

## CONTENTS

<b>I. INTRODUCTION .....</b>	<b>1</b>
References to Chapter I .....	3
<b>II. SUMMARY, CONCLUSIONS AND RECOMMENDATIONS .....</b>	<b>5</b>
1. Plasma performance .....	5
1.1. Bulk heating .....	5
1.2. Current drive .....	7
1.3. Beta limits and energy confinement .....	8
1.4. Other issues .....	9
2. Impurity control and first wall .....	10
2.1. Poloidal divertor and pumped limiter .....	10
2.2. First-wall design .....	14
2.3. Erosion due to disruptions .....	14
2.4. Other impurity control methods .....	15
3. Testing .....	15
3.1. Fluence requirements for structural materials radiation damage tests .....	15
3.2. Long-term operation component reliability .....	16
3.3. Blanket testing requirements .....	16
4. Tritium and blanket .....	16
4.1. Tritium permeation .....	16
4.2. Tritium contamination in reactor room .....	17
4.3. Tritium-breeding blanket .....	18
4.4. Tritium inventory .....	19
4.5. Safety considerations .....	19
5. Mechanical configuration .....	20
5.1. Toroidal field (TF) coil size .....	20
5.2. Torus segmentation .....	20
5.3. Universal design concept .....	21
6. Magnetics and torus electromagnetics .....	22
6.1. Magnetic systems .....	22
6.1.1. Conductor/coolant options for TF coils .....	22
6.1.2. Fault studies .....	23
6.1.3. Toroidal field coil R and D requirements .....	23

6.1.4.	PF coil distribution studies .....	23	3.4.8.	Torus electromagnetics .....	63
6.1.5.	PF coil design .....	23	3.4.9.	Cryostat .....	63
6.1.6.	PF system fault studies .....	24	3.4.10.	Cryogenic system .....	63
6.2.	Torus electromagnetics .....	24	3.5.	Heating and fuelling systems .....	64
6.2.1.	Disruption effect .....	24	3.5.1.	Ion cyclotron heating system .....	64
6.2.2.	Passive stabilization .....	25	3.5.2.	Electron cyclotron start-up assist system .....	66
6.2.3.	Active stabilization .....	25	3.5.3.	Fuelling system .....	68
6.2.4.	Start-up .....	26	3.6.	First-wall system .....	68
7.	Cost-risk-benefit and schedule .....	26	3.7.	Impurity control system .....	72
7.1.	Cost reductions .....	26	3.7.1.	Divertor option .....	72
7.2.	Cost-risk-benefit assessment of performance objectives .....	27	3.7.2.	Limiter option .....	74
7.3.	Schedule .....	28	3.8.	Tritium-breeding blanket .....	75
8.	Research and development .....	29	3.9.	Radiation shield system .....	81
9.	Conclusion .....	29	3.10.	Tritium and vacuum systems .....	83
10.	Recommendation for future work .....	29	3.10.1.	Tritium systems .....	83
<b>III. INTOR CONCEPT</b>	.....	33	3.10.2.	Torus vacuum system .....	84
1.	Role of INTOR in the fusion programme .....	33	3.11.	Site criteria and facility layout .....	85
2.	INTOR objectives .....	35	3.11.1.	Site criteria .....	85
3.	Design description .....	38	3.11.2.	Facility layout .....	86
3.1.	Overviews .....	38	4.	Machine operation and test programme .....	86
3.2.	Physics basis .....	43	5.	Schedule .....	91
3.3.	Mechanical configuration and maintenance .....	46	References to Chapter III .....	93	
3.3.1.	Toroidal magnetic field coil design – access requirements .....	47			
3.3.2.	Poloidal magnetic field coil system .....	48			
3.3.3.	Combined cryogenic and torus vacuum chamber topology .....	49			
3.3.4.	Torus modularization and segmentation .....	49			
3.3.5.	Impurity control .....	49			
3.3.6.	Structural support system .....	55			
3.3.7.	Tokamak radial build .....	55			
3.3.8.	Dedicated torus sectors .....	55			
3.3.9.	Assembly and maintenance .....	55			
3.4.	Magnetic and electrical systems .....	57			
3.4.1.	Toroidal field coil system .....	57			
3.4.2.	Poloidal field coil system .....	57			
3.4.3.	Active position control and start-up voltage .....	59			
