

Contents

Disclaimer of Liability	1
Introduction	2
1 Welcome	3
2 The Science of Thermal Treatment	6
2.1 What is Heat Treatment?	6
2.2 Is Heat Treatment Really That Important?	6
2.3 Why Is This Chapter Titled "The Science of Thermal Treatment"?	6
2.4 What Temperatures Are Involved in Thermal Treatment?	8
2.5 What Happens during the Heat Treatment Hardening Process?	8
2.6 Why is Heat-Treated Steel Referred to as a Crystal Structure?	8
2.7 There Are All Kinds of Metals; Will This Manual Deal with Which Ones to Use?	9
2.8 What Is Steel?	9
2.9 It Appears That There Are Many Types of Heat-Treating; Is That So?	9
2.10 Why Does Tempering a Heat-Treated Steel Sound So Critical?	11
2.11 How Do They Keep a Steel from Losing Hardness?	12
2.12 Does Heat-Treated Steel Age and Change Its Hardness over Time?	12
2.13 How Did They Heat-Treat Steel in a Forge without Temperature Controls?	13
2.14 Is Heat Treatment in Forges Still Practiced?	14
2.15 Why Does Tool Steel Cost So Much versus Carbon Steel?	15
3 The Focus of Thermal Treatment	16
4 Safety	18
5 Heat-Treating is a Science	20
6 Making Metal	24
7 Making Steel	26
7.1 Iron: the Basic Building Block for Ferrous Metals	26
7.2 Additional Forms of Iron	26
7.3 The Steel-Making Process	28
7.4 Carbon Steel Grades	31
7.5 Decarburized Steel Surfaces	33
8 Making Stainless Steel	35
8.1 Austenitic Stainless	35
8.2 Martensitic Stainless	36

8.3	Ferritic Stainless	36
8.4	Duplex Stainless	36
8.5	Precipitation-Hardening Stainless	37
8.6	Superalloy Materials	37
9	Basic Metallurgy	38
9.1	Temperatures and Transformations	38
9.2	The TTT Diagram	40
9.3	Other Areas of Metallurgy	42
10	Heat-Treating Equipment	51
10.1	Open-Atmosphere Furnaces	51
10.2	Controlled-Atmosphere Furnaces	56
10.3	Popular Furnace Types and their Hardening Processes	60
11	Heat-Treatment Tools	66
11.1	Support Racks	66
11.2	Pyrometer	67
11.3	Tongs	68
11.4	Parts Mover	68
11.5	Hardness Testers	68
11.6	Racks and Fixtures	70
11.7	Clothes and Apparel	70
11.8	Calibration Equipment	70
11.9	Fire Protection	71
12	Surface Decarb Protection	72
12.1	Diamond Block	73
12.2	Stainless Steel Foil	74
12.3	Decarb Protective Paints	76
12.4	Anti-Scaling Powder	76
13	Grain Structure	78
13.1	Grain Size	79
14	The Many Types of Thermal Treatment	83
14.1	Overview of Processes	83
14.2	Stress Relieving	84
15	Annealing	87
15.1	Spheroidize Annealing (Process)	88
15.2	Full Annealing (Process)	88
15.3	Box Annealing (Method)	89
15.4	In-Process Anneal (Method)	89
15.5	Bright Annealing (Method)	89
15.6	Normalizing (Process)	89
15.7	Flame Annealing (Method)	90
15.8	Isothermal Annealing (Method)	90

16 Loading the Furnace	91
16.1 Racks	91
16.2 Fixtures	93
17 Heat-Treating Processes. Step 1: Preheating	95
17.1 Why Preheat?	95
17.2 Equalizing	96
17.3 Physical Loading the Furnace	97
18 The Heat-Treating Processes. Step 2: Austenization	99
18.1 Austenization or Solution Heat-Treating	99
19 The Heat-Treating Processes. Step 3: Quenching	102
19.1 Quench Media	102
20 The Heat-Treating Processes. Step 4: Tempering	108
20.1 The Time Factor	108
20.2 Circulation and Loading	109
20.3 What to Watch for When Tempering	109
20.4 Multiple Tempering Cycles	110
20.5 Tempering Cost and Time Savers	111
21 The Heat-Treating Processes. Step 5: Cryogenics	112
21.1 Cryogenic Levels	113
21.2 Cryogenics as an Aging Tool	115
21.3 Cryogenic Stress Relief	115
21.4 Nonferrous Metals	116
21.5 Summary	117
Introduction for Chapters 22, 23 & 24	118
22 Heat-Treating Air-Hardening Tool Steels	120
22.1 Introduction	120
22.2 Steps for the Heat-Treating of Air-Hardening Steels	120
22.3 Surface Finishing	136
23 Heat-Treating: Oil-Hardening Tool Steels	137
23.1 Introduction	137
23.2 Steps for the Heat-Treating of Oil-Hardening Steels	137
23.3 Surface Finishing	153
24 Heat-Treating: Water-Hardening Tool Steels	154
24.1 Introduction	154
24.2 Steps for the Heat-Treating of Water-Hardening Steels	154
24.3 Surface Finishing	168
25 Case Hardening	170
25.1 Carburization	170
25.2 Pack Hardening Box	172

25.3	Liquid Salts Carburizing	172
25.4	Gas Carburizing	173
25.5	Carbonitriding	173
25.6	Nitriding	173
25.7	Carburizing Paste or Powders	174
25.8	Hardening Case-Hardening Steels	174
26	Gizmo Heat-Treat Failures	176
26.1	Thermal Treatment CSI* Detective	176
26.2	“For The Record” (Record Keeping)	176
26.3	Failure Detection	178
26.4	Metallurgist Analyses	180
27	Furnace Temperature Uniformity	189
27.1	Testing for Temperature Uniformity	189
27.2	Minimal Testing	190
28	Selection Of Tool Steel Grades	191
28.1	The Steel Selection	191
28.2	Guidelines	191
29	Material Testing	194
29.1	Spark Testing	194
29.2	Chemical Testing Metals	196
30	Grade Heat-Treating Charts	201
Appendix A: Suggested Tool Steels Uses		309
Appendix B: Glossary		318

Grade Heat-Treating Charts

A2	202
A6	204
A8	206
A9	208
A10	210
D2	212
D3	214
D5	216
D7	218
H11	220
H12	222
H13	224
H19	226
H21	228
L2	230
L6	232
M1	234
M2	236
M3-Type 1	238
M3-Type 2	240
M4	242
M7	244
M42	246
O1	248
O6	250
P2	252
P6	253
P20	254
P21	255
S1	256
S2	258
S5	260

S7	262
T1	264
T5	266
T15	268
W1	270
W2	272
W5	274
17-4 PH	276
17-7 PH	277
410	278
416	280
420	282
440A	284
440B	286
440C	287
1030	288
1040	289
1045	290
1050	291
1060	292
1080	293
1095	294
1141	295
4130	296
4140	298
4150	300
4340	302
6150	304
8620	306
E9310	307
Powdered Metals	308