

Contents

Chapter 1 - Overview of a Ship's Electrical System		
Article No.	Article	Page No.
1.1	The Marine Environment	1
1.2	Effects of Inclination	2
1.2.1	Designed Angles of Inclination	4
1.3	General Provisions	4
1.3.1	Definitions relating to some conditions and important electrical equipment onboard a ship	5
1.3.2	Electrical Services	6
1.3.2.1	Primary Essential Services	7
1.3.2.2	Secondary Essential Services	8
1.3.3	Main / Emergency Electrical Systems	9
1.4	Installation and Basic Maintenance	9
1.5	Effects of Temperature	9
1.6	Systems and Major Components	10
1.6.1	Generators	10
1.6.2	Power Supplies Commonly Available	12
1.6.3	Maximum Voltages	14
1.6.4	Main Switchboard	15
1.6.5	Motor Control Centre (MCC)	15
1.6.6	Motor Controls	16
1.6.7	Emergency Services	17
1.6.8	Emergency Stop Panel	17
1.6.9	Ship's Auxiliary Services	17
1.7	Load Analysis	18
1.7.1	Dimensioning the Electrical Network	18
1.8	Power Management Systems	20
1.8.1	Load Demand Monitoring	21
1.8.2	Generator Management	21
1.8.3	Load Sharing	21
1.8.4	Frequency Control	21
1.8.5	Load Inhibit	21
1.9	Electrical Diagrams	23
1.9.1	Basic or Line Diagram	24
1.9.2	Block Diagram	26
1.9.3	System Diagram	27

Contents

Chapter 1 - Overview of a Ship's Electrical System (Continued)		
Article No.	Article	Page No.
1.9.4	Circuit Diagram	28
1.9.5	Wiring Diagram	31
1.9.6	Branch Circuit	32
1.9.6.1	Power Circuit	32
1.9.6.2	Control Circuit	32
1.9.7	Additional Diagram Aids, Symbols and Units	33
1.10	Relevant SOLAS Regulations / Summary of Regulations	34
	Find the Answers	34

Chapter 2 - Electrical Safety		
Article No.	Article	Page No.
2.1	Compliance with Regulations	37
	Relevant SOLAS Regulations / Summary of Regulations	40
2.2	The Inherent Dangers and Avoidance of Disastrous Consequences	41
2.2.1	High Voltage Safety	43
2.3	Passive Safety Measures	44
2.3.1	Component Quality or Reliability Level	44
2.3.2	Protection against Erroneous Operation	45
2.3.3	Maintenance	46
2.3.4	Personnel Protection	46
2.4	Active Safety Measures	47
2.4.1	Redundancy Requirements	47
2.4.1.1	Essential Users	47
2.4.1.2	Important Users	48
2.4.2	Circuit Protection	49
2.4.2.1	Short-circuits	50
2.4.2.2	Overload	52
2.4.2.3	Loss of system voltage	52
2.5	Fundamental Requirements for Safe Installation of Equipment	52
2.6	Dos and Don'ts While Working With Electrical Equipment	53
2.6.1	Additional Precautions While Working on Electronic Equipment	55
2.6.2	Special Protection for Workshop Machinery	56
2.7	Danger Signals	57

Contents

Chapter 2 - Electrical Safety (Continued)		
Article No.	Article	Page No.
2.8	Safety Precautions for Preventing an Electric Shock	56
2.8.1	Working on High-voltage Equipment	58
2.9	Conditions which Increase Danger to Personnel	58
2.10	Shock Risk with Portable AC Appliances	59
2.10.1	Safe Practices for Welding Equipment	61
2.11	Electrical Accidents	62
2.11.1	Arc Flash	62
2.11.2	Arc Blast	62
2.11.3	Shock	62
2.11.3.1	Microshock	62
2.11.3.2	Macroshock	62
2.11.4	First Aid	66
2.11.4.1	The Basic Procedure	66
2.11.4.2	Mouth-to-mouth Resuscitation	68
2.11.4.3	Holger-Neilson Resuscitation	68
2.12	Tanker Installations	69
2.12.1	Awareness of Hazardous Areas	69
2.12.2	Static Electricity	72
2.13	Safe Electrical Equipment for Hazardous Areas	73
2.13.1	International Electrotechnical Committee Ex Scheme	73
2.13.2	Effect of Added Oxygen on Mixture of Oil Vapour and Inert Gas	74
2.13.3	Reasons for Specially-designed Equipment	75
2.13.3.1	Lighting	76
2.13.3.2	Pulley Drives	76
2.13.3.3	Miscellaneous Equipment	76
2.14	European Safety Standards	76
2.14.1	Flameproof (Ex d) Equipment	79
2.14.2	Flameproof (Ex d) Equipment Protection	81
2.14.3	Explosion Test	81
2.14.4	Flameproof Test	81
2.14.5	General Comments	81
2.14.6	Increased Safety (Ex e) Equipment	82
2.14.7	Pressurised (Ex p) Equipment	83

Contents

Chapter 2 - Electrical Safety (Continued)		
Article No.	Article	Page No.
2.14.8	Pressurised (Ex p) Equipment Protection	84
2.14.9	Intrinsically Safe (Ex i) Equipment	86
2.14.10	Non-incendive (Ex n or N) Equipment	88
2.14.11	Non-incendive (Ex n or N) Equipment Protection	88
2.14.12	Class I Certified Equipment Comparison Chart	89
2.14.13	Other Methods of Protection	89
2.15	Ventilation when using volatile varnishes, paints, etc., having solvents	90
2.16	Maintenance of Records	91
	Find the Answers	

Chapter 3 – AC Distribution Systems		
Article No.	Article	Page No.
3.1	The General Concept	97
3.2.	Common Systems for the Distribution of AC Power	98
3.2.1	Single-Phase 2-Wire System	98
3.2.2	Single-Phase 3-Wire System	98
3.2.3	Three-Phase 3-Wire System	99
3.2.4	Three-Phase 4-Wire System	100
3.3	Specific Systems for Ship's Service	100
3.3.1	Generation	100
3.3.2	Primary Distribution	101
3.3.3	Secondary Distribution	101
3.3.4	Voltages and Frequencies	101
3.4	Distribution Systems Onboard Ships	102
3.4.1	Radial Distribution	103
3.4.2	Other Types of Distribution	103
3.5	General Distribution Scheme Onboard a Ship	104
3.6	General Scheme Applicable to all Types of Tankers	106
3.6.1	Ship's Service	106
3.6.2	Distribution	106
3.7	Example of a High-voltage System for a Liquefied Natural Gas Carrier	107
3.7.1	Generating Plant	107
3.7.2	Automatic Power and Frequency Control	108
3.7.3	Automatic Synchronising Control	108

Contents

Chapter 3 – AC Distribution Systems (Continued)		
Article No.	Article	Page No.
3.7.4	Cargo Switchboards	108
3.7.5	Main and Emergency Switchboards	108
3.7.6	Feeder Circuit Breakers	109
3.8	Primary Power Bus	109
3.9	Relevant Regulations	110
3.9.1	Relevant SOLAS Regulations (Chapter II-1)	110
3.9.2	Relevant ABS Rules for Building and Classing Steel Vessels – 2007	110
	Find the Answers	111

Chapter 4 - Emergency Power and Shore Supply		
Article No.	Article	Page No.
4.1	The Method of Supplying Emergency Power	113
4.1.1	Power Source	113
4.1.2	Starting Arrangements for Emergency Generator Sets	114
4.1.2.1	Operation	115
4.1.2.2	Emergency Switchboard (ESB)	115
4.1.2.3	The Basic Indicators Available on the Emergency Switchboard	116
4.1.2.4	Inter-connector Feeder between Emergency and Main Switchboards	116
4.1.3	Critical equipment to be supplied with power from an emergency generator	119
4.1.3.1	Lighting	119
4.1.3.2	Other Emergency Services	119
4.1.3.3	Steering Gear and Propulsion Equipment	119
4.1.3.4	Other Equipment	120
4.1.4	Arrangements for Periodic Testing	122
4.1.5	Transitional Source of Power	124
4.1.6	Operating Instructions	124
4.2	Actions by Engineers during a Blackout Situation	125
4.2.1	Chief Engineer's Responsibility	126
4.2.2	Second Engineer's Responsibility	126
4.2.3	Third Engineer's Responsibility	126
4.2.4	Fourth Engineer's Responsibility	126

