

# Contents

	<b>Preface.....</b>	<b>15</b>
<b>1</b>	<b>Basic Characteristics of Railway Systems and the Requirements for Signalling.....</b>	<b>17</b>
1.1	Introduction.....	17
1.2	Specific of Railway Systems.....	17
1.3	Railway Signalling and Control.....	18
1.3.1	Definitions.....	18
1.3.2	The Safety-related Railway Theory.....	18
1.3.3	Functional Structure.....	21
<b>2</b>	<b>Safety and Reliability in Signalling Systems.....</b>	<b>24</b>
<b>2.1</b>	<b>Safety Basics.....</b>	<b>24</b>
2.1.1	What is RAMS(S)?.....	24
2.1.2	Safety/Security.....	24
2.1.3	Availability, Reliability and Maintainability.....	25
2.1.4	Role of the RAMS Components in the Railway System.....	26
<b>2.2</b>	<b>Safety Principles in Railway Operation.....</b>	<b>27</b>
2.2.1	Dealing with Errors, Failures and Disturbances (E/F/D).....	27
2.2.2	Analysis of Errors, Failures and Disturbances (E/F/D) by System States.....	29
<b>2.3</b>	<b>Conception of Safety and Reliability of Railway Signalling Equipment.....</b>	<b>30</b>
<b>2.4</b>	<b>Characteristics of Reliability and Safety.....</b>	<b>31</b>
<b>2.5</b>	<b>Evaluation of Safety Level of Signalling Equipment.....</b>	<b>32</b>
<b>2.6</b>	<b>Rating of Safety Parameters.....</b>	<b>35</b>
<b>2.7</b>	<b>Calculations of the Safety Parameters.....</b>	<b>36</b>
<b>2.8</b>	<b>Methodology of Safety Case for Railway Signalling Equipment.....</b>	<b>38</b>

- 3 Railway Operation Processes.....39**
- 3.1 Historical Background.....39**
- 3.2 Classification of Tracks, Stations and Signals .....42**
  - 3.2.1 Main Tracks and Secondary Tracks.....42
  - 3.2.2 The Role of Signals .....43
  - 3.2.3 Definitions of Stations and Interlocking Areas .....44
  - 3.2.4 Signal Arrangement on Double Track Lines .....47
- 3.3 Movements with Railway Vehicles.....48**
  - 3.3.1 Train Movements .....48
  - 3.3.2 Shunting Movements .....49
- 3.4 Principles of Train Separation .....51**
  - 3.4.1 Signalled Fixed Block Operation.....52
  - 3.4.2 Cab Signal Operation.....55
  - 3.4.3 Non Signal-controlled Operation .....58
- 3.5 Dispatching Principles.....58**
  - 3.5.1 Decentralised Operation .....58
  - 3.5.2 Centralised Traffic Control .....60
- 4 Interlocking Principles.....61**
- 4.1 Overview .....61**
  - 4.1.1 Introduction .....61
  - 4.1.2 Basic Requirements.....61
  - 4.1.3 Basic Principles of Safeguarding a Train's Path .....62
- 4.2 Element Dependences .....63**
  - 4.2.1 Classification.....63
  - 4.2.2 Coupled Elements .....63
  - 4.2.3 Unidirectional Locking.....64
  - 4.2.4 Simple Bidirectional Locking .....65
  - 4.2.5 Conditional Bidirectional Locking .....65
- 4.3 Routes.....66**
  - 4.3.1 Introduction .....66
  - 4.3.2 Extension of Routes and Related Speed Restrictions.....67

4.3.3	Basic Route Locking Functions.....	70
4.3.4	Route Selection by the Signaller or automatic system .....	75
4.3.5	Flank Protection.....	76
4.3.6	Overlaps and Front Protection .....	79
4.3.7	Route Elements in the Start Zone.....	83
4.3.8	Life Cycle of Routes.....	84
4.3.9	Principles of Route Formation in the Track Layout.....	89
4.3.10	Shunting Routes.....	91
4.3.11	Automation of Route Operation.....	93
<b>4.4</b>	<b>Block Dependences .....</b>	<b>94</b>
4.4.1	Introduction .....	94
4.4.2	Geographical Assignment of Block Sections .....	96
4.4.3	Classification of Block Systems.....	97
4.4.4	Process of Block Working in Token Block Systems .....	99
4.4.5	Process of Block Working in Tokenless Block Systems .....	100
4.4.6	Locking Functions of Tokenless Block Systems .....	102
4.4.7	Returning Movements.....	103
<b>4.5</b>	<b>Special Issues.....</b>	<b>105</b>
4.5.1	Overlaying Block and Route Interlocking Systems.....	105
4.5.2	Protection of Trains by a Signal at Stop in Rear .....	106
4.5.3	Several Trains between two Signals .....	106
4.5.4	Degraded Mode Operation .....	107
<b>5</b>	<b>Detection .....</b>	<b>113</b>
<b>5.1</b>	<b>Requirements and Methods of Detection .....</b>	<b>113</b>
5.1.1	Introduction .....	113
5.1.2	Types of Objects .....	113
5.1.3	Safety Requirements.....	113
5.1.4	Detection Purposes .....	114
<b>5.2</b>	<b>Technical Means of Detection.....</b>	<b>116</b>
5.2.1	Classification.....	116
5.2.2	Spot Wheel Detectors.....	116
5.2.3	Linear Wheel and Axle Detectors .....	120
5.2.4	Area Detectors for Vehicles and External Objects.....	121
5.2.5	Three-Dimensional Detection .....	123
5.2.6	Systems with Active Reporting from the Train.....	124
5.2.7	End of Train (EOT) Detection Systems.....	127

