

FULL HANDBOOK TABLE of CONTENTS

Chapter 1

1.0	General	1-1
1.1	Purpose and Use of Document	1-1
1.1.1	Introduction	1-1
1.1.2	Scope of Handbook	1-1
1.2	Nomenclature	1-3
1.2.1	Symbols and Definitions	1-3
1.2.2	International Systems of Units (SI)	1-3
1.3	Commonly Used Formulas	1-5
1.3.1	General	1-5
1.3.2	Simple Unit Stresses	1-5
1.3.3	Combined Stresses (see Section 1.5.3.5)	1-5
1.3.4	Deflections (Axial)	1-5
1.3.5	Deflections (Bending)	1-5
1.3.6	Deflections (Torsion)	1-6
1.3.7	Biaxial Elastic Deformation	1-6
1.3.8	Basic Column Formula	1-6
1.3.9	Inelastic Stress-Strain Response	1-7
1.4	Basic Principles	1-9
1.4.1	General	1-9
1.4.2	Stress	1-10
1.4.3	Strain	1-10
1.4.4	Tensile Properties	1-11
1.4.5	Compressive Properties	1-17
1.4.6	Shear Properties	1-18
1.4.7	Bearing Properties	1-19
1.4.8	Temperature Effects	1-21
1.4.9	Fatigue Properties	1-22
1.4.10	Metallurgical Instability	1-25
1.4.11	Biaxial Properties	1-25
1.4.12	Fracture Toughness	1-27
1.4.13	Fatigue Crack Growth	1-36
1.4.14	Use of Values for Heat Treat by User Materials	1-39
1.5	Types of Failures	1-41
1.5.1	General	1-41
1.5.2	Material Failures	1-41
1.5.3	Instability Failures	1-42
1.6	Columns	1-43
1.6.1	General	1-43
1.6.2	Primary Instability Failures	1-43
1.6.3	Local Instability Failures	1-43
1.6.4	Correction of Column Test Results	1-44
1.7	Thin-Walled and Stiffened Thin-Walled Sections	1-53
1.8	Allowables-Based Flow Stress for Nonlinear Static Analysis	1-55
1.8.1	Introduction	1-55
1.8.2	Procedure	1-55
1.8.3	Reporting Requirements	1-57

FULL HANDBOOK TABLE of CONTENTS

1.9	Estimation of Average Tensile Properties from A- and B-Basis Design Allowables	1-59
1.9.1	Introduction	1-59
1.9.2	General Trends	1-59
References	1-63
Chapter 2		
2.0	Steel	2-1
2.1	General	2-1
2.1.1	Alloy Index	2-1
2.1.2	Material Properties	2-2
2.1.3	Environmental Considerations	2-7
2.1.4	Obsolete Alloys, Heat Treatments, and Product Forms	2-7
2.2	Carbon Steels	2-11
2.2.0	Comments on Carbon Steels	2-11
2.2.1	AISI 1025	2-12
2.3	Low-Alloy Steels (AISI Grades and Proprietary Grades)	2-15
2.3.0	Comments on Low-Alloy Steels (AISI and Proprietary Grades)	2-15
2.3.1	Specific Alloys	2-19
2.4	Intermediate Alloy Steels	2-71
2.4.0	Comments on Intermediate Alloy Steels	2-71
2.4.1	5Cr-Mo-V	2-71
2.4.2	9Ni-4Co-0.20C	2-79
2.4.3	9Ni-4Co-0.30C	2-84
2.5	High-Alloy Steels	2-95
2.5.0	Comments on High-Alloy Steels	2-95
2.5.1	18 Ni Maraging Steels	2-97
2.5.2	AF1410	2-107
2.5.3	AerMet 100	2-110
2.5.4	Ferrium S53	2-117
2.5.5	Ferrium M54	2-129
2.6	Precipitation- and Transformation-Hardening Steels (Stainless)	2-135
2.6.0	Comments on Precipitation- and Transformation-Hardening Steels (Stainless)	2-135
2.6.1	AM-350	2-135
2.6.2	AM-355	2-145
2.6.3	Custom 450	2-148
2.6.4	Custom 455	2-160
2.6.5	Custom 465	2-172
2.6.6	PH13-8Mo	2-178
2.6.7	15-5PH	2-196
2.6.8	PH15-7Mo	2-212
2.6.9	17-4PH	2-224
2.6.10	17-7PH	2-242
2.6.11	HSL 180	2-249
2.6.12	MLX17	2-256
2.7	Austenitic Stainless Steels	2-267
2.7.0	Comments on Austenitic Stainless Steel	2-267
2.7.1	AISI 301 and Related 300 Series Stainless Steels	2-269
2.8	Element Properties	2-289
2.8.1	Beams	2-289