3.4.4.	Alternating current power system .....	60			
3.4.5.	TF coil power conversion and protection .....	61			
3.4.6.	PF coil power conversion and protection .....	61			
3.4.7.	Electrical energy storage system .....	62			
			<b>IV. PLASMA CONFINEMENT AND CONTROL</b>		
1.	Plasma confinement and beta limits .....	95			
1.1.	Experimental status .....	96			
1.1.1.	Pre-saturation auxiliary-heating regime .....	96			
1.1.2.	Saturated auxiliary-heating regime .....	100			
1.1.3.	Particle transport .....	101			
1.2.	Ideal-MHD limits .....	102			
1.3.	Discussion and conclusions .....	104			
2.	Modelling of plasma energetics .....	105			
2.1.	Ripple losses .....	105			
2.1.1.	Thermal ripple losses .....	105			
2.1.2.	Suprathermal ripple losses (beam ions and fusion $\alpha$ -particles) .....	110			
2.1.3.	Conclusions .....	112			
2.2.	Neutral-beam heating energy and power .....	113			
3.	Discharge control issues .....	115			
3.1.	Burn temperature control and shut-down .....	115			
3.1.1.	Burn control by a variable toroidal ripple .....	116			

3.1.2. Burn control at a beta limit .....	117	2.2. Lower hybrid launching system .....	166	
3.1.3. Burn control by impurity injection .....	117	2.2.1. Design concepts .....	167	
3.1.4. Burn control by modulation of fuelling .....	117	2.2.2. Conclusions .....	173	
3.1.5. The compression-decompression scheme .....	118	2.3. Electron cyclotron wave launching system .....	175	
3.1.6. Control by auxiliary heating .....	118	2.3.1. Design concept .....	175	
3.1.7. Shut-down .....	118	2.3.2. Conclusions .....	178	
3.1.8. Conclusions .....	119	3. Conclusions and reference heating systems for INTOR .....	179	
3.2. Equilibrium control requirements .....	119	3.1. Heating .....	179	
3.3. Disruption characteristics and control .....	121	3.2. Current drive .....	181	
4. Conclusions for INTOR .....	123	3.3. Recommendations .....	182	
References to Chapter IV .....	126	References to Chapter V .....	183	
<b>V. RADIO-FREQUENCY HEATING AND CURRENT DRIVE</b>				
1. Physics basis .....	127	<b>VI. IMPURITY CONTROL PHYSICS</b> .....		185
1.1. Ion cyclotron heating to ignition .....	127	1. Introduction .....	185	
1.1.1. Experimental status .....	129	2. Pumped limiter .....	187	
1.1.2. Comparison between ICRF theory and experiment .....	132	2.1. Introduction .....	187	
1.1.3. Code development for INTOR applications .....	134	2.2. Location .....	189	
1.1.4. Conclusions and choice of heating mode for INTOR .....	135	2.3. Low edge density – high edge temperature (with low radiation) .....	191	
1.2. Lower hybrid heating to ignition .....	137	2.4. High edge density – medium edge temperature (with low radiation) .....	193	
1.2.1. Experimental data base and physics mechanisms .....	137	2.5. High edge density – low edge temperature (with high radiation) .....	195	
1.2.2. Modelling of lower-hybrid heating and parameter choice of a heating system for INTOR .....	141	3. Single-null poloidal divertor .....	200	
1.2.3. Conclusions .....	143	3.1. Introduction .....	200	
1.3. Start-up assist .....	143	3.2. Low-density (pellet-fuelled) plasma .....	202	
1.3.1. Experimental data base for radio-frequency start-up assist .....	144	3.3. High edge density – medium or low edge temperature .....	203	
1.3.2. Modelling of start-up assist by electron cyclotron waves .....	146	4. Pumping and neutral-particle dynamics .....	206	
1.3.3. Profile control by electron cyclotron waves .....	147	4.1. Introduction .....	206	
1.3.4. Conclusions .....	150	4.2. Limiter pumping .....	208	
1.4. Current drive .....	151	4.3. Divertor pumping .....	209	
1.4.1. Survey of current drive techniques .....	151	4.4. Neutral-particle dynamics .....	209	