<b>5.3</b>	<b>Track Circuits .....</b>	<b>128</b>
5.3.1	Basic Structure of Track Circuits .....	128
5.3.2	Geometrical Assembly of Track Circuits .....	130
5.3.3	Treatment of Traction Return Currents.....	132
5.3.4	Additional Functions of Track Circuits.....	135
5.3.5	Immunity against Foreign Currents.....	135
5.3.6	Electrical Parameters and Dimensioning.....	136
5.3.7	Application of the Types of Track Circuits .....	139
<b>5.4</b>	<b>Axle Counters .....</b>	<b>143</b>
5.4.1	General Structure and Functioning.....	143
5.4.2	The Rail Contact .....	145
5.4.3	Treatment of Counting Errors .....	146
<b>5.5</b>	<b>Comparison of Track Circuits and Axle Counters.....</b>	<b>147</b>
5.5.1	Advantages and Disadvantages.....	147
5.5.2	Application.....	147
<b>6</b>	<b>Movable Track Elements.....</b>	<b>149</b>
<b>6.1</b>	<b>Kinds of Movable Track Elements and their Geometry .....</b>	<b>149</b>
6.1.1	Overview.....	149
6.1.2	Simple Points.....	149
6.1.3	Other Solutions for Connection of Tracks .....	152
6.1.4	Arrangements of Several Movable Track Elements .....	153
6.1.5	Derailing Devices .....	155
<b>6.2</b>	<b>Safety Requirements at Movable Track Elements .....</b>	<b>156</b>
<b>6.3</b>	<b>Track Clear Detection at Points and Crossings .....</b>	<b>156</b>
<b>6.4</b>	<b>Point Machines .....</b>	<b>157</b>
6.4.1	Overview.....	157
6.4.2	Electric Point Machines.....	159
6.4.3	Supervision of Point Position on the Example of SP-6.....	161
<b>6.5</b>	<b>Point Locking Mechanisms.....</b>	<b>163</b>
6.5.1	External Locking Mechanism: Clamp Lock.....	163
6.5.2	Internal Locking Mechanism .....	164

6.5.3	Monitoring of Locking Mechanism .....	165
6.5.4	Mechanical Key Lock.....	167
<b>6.6</b>	<b>Circuitry of Point Operation and Control in Relay Technology .....</b>	<b>167</b>
6.6.1	General Overview.....	167
6.6.2	Example with Type N Relays: Russian Five-Wire Point Circuitry .....	168
6.6.3	Example with Type C Relays: GS II DR (Germany) .....	171
<b>7</b>	<b>Signals .....</b>	<b>179</b>
<b>7.1</b>	<b>Requirements and Basic Classification.....</b>	<b>179</b>
<b>7.2</b>	<b>Technical Characteristics of Trackside Signals.....</b>	<b>181</b>
7.2.1	Structure of Light Signals.....	181
7.2.2	Optical Parameters .....	184
7.2.3	Retro-Reflection of Passive Signal Boards.....	184
7.2.4	Control and Supervision of Signal Lamps.....	185
<b>7.3</b>	<b>Principles of Signalling by Light Signals .....</b>	<b>187</b>
7.3.1	Utilisation of Signal Colours.....	187
7.3.2	Stop Aspects.....	188
7.3.3	Signalling of Movement Authorities.....	188
7.3.4	Signalling of Speed Reductions.....	192
7.3.5	Combination of Main and Distant Signals.....	195
7.3.6	Shunting Signals.....	196
<b>7.4</b>	<b>Redundancy and Degraded Mode Operation .....</b>	<b>197</b>
<b>7.5</b>	<b>Signal System Examples.....</b>	<b>198</b>
7.5.1	German Mechanical and 'H/V' Light Signals .....	198
7.5.2	Belgian Mechanical Signals.....	199
7.5.3	British Light Signals.....	200
7.5.4	OSŽD Signals .....	201
7.5.5	Modern Dutch Signal System.....	202
7.5.6	German System 'Ks' .....	204
7.5.7	Signal System on Japanese Commuter Lines .....	205
7.5.8	NORAC Signals .....	205

