	rf heating		7.547e-01 \$/W	9.671e+07 28+	
22. 1. 4. 3	laser heating		0.	1.000e+00	
22. 1. 4. 4	other heating systems		0.	1.000e+00	
22. 1. 4. 0	supplemental-heating/CD systems		0.	1.000e+00	
22. 1. 5. 1	reactor structure		0.	1.000e+00	
22. 1. 5. 2	equipment support structure		0.	1.000e+00	
22. 1. 5. 0	primary structure & support		1.855e+01 \$/kg	2.407e+06 28	
22. 1. 6. 1	plasma chamber vacuum(incl. pumps/comp./pipe)		8.393e+04 \$/m^3/s	5.204e+01 26	
22. 1. 6. 2	magnet dewar vacuum(incl. pumps/comp./pipe)		0.	1.000e+00	
22. 1. 6. 3	suppl. heating vacuum(incl. pumps/comp./pipe)		0.	1.000e+00	
22. 1. 6. 4	direct converter vacuum(incl. pumps/comp./pipe)		0.	1.000e+00	
22. 1. 6. 5	reactor vacuum system(low grade)		0.	1.000e+00	
22. 1. 6. 6	reactor vacuum wall		0.	1.000e+00	
22. 1. 6. 7	reactor vacuum tank/enclosure		1.500e+01 \$/kg	1.218e+06 9	
22. 1. 7. 0	reactor vacuum systems(unless integral elsewhere)		0.	1.000e+00	
22. 1. 7. 1	EF-coil power supplies		7.460e+02 \$/kVA	1.000e-02 10	
22. 1. 7. 2	OH-coil power supplies		1.855e+01 \$/kVA	1.000e-02 10	
22. 1. 7. 3	TF-coil power supplies		3.709e+01 \$/kVA	4.365e-06 10	
22. 1. 7. 4	DF-coil power supplies		3.709e+01 \$/kVA	3.269e-07 10	
22. 1. 7. 5	other power supplies		1.000e+06	1.000e+00	
22. 1. 7. 6	current drive power supplies		3.709e+01 \$/kVA	0.	10
22. 1. 7. 7	control system		0.	1.000e+00	
22. 1. 7. 8	central energy storage		0.	1.000e+00	
22. 1. 7. 9	other incl. busbars		3.500e+07 \$	1.000e+00	
22. 1. 8. 0	power supply, switching & energy storage		0.	1.000e+00	
22. 1. 8. 1	impurity control		4.450e+04 \$/m^2	1.239e+02 10	
22. 1. 9. 1	vacuum tank		0.	1.000e+00	
22. 1. 9. 2	direct converter modules		0.	1.000e+00	
22. 1. 9. 3	thermal panels		0.	1.000e+00	
22. 1. 9. 4	power conditioning equipment		0.	1.000e+00	
22. 1. 9. 0	direct energy conversion system		0.	1.000e+00	
22. 1.10. 0	ecrh breakdown system		0.	1.000e+00	
22. 1. 0. 0	reactor equipment		1.617e+07 \$	0.	13
22. 2. 1. 1	pumps & motor drives(modular & nonmodular)		0.	1.000e+00	
22. 2. 1. 2	pipng		0.	1.000e+00	
22. 2. 1. 3	heat exchangers		0.	1.000e+00	
22. 2. 1. 4	tanks(dump,make-up, clean-up, trit., hot storage)		0.	1.000e+00	
22. 2. 1. 5	clean-up system		0.	1.000e+00	
22. 2. 1. 6	thermal insulation, piping & equipment		0.	1.000e+00	
22. 2. 1. 7	tritium extraction		0.	1.000e+00	
22. 2. 1. 8	pressurizer		0.	1.000e+00	
22. 2. 1. 9	other		0.	1.000e+00	
22. 2. 1. 0	primary coolant system		4.195e+04 \$/MWth	2.544e+03 10	

acc. no.	account title	UC(1988) = 1.424 x UC(1980)	unit cost(1980)	no. of units	refs.