1.4.2. Status of lower hybrid current drive experiments .....	153	5. Other studies .....	211	
1.4.3. Prospects for tokamak reactors .....	155	5.1. Local hybrid divertor .....	211	
2. Launching systems .....	157	5.2. Charge state distribution of impurity ions in the boundary plasma .....	214	
2.1. Ion cyclotron wave launching system .....	157	5.3. Effects of inclinations of magnetic field upon sputtering and secondary-electron emission .....	216	
2.1.1. Design concepts .....	157	5.4. Impurity screening .....	218	
2.1.2. Conclusions .....	166	5.5. Beam trapping in radiating plasma edge .....	219	
		5.6. Neutral-beam-driven impurity flow reversal .....	219	

6.	Conclusion .....	220
6.1.	Boundary plasma conditions .....	220
6.2.	Single-null poloidal divertor .....	222
6.3.	Pumped limiter .....	222
6.3.1.	Condition: high edge density, medium edge temperature (low radiation with low or medium sheath temperature) .....	222
6.3.2.	Condition: high edge density, medium edge temperature (high radiation with very low sheath temperature) .....	223
6.4.	Comparison of divertor and limiter .....	223
6.5.	Recommendations based upon physics issues .....	224
	References to Chapter VI .....	224
	<b>VII. IMPURITY CONTROL AND FIRST-WALL ENGINEERING .....</b>	<b>225</b>
1.	Introduction .....	225
2.	Operating conditions .....	226
2.1.	Common parameters .....	226
2.2.	Divertor/first wall .....	229
2.2.1.	Low temperature at divertor plate .....	229
2.2.2.	Medium temperature at divertor plate .....	229
2.3.	Limiter/first wall .....	229
2.3.1.	Low edge temperature .....	229
2.3.2.	Medium edge temperature .....	230
2.3.3.	High edge temperature .....	231
3.	Mechanical configuration .....	232
3.1.	Divertor .....	232
3.2.	Pumped limiter .....	233
3.2.1.	Location .....	233
3.2.2.	Limiter shape .....	234
3.2.2.1.	The plate limiter .....	235
3.2.2.2.	The tube limiter .....	238
3.3.	First wall .....	239
4.	Materials considerations .....	239
4.1.	Plasma-side materials .....	239
4.1.1.	Physical sputtering .....	239
4.1.2.	Chemical sputtering .....	243
4.1.3.	Arcing .....	246
4.1.4.	H/He retention/release .....	248
4.1.5.	Bulk properties and radiation effects .....	249
4.1.5.1.	Low-Z materials .....	249
4.1.5.2.	High-Z materials .....	251
4.1.6.	Re-deposited material .....	252
4.2.	Heat sink materials .....	254
4.2.1.	Bulk properties .....	254
4.2.2.	Radiation effects .....	255
4.2.2.1.	Copper .....	255
4.2.2.2.	Vanadium .....	257
4.2.2.3.	Zirconium .....	257
4.2.3.	Corrosion/compatibility .....	257
4.2.4.	Fabrication .....	258
5.	Tile attachment concepts and fabrication .....	258
5.1.	Tile attachment concepts .....	258
5.1.1.	Radiation-cooled concept .....	260
5.1.2.	Radiation-plus-conduction-cooled concept .....	260
5.1.3.	Conduction-cooled concept .....	261
5.2.	Fabrication .....	261
5.2.1.	Graphite .....	261
5.2.2.	Silicon carbide .....	262
5.2.3.	Beryllium .....	263
5.2.4.	Beryllium oxide .....	263
5.2.5.	Tungsten .....	263
5.2.6.	Tantalum .....	264
6.	Thermal hydraulic and stress analysis .....	264
6.1.	Limiter design description .....	265
6.2.	Limiter temperature distribution .....	267
6.3.	Stress analysis .....	268
6.4.	Conclusions .....	271
7.	Electromagnetics .....	271
7.1.	Introduction .....	271
7.2.	Analysis without conducting-shell effect .....	272
7.3.	Analysis with conducting first wall .....	274
7.3.1.	Variation of force with first-wall time constant .....	276
7.3.2.	Variation of force with limiter resistivity .....	277
7.4.	Induced voltages between limiter segments .....	277
8.	Disruptions .....	279
8.1.	Disruption scenario .....	279