<b>8</b>	<b>Train Protection.....</b>	<b>208</b>
<b>8.1</b>	<b>Requirements, Classification and Conditions for Application.....</b>	<b>208</b>
8.1.1	General Overview.....	208
8.1.2	Cab Signalling Functions.....	208
8.1.3	Supervision Functions.....	209
8.1.4	Intervention Functions.....	211
8.1.5	Role in the Railway Operation Process.....	212
8.1.6	Automation of Train Operation.....	212
<b>8.2</b>	<b>Technical Solutions for Data Transmission.....</b>	<b>213</b>
8.2.1	Overview over Forms of Transmission .....	213
8.2.2	Spot Transmission .....	214
8.2.3	Linear Transmission .....	216
<b>8.3</b>	<b>Particular Systems.....</b>	<b>219</b>
8.3.1	Classification of Systems .....	219
8.3.2	Group 1: Systems with Intermittent Transmission and without Braking Supervision ...	219
8.3.3	Group 2: Systems with Intermittent Transmission at Low Data Volume and with Braking Supervision .....	223
8.3.4	Group 3: Systems with Continuous Transmission of Signal Aspects by Coded Track Circuits.....	227
8.3.5	Group 4: Systems with Intermittent Transmission at High Data Volume and Dynamic Speed Supervision .....	235
8.3.6	Group 5: Systems with Continuous Transmission at High Data Volume and Dynamic Speed Supervision .....	238
<b>8.4</b>	<b>ETCS .....</b>	<b>240</b>
8.4.1	History + Motivation.....	240
8.4.2	Application Levels and Technical Components.....	242
8.4.3	Functional Concepts.....	245
8.4.4	Operation Modes.....	249
8.4.5	Data Structure .....	251
<b>9</b>	<b>Interlocking Machines .....</b>	<b>252</b>
<b>9.1</b>	<b>Classification .....</b>	<b>252</b>
<b>9.2</b>	<b>Mechanical Interlocking .....</b>	<b>253</b>
9.2.1	Historical Development .....	253
9.2.2	System Safety in Mechanical Interlocking.....	253

9.2.3	Structure of Mechanical Interlocking Systems .....	254
9.2.4	Example: British Origin Mechanical Interlocking.....	255
9.2.5	Example: German Type 'Einheit'.....	258
<b>9.3</b>	<b>Relay Interlocking .....</b>	<b>263</b>
9.3.1	Historical Development .....	263
9.3.2	System Safety in Relay Interlocking.....	263
9.3.3	Design of Relay Interlocking Systems.....	267
9.3.4	Example: SGE 1958 (Britain).....	270
9.3.5	Example: SpDrS60 (Germany) .....	271
9.3.6	Example: UBRI (Russia) .....	276
<b>9.4</b>	<b>Electronic Interlocking.....</b>	<b>280</b>
9.4.1	Historical Development .....	280
9.4.2	System Safety in Electronic Interlocking .....	281
9.4.3	Structure of Electronic Interlocking Systems.....	282
9.4.4	SSI (Britain) .....	285
9.4.5	SMILE (Japan) .....	289
9.4.6	Simis and L90 with Derivates (German origin) .....	291
9.4.7	Ebilock.....	294
9.4.8	EC-EM (Russia).....	298
9.4.9	ACC (Italy).....	300
9.4.10	Local-electrical Operated Point Switches (LOPS) .....	302
<b>9.5</b>	<b>Hybrid Technologies.....</b>	<b>303</b>
9.5.1	Hybrid Mechanical and Electrical/Pneumatic/Hydraulic Forms .....	303
9.5.2	Hybrid Relay and Electronic Forms .....	305
<b>10</b>	<b>Line Block Systems .....</b>	<b>306</b>
<b>10.1</b>	<b>Classification .....</b>	<b>306</b>
<b>10.2</b>	<b>Safety Overlays for Systems with Safety Responsibility at Staff .....</b>	<b>306</b>
<b>10.3</b>	<b>Decentralised Block Systems .....</b>	<b>307</b>
10.3.1	Overview.....	307
10.3.2	Token Block Systems.....	308
10.3.3	Systems with Singular Unblocking upon Clearing.....	309
10.3.4	Systems with Continuous Unblocking .....	316