22. 2. 2. 1	pumps & motor drives(modular & nonmodular)		0.	1.000e+00	
22. 2. 2. 2	piping		0.	1.000e+00	
22. 2. 2. 3	heat exchangers		0.	1.000e+00	
22. 2. 2. 4	tanks(dump,make-up, clean-up, trit., hot storage)		0.	1.000e+00	
22. 2. 2. 5	clean-up system		0.	1.000e+00	
22. 2. 2. 6	thermal insulation, piping & equipment		0.	1.000e+00	
22. 2. 2. 7	tritium extraction		0.	1.000e+00	
22. 2. 2. 8	pressurizer		0.	1.000e+00	
22. 2. 2. 9	other		0.	1.000e+00	
22. 2. 2. 0	intermediate coolant system		2.146e+04 \$/MWth	2.544e+03 10	
22. 2. 3. 1	pumps & motor drives(modular & nonmodular)		0.	1.000e+00	
22. 2. 3. 2	piping		0.	1.000e+00	
22. 2. 3. 3	heat exchangers		0.	1.000e+00	
22. 2. 3. 4	tanks(dump,make-up, clean-up, trit., hot storage)		0.	1.000e+00	
22. 2. 3. 5	clean-up system		0.	1.000e+00	
22. 2. 3. 6	thermal insulation, piping & equipment		0.	1.000e+00	
22. 2. 3. 7	tritium extraction		0.	1.000e+00	
22. 2. 3. 8	pressurizer		0.	1.000e+00	
22. 2. 3. 9	other		0.	1.000e+00	
22. 2. 3. 0	secondary coolant system		2.146e+05 \$/MWth	2.544e+02 10	
22. 2. 0. 0	main heat transfer & transport systems		0.	1.000e+00	
22. 3. 1. 1	refrigeration		7.546e+01 \$/unit	1.262e-02 23	
22. 3. 1. 2	piping		0.	1.000e+00	
22. 3. 1. 3	fluid circulation driving system		0.	1.000e+00	
22. 3. 1. 4	tanks		0.	1.000e+00	
22. 3. 1. 5	purification		0.	1.000e+00	
22. 3. 1. 0	magnet cooling system		0.	1.000e+00	
22. 3. 2. 1	refrigeration		0.	1.000e+00	
22. 3. 2. 2	piping		0.	1.000e+00	
22. 3. 2. 3	fluid circulation driving system		0.	1.000e+00	
22. 3. 2. 4	tanks		0.	1.000e+00	
22. 3. 2. 5	purification		0.	1.000e+00	
22. 3. 2. 0	shield & structure cooling system		6.700e+02 \$/MWth	2.544e+03 13	
22. 3. 3. 1	refrigeration		0.	1.000e+00	
22. 3. 3. 2	piping		0.	1.000e+00	
22. 3. 3. 3	fluid circulation driving system		0.	1.000e+00	
22. 3. 3. 4	tanks		0.	1.000e+00	
22. 3. 3. 5	purification		0.	1.000e+00	
22. 3. 3. 0	supplemental heating system cooling system		0.	1.000e+00	
22. 3. 4. 1	refrigeration		0.	1.000e+00	
22. 3. 4. 2	piping		0.	1.000e+00	
22. 3. 4. 3	fluid circulation driving system		0.	1.000e+00	
22. 3. 4. 4	tanks		0.	1.000e+00	
22. 3. 4. 5	purification		0.	1.000e+00	
22. 3. 4. 0	power supply cooling system		0.	1.000e+00	
22. 3. 5. 0	other cooling systems (BCCS)		0.	1.000e+00	
22. 3. 0. 0	auxiliary cooling systems		0.	1.000e+00	
22. 4. 1. 0	liquid waste processing & equipment		0.	1.000e+00	
22. 4. 2. 0	gaseous wastes & off-gas processing system		0.	1.000e+00	
22. 4. 3. 0	solid waste processing equipment		0.	1.000e+00	
22. 4. 0. 0	radioactive waste treatment & disposal		1.200e+03 \$/MWth	2.544e+03 13,14	

acc. no.	account title	UC(1988) = 1.424 x UC(1980)	unit cost(1980)	no. of units	refs.