Contents

Chapter 4 - Emergency Power and Shore Supply (Continued)		
Article No.	Article No.	Article No.
4.3	Shore Supply	127
4.3.1	Effect of Change in Supply Voltage on Torque and Speed	129
4.3.1.1	Running at Reduced Voltage (e.g., 440V-rated and running at 380V)	129
4.3.1.2	Running at Increased Voltage (e.g., 380V-rated and running at 440V)	129
4.3.2	Effect of Change in Supply Frequencies on Torque and Speed	130
4.3.2.1	Running at Reduced Frequency (e.g., 60Hz-rated and running at 50Hz)	130
4.3.2.2	Running at Increased Frequency (e.g., 50Hz-rated and running at 60Hz)	131
	Relevant SOLAS Regulations and ABS Rules	131
	Find the Answers	131

Chapter 5 - Isolated and Earthed Neutral Systems		
Article No.	Article	Page No.
5.1	Electromagnetic Compatibility	135
5.1.1	The Basics	136
5.1.2	Earthing and Bonding	136
5.1.2.1	Earthing	136
5.1.2.2	Bonding	137
5.2	Isolated and Earthed Neutral Systems	138
5.2.1	Electrolysis	140
5.3	Grounding	141
5.3.1	Ground	141
5.3.2	Grounded	141
5.3.3	Grounded Conductor	141
5.3.4	Grounding Conductor, Equipment	141
5.3.5	Current-carrying Grounds	142
5.3.6	Non-current-carrying Grounds	142
5.3.7	The 'Earth'	143
5.4	Significance of Earth Faults	144
5.5	Multiple Systems	149
5.6	Causes of Earth Faults	149
5.6.1	Dampness	150
5.6.2	Mechanical Damage	150
5.6.3	Contamination due to Dirt	150
5.6.4	Temperature Rise	150

Contents

Chapter 5 - Isolated and Earthed Neutral Systems (Continued)		
Article No.	Article	Page No.
5.6.5	Ageing	151
5.7	Prevention of Earth Faults	151
5.7.1	Equipment	151
5.7.2	Maintenance	151
5.8	Earth Fault Indicators	152
5.9	Insulation Monitoring	156
5.10	Detection and Clearance of an Earth Fault	158
5.11	Relevant Rules	161
5.11.1	Summary of SOLAS Regulations	162
	Find the Answers	164

Chapter 6 – Alternators		
Article No.	Article	Page No.
6.1	The Basic Concept	167
6.1.1	The EMF Equation	168
6.2	The Elementary Alternator	169
6.3	Rotor and Stator	171
6.4	Armature and Field	172
6.5	Rotating Armature Alternators	172
6.6	Rotating Field Alternators	173
6.6.1	The Stator	174
6.6.1.1	The Sealing Procedure	177
6.6.2	The Rotor	177
6.6.3	Cylindrical Rotor Construction	178
6.6.4	Salient Pole Rotor Construction	181
6.7	The Brushless Alternator	183
6.7.1	The Unique Features	183
6.7.1.1	The Exciter	185
6.7.1.1.1	Exciter Field	185
6.7.1.1.2	Exciter Armature	186
6.7.1.2	Rotating Rectifier	186
6.7.1.2.1	Effects of Diode Failure	187
6.7.1.3	Main Rotating Field	187
6.7.1.4	Amortisseur or Damper Winding	187

Contents

Chapter 6 – Alternators (Continued)		
Article No.	Article	Page No.
6.7.1.5	Main Armature	187
6.7.1.6	Flange-mounted Sleeve Bearing	188
6.7.1.7	Integral Pedestal Sleeve Bearing	189
6.7.2	Possible Damages Due To Shaft Current	190
6.7.2.1	Frosting	190
6.7.2.2	Spark Tracks	190
6.7.2.3	Pitting	190
6.7.2.4	Welding	191
6.8	High-voltage Brushless Alternator	191
6.8.1	Frame and Stator Core	191
6.8.2	Main Stator Winding	191
6.8.3	Cylindrical Rotor	192
6.9	Outline of Operation of a Brushless Alternator	193
6.10	Generator Cooling	194
6.10.1	Air-to-water closed circuit cooling	194
6.10.2	Air-to-air closed circuit cooling	195
6.11	Generator Heating	196
6.12	Shaft-driven Alternators	196
6.12.1	Conventional Shaft Generator System	197
6.12.2	Static Frequency Converter for a Shaft Generator	198
6.12.3	Power Factor Correction using a Synchronous Motor	202
6.12.4	Synchronous Condensers	203
6.13	Exhaust Gas Turbo-generator System	205
6.14	Advantage of Shaft Generators	207
6.14.1	Less Space Required	207
6.14.2	Low Investment and Installation Cost	207
6.14.3	Reliability	207
6.14.4	Low Maintenance Cost	207
6.14.5	Long Life	207
6.15	Disadvantages of Shaft Generators	207
6.15.1	No Power Production in Harbour	207
6.15.2	Increased Load on the Main Engine	208
6.15.3	Reduced Propeller and Engine Efficiency at Low Propulsion	208
6.15.4	More Complex Shaft Arrangement	208

Contents

Chapter 6 – Alternators (Continued)		
Article No.	Article	Page No.
6.16	High Voltage Systems	208
6.16.1	High Voltage System for a Dredger	208
6.16.2	High Voltage System for a Liquefied Natural Gas Carrier	209
6.17	Alternator Starting	210
6.18	Harmonics	212
6.18.1	Motor Starting Options	215
6.18.2	Things to Keep in Mind	215
6.19	Summary of Regulations	216
6.19.1	Relevant SOLAS Regulations (Chapter II-1)	216
	Find the Answers	217

Chapter 7 - Direct Current Machines		
Article No.	Article	Page No.
7.1	DC Generators	221
7.2	Field Poles	222
7.3	Armature Windings	223
7.4	Commutator	224
7.5	Armature Reaction	226
7.6	Reduced Cross-Sectional Area of the Pole Tip	228
7.7	Compensating Windings	228
7.8	Commutating Poles	229
7.9	Commutation	230
7.10	Multi-polar Machines	232
7.11	Types of Direct Current Generators	232
7.12	Series Wound Generator	233
7.12.1	Building-up Series Field Strength	234
7.12.2	Restoring the Residual Field	234
7.12.3	Applying the Series Generator	235
7.13	Shunt Wound Generator	235
7.13.1	Inherent Regulation of the Shunt Generator	236
7.13.2	External Voltage Characteristics	237
7.13.3	Build-up of Shunt Field Strength	237
7.13.4	Applications	238
7.14	Compound Wound Generators	238

Contents

Chapter 7 - Direct Current Machines (Continued)		
Article No.	Article	Page No.
7.14.1	Flashing the Field of Compound Generators	239
7.14.2	Short and Long Shunt	240
7.14.3	Series and Shunt Field Comparison	240
7.14.4	Stabilised Shunt	242
7.14.5	Over-, Flat-, and Under-Compounding	242
7.14.6	Diverter	243
7.14.7	Applications	244
7.15	Generator Control	244
7.15.1	Speed Control of Generator Output	244
7.15.2	Field Strength Control of Generator Output	245
7.15.3	No-Load Voltage Control	246
7.15.4	Critical Field Resistance	247
7.15.5	Taking One Generator on Load	247
7.15.6	Paralleling of Generators	247
7.16	DC Motors	248
7.17	Principle of DC Motor Operation	249
7.17.1	Back EMF (E_b)	252
7.17.2	Armature Reaction	253
7.18	Shunt Wound Motor	255
7.18.1	No-Field Condition	256
7.18.2	Speed Control	257
7.18.2.1	Above Normal Speed Control	257
7.18.2.2	Below Normal Speed Control	258
7.18.2.3	Use of Shunt Motors	258
7.19	Series Wound Motor	258
7.19.1	Series Motor Speed	259
7.19.2	No-Load Operation	259
7.20	Compound Motors	260
7.20.1	Separately Excited Motor	261
7.21	DC Motor Rotation Reversal	262
7.22	Motor Braking	263
7.22.1	Electromechanical Braking	263
7.22.2	Dynamic Braking	263
	Find the Answers	265

