

Contents

Preface	iii
Australian Preface	v
Acknowledgements	vii
Chapter 1: Introduction	1
1.1 Purpose	1
1.2 Performance-based Design	2
1.3 Regulatory Environments	2
New Zealand	2
Australia	3
1.4 Specific Fire Engineering Design	4
Quantifying performance	4
Owner’s requirements	4
1.5 Design Considerations	5
1.6 Compliance Schedule in New Zealand	5
1.7 Insurance and Building Design	6
1.8 Design Documentation	8
1.9 Peer Review	9
Chapter 2: Fire Engineering Design Strategy	11
2.1 Introduction	11
2.2 Building and Occupant Characteristics	12
2.3 Fire Protection Features	12
2.4 Acceptable Performance	15
2.5 Performance Requirements	15
2.6 Fire Engineering Analysis	16
2.7 Fire During Construction	17
2.8 Fire Following Earthquake	17
Chapter 3: Fire Risk	19
3.1 Introduction	19
3.2 About Risk and Risk Management	19

Risk	19
Risk management	19
Risk tolerance	20
Risk management process	20
Risk naming	22
3.3 Risk Management and Fire	22
Communicate and consult	22
Context	22
Risk criteria	23
Risk assessment	23
Risk identification	23
Risk analysis	23
Risk evaluation	24
Risk treatment	24
Monitor and review	24
3.4 Practical Examples	24
Dust explosion	24
Fire	26
3.5 Conclusions	26
Standards	26
Benefits of risk management	26
Chapter 4: Fire Behaviour	29
4.1 Introduction	29
4.2 Fire Initiation	30
4.3 Incipient Stage	31
4.4 Combustion	31
Smouldering combustion	31
Flaming combustion	32
4.5 Fire Growth Stage	32
4.6 Flashover	34
4.7 Fully-developed Fire	35
4.8 Decay Stage	38
4.9 Intervention	38
4.10 Design Fires	38

Chapter 5: Pre-flashover Fires	41
5.1 Introduction	41
5.2 Calorific Value of Fuels	41
5.3 Design Fires	41
Liquid fuels	42
Solid fuels	42
Burning objects	43
Calculations	45
Worked example	47
5.4 Room Fires	48
5.5 Detector and Sprinkler Response	49
Activation time	49
Life safety	50
Chapter 6: Post-flashover Fires	53
6.1 Introduction	53
6.2 Firecells and Fire Compartments	53
6.3 Fires	53
Fire loads	53
Fire duration and temperatures	54
Thomas’s flashover correlation	56
Worked example	56
6.4 Fire Severity	57
Equivalent time of fire exposure	57
Ventilation factor	58
Tabulated values	59
Single storey buildings	60
Worked example	60
6.5 Expected Structural Performance in Fire	61
Load ratio	63
6.6 Fire Resistance	64
Introduction	64
Design based on limiting temperature	65
Design based on equivalent time	65
Determination of fire resistance	65
Standard fire resistance test	66
Fire test facilities	67

	Fire resistance by calculation	68
	Fire emergency design loads	69
	Proprietary listings	69
	Generic listings	70
6.7	Structural Steel	70
	Design using unprotected steel members	70
	Alternative design solutions incorporating unprotected steel	72
	Limiting steel temperature	73
	Determination of time to reach limiting steel temperature in standard fire exposure	74
	Passive fire protection	77
	Design tables for passive fire protection	78
	Worked examples of simple application	79
6.8	Reinforced Concrete and Masonry	82
	Introduction	82
	Simple design methods	82
	Temperatures and material properties	83
	Structural calculation	83
	Worked example	84
	Advanced Calculation methods	88
6.9	Structural Timber	88
	Introduction	88
	Recommended design methods	88
	Heavy timber	89
	Connections	90
	Worked example	90
6.10	Lightweight Drywall Systems	92
	Timber framed walls	93
	Steel framed walls	93
	Floor/ceiling systems	93
	Predicting fire resistance of drywall construction exposed to compartment fires	95
	Design guidelines	96
	Chapter 7: Fire Spread	101
7.1	Introduction	101
7.2	Fire Spread within a Firecell	101
	Objective	101

	Surface spread of flame	101
	Concealed spaces	102
	Partitions	103
7.3	Fire Separations	104
	Objective	104
	Separations	104
	Method 1 – FRR/3	106
	Method 2 – Hand Calculation Method	107
	Method 3 – Radiant Exposure Area Method	108
	Method 4 – Numerical Modelling	108
	Penetrations and closures	108
	Doors	110
7.4	Fire Spread to Other Storeys	111
	Floor-ceiling separations	111
	Service ducts and shafts	111
	Concealed spaces	113
	Stairways	113
	Combustible cladding materials	113
	Exterior windows	113
	Worked example	115
7.5	Fire Spread to Other Buildings	116
	Fire resistance	116
	Modes of fire spread	116
	Direct contact	116
	Radiation	117
	Glazing	118
	Multiple openings	119
	Configuration factor	119
	Separation distances for calculations	119
	Received radiation	120
	Worked example	121
	Flying brands	122
7.6	Urban Conflagrations and Fire Following Earthquake	122
	Mitigation measures	123
Chapter 8: Detection and Suppression System Design		127
8.1	Introduction	127

