CONTENTS OF VOLUME 2

XIII. REPORT OF IAEA SPECIALISTS' MEETING ON INTOR-LIKE DESIGNS 1

1. Introduction 1
2. Objectives 2
   - 2.1. Comparison of objectives 2
   - 2.2. Discussion of objectives 2
3. Physics 13
   - 3.1. Introduction 13
   - 3.2. Physics design features 15
     - 3.2.1. Fusion performance (energy multiplication rate, Q) 15
     - 3.2.2. Burn pulse length 17
     - 3.2.3. Impurity and particle control method 18
     - 3.2.4. Plasma configuration 19
     - 3.2.5. Startup assist 20
     - 3.2.6. Operation scenario 21
     - 3.2.7. Duty factor 22
     - 3.2.8. Plasma heating method 23
     - 3.2.9. Frequency of disruptions 24
   - 3.3. Design constraints 26
     - 3.3.1. INTOR 26
     - 3.3.2. NET 26
     - 3.3.3. FER 27
     - 3.3.4. TIBER 31
     - 3.3.5. OTR 32
   - 3.4. Design specifications 65
4. Electromagnetics, heating and current drive technologies 65
   - 4.1. Introduction 65
     - 4.1.1. Load transmission with TF coils 77
     - 4.1.2. Operating scenarios 77
     - 4.1.3. PF coil conductors 80
5. Nuclear 81
   - 5.1. Design specifications and parameters 81
     - 5.1.1. Power and particle exhaust system 81
     - 5.1.2. First wall and limiter 91
     - 5.1.3. Blanket system 91
     - 5.1.4. Shield system 92
     - 5.1.5. Tritium 92
     - 5.1.6. Test facilities 92

5.2. Design drivers for nuclear components 93
5.2.1. Main design drivers for INTOR 93
5.2.2. Main design drivers for NET 96
5.2.3. Main design drivers for FER (neutron wall loadings, fluence, tritium supply and breeding requirements) 97
5.2.4. Main design drivers for TIBER 98
5.2.5. Main design drivers for OTR 99
5.3. Engineering design constraints 99
5.3.1. Comments on INTOR design constraints 103
5.3.1.1. First wall 103
5.3.1.2. Blanket 103
5.3.1.3. Shield 103
5.3.1.4. Divertor 104
5.3.1.5. Tritium system 104
5.3.2. Comments on NET design constraints 104
5.3.2.1. First wall 104
5.3.2.2. Divertor 105
5.3.2.3. Tritium system — local tritium inventory 106
5.3.3. Comments on FER constraints 106
5.3.3.1. First wall 106
5.3.3.2. Shield 108
5.3.3.3. Divertor 108
5.3.3.4. Disruption scenario 109
5.3.3.5. Tritium system 109
5.3.4. Comments on TIBER design constraints 110
5.3.4.1. First wall 110
5.3.4.2. Blanket 110
5.3.4.3. Shield 110
5.3.4.4. Divertor 110
5.3.4.5. Tritium system 111
5.3.5. Comments on OTR design constraints 111
5.3.5.1. First wall 111
5.3.5.2. Blanket 111
5.3.5.3. Shield 111
5.3.5.4. Divertor 111
5.3.5.5. Tritium system 112
6. Mechanical and configuration 112
6.1. Introduction 112
6.1.1. Specifications 112
6.1.2. Design features 113
6.1.3. Constraints 113
6.1.4. Others 113
6.2. Design specifications 113
6.2.1. Summary of design specifications 113
6.3. Comparative study of main design features 122
6.3.1. Introduction 122
6.3.2. Main design feature tabulation 122
6.3.3. Comments on main design features 122
6.3.3.1. Plasma configuration 122
6.3.3.2. Location of PF coil system 122
6.3.3.3. Maintenance 122
6.3.3.4. Location of vacuum boundary 122
6.3.3.5. Modularization 123
6.3.3.6. TF coil support 123
6.3.3.7. Shield material 123
6.3.3.8. Breeding requirements 123
6.4. Comparative study of design constraints 129
6.4.1. Introduction 129
6.4.2. Tabulation of engineering constraints 129
6.4.3. Comments and remarks 129
6.4.3.1. Coil configuration 129
6.4.3.2. Thickness of components 129
6.4.3.3. Gaps/voids 133
6.4.3.4. Auxiliary systems requirements 133
6.4.3.5. Plasma shape and size 147
6.4.3.6. Component replaceability 147
6.4.3.7. Structural support system 148
6.4.3.8. Heat transport 148
6.5. Some comparative studies of mechanical designs 148
Appendix 1 149
Appendix 2 152
Appendix 3 153

XIV. COMPARISON OF INTOR-LIKE DESIGNS 155

1. Objectives 155
2. Physics constraints 156
2.1. Confinement 157
2.2. Beta limit 157
2.3. Safety factor 157
2.4. Density limit 158
2.5. Plasma edge, scrape-off, fuelling 159
2.6. Toroidal field ripple 159
2.7. Plasma heating and non-inductive current drive 159