Contents

Chapter 8 - Automatic Voltage Regulators		
Article No.	Article	Page No.
8.1	Performance Requirements of Alternators	267
8.2	Operating Principle of an AVR	268
8.2.1	The Excitation Supply AVR	268
8.2.2	The Compounding Control AVR	268
8.3	Excitation Systems	268
8.3.1	Self-excited AVR Controlled Generator	269
8.3.2	Permanent Magnet Generator (Excited – AVR Controlled Generators)	270
8.4	Thyristor-based Static Automatic Voltage Regulator	271
8.4.1	Main Components	271
8.4.1.1	The Voltage Comparison Circuit	272
8.4.1.2	Role of the Zener Diodes in the Circuit	272
8.4.1.3	Amplifier and Conditioning Circuit	273
8.4.1.4	Excitation Control Element	274
8.4.1.5	Role of the Silicon Controlled Rectifiers in the Circuit	276
8.5	Alternative Thyristor-based AVR Circuits	278
8.6	Transformer-based Static Excitation System	280
8.7	Transient Voltage Dip and Alternator Response	282
8.8	Effect of kW Loading	285
8.9	Effect of kVAr Loading	287
8.10	Additional (Important) Features in a Modern AVR	288
8.10.1	Stability Adjustment	288
8.10.2	Under Frequency Roll Off	289
8.10.3	Excitation Trip	290
8.10.4	Over Voltage Protection	290
8.10.5	Transient Load Switching Adjustments	290
8.10.5.1	Dip	290
8.10.5.2	Dwell	291
8.10.6	Ramp	292
8.10.7	Droop	292
8.10.8	Over-voltage De-excitation Breaker	294
8.10.9	The Block Diagram	294
8.10.9.1	The Power Supply	294
8.10.9.2	The Potential Divider and Rectifier	294
8.10.9.3	The DC Mixer	294

Contents

Chapter 8 - Automatic Voltage Regulators (Continued)		
Article No.	Article	Page No.
8.10.9.4	The 3-Phase Rectifier	294
8.10.9.5	The Amplifier (Amp)	294
8.10.9.6	The Stability Circuit	295
8.10.9.7	The Low Hz Detector	295
8.10.9.8	The Synchronising circuit	295
8.10.9.9	Power Control Devices	295
8.10.9.10	The Circuit Breaker	296
8.10.9.11	The Over Excitation Detector	296
8.10.9.12	The Over Voltage Detector	296
	Find the Answers	296

Chapter 9 – Panel Instrumentation		
Article No.	Article	Page No.
9.1	The Basics	299
9.2	Measuring System Terminology	300
9.2.1	Information	300
9.2.2	Instrumentation	300
9.2.3	Measurement	300
9.2.4	Standard	300
9.2.5	Calibration	300
9.2.6	Static Sensitivity	300
9.2.7	Linearity	301
9.2.8	True Value	301
9.2.9	Accuracy	301
9.2.10	Precision	301
9.2.11	Reproducibility	301
9.2.12	Repeatability	301
9.2.13	Stability	301
9.2.14	Constancy	301
9.2.15	Errors	301
9.2.16	Tolerance	301
9.2.17	Hysteresis	302
9.2.18	Threshold	302

Contents

Chapter 9 – Panel Instrumentation (Continued)		
Article No.	Article	Page No.
9.2.19	Dead Zone	302
9.2.20	Resolution	302
9.2.21	Span	302
9.2.22	Range	302
9.3	Some Useful Fundamentals	302
9.3.1	The Relationship between V, I, W and R	302
9.3.2	Why do modern vessels choose to generate high voltages?	302
9.3.3	Power factor	303
9.4	In-Circuit Meters	304
9.5	Out-of-Circuit Meters	305
9.6	Permanent Magnet Moving Coil Meter	305
9.7	Power Measurement	308
9.8	The Electrodynamicometer Wattmeter	311
9.8.1	Fixed Coil	311
9.8.2	Moving Coil	312
9.8.3	Control	313
9.8.4	Damping	313
9.8.5	Scale and Pointer	314
9.9	Theory of an Electrodynamicometer Wattmeter	314
9.10	Shape of the Scale of an Electrodynamicometer Wattmeter	316
9.11	Power in Poly-Phase Systems - Blondel's Theorem	317
9.12	Measurement of Active Power in Three-Phase Circuits	317
9.12.1	Three Wattmeter Method	317
9.12.2	Two Wattmeter Method	317
9.12.3	Star (Wye or Y) Connection	317
9.12.4	Delta Connection	321
9.12.6	Three-Phase Wattmeter	322
9.13	Measurement of Reactive Power	323
9.13.1	Single-Phase Varmeter	323
9.13.2	Poly-phase Varmeter	324
9.13.3	Reactive Power Measurement in Three-Phase Circuits	326
9.14	Power Factor Measurement	328
9.14.1	Power Factor	328
9.14.2	Power Factor Meters	329

Contents

Chapter 9 – Panel Instrumentation (Continued)		
Article No.	Article	Page No.
9.14.2.1	Single-Phase Electrodynamometer Power Factor Meter	330
9.14.2.2	Three-Phase Electrodynamometer Power Factor Meter	332
9.14.2.3	Three-Phase Moving Iron Power Factor Meter	334
9.15	Frequency Meters	336
9.15.1	Mechanical Resonance Type Frequency Meter (Vibrating Reed Type)	336
9.15.2	Electrodynamometer Type Frequency Meter	339
9.16	Synchroscope	340
9.16.1	Electrodynamometer (Weston Type) Synchroscope	341
9.17	Phase Sequence Indicators	345
9.17.1	Rotating Type	345
9.17.2	Static Type	346
9.18	Electric Tachometer	347
9.19	Digital Meters	349
9.19.1	TEMA 96 / TEMA 96H - Electrical Multi function Analyser	352
9.19.1.1	Functions only available via NRG software	352
9.20	Relevant Rules	353
9.20.1	Relevant Lloyd's Register Rules for the Classification of Ships	354
	Find the Answers	354

Chapter 10 - Paralleling of Alternators		
Article No.	Article	Page No.
10.1	The Basics	357
10.2	Manual Synchronising	359
10.3	Check-Synchronising Unit	362
10.4	Auto-Synchronising	362
10.5	Synchronising with the aid of Lamps	366
10.6	Synchronising with the Aid of a Voltmeter	368
10.7	Parallel Operation	368
10.8	Excitation Control	370
10.8.1	Loss of Excitation	371
10.9	Throttle Control	372
10.10	Load Sharing	374
10.10.1	kW Load Sharing	374

Contents

Chapter 10 - Paralleling of Alternators (Continued)		
Article No.	Article	Page No.
10.10.1.1	Prime-mover Characteristics	375
10.10.1.2	Load Sharing by Two Alternators	377
10.10.1.3	Load sharing between alternators of equal capacities and different droop characteristics	378
10.10.1.4	Load sharing between alternators with both unequal capacities and same droop characteristics	380
10.10.2	kVAr Load Sharing	382
10.10.3	Manual Load Sharing	383
10.11	The Induction Generator	385
10.12	Speed Droop and Power Generation	386
	Find the Answers	394

Chapter 11 - Switchboards and Switchgear		
Article No.	Article	Page No.
11.1	Switchboards	399
11.1.1	The Main Switchboard	400
11.1.1.1	AC Switchboards	402
11.1.1.2	DC Switchboards	404
11.1.2	Section Switchboards or Sub-switchboards	404
11.1.3	Group Starter Boards (or Panels)	405
11.1.4	Distribution Fuse boards	405
11.2	Bus bars	406
11.2.1	Skin Effect	407
11.3	Instrumentation and Controls	407
11.4	Circuit Breaker (CB)	410
11.4.1	Voltage Rating	411
11.4.2	Current Rating	411
11.4.3	Fault Rating	411
11.4.4	Important Aspects of a Circuit Breaker	412
11.4.5	Contacts	412
11.5	Circuit Breakers for Alternators	414
11.6	Moulded Case Circuit Breakers (MCCBs)	420
11.6.1	Feeder Protection	421
11.6.2	Capacitor Control	421
11.6.3	Diesel-Generator Set Protection	422

Contents

Chapter 11 - Switchboards and Switchgear (Continued)		
Article No.	Article	Page No.
11.6.4	Hoist / Elevator / Crane Control	422
11.6.5	Furnace Control	422
11.6.6	DC Power Supply Control	422
11.6.7	Miscellaneous Marine Applications	422
11.7	Miniature Circuit Breakers (MCBs)	422
11.7.1	Advantages	423
11.7.2	Disadvantages	423
11.8	Residual Current Circuit Breakers (RCCBs)	424
11.8.1	Application and Scope of the Residual Current Circuit Breaker	425
11.9	Arc Fault Current Interrupters	426
11.10	Fused Isolators	426
11.11	Effect of Harmonics at Receptacle Load Centres	426
11.12	Corrective and Preventive Actions In Case of Fire in the Main Switchboard	427
11.13	Relevant Rules	428
11.13.1	Relevant SOLAS Regulations (Chapter II-1)	428
11.13.2	Summary of Regulations	428
	Find the Answers	428

Chapter 12 – Starters for Alternating Current Motors		
Article No.	Article	Page No.
12.1	The Basics of Starters	433
12.2	The Contactor	438
12.3	The Direct-on-line or D.O.L. Starter	440
12.3.1	Local Control	440
12.3.2	Protection	440
12.3.3	Operation	441
12.3.4	Remote Control	441
12.3.5	Pump Control	442
12.3.5.1	Manual Mode (Local Control)	442
12.3.5.2	Automatic Mode	444
12.3.6	Engine Room Crane Control	445
12.3.6.1	Dual-motor Single-speed Crane	445
12.3.7	Special Features of the Dreggen AS Engine Room Crane	447
12.3.7.1	Hoisting Machinery	447