22. 5. 1. 0	fuel injection systems		3.709e+06 \$	2.000e+00	10
22. 5. 2. 0	fuel processing systems		3.709e+04 \$/unit	2.416e+02	10
22. 5. 3. 0	fuel storage		3.709e+06 \$	1.000e+00	10
22. 5. 4. 0	atmospheric tritium recovery		1.484e+04 \$/m ³ /hr	1.152e+02	10
22. 5. 5. 0	water tritium recovery systems		3.709e+06 \$	1.000e+00	10
22. 5. 6. 0	blanket tritium recovery systems		3.709e+06 \$	1.000e+00	10
22. 5. 7. 0	other		0.	1.000e+00	
22. 5. 0. 0	fuel handling & storage systems		0.	1.000e+00	
22. 6. 1. 1	blanket & coil maintenance equipment		0.	1.000e+00	
22. 6. 1. 2	components rotated into service to allow maint.		0.	1.000e+00	
22. 6. 1. 3	other maintenance equipment		0.	1.000e+00	
22. 6. 1. 0	maintenance equipment		0.	1.000e+00	
22. 6. 2. 0	special heating systems(start-up,trace, etc.)		0.	1.000e+00	
22. 6. 3. 0	coolant receiving, storage & make-up systems		0.	1.000e+00	
22. 6. 4. 0	gas systems		0.	1.000e+00	
22. 6. 5. 0	building vacuum systems		0.	1.000e+00	
22. 6. 0. 0	other reactor plant equipment		1.094e+04 \$/MWth	2.544e+03	13,14
22. 7. 1. 0	reactor i/c equip.(burn control, diagnostics, etc.		0.	1.000e+00	
22. 7. 2. 0	radiation monitoring systems		0.	1.000e+00	
22. 7. 3. 0	isolated indicating & recording gauges, etc.		0.	1.000e+00	
22. 7. 0. 0	instrumentation & control(i/c)		0.	1.000e+00	
22. 98. 0. 0	spare parts allowance		2.341e+07 \$	1.000e+00	13,14
22. 99. 0. 0	contingency allowance		0.	-1.000e+00	2,13,14
22. 0. 0. 0	reactor plant equipment		0.	-1.000e+00	2,13,14
23. 1. 1. 0	turbine-generators & accessories		0.	1.000e+00	
23. 1. 2. 0	foundations		0.	1.000e+00	
23. 1. 3. 0	standby exciters		0.	1.000e+00	
23. 1. 4. 0	lubricating system		0.	1.000e+00	
23. 1. 5. 0	gas systems		0.	1.000e+00	
23. 1. 6. 0	reheaters		0.	1.000e+00	
23. 1. 7. 0	shielding		0.	1.000e+00	
23. 1. 8. 0	weather-proof housing		0.	1.000e+00	
23. 1. 0. 0	turbine-generators		4.758e+05 \$/unit	1.469e+02	2,13,14
23. 2. 0. 0	main steam (or other fluid) system		1.678e+03 \$/MWth	2.544e+03	12
23. 3. 1. 0	water intake common facilities		0.	1.000e+00	
23. 3. 2. 0	circulating water systems		0.	1.000e+00	
23. 3. 3. 0	cooling towers		0.	1.000e+00	
23. 3. 4. 0	other systems which reject heat to the atmosphere		0.	1.000e+00	
23. 3. 0. 0	heat rejection systems		6.319e+04 \$/unit	3.093e+02	10

A.4. COST DATA BASE FOR ARIES-I REACTOR

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acc. no.	account title	UC(1988) = 1.424 x UC(1980)	unit cost(1980)	no. of units	refs.