FULL HANDBOOK TABLE of CONTENTS

2.8.2	Columns	2-289
2.8.3	Torsion	2-292
References		2-299
Chapter 3		
3.0	Aluminum	3-1
3.1	General	3-1
3.1.1	Aluminum Alloy Index	3-1
3.1.2	Material Properties	3-2
3.1.3	Manufacturing Considerations	3-26
3.1.4	Obsolete Alloys, Tempers, and Product Forms	3-31
3.2	2000 Series Wrought Alloys	3-35
3.2.1	2013 Alloy	3-35
3.2.2	2014 Alloy	3-52
3.2.3	2017 Alloy	3-91
3.2.4	2024 Alloy	3-94
3.2.5	2025 Alloy	3-178
3.2.6	2026 Alloy	3-180
3.2.7	2027 Alloy	3-182
3.2.8	2050 Alloy	3-191
3.2.9	2056 Alloy	3-203
3.2.10	2090 Alloy	3-209
3.2.11	2098 Alloy	3-212
3.2.12	2099 Alloy	3-222
3.2.13	2124 Alloy	3-234
3.2.14	2195 Alloy	3-252
3.2.15	2196 Alloy	3-258
3.2.16	2198 Alloy	3-262
3.2.17	2219 Alloy	3-275
3.2.18	2297 Alloy	3-303
3.2.19	2397 Alloy	3-312
3.2.20	2424 Alloy	3-315
3.2.21	2519 Alloy	3-318
3.2.22	2524 Alloy	3-321
3.2.23	2618 Alloy	3-325
3.2.24	2624 Alloy	3-334
3.3	3000 Series Wrought Alloys	3-343
3.4	4000 Series Wrought Alloys	3-343
3.5	5000 Series Wrought Alloys	3-343
3.5.1	5052 Alloy	3-343
3.5.2	5083 Alloy	3-357
3.5.3	5086 Alloy	3-363
3.5.4	5454 Alloy	3-373
3.5.5	5456 Alloy	3-378
3.6	6000 Series Wrought Alloys	3-385
3.6.1	6013 Alloy	3-385
3.6.2	6061 Alloy	3-389
3.6.3	6151 Alloy	3-417
3.6.4	6156 Alloy	3-420

FULL HANDBOOK TABLE of CONTENTS

3.7	7000 Series Wrought Alloys	3-425
3.7.1	7010 Alloy	3-425
3.7.2	7037 Alloy	3-433
3.7.3	7040 Alloy	3-441
3.7.4	7049/7149 Alloy	3-445
3.7.5	7050 Alloy	3-462
3.7.6	7055 Alloy	3-512
3.7.7	7056 Alloy	3-527
3.7.8	7068 Alloy	3-533
3.7.9	7075 Alloy	3-540
3.7.10	7085 Alloy	3-614
3.7.11	7136 Alloy	3-641
3.7.12	7140 Alloy	3-646
3.7.13	7150 Alloy	3-660
3.7.14	7175 Alloy	3-673
3.7.15	7249 Alloy	3-688
3.7.16	7255 Alloy	3-696
3.7.17	7349 Alloy	3-700
3.7.18	7449 Alloy	3-704
3.7.19	7475 Alloy	3-720
3.8	200.0 Series Cast Alloys	3-749
3.8.1	A201.0 Alloy	3-749
3.8.2	A205/T1B2/3p	3-759
3.9	300.0 Series Cast Alloys	3-771
3.9.1	354.0 Alloy	3-771
3.9.2	355.0 Alloy	3-773
3.9.3	C355.0 Alloy	3-776
3.9.4	356.0 Alloy	3-778
3.9.5	A356.0 Alloy	3-781
3.9.6	A357.0/F357.0 Alloy	3-785
3.9.7	D357.0/E357.0 Alloy	3-789
3.9.8	359.0 Alloy	3-793
3.10	Element Properties	3-795
3.10.1	Beams	3-795
3.10.2	Columns	3-796
3.10.3	Torsion	3-798
References		3-803
Chapter 4		
4.0	Magnesium Alloys	4-1
4.1	General	4-1
4.1.1	Alloy Index	4-1
4.1.2	Material Properties	4-1
4.1.3	Physical Properties	4-2
4.1.4	Environmental Considerations	4-2
4.1.5	Alloy and Temper Designations	4-2
4.1.6	Joining Methods	4-5
4.1.7	Obsolete Alloys, Tempers, and Product Forms	4-5
4.2	Magnesium-Wrought Alloys	4-9