8.2.	Thermal response .....	280
8.3.	Melt layer stability .....	284
9.	Erosion/re-deposition .....	289
9.1.	Introduction .....	289
9.2.	Computational models .....	289
9.3.	Limiter analysis .....	291
9.4.	Divertor .....	299

10. Lifetime analysis .....	302	3. Tritium contamination of reactor environment .....	353
10.1. Maximum allowable thickness .....	303	3.1. Sources of tritium contamination .....	353
10.1.1. Maximum allowable temperature .....	303	3.2. Tritium concentration levels in air .....	355
10.1.2. Allowable thickness .....	305	3.3. Air detritiation system and cost .....	357
10.1.3. Other limiting factors .....	306	3.4. Personnel access .....	360
10.2. Lifetime estimates .....	307	4. Tritium-breeding blanket .....	362
10.2.1. The limiter top surface .....	307	4.1. Solid breeder materials .....	362
10.2.2. The leading edge .....	309	4.1.1. New data on solid breeder materials properties .....	362
10.2.3. The first wall .....	309	4.1.2. Radiation effects .....	370
10.2.4. First-wall strips .....	311	4.1.3. Tritium recovery .....	370
10.3. Conclusions .....	312	4.1.4. Blanket design .....	375
11. Recommendations on design concepts .....	312	4.1.5. Methods of accommodating power variations in the blanket .....	376
11.1. Introduction .....	312	4.1.6. Hydrogen influence on weldability .....	378
11.2. Divertor .....	313	4.2. Liquid breeders .....	379
11.2.1. Low-edge-temperature regime .....	314	4.2.1. Data base .....	379
11.2.2. Medium-edge-temperature regime .....	315	4.2.1.1. Physical and chemical properties .....	379
11.3. Limiter .....	317	4.2.1.2. Compatibility with structural materials .....	379
11.3.1. Low-edge-temperature regime .....	317	4.2.1.3. Chemical reactivity .....	383
11.3.2. Medium-edge-temperature regime .....	318	4.2.2. Design aspects .....	384
12. Conclusions and recommendations .....	318	4.2.2.1. Tritium recovery and permeation into coolant .....	387
13. Major uncertainties and future effort .....	322	4.2.2.2. Pre-heating systems .....	388
13.1. Major uncertainties .....	322	4.2.3. Conclusions .....	389
13.2. Future effort .....	323	5. Tritium system .....	389
References to Chapter VII .....	324	5.1. Introduction .....	389
 <b>VIII. TRITIUM AND BLANKET .....</b>	327	5.2. Plasma reprocessing system .....	390
1. Introduction .....	327	5.3. Breeding tritium processing system .....	391
2. Tritium permeation into coolant .....	328	5.4. Waste processing system .....	392
2.1. Tritium permeation rate .....	328	5.5. Tritium inventory .....	393
2.1.1. Theoretical models and calculations .....	329	5.6. Atmosphere processing system .....	394
2.1.2. Experimental results .....	331	5.7. Conclusions .....	394
2.1.3. Calculational results .....	333	6. Safety considerations .....	396
2.1.4. First-wall permeation barriers .....	339	6.1. Accident analysis .....	396
2.1.5. Gas release during dwell time and maintenance .....	342	6.2. INTOR radiation impact on population .....	398
2.1.6. Radiation effects .....	343	References to Chapter VIII .....	404
2.1.7. Conclusions .....	346	 <b>IX. MAGNETS .....</b>	407
2.2. Tritium processing of the primary coolant .....	347	1. TF coil system .....	407
2.2.1. Methods for tritium separation from water .....	347	1.1. TF coil design and concept evaluation .....	408
2.2.2. Cost and process comparison .....	348	1.1.1. Alternative coolant/conductor designs .....	409
2.2.3. Tritium concentration in water coolant .....	351	1.1.1.1. Design descriptions .....	409
2.3. Conclusions and recommendations .....	352		

1.1.1.2. Heat treatment of superconductors .....	419	2.1. Heating of the coils .....	470