8.2	Fire Alarm Systems	127
8.3	Detectable Effects of Fire	129
8.4	Detector Response	130
8.5	Thermal (heat) Detectors	130
8.6	Smoke Detectors	132
	Photoelectric smoke detectors (light scatter/Tyndall effect)	133
	Ionisation chamber smoke	134
	Linear beam (obscuration) detectors	135
	Aspirating smoke detector	135
	Domestic (residential) smoke alarms	136
8.7	Other Detection Types	137
	Manual call points	137
	Electro-magnetic radiation flame detectors	137
	Gas detectors	138
	Duct smoke detector housings	139
	Fire sprinkler system	139
	Multiple-criteria (multi-sensor) detectors	139
	Video smoke and fire detection	140
8.8	Fire Detection and Alarm System Types	140
	Integration of fire and other building services	142
	Type 5 and Type 7 systems	142
8.9	False (nuisance) Activation Alarms	142
8.10	Automatic Fire Sprinkler Systems	143
	General	143
	Sprinklers	146
	Method of operation	147
	Sprinkler response	147
	Control versus suppression	149
	Distribution patterns	149
	Recessed sprinklers	150
	Concealed sprinklers	150
	Residential sprinklers	151
	Suppression mode sprinklers	151
	Control mode specific application sprinklers	151
	Extended coverage sprinklers	151
	Dry sprinklers	152
	On-off sprinklers	152

Special application sprinklers	152
Orifice size	153
Types of sprinkler systems	154
Wet pipe	154
Dry pipe	154
Antifreeze systems	154
Pre-action sprinklers	155
Deluge systems	155
Drencher systems	156
Foam water systems	156
Water mist systems	157
Hazard classification	158
Residential	159
Domestic sprinkler systems	159
Design calculations	159
Sprinkler spacing	160
Sprinkler location	160
Approval of sprinkler systems	160
Sprinkler system failures	161
Design alternatives	162
8.11 Other Systems	162
Hydrant mains systems	162
Gas flood fire extinguishing systems	162
Other specialised fire protection systems	164
Hand-held fire extinguishers	165
Extinguishing agents	165
Fire hose reels	166
Installation of fire extinguishers and hose reels	166
8.12 EWIS Systems	166
Chapter 9: Mechanical Smoke Movement	173
9.1 Introduction	173
9.2 Mechanics of Smoke Production	173
General description	173
Constituents of smoke	174
Smoke formation	174
Smoke exhaust	175
Fundamentals of design	176
Estimating the volume of smoke produced by a fire	176

	Determining the size of the fire	177
9.3	Smoke Migration	178
9.4	Wind and Stack Effect	180
9.5	Smoke Clearance Systems	182
	General	182
	System components	182
	System design	183
9.6	Typical HVAC Systems	184
9.7	Configuring HVAC Systems to Control Smoke Migration	185
9.8	Escape Route Pressurisation	189
	General	189
	Pressurisation systems design	193
	Air leakage via door gaps, etc.	194
	Open doors	194
	Door opening forces	197
	Positive pressurisation of exit ways	198
	Objective	198
	Single-stage pressurisation	199
	Two-stage pressurisation	199
	Pressurisation of stairwells	199
	Pressurisation of lobbies and corridors	200
	Summary	200
9.9	HVAC Equipment Testing and Rating	202
9.10	Emergency Control of HVAC Systems	203
9.12	Conclusions	203
	Chapter 10: Fire Safety System Interfaces	205
10.1	Introduction	205
10.2	Methodology	205
10.3	Systems	205
10.4	Interfaces	207
10.5	HVAC and Active Fire Systems	209
	General	209
	Identifying the fire floor	209
10.6	Fire Sprinklers	210
10.7	Automatic Fire Alarms	212

10.8	Emergency Electrical Power Supply	214
10.9	Commissioning and Certification	216
Chapter 11: Means of Escape		217
11.1	Introduction	217
11.2	Occupant Behaviour	217
11.3	Basis for Engineered Design of Escape Routes	218
11.4	Number of Occupants	219
11.5	Escape Route Geometry	221
	Number and use of escape routes	221
	Separation of exits	221
	Exit width	221
11.6	Decision and Investigation Time	222
11.7	Travel Time	222
11.8	Time for Conditions to become Life Threatening	225
11.9	Tenability Limits	225
	Convection	226
	Radiant Heat	226
	Visibility	226
	Narcotic or asphyxiant gases	227
	Irritant gases	228
11.10	Other Issues	228
	Discounting of exits	228
	People with disabilities	228
	Multi-storey buildings	228
	Worked example — egress design	229
Chapter 12: Fire Modelling with Computers		235
12.1	Introduction	235
12.2	Warnings	235
12.3	Categories of Models	236
	Probabilistic models	236
	Deterministic models	236
12.4	Fire Growth Models	237
	General	237
	Zone models	237