Contents

Chapter 12 – Starters for Alternating Current Motors (Continued)		
Article No.	Article	Page No.
12.3.7.2	Travel Machinery	448
12.3.7.3	Motors	448
12.3.7.4	Electrical Equipment	448
12.3.7.5	Electrical Power Supply	448
12.3.7.6	Operation of the Crane	448
12.3.7.7	Safety Features	448
12.3.7.8	Parking	449
12.4	Star-delta Starter	449
12.5	Additional Features in a Star-delta Starter	455
12.5.1	Overload Relay Setting	455
12.5.2	Overload Trip Reset	455
12.5.3	Back-up Fuses	456
12.5.4	Pilot Wire Fuse	456
12.5.5	Solenoid Coil	456
12.5.6	Time Delay	456
12.5.7	Single Pole Float Switch, Thermostat or Similar Device	457
12.5.8	Low voltage protection	457
12.6	Star-delta Starter with Fusible Isolator	457
12.6.1	Power circuit operation (Refer Figure 12.19 (a))	457
12.6.2	Features	457
12.6.3	Control-circuit Operation (Refer Figure 12.19 (b))	458
12.6.4	Electrical interlock between KM_1 and KM_3	460
12.6.5	Star-delta Circuit for a Main Seawater Pump	461
12.6.6	Starting torque of a Squirrel-cage type of Motor	464
12.6.7	Asynchronous 3-phase Squirrel Cage Motor Data	467
12.7	Autotransformer Starter	468
12.7.1	Operating Principle	4698
12.8	Starting of Special High Torque Induction Motors	471
12.8.1	Operation of the Circuit	473
12.9	Low voltage protection	473
12.10	Electronic or “Soft” Starter	474
12.10.1	Why do we need a Soft Starter?	474
12.10.2	The Basics	474
12.10.3	Voltage Ramp	476

Contents

Chapter 12 – Starters for Alternating Current Motors (Continued)		
Article No.	Article	Page No.
12.10.4	Current Limit	477
12.10.5	Initial Firing Angle	478
12.10.6	Solid-state switches	478
12.10.7	Switching Elements	478
12.10.8	Open Loop Soft Starters	479
12.10.9	Closed Loop Soft Starters	480
12.10.10	Starting Torque	481
12.10.11	Slip Ring Motors	482
12.10.12	Soft-starter Ratings	483
12.11	Speed Control of Induction Motors	484
12.11.1	Slip	484
12.11.2	Control of Speed	484
12.11.3	Dual-speed Control applied in a Crane Circuit	485
	Find the Answers	487

Chapter 13 - Fault Protection Devices		
Article No.	Article	Page No.
13.1	The Basics	491
13.2	Direct Shorts	492
13.3	Excessive Current	493
13.4	Excessive Heat	493
13.5	Over-voltage	493
13.5.1	Operator-induced Over-voltage Problems	494
13.6	Surge	495
13.6.1	DC Surge	495
13.6.2	AC Surge	496
13.7	Transients	496
13.7.1	Load Dump Transients	497
13.7.2	Field Decay Transients	497
13.7.3	Other Transient Sources	497
13.8	Ripple	498
13.9	Spikes	499
13.10	Circuit Protection	499
13.11	Alternator and Associated Systems' Protection	500

Contents

Chapter 13 - Fault Protection Devices (Continued)		
Article No.	Article	Page No.
13.11.1	Over-current Protection	502
13.11.1.1	Electromagnetic Trip	502
13.11.1.2	Thermal Trip	502
13.11.1.3	Electronic Trip	502
13.11.2	Inverse Definite Minimum Time (IDMT) Relay	504
13.11.3	Preference Tripping	505
13.11.3.1	First Stage Preference Trips (after 10 seconds)	507
13.11.3.2	Second Stage Preference Trips (5 seconds after the First Stage Equipment)	509
13.11.3.3	Abnormality Due to Overcurrent (Long Time Delay Trip)	509
13.11.4	Sequential Restarting	509
13.11.4.1	When Normal Power is restored After a Blackout	509
13.11.4.2	Automatic Standby Start	510
13.11.5	Reverse Power Protection (Electromagnetic Type)	510
13.11.6	Under-voltage Protection	512
13.11.7	Lockout Relay	514
13.12	Protection Scheme on a High-voltage System (LNG Vessel)	514
13.13	Protection through Fuses	515
13.13.1	Back in Time...	515
13.13.2	Regulatory Requirements	515
13.13.3	The Pros and Cons	516
13.13.4	Safety Precautions	517
13.13.5	Replacing Open Fuses	517
13.13.6	Types of Fuses	519
13.13.6.1	Cartridge Fuse	519
13.13.6.2	Enclosed Fuse	520
13.13.6.3	Semi-enclosed Re-wireable Fuse	522
13.13.6.4	Diased (Bottle) Fuses	522
13.13.6.5	Colour Codes and Dimensions	524
13.13.6.6	Neozed Fuses	525
13.13.6.7	NH Fuses	526
13.13.6.8	High Rupturing Capacity or HRC Fuse	527
13.13.6.9	Semiconductor Fuses	529
13.13.6.10	Screw Caps	530

Contents

Chapter 13 - Fault Protection Devices (Continued)		
Article No.	Article	Page No.
13.13.6.11	Adapter Screw / Ring	531
13.13.6.12	Fuse Bases	531
13.13.6.13	Fuse Base Covers	531
13.13.6.14	Rating	531
13.13.6.15	Table of Ratings	532
13.14	Protection Discrimination	535
13.15	Motor Protection	537
13.15.1	Co-ordination	539
13.15.2	Single-phasing	540
13.15.3	Over-current Relays	542
13.15.4	Setting a Thermal Over-current Relay	544
13.15.5	Thermistor-based Protection	544
13.15.6	Electromagnetic Over-current Relays	548
13.15.7	Electronic Relays	548
13.16	Cable Protection	549
13.18	Relevant Rules	550
13.18.1	Relevant SOLAS Regulations (Chapter II-1)	550
13.18.2	Summary of SOLAS Regulations	550
	Find the Answers	551

Chapter 14 - Electric Cables		
Article No.	Article	Page No.
14.1	The Basics	557
14.2	Conductors	558
14.3	Temperature Coefficient	559
14.4	Cable Sizes	559
14.5	Current Rating	560
14.6	US and British Comparative Sizes for Cables and Lines	562
14.7	Cable Testing	564
14.8	Electrical Cable Codes	565
14.9	Practical Tips on Wiring	567
14.9.1	Minimising Electromagnetic Interference	568
14.9.2	Simple Daily-Use Terms Related To Cables	569
14.9.2.1	Cable Tags	569

Contents

Chapter 14 - Electric Cables (Continued)		
Article No.	Article	Page No.
14.9.2.2	Distribution Cables	569
14.9.2.3	Control Cables	569
14.9.2.4	Signal Cables	569
14.9.3	Portable Cords	569
14.9.4	Other important points to bear in mind when working on your electrical system	570
14.9.5	Determining a Cable's Reaction to Flames	570
14.10	Relevant Rules	570
14.10.1	Relevant SOLAS Regulations (Chapter II-1)	570
14.10.2	Summary of SOLAS Regulations	570
	Find the Answers	572

Chapter 15 - Cable Insulation and Ingress Protection		
Article No.	Article	Page No.
15.1	The Basics	575
15.2	Classes of Insulation	575
15.2.1	Class A Insulation	575
15.2.2	Class E Insulation	576
15.2.3	Class B Insulation	576
15.2.4	Class F Insulation	576
15.2.5	Class H Insulation	577
15.3	Insulation for Temperature above 180°C (356°F)	577
15.4	Insulating Materials generally used in a Low to Medium Power AC Motor	577
15.5	Motor Ratings versus Temperature	579
15.5.1	Rated Current	579
15.5.2	Rated Voltage	579
15.5.3	Rated Frequency	579
15.5.4	Rated Power	579
15.5.5	Rated Speed	579
15.6	Temperature Ratings	579
15.7	Temperature Rise	580
15.8	Determination of Hot Temperature	580
15.9	Conductor Insulation	583
15.9.1	Insulation Resistance	583
15.9.2	Dielectric Strength	583