1.1.1.3. Stabilization analysis .....	421	2.2. Forces, torques and overturning moments .....	473
1.1.2. Toroidal field coil structure definition .....	421	2.3. Induced voltages .....	480
1.1.3. Comparison of alternative approaches .....	425	2.3.1. Voltages between limiter segments .....	481
1.1.3.1. Maturity of technology .....	425	2.3.2. PF coil currents and voltages .....	482
1.1.3.2. Reactor compatibility .....	426	2.3.3. Sector gap voltages .....	483
1.1.3.3. Reliability .....	427	3. Passive stabilization .....	487
1.1.3.4. Complexity .....	427	3.1. Vertical stabilization .....	487
1.1.3.5. Summary of comparative study .....	427	3.2. Radial stabilization .....	498
1.2. Power conversion and protection .....	428	4. Active stabilization and control .....	498
1.3. Safety aspects and fault conditions .....	431	4.1. Vertical control .....	501
1.3.1. Abnormal operating conditions .....	431	4.2. Radial control .....	504
1.3.2. Accident situations .....	433	5. Other studies .....	507
1.3.3. TF coil sensitivity to short-circuit fault .....	433	5.1. Field and flux penetration through shells .....	507
1.3.4. Time required for replacement of one TF coil .....	436	5.2. Start-up .....	509
1.4. Research and development required .....	436	6. Conclusions .....	512
1.4.1. Intermediate-scale coil fabrication and operation ....	438	6.1. Disruption effects .....	512
1.4.2. TF coil superconductor property cost and improvement .....	438	6.2. Passive stabilization .....	513
1.4.3. TF coil mechanical and electrical properties of composites and components .....	439	6.2.1. Stabilization concept .....	513
1.4.4. Magnet status detection techniques .....	439	6.2.2. Passive elements .....	514
1.4.5. Low-eddy-current-loss vessel for He II .....	440	6.3. Active position control .....	514
1.5. Conclusions .....	440	6.4. Start-up .....	515
2. PF coil system .....	441	6.5. Eddy current modelling codes .....	515
2.1. Introduction .....	441	References to Chapter X .....	516
2.2. PF distribution studies .....	441		
2.3. Typical PF coil distributions .....	448	<b>XI. MECHANICAL CONFIGURATION .....</b>	517
2.4. PF coil design (central solenoid coil/ring coil) .....	449	1. Introduction .....	517
2.4.1. Conductor and cooling method .....	449	1.1. Objectives .....	517
2.4.2. Coil structure and mechanical stress .....	449	1.2. Design requirements .....	519
2.4.3. AC losses in PF coils .....	455	1.3. Design summary .....	519
2.4.4. Stability analysis .....	456	2. TF system .....	521
2.5. Power handling and conversion.....	457	2.1. Evaluation of TF coil size .....	521
2.6. Safety aspects and fault conditions .....	464	2.1.1. Ripple requirement .....	521
2.7. Research and development required .....	466	2.1.2. Winding configuration .....	524
2.8. Conclusions .....	466	2.1.3. Structural design implications .....	524
References to Chapter IX .....	468	2.2. Design description .....	526
<b>X. ELECTROMAGNETICS .....</b>	469	2.3. Coil maintenance and replacement approach .....	531
1. Influence of electromagnetics on machine design .....	469	2.4. Supporting analysis .....	532
2. Plasma disruption effects .....	470	3. PF system .....	533
		3.1. Comparison of Phase-One and Phase-Two-A coil systems ....	533
		3.2. Pumped-limiter versus poloidal-divertor configuration ....	533

3.3.	Structural design, maintenance and access .....	535	2.4.2.	Boundary conditions .....	599
3.4.	Universal PF configuration .....	537	2.4.3.	Development scenarios .....	600
4.	Vacuum boundary .....	539	2.4.4.	Choice of scenario .....	605
4.1.	Design options .....	539	2.4.5.	Strategy .....	605
4.2.	Evaluation and selection .....	547	2.5.	Conclusions .....	606