2.8. Current drive methods 161
2.9. Design parameters 163
2.10. Conclusions 164
3. Engineering constraints and specifications 165
3.1. Mechanical and configuration 165
3.2. Electromagnetics, heating and current drive technologies 170
3.3. Nuclear 172
3.3.1. Lifetime fluence 173
3.3.2. Allowable stress for structural materials 173
3.3.3. Number of lifetime cycles 173
3.3.4. Disruption scenario 173
3.3.5. First wall protection 174
3.3.6. Tritium breeding requirement 174
3.3.7. Divertor 175
3.3.8. Alternate divertor designs for phased operations 175
3.3.9. Shield requirements 175
4. Design driving features 176
4.1. Ignition or finite Q 176
4.2. Operation scenario and pulse length 178
4.3. Plasma configuration and impurity control 179
4.4. Startup assist 179
4.5. Plasma heating method 180
4.6. Tritium breeding capability 181
4.7. Fluence target and nuclear testing 182
4.8. Access for maintenance 183
4.9. Conclusions 184

XV. OPERATIONAL FLEXIBILITY OF INTOR-LIKE DESIGNS 185

1. Introduction 185
2. Operational flexibility of NET 191
3. Operational flexibility of TIBER 193
3.1. Introduction 193
3.2. TIBER advanced steady state operation 194
3.3. TIBER pulsed inductive scenarios — ignition and LH assisted operation 195
4. Operational flexibility of FER 201
4.1. Introduction 201
4.2. Plasma size flexibility 202
4.3. Plasma shape flexibility 203
4.4. Flexibility of heating and current drive control 204
4.5. Advanced operation scenarios 204
5. Operational flexibility of OTR 207
6. Operational flexibility of INTOR 208

XVI. SYSTEMS ANALYSIS OF INTOR-LIKE DESIGNS 213

1. Introduction 213
2. Major features and parameters 214
3. Description of systems analysis codes and analysis process 216
3.1. European Community systems analysis codes and analysis process 216
3.1.1. Introduction 216
3.1.2. General structure of SUPERCOIL 217
3.1.3. Short description of component models 219
3.1.4. Plasma 219
3.1.5. Blanket and shield 220
3.1.6. TF coil system 220
3.1.6.1. Resistive coils 220
3.1.6.2. Superconducting coils 221
3.1.6.3. Bath cooling 221
3.1.6.4. Forced cooling 221
3.1.7. PF coil system and solenoid 221
3.1.8. Geometrical modelling 222
3.1.9. Costing 222
3.1.10. Typical modes of running SUPERCOIL 223
3.2. Japan systems analysis code and analysis process 226
3.3. USA systems analysis codes and analysis process 228
3.3.1. Introduction 228
3.3.2. Global constraint description 231
3.3.2.1. General constraints 232
3.3.2.2. Plasma constraints 232
3.3.2.3. Stress constraints 232
3.3.2.4. Superconductor constraints 232
3.3.2.5. Shielding constraints 233
3.3.3. Module descriptions 233
3.3.3.1. Physics 233
3.3.3.2. TF coil 233
3.3.3.3. PF coils 234
3.3.3.4. Shielding 234
3.3.3.5. Costs 234
3.4. USSR systems analysis code and analysis process 234
3.4.1. Introduction 234
3.4.2. Structure of the code complex 235

3.4.3. Functional codes 236
3.4.3.1. Codes for plasma description 236
3.4.3.2. Plasma engineering codes 237
3.4.3.3. Codes for magnet system description 237
3.4.3.4. Code for blanket/shield description 238
3.4.3.5. Code for reactor power balance description ... 238
3.4.3.6. Reactor safety related codes 238
3.4.3.7. Codes for reactor maintenance description 238
3.4.3.8. Economic model codes 238
4. Representation of INTOR-like designs 239
4.1. Comparison of physics assumptions 239
4.2. Benchmark calculation of INTOR-like design by each delegation 274
5. Sensitivity analysis 275
5.1. Design guidelines 275
5.1.1. EC design guidelines 275
5.1.2. Japan design guidelines 278
5.1.3. USA design guidelines 278
5.1.4. USSR design guidelines 280
5.2. Individual sensitivities 281
5.2.1. Purpose 281
5.2.2. Description of national studies 281
5.2.3. Discussion of results 300
5.2.4. Observations and conclusions 306
5.3. Global effects 307
5.3.1. Purpose 307
5.3.2. Description of national studies 307
5.3.3. Observations and conclusions — global effects 320
6. Relative capital cost comparisons 320
6.1. Comparison of direct capital costs 321
6.2. Major cost items 324
7. Conclusions 326
7.1. Replication 326
7.2. Individual sensitivity 326
7.3. Global effect 328
7.4. Relative costs 328

References to Chapter XVI 329