Contents

Chapter 15 - Cable Insulation and Ingress Protection (Continued)		
Article No.	Article	Page No.
15.10	Insulating Materials	585
15.10.1	Polyvinyl Chloride (PVC) (designated T)	585
15.10.2	Butyl Rubber	585
15.10.3	Ethylene propylene rubber (designated E)	585
15.10.4	Cross-linked Polyethylene (XLPE)	586
15.10.5	Mineral (MI) (designated M)	586
15.10.6	Silicon rubber (designated S)	586
15.10.7	Impregnated glass, varnished cloth(designated GTV)	586
15.10.8	Enamel Coating	586
15.11	Separators and Fillers	587
15.12	Cable Sheath	587
15.12.1	Flame test	589
15.13	Formation of Polymers	589
15.14	Classification of Polymers	591
15.15	Polymerization Mechanisms	592
15.15.1	Addition polymerization	592
15.15.2	Condensation Polymerisation	594
15.15.3	Fillers	594
15.15.4	Cross-linking	594
15.16	Cable Gland	595
15.16.1	Cable Gland Preparation for Use in Hazardous Zones	596
15.17	Plugs and Sockets for Reefer Containers	598
15.18	Degrees of Protection for an Enclosure	598
	Find the Answers	602

Chapter 16 – Transformers		
Article No.	Article	Page No.
16.1	Basic Operation of a Transformer	605
16.2	Transformer Components	607
16.2.1	Core Characteristics	607
16.2.2	Transformer Windings	610
16.3	Transformer Ratings	611
16.4	The EMF Equation	612
16.5	Relationship between Voltage and Turns	613

Contents

Chapter 16 – Transformers (Continued)		
Article No.	Article	Page No.
16.6	Relationship between Current and Turns	613
16.7	The Ideal kVA Relationship	614
16.8	No-Load Condition	614
16.9	Voltage in the Secondary	615
16.10	Effect of a Load	615
16.11	Transformer Losses	615
16.11.1	Copper Loss	616
16.11.2	Eddy Current Loss	617
16.11.3	Hysteresis Loss	617
16.12	Efficiency	617
16.13	Distribution Transformers	618
16.14	Effect of Harmonics on Distribution Transformers	623
16.15	Isolation Transformers	623
16.15.1	Hull Isolation Transformers	624
16.16	Auto-transformers	625
16.16.1	The Fixed Ratio Auto-transformer	625
16.16.2	The Variable Ratio Auto-transformer	627
16.17	Instrument Transformers	627
16.17.1	Salient Features of Instrument Transformers	629
16.18	Miscellaneous Applications of Transformers	631
16.19	Transformer Feeders	631
16.20	Relevant Rules	632
16.20.1	Relevant SOLAS Regulations (Chapter II-1)	632
16.20.2	Summary of Regulations	632
	Find the Answers	632

Chapter 17 – Electrical Propulsion Systems		
Article No.	Article	Page No.
17.1	Layout and General Features	635
17.1.1	A Propulsion System	635
17.1.2	A Steering System	635
17.1.3	A Manoeuvring System	636
17.2	Optimising Storage Space	638
17.3	Ships Equipped with an Auxiliary Propulsion System	639

Contents

Chapter 17 – Electrical Propulsion Systems (Continued)		
Article No.	Article	Page No.
17.3.1	Auxiliary Propulsion System / Take Home System	639
17.4	Electrical Propulsion	641
17.5	Advantages of Electrical Propulsion	643
17.6	Disadvantages of Electrical Propulsion	644
17.7	Turbo-electric Propulsion	645
17.8	The Synchronous Motor	647
17.8.1	Operation	648
17.8.2	Starting	649
17.9	AC Single-Speed Drive with a Controllable Pitch Propeller	652
17.10	AC Induction Motor Drive with a Controllable Pitch Propeller	653
17.11	Fixed-Speed Alternators with Variable-Speed Synchronous Motors	655
17.12	Cycloconverter Method of Speed Control	656
17.13	Advanced Diesel-electric Propulsion Systems	657
17.13.1	Salient Features	657
17.13.1.1	Economical Operation	657
17.13.1.2	Availability	659
17.13.1.3	Environmental Compatibility	659
17.13.1.4	Operating Convenience	659
17.13.1.5	Flexibility	659
17.13.1.6	Use of Harmonic Filters	660
17.13.2	SIMAR Drive Cyclo - The drive with the Cycloconverter	660
17.13.3	SIMAR Drive Synchro - The Drive with the Electronic Commutator	661
17.13.4	SIMAR Drive PWM - The drive with IGBTs (Insulated Gate Bipolar Transistors)	663
17.13.4.1	The Basics of PWM	665
17.13.4.2	Precautions while Handling IGBTs	666
17.13.4.3	IGBT Testing	666
17.13.4.3.1	Test Procedure (with a Digital Multi-meter)	667
17.13.5	Modular Converters	667
17.13.5.1	Water-cooled converters	667
17.13.5.2	Air-cooled converters	667
17.13.6	SSP Propulsor	667
17.13.6.1	Benefits of SSP	670
17.13.7	Electrical Booster Drives	671
17.13.7.1	Advantages of Booster Drives	674

Contents

Chapter 17 – Electrical Propulsion Systems (Continued)		
Article No.	Article	Page No.
17.14	Thruster Propulsion Systems	674
17.14.1	Hydrodynamic Performance	675
17.14.2	Machinery Arrangements	676
17.14.3	Shipbuilding Aspects	677
17.14.4	Thruster Machinery and Propeller Concepts	677
17.14.5	Diesel - Mechanical Drives	678
17.14.6	Diesel-Electric Drives	680
17.14.7	Reliability Service and Maintenance	680
17.14.8	Thrusters for Booster Propulsion of Existing Ships	681
17.14.9	Rotatable Thrusters	683
17.14.9.1	Main Control System Type TPC	683
17.14.9.2	Indication of Thrust / Pitch and Back-up Control	685
17.14.10	Additional Subsystems	687
17.14.10.1	Polar Joystick Control System	687
17.14.10.2	Manoeuvre Responsibility System	687
17.14.10.3	Thrust Reduction Unit	687
17.14.11	Features of the Electronic Control System for Rotatable Thrusters	687
17.14.12	Description of the Main Control System	688
17.14.12.1	Transmitter Alarm Circuit	688
17.14.12.2	Thrust Controller	688
17.14.12.3	Rotation Controller	689
17.14.13	Indication of Thrust / Pitch – Rotation and Back-up Control	690
17.14.13.1	Indication of Thrust / Pitch	690
17.14.13.2	Thrust Indication Mode	690
17.14.13.3	Pitch Indication Mode	690
17.14.13.4	Indication of Rotation	690
17.14.13.5	Back-up Control of Pitch-Rotation	691
17.14.14	Tunnel Thruster	691
17.14.15	Thruster Applications	693
17.14.15.1	Side Thruster on a LNG Vessel	693
17.15	Integrated Steering / Propulsion Systems	695
17.15.1	Voith-Schneider Propulsion System	695
17.15.2	The Active Rudder	695
17.15.3	Dynamic Positioning Systems	696

Contents

Chapter 17 – Electrical Propulsion Systems (Continued)		
Article No.	Article	Page No.
17.15.3.1	Basic Principle	697
17.15.3.2	User Interface	700
17.15.3.3	Reference Systems	700
17.15.3.3.1	Ultra- or Super-Short Baseline Acoustic System	700
17.15.3.3.2	Taut Wire Position Reference	702
17.15.3.3.3	Long Baseline System	703
17.16	Water Jet Propulsion	704
17.16.1	Kamewa S-series	704
17.16.2	Kamewa A-series	705
17.16.3	The SCHOTTEL Pump-Jet	706
17.16.3.1	Principle of Operation	706
17.16.3.2	Self-cleaning of Pump-Jet	707
17.16.3.3	Steering	707
17.17	Relevant Rules	709
17.17.1	Relevant SOLAS Regulations	709
17.17.2	Summary of Regulations	709
	Find the Answers	712

Chapter 18 - Steering and Stabiliser Systems		
Article No.	Article	Page No.
18.1	Fundamental Concepts	715
18.1.1	Steering Gear	715
18.1.2	Steering Gear Power Unit	716
18.1.3	Auxiliary Steering Gear	716
18.1.4	Steering Gear Control	716
18.1.5	Non – follow up steering (or time dependent steering)	718
18.1.6	Remote Control Systems	719
18.1.7	Electro-hydraulic Control	719
18.1.7.1	The Four Ram Type of Steering Gear	722
18.1.7.2	Procedure to Put the Steering Gear into Operation	723
18.1.8	Automatic Isolation System	723
18.1.8.1	Construction	723
18.1.8.2	Operation	724
18.1.8.3	Failure Sequence with One Pump Running	724