FULL HANDBOOK TABLE of CONTENTS

4.2.1	AZ31B	4-9
4.2.2	AZ61A	4-21
4.2.3	WE43C (Elektron 43)	4-23
4.2.4	ZK60A	4-29
4.3	Magnesium Cast Alloys	4-37
4.3.1	AM100A	4-37
4.3.2	AZ91C/AZ91E	4-39
4.3.3	AZ92A	4-43
4.3.4	EV31A	4-49
4.3.5	EZ33A	4-55
4.3.6	QE22A	4-60
4.3.7	ZE41A	4-64
4.4	Element Properties	4-69
4.4.1	Beams	4-69
4.4.2	Columns	4-69
4.4.3	Torsion	4-72
References		4-73
Chapter 5		
5.0	Titanium	5-1
5.1	General	5-1
5.1.1	Titanium Index	5-1
5.1.2	Material Properties	5-1
5.1.3	Manufacturing Considerations	5-4
5.1.4	Environmental Considerations	5-4
5.1.5	Obsolete Alloys, Tempers, and Product Forms	5-5
5.2	Unalloyed Titanium	5-7
5.2.1	Commercially Pure Titanium	5-7
5.3	Alpha and Near-Alpha Titanium Alloys	5-17
5.3.1	Ti-5Al-2.5Sn	5-17
5.3.2	Ti-8Al-1Mo-1V	5-32
5.3.3	Ti-6Al-2Sn-4Zr-2Mo	5-48
5.4	Alpha-Beta Titanium Alloys	5-57
5.4.1	Ti-6Al-4V	5-57
5.4.2	Ti-6Al-6V-2Sn	5-122
5.4.3	Ti-4.5Al-3V-2Fe-2Mo	5-140
5.4.4	Ti-4Al-2.5V-1.5Fe	5-149
5.5	Beta, Near-Beta, and Metastable-Beta Titanium Alloys	5-171
5.5.1	Ti-13V-11Cr-3Al	5-171
5.5.2	Ti-15V-3Cr-3Sn-3Al (Ti-15-3)	5-188
5.5.3	Ti-10V-2Fe-3Al (Ti-10-2-3)	5-192
5.6	Element Properties	5-197
5.6.1	Beams	5
References		5-199
Chapter 6		
6.0	Heat-Resistant Alloys	6-1
6.1	General	6-1
6.1.1	Material Properties	6-3

FULL HANDBOOK TABLE of CONTENTS

6.1.2	Obsolete Heat Resistant Alloys, Tempers, and Product Forms	6-3
6.2	Iron-Chromium-Nickel-Base Alloys	6-5
6.2.0	General Comments	6-5
6.2.1	A-286	6-5
6.2.2	N-155	6-16
6.3	Nickel-Base Alloys	6-21
6.3.0	General Comments	6-21
6.3.1	Hastelloy X	6-23
6.3.2	Inconel 600	6-29
6.3.3	Inconel 625	6-36
6.3.4	Inconel 706	6-47
6.3.5	718 alloy	6-53
6.3.6	Inconel X-750	6-92
6.3.7	Rene 41	6-98
6.3.8	Waspaloy	6-121
6.3.9	230 alloy	6-127
6.3.10	HR-120	6-140
6.4	Cobalt-Base Alloys	6-147
6.4.0	General Comments	6-147
6.4.1	L-605 (25 alloy)	6-148
6.4.2	188 alloy	6-171
References		6-187

Chapter 7

7.0	Miscellaneous Alloys and Hybrid Materials	7-1
7.1	General	7-1
7.1.1	Obsolete Alloys, Tempers, and Product Forms	7-1
7.2	Beryllium	7-3
7.2.0	General	7-3
7.2.1	Standard Grade Beryllium	7-3
7.3	Copper and Copper Alloys	7-13
7.3.0	General	7-13
7.3.1	Maganese Bronzes	7-14
7.3.2	Copper Beryllium	7-17
7.3.3	Copper-Nickel-Tin (Spinodal Alloy)	7-26
7.3.4	Aluminum Bronzes	7-35
7.4	Multiphase Alloys	7-37
7.4.0	General	7-37
7.4.1	MP35N Alloy	7-37
7.4.2	MP159 Alloy	7-43
7.5	Aluminum Alloy Sheet Laminates	7-49
7.5.0	General	7-49
7.5.1	2024-T3 Aramid Fiber Reinforced Sheet Laminate	7-49
7.5.2	7475-T761 Aramid Fiber Reinforced Sheet Laminate	7-58
7.6	Aluminum-Beryllium Hybrids	7-67
7.6.0	General	7-67
7.6.1	AL-62Be	7-67
References		7-79