Field models	237
12.5 Structural Fire Models	238
12.6 Evacuation Modelling	239
12.7 Risk Assessment Models	240
12.8 BRANZFIRE	240
Features	241
Limitations	241
Validation	241
12.9 Fire Dynamics Simulator (FDS)	242
Limitations	243
Chapter 13: Provision for Fire Service Operations	247
13.1 Introduction	247
13.2 Scope	247
13.3 Fire Service Access and Water Supplies	248
Fire service access	248
Fire fighting water supplies	249
13.4 New Zealand Fire Service Operations Guide	250
13.5 Fire Brigade Intervention Model	251
13.6 Fire Resistance Ratings	251
Chapter 14: Fire Fighting Water Supplies	253
14.1 Introduction	253
14.2 Scope	253
14.3 Principal Considerations	253
14.4 Water Supply Requirements	255
Water quantity	255
Reliability	255
Water conservation	256
Water quality	256
Statutory requirements	256
Worked examples	257
14.5 Fire Service Operational Fire Fighting	258
Fire hydrant systems	258
14.6 Testing of Water Supplies	259
Timing of water supply tests	259

Fire sprinkler system flow tests	259
Flow tests for fire hydrant systems in buildings	260
Fire hose reel system flow tests	260
Fire Service water flow tests	260
Water supply system computer simulation	261
14.7 Design of Fire Fighting Water Supply Networks	261
General	261
Sources of supply	261
Water supply network design criteria	262
Domestic and industrial water supply design	262
Fire fighting water supply design	262
Hydraulic design procedure	263
14.8 Design of Water Supplies for Fixed Fire Fighting Systems	263
General	263
Pipework design for fire sprinkler systems	264
Fire hydrant systems in buildings	264
Fire hose reel systems	265
Notification to the fire service	265
14.9 Operational Fire Fighting	265
Fire service procedure	265
Fire service access and facilities	266
14.10 New Zealand Legislation	266
Chapter 15: Domestic Fire Safety	269
15.1 Introduction	269
15.2 Scale of the Domestic Fire Problem	269
15.3 Prevention of Ignition	269
Human activities	270
Equipment failure	270
15.4 Domestic Smoke Alarms	270
Location of smoke alarms	271
Interconnected smoke alarms	271
Battery powered versus mains-wired	271
Maintenance of smoke alarms	271
Waking effectiveness of alarms	272
15.5 Suppression Systems	272
Domestic sprinklers	272

Hand-held fire fighting devices	273
Fire extinguishers	273
Hoses	273
Fire blankets	273
15.6 Materials	273
Upholstered furniture	273
Plastics materials	274
Curtain fabrics and carpets	274
15.7 House Construction	275
Linings	275
Doors	275
Fire resistance	276
Escape routes	276
15.8 Education	276
Doors open or closed	276
Escape planning	277
Flammability of fabrics	277
15.9 Recommendations	277
Chapter 16: Rural Fire	281
16.1 Introduction	281
16.2 NZ Fire History and Current Fire Problem	282
Fire history	282
Fire losses	283
Rural fire causes	285
Regional fire risk	285
16.3 The Fire Environment	286
Weather	287
Topography	288
Fuels	288
16.4 Vegetation Fire Behaviour	289
Vegetation fire science	290
Flame front characteristics	293
16.5 Fire Danger Rating	295
New Zealand fire danger rating system	296
16.6 Rural Fire Legislation and Management	298
Fire management activities	299

16.7	The Rural-Urban Interface Problem	303
16.8	Conclusions	305
Chapter 17: Regulatory Framework in Australia		313
17.1	Introduction	313
17.2	Regulatory Framework	313
17.3	Building Code of Australia	314
17.4	State Legislation and Regulation	315
17.5	Building Approvals	317
17.6	Registered Professionals	318
17.7	Maintenance and Essential Services	318
Chapter 18: Regulatory Framework in New Zealand		321
18.1	Introduction	321
18.2	Building Control Framework	321
	The Building Act 2004	321
	Purpose	321
	Principles	323
	Application	324
	Structure	324
	Building regulations	325
	The New Zealand Building Code	325
18.3	Compliance Paths	326
	Compliance documents	326
18.4	Building Requirements for Flammable Liquids and Gases under the HSNO Act 1996	327
18.5	Australian/New Zealand Standards	329
18.6	International Fire Engineering Guidelines	329
Appendix A: Notation		331
Appendix B: Heat Release Rates		337
Appendix C: Fuel Load Energy Densities		341
Appendix D: Section Factors for Steel Beams		353
Index		355