Contents

Chapter 18 - Steering and Stabiliser Systems (Continued)		
Article No.	Article	Page No.
18.1.8.4	Failure Sequence with Both Pumps Running	724
18.1.8.5	System Testing	725
18.1.9	Electronic Steering Control	725
18.1.10	Indicators for Monitoring the Operating Conditions of the Steering Gear	727
18.1.11	Procedure for Change-Over from Normal to Emergency Mode of Operations	727
18.1.11.1	Requirements	727
18.1.11.2	Basic Actions	728
18.2	AutoNav Steering Systems	728
18.2.1	AutoNav's New Helm Pump Features	729
18.2.2	Cylinders	730
18.2.2.1	Cylinder Features	731
18.2.3	AutoNav Type P Electro hydraulic Steering	731
18.2.4	Control Systems and their Features	732
18.2.4.1	Model Designation Example	733
18.2.4.2	Model Designation	734
18.2.5	Typical System Configuration	734
18.2.6	Typical Components	735
18.2.6.1	Panorama Rudder Angle Indicator	735
18.2.6.2	The LFU 100 Full Follow-Up Lever Controller	735
18.2.6.3	The WFU 100 Full Follow-Up Wheel Controller	736
18.2.6.4	MCA 100 Motor Control / Alarm Panel	736
18.2.6.5	The LCB 101 Local Control and Bridge Disconnect Panel	737
18.2.6.6	Pump sets	737
18.2.6.7	Double-acting Cylinders	738
18.2.6.8	Modular Components	739
18.2.6.9	Non-Modular Components	739
18.2.7	AutoNav Autopilot Model A-1500	739
18.2.7.1	The Distribution Unit	741
18.3	Anschütz Auto Steering	742
18.3.1	Salient Features of NautoSteer	744
18.3.2	System Types	744
18.3.2.1	Dual Follow-Up (Dual FU)	744
18.3.2.2	Dual Non-Follow-Up (Dual NFU)	745
18.3.2.3	Follow-Up/Dual Non-Follow-Up	745

Contents

Chapter 18 - Steering and Stabiliser Systems (Continued)		
Article No.	Article	Page No.
18.3.3	System Structure	745
18.3.3.1	Control Components	745
18.4	Sperry Marine Steering Gear	749
18.4.1	Steering Design Specifications	749
18.4.2	Dual Control Gyro Pilot Steering Stand	750
18.4.3	Linear Hydraulic Power Unit	750
18.4.4	Piston Operation	751
18.4.5	Limit Switches, Relay, and Follow-up Potentiometer	752
18.4.6	Inside Limit Switches	752
18.4.7	Outside Limit Switches	752
18.5	Gyroscopes	753
18.5.1	Definition	753
18.5.2	The Three-Frame Gyroscope	754
18.5.3	Controlled Gyroscopes	755
18.6	Compass Considerations for Steering and Autopilots	756
18.7	The AutoNav Flux Gate Compass (as installed on ships)	762
18.7.1	Easy-Mounting Sensor	763
18.7.2	Gyro Interface for Accuracy and Stability	763
18.8	Rudder Position Indicator	763
18.8.1	The Precision Potentiometer and Stepper Motor Type (Type A070)	763
18.8.2	Operating Principle	763
18.8.3	Technical Data	764
18.8.4	Outstanding Features	765
18.9	Synchros for Rudder Angle and Course Indication	765
18.10	Steering Gear Testing and Drills	767
18.11	Roll Stabiliser for Ships	769
18.11.1	How Lift Control Works	770
18.11.2	Lift Control Advantages	771
18.11.3	Key Benefits and Highlights	771
18.11.4	New Digital Control System	771
18.12	Relevant Rules	773
18.12.1	Relevant SOLAS Regulations	773
18.12.2	Summary of Regulations	773
	Find the Answers	776

Contents

Chapter 19 – Deck Machinery		
Article No.	Article	Page No.
19.1	The Anchor Windlass	779
19.1.1	The Horizontal Windlass	779
19.1.2	Typical Deck Mooring Electro-hydraulic System on a VLCC	783
19.1.2.1	Forward System	783
19.1.2.2	Aft System	783
19.1.2.3	Suggested Procedure for the Operation of the Hydraulic Power Units	783
19.1.2.4	Pressure Selection Definition	784
19.1.2.5	Stopping the Units	784
19.1.2.6	Controls	784
19.1.3	The Vertical Windlass	785
19.1.4	Indication and Control	787
19.1.5	All-Electric Windlass	788
19.1.6	Line Speed and Drum Torque	789
19.1.7	Safe Methods to Test the Speed Control of Winches	789
19.2	Safety Cutouts of Passenger Lifts	790
19.3	Deck Cranes	790
19.4	Control Systems	791
19.4.1	Application of the Ward-Leonard System for Deck Machinery	791
19.4.2	Alternating Current Systems	793
19.4.2.1	Squirrel Cage Motor Controls	793
19.4.2.2	Wound Rotor Induction Motors	794
19.5	Safety Features in Modern Cranes	795
19.5.1	High-Pressure Sensing in the System	795
19.5.2	High Oil Temperature	795
19.5.3	Overloading of the Electric Motor	795
19.5.4	Emergency Stop	796
19.5.5	Slack Wire Trip	796
19.5.6	Low Level	797
19.5.7	Limit Switches	797
19.5.7.1	Testing of Limit Switches	797
19.5.8	Anti Collision Devices in Gantries / Cranes	799
	Find the Answers	799

Contents

Chapter 20 - Control of Air Compressors		
Article No.	Article	Page No.
20.1	Selection of Compressors	801
20.1.1	Compression	801
20.1.2	Kinematic Energy	801
20.2	Choice of a Correct Machine	801
20.3	Oil Free and Non-Oil Free Air	802
20.4	Instrument Air	802
20.4.1	Low Pressure Machines(7-8 bars)	802
20.4.2	Intermediate Pressure Machines (25-35 bars)	803
20.4.3	Oil Removal	804
20.5	Air Cooled versus Water Cooled Machines	804
20.5.1	Air-cooled Machines	804
20.5.2	Water-cooled machines	804
20.6	Reciprocating Compressors	805
20.7	Starting and Control	805
20.7.1	Starting Procedure	805
20.7.2	Methods of Unloading Compressors	805
20.7.3	Normal Running	806
20.7.4	Stopping the Machine	806
20.7.5	Automatic Drains	806
20.8	Safety Protection Equipment	807
20.8.1	Water Blockage	807
20.8.2	Unbalanced Load between Stages	807
20.9	Automatic Operation	808
20.9.1	Starting / Stopping	809
20.9.2	Running Unloaded	810
20.10	Main Air Compressor Control	812
20.10.1	Manual Starting	814
20.10.2	Manual Stopping	816
20.10.3	Automatic Starting	816
20.10.4	Automatic Stopping	817
20.10.4.1	Overload	817
20.10.4.2	Low Lubricating Oil-pressure	817
20.10.4.3	High Cooling-water Temperature	818
20.11	Air Drier	818
20.12	Relevant ABS Rules	819
	Find the Answers	821

Contents

Chapter 21 - Batteries and Battery Charging		
Article No.	Article	Page No.
21.1	The Primary Cell	823
21.2	The Secondary Cell	824
21.3	Electrochemical Action	824
21.4	Battery Supplies	825
21.5	Lead-Acid Storage Batteries	825
21.6	The Wet or Flooded Cell	827
21.6.1	Positive and Negative Plates	828
21.6.2	Electrolyte	829
21.6.3	Separators	829
21.6.4	Additional Features in some larger cells	830
21.6.4.1	Container	830
21.6.4.2	Rubber Bag	830
21.6.4.3	Lead Tape	831
21.6.4.4	Slotted Support Strip	831
21.6.4.5	Terminal Plate	831
21.7	Maintenance-free Sealed Lead-acid Batteries	832
21.7.1	<i>Main Features</i>	832
21.7.2	<i>The Valve Regulated Lead Acid (VRLA) Battery</i>	832
21.7.3	<i>The Absorbed Glass Mat Battery</i>	833
21.7.3.1	<i>Advantages of the AGM Battery</i>	835
21.7.4	<i>The Gel Cell</i>	835
21.7.4.1	<i>Gel Cell Design</i>	836
21.7.5	<i>Gel Cell and AGM Cell Applications</i>	836
21.8	Electrical Characteristics of the Lead-acid Cell	837
21.8.1	Voltage	837
21.8.2	Capacity	839
21.8.2.1	Specifying battery capacity	842
21.8.3	Battery Efficiency	842
21.8.4	Discharge Action	843
21.8.5	<i>Additional Indicators</i>	844
21.8.5.1	<i>Open Circuit Voltage Test</i>	844
21.8.5.2	<i>Discharge Test</i>	844
21.9	Polarization of the Cell	844
21.10	Local Action	845