FULL HANDBOOK TABLE of CONTENTS

Chapter 8

8.0	Structural Joints	8-1
8.1	Mechanically Fastened Joints	8-3
8.1.1	Introduction and Fastener Indexes	8-3
8.1.2	Solid Rivets	8-27
8.1.3	Blind Fasteners	8-53
8.1.4	Swaged Collar/Upset-Pin Fasteners	8-126
8.1.5	Threaded Fasteners	8-141
8.1.6	Special Fasteners	8-163
8.2	Metallurgical Joints	8-167
8.2.1	Introduction and Definitions	8-167
8.2.2	Welded Joints	8-167
8.3	Bearings, Pulleys, and Wire Rope	8-189
	References	8-191

Chapter 9

9.0	Index	9-1
9.1	General	9-7
9.1.1	Introduction	9-7
9.1.2	Cross Index Table for Chapter 9	9-7
9.1.3	Applicability	9-7
9.1.4	Approval Procedures	9-7
9.1.5	Documentation Requirements	9-7
9.1.6	Summary	9-10
9.1.7	Data Basis	9-12
9.1.8	Rounding Procedures	9-14
9.2	Material, Specification, Testing, and Data Requirements	9-15
9.2.1	Material Requirements	9-15
9.2.2	Specification Requirements	9-15
9.2.3	Required Test Methods/Procedures	9-15
9.2.4	Data Requirements	9-29
9.2.5	Experimental Design	9-53
9.3	Submission of Data	9-65
9.3.1	Recommended Procedures	9-65
9.3.2	Computer Software	9-65
9.3.3	Introductory Section	9-65
9.3.4	General Data Formats	9-65
9.4	Substantiation of Properties	9-75
9.4.1	S-Basis Minimum Properties	9-75
9.4.2	Validating Design Properties for Existing Material	9-76
9.4.3	Confirmation of Design Properties for Legacy Alloys	9-77
9.5	Analysis Procedures for Statistically Computed Minimum Static Properties	9-83
9.5.1	Specifying the Population	9-83
9.5.2	Regression Analysis	9-98
9.5.3	Combinability of Data	9-109
9.5.4	Determining the Form of Distribution	9-114
9.5.5	Direct Computation Without Regression	9-129
9.5.6	Direct Computation by Regression Analysis	9-137
9.5.7	Indirect Computation without Regression (Reduced Ratios/Derived Properties)	9-139