23.4.1.0	condensers		0.	1.000e+00	
23.4.2.0	condensate system		0.	1.000e+00	
23.4.3.0	gas removal system		0.	1.000e+00	
23.4.4.0	turbine by-pass systems(excl. piping)		0.	1.000e+00	
23.4.0.0	condensing systems		2.753e+04 \$/unit	6.111e+02	2,13,14
23.5.1.0	regenerators & recuperators		0.	1.000e+00	
23.5.2.0	pumps		0.	1.000e+00	
23.5.3.0	tanks		0.	1.000e+00	
23.5.0.0	feed heating system		2.640e+03 \$/unit	2.544e+03	2,13,14
23.6.1.0	turbine auxiliaries		0.	1.000e+00	
23.6.2.0	auxiliaries cooling system(excl. piping)		0.	1.000e+00	
23.6.3.0	make-up treat. system(excl. piping)		0.	1.000e+00	
23.6.4.0	chemical treat. & condensate purification systems		0.	1.000e+00	
23.6.5.0	central lubrication service system(excl. piping)		0.	1.000e+00	
23.6.0.0	other turbine plant equipment		6.482e+05 \$/unit	7.201e+01	2,13,14
23.7.0.0	instrumentation & control(i&c) equipment		9.820e+05 \$/unit	8.486e+00	2,13,14
23.98.0.0	spare parts allowance		0.	-1.000e+00	2,13,14
23.99.0.0	contingency allowance		0.	-1.000e+00	2,13,14
23.0.0.0	turbine plant equipment		0.	1.000e+00	
24.1.1.0	generator circuits		0.	1.000e+00	
24.1.2.0	station service		0.	1.000e+00	
24.1.0.0	switchgear		8.600e+03 \$/unit	1.246e+03	2,13,14
24.2.1.0	station service & startup transformers		0.	1.000e+00	
24.2.2.0	low voltage unit substation & lighting transformer		0.	1.000e+00	
24.2.3.0	battery system		0.	1.000e+00	
24.2.4.0	diesel engine generators		0.	1.000e+00	
24.2.5.0	gas turbine generators		0.	1.000e+00	
24.2.6.0	motor generator sets		0.	1.000e+00	
24.2.0.0	station service equipment		1.420e+04 \$/unit	1.246e+03	13,16
24.3.1.0	main control board for electric system		0.	1.000e+00	
24.3.2.0	auxiliary power & signal boards		0.	1.000e+00	
24.3.0.0	switchboards (incl. heat tracing)		5.400e+03 \$/unit	1.246e+03	2,13,14
24.4.1.0	gen. station grounding sys. & cathodic protection		0.	1.000e+00	
24.4.0.0	protective equipment		2.110e+06 \$	1.000e+00	13,14
24.5.1.0	concrete cable tunnels, trenches & envelopes		0.	1.000e+00	
24.5.2.0	cable trays & support		0.	1.000e+00	
24.5.3.0	conduit		0.	1.000e+00	
24.5.4.0	other structures		0.	1.000e+00	
24.5.0.0	electrical structures & wiring containers		1.656e+07 \$	1.000e+00	13,14,+
24.6.1.0	generator circuits wiring		0.	1.000e+00	
24.6.2.0	station service power wiring		0.	1.000e+00	
24.6.3.0	control wiring		0.	1.000e+00	
24.6.4.0	instrument wiring		0.	1.000e+00	
24.6.5.0	containment penetrations		3.425e+07 \$	1.000e+00	13,14,+
24.6.0.0	power & control wiring		0.	1.000e+00	
24.7.1.0	reactor building lighting		0.	1.000e+00	
24.7.2.0	turbine building lighting		0.	1.000e+00	
24.7.3.0	reactor auxiliaries building lighting		0.	1.000e+00	
24.7.4.0	radioactive waste building lighting		0.	1.000e+00	
24.7.5.0	fuel storage building lighting		0.	1.000e+00	
24.7.6.0	miscellaneous buildings lighting		0.	1.000e+00	
24.7.7.0	yard lighting		0.	1.000e+00	
24.7.0.0	electrical lighting		8.200e+06 \$	1.000e+00	13,14,+
24.98.0.0	spare parts allowance		0.	-1.000e+00	2,13,14
24.99.0.0	contingency allowance		0.	-1.000e+00	2,13,14

acc. no.	account title	UC(1988) = 1.424 x UC(1980)	unit cost(1980)	no. of units	refs.