Contents

Chapter 21 - Batteries and Battery Charging (Continued)		
Article No.	Article	Page No.
21.11	Nickel-Cadmium Storage Batteries	845
21.11.1	Discharge Action.	845
21.11.2	Electrolyte	846
21.11.3	Containers	847
21.11.4	Plates	847
21.11.5	Sealed Nickel-Cadmium Batteries	847
21.12	Silver-Zinc Cell	849
21.13	Silver-Cadmium Cell	849
21.14	Lithium Ion Battery for 406 MHz EPIRBs	850
21.15	Battery Charging	851
21.15.1	Initial Charge	852
21.15.2	Normal Charge	852
21.15.3	Equalizing Charge	852
21.15.4	Floating Charge	852
21.15.5	Fast Charge or Quick Charge	853
21.15.6	Charging Rate	853
21.16	Charging of Lead-Acid Batteries	853
21.16.1	Charging Systems	853
21.16.2	Constant-current System	854
21.16.3	Constant-voltage System	854
21.16.4	Calculations	855
21.16.5	Trickle Charging	855
21.16.6	Indications of a Fully – Charged Cell	856
21.16.7	Topping Up	858
21.17	Charging of Nickel Cadmium Batteries	859
21.17.1	Gassing - Nickel Cadmium Types	859
21.17.2	Topping-up	860
21.18	Thermal Runaway	860
21.18.1	Procedures for detecting and handling thermal runaway	860
21.19	Methods of Charging	861
21.19.1	Charging with Supply from a DC Source	861
21.19.2	Charging with Supply from an AC Source	862
21.20	Single-Rate and Two-Rate Battery Chargers	864

Contents

Chapter 21 - Batteries and Battery Charging (Continued)		
Article No.	Article	Page No.
21.20.1	Some Simple Steps to Select the Correct Charger	864
21.20.2	Single-Rate Charger	865
21.20.3	Two-Rate Charger	865
21.20.4	Smart Charger	866
21.20.5	Calculation of a Battery Charger's Capacity	866
21.21	Automatic Thyristor-controlled Battery Charger	867
21.21.1	Specifications	867
21.21.2	Control Modes	868
21.21.2.1	Auto Mode	868
21.21.2.2	Equalising Mode	868
21.21.2.3	Manual Mode	868
21.21.3	Operating Principle	868
21.22	Battery Installations and Safety Measures	873
21.22.1	Common Causes of Battery and Battery Charger Failure	873
21.22.1.1	Device Switches, Lights or Other Electrical Devices Left On	873
21.22.1.2	Short Engine Running Periods	873
21.22.1.3	Key off-loads	873
21.22.1.4	Parasitic Drain	874
21.22.1.5	Deficient Charging	874
21.22.1.5.1	Typical Causes	874
21.22.1.5.1	Solutions	874
21.22.1.6	Mixing Different Types of Batteries Together	874
21.22.1.7	Leaving Batteries in a Discharged Condition	874
21.22.1.8	Positive Grid Corrosion and Flaking	875
21.22.1.9	Loss of Electrolyte	875
21.22.1.10	Cell Poisoning	875
21.22.2	Failure of Soldered Joints Carrying High Currents as in Battery Chargers	876
21.22.3	Safety Measures When Working With Batteries	876
21.23	First Aid Treatment for Contact due to Spillage	878
21.24	Reclaiming, Recycling, Reusing of Lead Acid Batteries	879
21.25	Relevant Rules	879
21.25.1	Relevant SOLAS Regulations Chapter II-1	879
21.25.2	Summary of Regulations	880
	Find the Answers	880

Contents

Chapter 22 - Lighting Systems		
Article No.	Article	Page No.
22.1	The Basics	887
22.2	Incandescent Lamps	889
22.3	Discharge lamps	892
22.4	Hot Cathode Low Pressure Mercury Fluorescent Lamps	892
22.4.1	Advantages	896
22.4.2	Disadvantages	897
22.5	High Pressure Mercury Fluorescent Lamps	897
22.6	Low Pressure Sodium Vapour Lamps	898
22.7	High Pressure Sodium Vapour Lamps	898
22.8	Disposal of Lamps Containing Mercury	899
22.8.1	Identifying Bulbs that Contain Mercury	900
22.8.2	Bulb Storage and Handling	900
22.9	Lamp Caps	901
22.10	Effects of Voltage on the Performance of Lamps	902
22.11	Navigation and Signal Lights	902
22.11.1	Summary of Regulations	902
22.11.2	Operation	905
22.12	Signals for a Power-driven Ship Under Way (At Night)	907
22.12.1	Two Masthead Lights	907
22.12.2	Two Side Lights	907
22.12.3	One Stern Light	907
22.12.4	Ship at Anchorage	907
22.12.5	Ship Not Under Command	907
22.12.6	Ship Aground	907
22.13	Emergency Lighting	908
22.14	Relevant Rules	909
22.14.1	Relevant SOLAS Regulations (Chapter II-1)	909
22.14.2	Summary of Regulations	909
	Find the Answers	911

Contents

Chapter 23 - Alarm Indication Systems		
Article No.	Article	Page No.
23.1	Fire Alarms and Detection	913
23.1.1	Requirements of a Basic Fire Alarm System	913
23.1.2	Requirements of a Typical Fire Detection System	913
23.1.3	Initiating Devices	914
23.1.4	Indicating Devices	914
23.1.5	Control Panel	914
23.1.6	Power Supply	915
23.1.7	Virtues of an Intelligent Fire Alarm System	915
23.2	Heat Detectors	916
23.2.1	Fixed Temperature Type	916
23.2.2	Rate of Rise Type	916
23.3	Combustion Detector	919
23.4	Detectors Reacting to Radiation Emanating from Flames	922
23.5	Fire Fighting Systems	923
23.6	The Fire Alarm Control Panel	929
23.6.1	Alarms for Engine Room and Pump Room Systems	930
23.7	Modern Methods of Fire Detection and Suppression	933
23.7.1	Early Fire Warning and Detection	933
23.7.2	The Supervisory Control System	934
23.8	Crankcase Oil Mist Detector	934
23.8.1	Crankcase Explosions	935
23.8.2	Construction and Operating Principle of a Basic Detector	937
23.8.3	The Comparison-type Crankcase Oil Mist Detector	938
23.8.4	The Line of Sight Oil Mist Detector	940
23.8.4.1	Principle of Operation	941
23.8.4.2	Applications	942
23.8.4.3	Detection Mode	942
23.8.4.4	Model I.R. 6003/1	942
23.8.4.5	Advantages over Conventional Techniques	942
23.8.4.6	Features	943
23.8.4.7	Conclusions	943
23.8.5	Immediate Steps to be taken in Case of an Alarm from an Oil Mist Detector	943
23.9	Dead Man Alarm	944
23.9.1	General Description Location of Unit	944

Contents

Chapter 23 - Alarm Indication Systems (Continued)		
Article No.	Article	Page No.
23.9.2	System Specifications	945
23.9.3	Modes of Operation	945
23.9.3.1	Standby	945
23.9.3.2	Unmanned	945
23.9.3.3	Running	945
23.9.3.4	Pre-warning	946
23.9.3.5	Dead Man Alarm	946
23.9.3.6	Starting the Running Sequence	946
23.9.4	SafePage 3000™ Wireless Paging, Info & Dead Man Alarm System	946
23.10	Miscellaneous Alarm Indication Systems	948
23.10.1	The Bridge Alarm Console	949
23.10.2	Group Control Panel	949
23.10.3	Operation of a Basic System	950
23.11	Scanning-type System	950
23.11.1	Scanners	952
23.11.2	Converter	953
23.11.3	Central Processor	953
23.11.4	Display Register, Decoder and Lamp Drivers	954
23.11.5	Timing Circuits	954
23.11.6	Program Distribution Board	954
23.11.7	Command Control	955
23.11.8	Alarm System	955
23.11.9	Contact Alarms	956
23.11.10	Self-checking System	956
23.12	Communication Systems	957
23.12.1	Sound Powered and Intrinsically Safe Telephone System	957
23.12.2	The Engineer's Call Alarm	957
23.13	Relevant Rules	958
23.13.1	Relevant SOLAS Regulations	958
23.13.2	Summary of Regulations	959
	Find the Answers	961