FULL HANDBOOK TABLE of CONTENTS

9.5.8	Indirect Computation using Regression	9-142
9.5.9	Handling of Derived Property Test Results Below Estimated Design Allowable ...	9-143
9.5.10	Indirect Computation of Edgewise Bearing Reductions	9-145
9.6	Analysis Procedures for Dynamic and Time Dependent Properties	9-147
9.6.1	Load and Strain Control Fatigue Data	9-147
9.6.2	Fatigue Crack Growth Data	9-167
9.6.3	Fracture Toughness Data	9-170
9.6.4	Creep and Creep-Rupture Data	9-178
9.7	Analysis Procedures for Structural Joint Properties	9-185
9.7.1	Mechanically Fastened Joints	9-185
9.7.2	Fusion-Welded Joint Data	9-214
9.8	Examples of Data Analysis and Data Presentation for Static Properties	9-217
9.8.1	Direct Analyses of Mechanical Properties	9-217
9.8.2	Indirect Analyses of Mechanical Properties	9-230
9.8.3	Tabular Data Presentation	9-234
9.8.4	Room Temperature Graphical Mechanical Property Data	9-240
9.8.5	Elevated Temperature Graphical Mechanical Properties	9-262
9.9	Examples of Data for Dynamic and Time Dependent Properties	9-281
9.9.1	Fatigue	9-281
9.9.2	Fatigue Crack Growth	9-299
9.9.3	Fracture Toughness	9-305
9.9.4	Creep and Creep Rupture	9-306
9.9.5	Mechanically Fastened Joints	9-313
9.9.6	Fusion-Welded Joints	9-356
9.10	Statistical Tables	9-359
9.10.1	One-Sided Tolerance Limit Factors, K, for the Normal Distribution, 0.95 Confidence, and n-1 Degrees of Freedom	9-360
9.10.2	0.950 Fractiles of the F Distribution Associated with n ₁ and n ₂ Degrees of Freedom	9-362
9.10.3	0.950 Fractiles of the F Distribution Associated with n ₁ and n ₂ Degrees of Freedom	9-363
9.10.4	0.95 and 0.975 Fractiles of the t Distribution Associated with df Degrees of Freedom	9-364
9.10.5	Area Under the Normal Curve from -∞ to the Mean +Z _p Standard Deviations ...	9-365
9.10.6	One-Sided Tolerance-Limit Factors for the Three-Parameter Weibull Acceptability Test with 95 Percent Confidence	9-366
9.10.7	One-Sided Tolerance Factors for the Three-Parameter Weibull Distribution With 95 Percent Confidence	9-367
9.10.8	γ-values for Computing Threshold of Three-Parameter Weibull Distribution ...	9-373
9.10.9	Ranks, r, of Observations, n, for an Unknown Distribution Having the Probability and Confidence of T99 and T90 Values	9-376
9.10.10	Fractiles of F Distribution Associated with n1(numerator) and n2 (denominator) Degrees of Freedom	9-378
References	9-381

CHAPTER 1 - CONTENTS

<u>Section</u>	<u>Page</u>
Chapter 1	
1.0 General	1-1
1.1 Purpose and Use of Document	1-1
1.1.1 Introduction	1-1
1.1.2 Scope of Handbook	1-1
1.2 Nomenclature	1-3
1.2.1 Symbols and Definitions	1-3
1.2.2 International Systems of Units (SI)	1-3
1.3 Commonly Used Formulas	1-5
1.3.1 General	1-5
1.3.2 Simple Unit Stresses	1-5
1.3.3 Combined Stresses (see Section 1.5.3.5)	1-5
1.3.4 Deflections (Axial)	1-5
1.3.5 Deflections (Bending)	1-5
1.3.6 Deflections (Torsion)	1-6
1.3.7 Biaxial Elastic Deformation	1-6
1.3.8 Basic Column Formula	1-6
1.3.9 Inelastic Stress-Strain Response	1-7
1.4 Basic Principles	1-9
1.4.1 General	1-9
1.4.2 Stress	1-10
1.4.3 Strain	1-10
1.4.4 Tensile Properties	1-11
1.4.5 Compressive Properties	1-17
1.4.6 Shear Properties	1-18
1.4.7 Bearing Properties	1-19
1.4.8 Temperature Effects	1-21
1.4.9 Fatigue Properties	1-22
1.4.10 Metallurgical Instability	1-25
1.4.11 Biaxial Properties	1-25
1.4.12 Fracture Toughness	1-27
1.4.13 Fatigue Crack Growth	1-36
1.4.14 Use of Values for Heat Treat by User Materials	1-39
1.5 Types of Failures	1-41
1.5.1 General	1-41
1.5.2 Material Failures	1-41
1.5.3 Instability Failures	1-42
1.6 Columns	1-43
1.6.1 General	1-43
1.6.2 Primary Instability Failures	1-43
1.6.3 Local Instability Failures	1-43
1.6.4 Correction of Column Test Results	1-44
1.7 Thin-Walled and Stiffened Thin-Walled Sections	1-53
1.8 Allowables-Based Flow Stress for Nonlinear Static Analysis	1-55
1.8.1 Introduction	1-55
1.8.2 Procedure	1-55
1.8.3 Reporting Requirements	1-57

CHAPTER 1 - CONTENTS

Section	Page
1.9 Estimation of Average Tensile Properties from A- and B-Basis Design Allowables	1-59
1.9.1 Introduction	1-59
1.9.2 General Trends	1-59
References	1-63
Appendices	
A.0 Glossary	A-1
A.1 Abbreviations	A-1
A.2 Symbols	A-5
A.3 Definitions	A-6
A.4 Conversion of U.S. Units of Measure Used in MMPDS to SI Units	A-17
B.0 Alloy Index	B-1
C.0 Specification Index	C-1
C.1 Cross Reference of Canceled MIL Specifications	C-11
D.0 Testing Standards	D-1
E.0 Subject Index	E-1