4.2.1.	Approach to evaluation .....	547	2.5.1.	Fluence criteria and risk for stainless steel .....	607
4.2.2.	Evaluation procedure .....	547	2.5.2.	Fluence criteria and risk for an advanced alloy (vanadium) .....	608
4.2.3.	Choice of the reference option .....	549	3.	Blanket testing .....	610
4.3.	Design description .....	549	3.1.	Introduction .....	610
4.4.	Supporting analysis .....	553	3.2.	Evaluation methods .....	611
5.	Torus system .....	555	3.2.1.	Selection of tests for evaluation .....	611
5.1.	INTOR Phase One – torus concept .....	555	3.3.	Results of the evaluation .....	614
5.2.	Segmentation options .....	559	3.3.1.	Neutronics test .....	614
5.3.	Evaluation and selection .....	560	3.3.2.	Tritium recovery tests .....	616
5.4.	Design description .....	561	3.3.3.	Materials compatibility tests .....	617
5.4.1.	12-sector configuration option .....	561	3.3.4.	Heat recovery tests .....	618
5.4.2.	24-sector configuration options .....	563	3.4.	Summary .....	619
5.5.	Supporting analysis .....	573	4.	Benefits to DEMO of long-term operation of INTOR components .....	620
6.	Impurity control .....	574	4.1.	Approach .....	620
6.1.	Pumped-limiter configuration .....	574	4.2.	Potential benefits of long-term INTOR component operation .....	620
6.1.1.	Alternative concept (outboard single pumped limiter) .....	575	4.3.	INTOR and DEMO requirements .....	621
6.2.	Poloidal-divertor configuration .....	576	4.4.	Determination of test time required in INTOR .....	627
6.3.	Universal concept .....	578	4.4.1.	Confidence building .....	627
7.	Heating system .....	578	4.4.2.	Reliability growth .....	628
7.1.	Radio-frequency heating and start-assist systems .....	579	4.5.	Specific component evaluation .....	631
7.2.	Neutral-beam heating systems .....	580	4.6.	Future effort required .....	631
7.3.	Conclusions .....	580	5.	Conclusions .....	632
8.	Conclusions and recommendations .....	581	6.	Appendix: Test modules for simultaneous tritium breeding and electricity generation .....	634
	References to Chapter XI .....	582	6.1.	Introduction .....	634
			6.2.	Overall design requirements .....	634
XII. ENGINEERING TESTING .....	585		6.3.	General considerations for blanket design .....	635
1.	Introduction .....	585	6.3.1.	Neutron multiplier .....	635
2.	Structural materials testing .....	587	6.3.2.	Coolant .....	635
2.1.	Introduction .....	587	6.4.	Helium-cooled solid-breeder blanket .....	636
2.2.	Evaluation methods .....	587	6.5.	Water-cooled solid-breeder blanket .....	637
2.3.	Data base and estimates of uncertainty .....	589	6.6.	Carbon-dioxide liquid-metal breeder blanket .....	642
2.3.1.	Stainless-steel data .....	589	6.7.	Conclusions .....	643
2.3.2.	Vanadium alloy data .....	595		References to Chapter XII .....	643
2.4.	Strategy for fusion materials development .....	596			
2.4.1.	Materials development .....	597			

<b>XIII. COST AND SCHEDULE .....</b>	645	P.8. High-power LH and EC heating .....	700
1. Introduction .....	645	P.9. Quasi-steady-state mode of operation .....	701
2. Cost evaluation .....	646	P.10. Characterization of high- and low-temperature edge regimes .....	702
2.1. Assessment of benchmark options for cost estimation and direct capital costs .....	646	P.11. Edge particle and energy fluxes .....	703
2.2. Modification for availability and reliability .....	651	P.12. Divertor channel behaviour .....	703
2.3. Indirect capital cost .....	654	P.13. Impurity behaviour .....	704
2.4. Operation costs .....	655	P.14. Limiter pumping characteristics .....	705
2.5. Total cost and result evaluation .....	658	P.15. Molecular and low-temperature charge-exchange data..	706