Contents

Chapter 24 - Gas Analysers		
Article No.	Article	Page No.
24.1	The Combustible Gas Indicator (CGI) or Explosimeter	965
24.1.1	Application	965
24.1.2	Principle of Operation	965
24.1.3	Guidelines for use	966
24.1.4	Limitations of the Instrument	968
24.1.5	MSA 40 – Calibration Procedure	968
24.1.6	MSA-40 Calibrated on Pentane	969
24.2	The Tankscope	970
24.2.1	Operation	972
24.2.2	Guidelines for use	973
24.2.3	Trouble Shooting	974
24.3	Thick Film Technology Gas Analysis	974
24.4	Carbon Dioxide Analysis	976
24.4.1	Influence of Carbon Dioxide	976
24.4.2	Monitoring of CO ₂	976
24.5	Portable Oxygen Analyser - Model: Draeger E-11	977
24.5.1	Operation of the Electrolytic Cell Type	977
24.5.2	Technical Specifications of the E-11 Draeger Oxygen Meter	978
24.5.3	Calibration	979
24.5.4	Replacement of the Polarographic Cell	980
24.5.5	Fault Finding	980
24.5.6	Setting the Alarm Level	981
24.6	Fixed Oxygen Analyser - Beckman Oxygen Analyser (Pauling Cell Type)	981
24.6.1	Principle of Operation	981
24.6.2	Construction	981
24.7	Beckman Oxygen Analyser (Munday Cell Type)	981
24.7.1	Principle of Operation	981
24.7.2	Construction	983
24.7.3	Starting Procedure	985
24.7.4	Shut Down Procedure	985
24.8	Zirconia Oxygen Analysis	985
24.9	Things to Remember	987
24.9.1	Presence of Gas	987
24.9.2	Pressure	987
24.9.3	In spaces declared gas-free, further gas may be released...	987
24.9.4	In other spaces...	987

Contents

Chapter 24 - Gas Analysers (Continued)		
Article No.	Article	Page No.
24.10	Relevant Rules	988
24.10.1	Relevant SOLAS Regulations	988
24.10.2	Summary of Regulations	988
	Find the Answers	988

Chapter 25 - Miscellaneous Systems		
Article No.	Article	Page No.
25.1	Introduction	991
25.2	Cathodic Protection	991
25.2.1	The Electrochemical Theory of Corrosion	991
25.2.2	Impressed Current Cathodic Protection	997
25.2.3	Routine Checks	1003
25.2.4	Dangers to be avoided	1003
25.3	Monitoring of Water Purity	1004
25.3.1	The Dionic Water Purity Meter	1004
25.3.2	The Salinometer	1005
25.4	Galley Equipment	1007
25.5	Laundry Equipment	1010
25.6	Water-tight Doors	1011
25.6.1	Control of Doors	1011
25.6.2	Monitoring of Doors	1011
25.6.3	Closing Alarm of Doors	1012
25.6.4	Electrical Power Supply	1012
25.6.5	Protection of Electric Power, Control and Monitoring Circuits	1013
25.6.6	Electrical Equipment	1013
25.6.7	Displays and Alarms	1013
25.6.8	Indicator Lights	1014
25.6.9	Power Supply	1014
25.6.10	Protection of Sensors	1014
25.6.11	Leakage Monitoring	1014
25.6.11.1	Bow Doors and Inner Doors	1014
25.6.11.2	Side Shell Doors and Stern Doors	1014
25.6.12	Drainage	1014
25.6.13	Door Surveillance	1015
25.6.14	Features of an Electrical System as Installed Onboard	1015

Contents

Chapter 25 - Miscellaneous Systems (Continued)		
Article No.	Article	Page No.
25.7	Refrigerating Machinery	1016
25.7.1	The Vapour Compression Refrigeration Cycle	1016
25.7.2	Refrigerants	1018
25.7.3	Compressor Safety Devices	1018
25.7.3.1	HP or High Pressure Switch	1018
25.7.3.2	LP or Low Pressure Switch	1018
25.7.3.3	OP switch or Oil Differential Pressure Switch	1018
25.7.4	Compressor Control Devices	1019
25.8	Air-conditioning Systems	1020
25.8.1	What Air-conditioning Means...	1020
25.8.2	Types of air-conditioners	1022
25.8.3	Cooling Mode	1024
25.8.4	Heating Mode	1024
25.8.5	Sea Water Cooling of the Air-conditioner	1024
25.8.6	Safety	1025
25.8.7	Automatic Temperature Controllers	1025
	Find the Answers	1027

Chapter 26 - Maintenance and Troubleshooting		
Article No.	Article	Page No.
	IACS A Guide to Managing Maintenance April 2001 - Recommendation 74	1029
26.1	The Basics	1039
26.2	Planned Preventive Maintenance	1040
26.2.1	Electrical Work Permit	1042
26.2.1.1	Example of an Electrical Work Permit	1043
26.3	Performance / Condition Monitoring	1044
26.3.1	Methods of Checking Running Motors	1045
26.3.2	Cold Checks with a Megger	1046
26.3.2.1	Constructional Features of an Analog Megger	1047
26.3.2.2	Safety Features	1049
26.3.2.3	The Format of a Megger Test Report	1050
26.3.2.4	Megger Reading (Sample)	1050
26.3.2.5	Earth Leakage Testers	1051
26.4	Life Maintenance	1054
26.5	Breakdown or Corrective Maintenance	1054

Contents

Chapter 26 - Maintenance and Troubleshooting (Continued)		
Article No.	Article	Page No.
26.6	Troubleshooting	1054
26.6.1	System Knowledge	1055
26.6.2	System Configuration	1055
26.6.3	System Parameters	1056
26.6.4	Test Equipment	1056
26.6.4.1	Procedures	1057
26.6.5	Understand how to use blueprints and diagrams	1057
26.6.6	The Alternative Approach to Troubleshooting	1058
26.6.6.1	Prepare for the task	1058
26.6.6.2	Observe	1058
26.6.6.3	Define the Problem Area	1059
26.6.6.4	Identify Possible Causes	1059
26.6.6.5	Determine the Most Probable Cause	1059
26.6.6.6	Test and Repair	1060
26.6.6.7	Follow-up	1061
26.6.8	High Voltage (HV) Equipment Testing	1061
26.6.8.1	Live Line Test	1062
26.6.8.2	Earthing Down	1062
26.6.8.2.1	Circuit Earthing	1062
26.6.8.3	Busbar Earthing	1063
26.6.8.4	Procedure to Carry-out an Insulation Resistance Test	1063
26.7	Maintenance of Specific Equipment	1063
26.7.1	Generators	1063
26.7.1.1	Precautionary measures to be taken after repairs	1066
26.7.1.2	Example of a Monthly Safety Check of Diesel-Generator Sets	1067
26.7.1.3	Overcoming Winding Contamination in Brushless Alternator	1068
26.7.2	Main Circuit Breakers	1069
26.7.2.1	Interlocks	1071
26.7.2.2	Re-installing	1072
26.7.2.3	Fused Isolators	1072
26.7.2.4	Maintenance of a Vacuum Circuit Breaker	1072
26.7.2.5	Maintenance of the SF6 Circuit Breaker	1072
26.7.3	Transformers	1072
26.7.3.1	Additional Actions for Welding Transformers	1073
26.7.4	Starters and Motor Control Gear	1074
26.7.4.1	Enclosure	1074

Contents

Chapter 26 - Maintenance and Troubleshooting (Continued)		
Article No.	Article	Page No.
26.7.4.2	Contactors and Relays	1074
26.7.4.3	Contacts	1074
26.7.4.4	Connections	1075
26.7.4.5	Over Current Relays	1075
26.7.4.6	Control Circuitry	1075
26.7.5	Motors	1076
26.7.6	Miscellaneous Control Gear	1078
26.7.7	Deck Cranes	1079
26.7.8	Batteries in General	1079
26.7.8.1	Lead-acid Cells	1080
26.7.8.2	Troubleshooting Battery-Powered Systems	1081
26.7.9	Explosion Proof Equipment	1082
26.7.9.1	Corrosion	1082
26.7.9.2	Bolts	1082
26.7.9.3	Mountings	1082
26.7.9.4	Flame paths	1082
26.7.9.5	Cement	1083
26.7.9.6	Re-assembling an Ex-d (flame-proof) enclosure	1083
26.7.10	Light Fittings in General	1083
26.7.11	Safety Flash Lights	1086
26.7.12	Fixed Oxygen Analyser	1086
26.7.12.1	Daily	1086
26.7.12.2	Weekly	1086
26.7.12.3	Monthly	1086
26.7.12.4	Yearly	1086
26.7.12.5	Calibration of the Oxygen Analyser	1087
26.7.13	Maintenance, Testing and Inspections of fire-fighting systems and appliances	1088
26.8	Routine Maintenance Checklist Suggested by a few Classification Societies	1088
26.8.1	General	1088
26.9	The Recommended List of Spares, Tools and Accessories for Maintenance	1095
26.10	Relevant Rules	1096
26.10.1	Relevant SOLAS Regulations	1096
26.10.2	Summary of Regulations	1096
	Find the Answers	1096