<b>10.4</b>	<b>Centralised Systems for Safety on Open Lines.....</b>	<b>321</b>
10.4.1	Overview.....	321
10.4.2	Centralised Block Systems for Secondary Lines.....	323
10.4.3	Radio Electronic Token Block.....	323
10.4.4	Open Line Controlled from Neighbouring Interlockings.....	324
10.4.5	Train Control Systems for High Speed Lines.....	325
<b>10.5</b>	<b>Moving Block Systems.....</b>	<b>326</b>
<b>11</b>	<b>Remote Control and Operation Technology.....</b>	<b>328</b>
<b>11.1</b>	<b>Remote Control and Monitoring.....</b>	<b>328</b>
11.1.1	Types of Dispatcher Control/Monitoring.....	328
11.1.2	Centralisation of Interlocking Control.....	330
11.1.3	Flexible Allocation of Control Areas.....	330
<b>11.2</b>	<b>Processes in Operation Control.....</b>	<b>331</b>
11.2.1	Information Input and its Viewing.....	331
11.2.2	Evaluation of Operational Situation.....	333
11.2.3	Command Output.....	334
<b>11.3</b>	<b>Data Transmission in Remote Control Systems.....</b>	<b>335</b>
11.3.1	Types of Communication between CTC and Stations.....	335
11.3.2	Interface between CTC and Relay Interlockings on the Relay Technology.....	336
11.3.3	Interface between CTC and Relay Interlockings on the Electronic Technology.....	339
<b>11.4</b>	<b>Operator's Workload.....</b>	<b>339</b>
11.4.1	Influence of Technology.....	340
11.4.2	Influence of Size of Infrastructure.....	340
11.4.3	Influence of Operation Programme.....	341
11.4.4	Influence of Moving Vehicles.....	341
11.4.5	Influence of Disturbances.....	342
11.4.6	Results and Conclusions of Calculating Operator's Workload.....	343
<b>11.5</b>	<b>Examples for Operation Control Systems.....</b>	<b>343</b>
11.5.1	Centralised Traffic Control in the USA.....	343
11.5.2	Operation Control Centres in Germany.....	346
11.5.3	Operation Control Centres in Russia.....	349



<b>12</b>	<b>Safety and Control of Marshalling Yards.....</b>	<b>351</b>
<b>12.1</b>	<b>Principles of Marshalling of Trains.....</b>	<b>351</b>
<b>12.2</b>	<b>Parts of Marshalling Yards and their Function .....</b>	<b>351</b>
12.2.1	General Structure and Functioning.....	351
12.2.2	Layout Variants .....	352
12.2.3	Automation .....	354
<b>12.3</b>	<b>Control of Marshalling Yards.....</b>	<b>355</b>
12.3.1	Introduction .....	355
12.3.2	Retarders.....	356
12.3.3	Handling Systems for Freight Wagons.....	360
12.3.4	Points .....	361
12.3.5	Sensors .....	362
12.3.6	Track Clear Detection.....	363
12.3.7	Yard Management Systems .....	363
<b>13</b>	<b>Level Crossings .....</b>	<b>369</b>
<b>13.1</b>	<b>Requirements and Basic Classification.....</b>	<b>369</b>
<b>13.2</b>	<b>Static Roadside Signs .....</b>	<b>370</b>
<b>13.3</b>	<b>Passive Level Crossings.....</b>	<b>371</b>
<b>13.4</b>	<b>Active Level Crossings .....</b>	<b>375</b>
13.4.1	Overview.....	375
13.4.2	Dynamic Roadside Safeguarding .....	376
13.4.3	Opening and Closing of Level Crossings.....	380
13.4.4	Supervision of Level Crossings.....	384
13.4.5	Possibilities of Degraded Mode Operation.....	389
13.4.6	Combination with Road Junctions.....	390
<b>13.5</b>	<b>Removal of Level Crossings.....</b>	<b>391</b>
<b>14</b>	<b>Hazard Alert Systems .....</b>	<b>393</b>
<b>14.1</b>	<b>Hazards in Railway Systems .....</b>	<b>394</b>
14.1.1	Safety Related Hazards.....	394
14.1.2	Security Related Hazards.....	395

<b>14.2</b>	<b>Solutions for Hazard Detection.....</b>	<b>395</b>
14.2.1	Ways of Inspection.....	396
14.2.2	Fault States to Monitor.....	397
14.2.3	New Approach of Inspection – The Checkpoint Concept.....	398
14.2.4	Extract of Available Technologies and Products.....	399
<b>14.3</b>	<b>Choice of Location .....</b>	<b>405</b>
14.3.1	Operational Handling .....	405
14.3.2	Classification of Risky Elements .....	407
14.3.3	Strategies for Infrastructure Manager .....	408
	<b>References .....</b>	<b>409</b>
	<b>Glossary .....</b>	<b>416</b>
	<b>Explanation of Symbols in Track Layout Schemes.....</b>	<b>435</b>
	<b>The Authors.....</b>	<b>437</b>
	<b>Index.....</b>	<b>443</b>
	<b>Appendix .....</b>	<b>449</b>