24. 0. 0. 0	electric plant equipment		0.	1.000e+00	
25. 1. 1. 0	cranes, hoists, monorails, & conveyors		0.	1.000e+00	
25. 1. 2. 0	railway		0.	1.000e+00	
25. 1. 3. 0	roadway equipment		0.	1.000e+00	
25. 1. 4. 0	watercraft		0.	1.000e+00	
25. 1. 5. 0	vehicle maintenance equipment		0.	1.000e+00	
25. 1. 0. 0	transportation & lifting equipment		1.568e+07 \$	1.000e+00	13,14
25. 2. 1. 0	air systems(excl. piping)		0.	1.000e+00	
25. 2. 2. 0	water systems(excl. piping)		0.	1.000e+00	
25. 2. 3. 0	auxiliary heating boilers(excl. piping)		0.	1.000e+00	
25. 2. 0. 0	air & water service systems		1.235e+07 \$	1.000e+00	13,14
25. 3. 1. 0	local communications systems		0.	1.000e+00	
25. 3. 2. 0	signal systems		0.	1.000e+00	
25. 3. 0. 0	communications equipment		6.220e+06 \$	1.000e+00	13,14
25. 4. 1. 0	safety equipment		0.	1.000e+00	
25. 4. 2. 0	shop, laboratory, & test equipment		0.	1.000e+00	
25. 4. 3. 0	office equipment & furnishings		0.	1.000e+00	
25. 4. 4. 0	change room equipment		0.	1.000e+00	
25. 4. 5. 0	environmental monitoring equipment		0.	1.000e+00	
25. 4. 6. 0	dining facilities		0.	1.000e+00	
25. 4. 0. 0	furnishings & fixtures		0.	1.000e+00	
25. 98. 0. 0	spare parts allowance		1.200e+06 \$	1.000e+00	2
25. 99. 0. 0	contingency allowance		0.	fraction	2,13,14
25. 0. 0. 0	miscellaneous plant equipment		0.	fraction	2,13,14
26. 1. 0. 0	reactor coolant		8.772e+02 \$/kg	0.	15,18
26. 2. 0. 0	intermediate coolant		0.	1.000e+00	
26. 3. 0. 0	turbine cycle working fluids		0.	1.000e+00	
26. 4. 0. 0	other materials		2.500e+05 \$	1.000e+00	13,14
26. 5. 0. 0	Ar reactor-building cover gas		7.500e-01 \$/m^3	1.964e+05	
26. 98. 0. 0	spare parts allowance		0.	fraction	
26. 99. 0. 0	contingency allowance		0.	fraction	
26. 0. 0. 0	special materials		0.	1.000e+00	
90. 0. 0. 0	direct cost (not incl. spares and contingency)		0.	1.000e+00	
91. 0. 0. 0	construction services & equipment		1.000e-01 fraction	1.000e+00	4,10
92. 1. 0. 0	systems engineering		0.	1.000e+00	
92. 2. 0. 0	management		0.	1.000e+00	
92. 3. 0. 0	quality assurance		0.	1.000e+00	
92. 4. 0. 0	safety & environmental engineering		0.	1.000e+00	
92. 0. 0. 0	home office engineering & services		0.	1.000e+00	
93. 1. 0. 0	construction management		1.000e-01 fraction	1.000e+00	4,10
93. 2. 0. 0	inspection		0.	1.000e+00	
93. 3. 0. 0	preoperational testing		0.	1.000e+00	
93. 0. 0. 0	field office engineering & services		1.000e-01 fraction	1.000e+00	4,10
94. 1. 0. 0	project administration		0.	1.000e+00	
94. 2. 0. 0	staff training & plant startup		0.	1.000e+00	
94. 3. 0. 0	inventories & spares		0.	1.000e+00	
94. 0. 0. 0	owner's cost		5.000e-02 fraction	1.000e+00	4,10
95. 0. 0. 0	process contingency		0.	1.000e+00	
96. 0. 0. 0	project contingency		0.	1.000e+00	
97. 0. 0. 0	interest during construction (IDC)		1.000e-01 fraction	1.000e+00	4,10
98. 0. 0. 0	escalation during construction (EDC)		1.652e-01 fraction	1.000e+00	4,10
99. 0. 0. 0	total cost		0.	1.000e+03 MWe	

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