3. Major influential factors on cost .....	662	3.2. Nuclear .....	706
3.1. Key parameters for cost reduction .....	662	N.1. Self-sputtering yield of main candidate materials .....	706
3.2. Key options for cost reduction .....	668	N.2. Sputtering by tritium .....	707
4. Schedule evaluation .....	669	N.3. Properties of re-deposited metals .....	708
4.1. Introduction .....	669	N.4. Irradiation effects on non-replaceable high-flux materials (60 dpa) .....	708
4.2. Effect of start date on project initiation .....	672	N.5. Irradiation effects on replaceable high-flux materials (30 dpa) .....	709
4.3. Effect of start date on degree of support obtained from complementary R and D programme .....	672	N.6. Tritium permeation and inventory, including irradiation effects .....	710
4.4. Effect of start date on a demonstration point ('DEMO') .....	675	N.7. Eutectics development .....	711
5. Conclusions .....	675	N.8. 14-MeV neutronics integral experiments .....	712
References to Chapter XIII .....	677	3.3. Engineering .....	713
<b>XIV. COST-RISK-BENEFIT .....</b>	679	E.1. High-power ICRF system demonstration .....	713
1. Introduction .....	679	E.2. Improved structural concepts for first wall/ divertor/limiter .....	713
2. Cost-risk-benefit study .....	679	E.3. First-wall outgassing procedure .....	715
2.1. Risk-benefit assessment .....	682	E.4. Tritium pellet injector .....	715
2.2. Cost comparison .....	685	E.5. Superconductors for fields above 10T .....	716
2.3. Cost-risk-benefit assessment performance objectives .....	690	E.6. Low-loss, high-current 8T superconductors .....	717
<b>XV. RESEARCH AND DEVELOPMENT .....</b>	693	E.7. TF coil mechanical and electrical properties .....	717
1. Introduction .....	693	E.8. Safety circuits to cope with short-circuiting of superconducting coils .....	718
2. Status of R and D identified in Phase One .....	693	E.9. Low-loss PF coil concept .....	718
3. Research and development needs identified in Phase Two A .....	695	E.10. Intermediate-scale PF coil demonstration .....	719
3.1. Physics .....	695	E.11. Computational tools for transient electromagnetics ...	719
P.1. Plasma behaviour near beta limits .....	695	E.12. Torus maintenance methods and procedures .....	720
P.2. Confinement scaling in auxiliary-heated discharges ....	696	E.13. Adequate torus resistance .....	720
P.3. Plasma equilibrium control .....	697	E.14. Voltage withstand criteria for components within the torus .....	721
P.4. Plasma profile control .....	698	E.15. Pump development .....	721
P.5. Reactor prototypical ICRF heating .....	698	E.16. PF coil power supply system optimization .....	722
P.6. ICRF code development .....	699	References to Chapter XV .....	722
P.7. RF start-up assist .....	700		

<b>XVI. DESIGN SPECIFICATIONS .....</b>	<b>723</b>
<b>XVII. ADMINISTRATIVE APPENDICES .....</b>	<b>747</b>
1. INTOR Phase-Two-A Workshop Sessions .....	747
2. European INTOR home-base organization .....	747
2.1. Euratom INTOR Workshop Team .....	747
Workshop participants and attendees .....	747
INTOR/NET Steering Group .....	747
Contributors to individual chapters .....	748
Organizational index .....	754
3. Japan INTOR Workshop Teams .....	755
Workshop participants and attendees .....	755
Contributors to individual chapters .....	755
Organizational index .....	759
4. USA INTOR Workshop Teams .....	760
Workshop participants and attendees .....	760
INTOR Review Committee .....	760
Contributors to individual chapters .....	760
Organizational index .....	765
5. USSR INTOR Workshop Team .....	766
Workshop participants and attendees .....	766
Contributors to individual chapters .....	766
Organizational index .....	772