

Table of Contents

CHAPTER 1 - 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 SYSTEM OF UNITS	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 FORMULAS	1-6
1.3.9 INELASTIC STRESS-STRAIN RESPONSE	1-7
1.4 BASIC PRINCIPLES.	1-9
1.4.1 GENERAL	1-9
1.4.1.1 Basis.	1-9
1.4.1.2 Statistically Calculated Values	1-10
1.4.1.3 Ratioed Values.	1-10
1.4.1.4 Choosing Appropriate Allowables	1-10
1.4.2 STRESS.	1-10
1.4.3 STRAIN	1-10
1.4.3.1 Poisson's Ratio Effect	1-11
1.4.3.2 Shear Strain	1-11
1.4.3.3 Strain Rate	1-11
1.4.3.4 Elongation and Reduction of Area	1-11
1.4.4 TENSILE PROPERTIES	1-11
1.4.4.1 Modulus of Elasticity (E).	1-15
1.4.4.2 Tensile Proportional Limit Stress (F _{tp})	1-16
1.4.4.3 Tensile Yield Stress (TYS or F _{ty})	1-17
1.4.4.4 Tensile Ultimate Stress (TUS or F _{tu})	1-17
1.4.4.5 Elongation (e)	1-17
1.4.4.6 Reduction of Area (RA)	1-17
1.4.4.7 Design Stress-Strain Curves	1-17
1.4.4.8 Dynamic Modulus (ED)	1-18
1.4.5 COMPRESSIVE PROPERTIES	1-19
1.4.5.1 Compressive Ultimate Stress (F _{cu})	1-19
1.4.5.2 Compressive Yield Stress (CYS or F _{cys})	1-19

MMPDS-10
1 April 2015

1.4.6 SHEAR PROPERTIES	1-19
1.4.6.1 Modulus of Rigidity (G)	1-19
1.4.6.2 Ultimate and Yield Stresses in Shear (SUS or F _{su}) and (SYS or F _{sy})	
.	1-20
1.4.7 BEARING PROPERTIES	1-21
1.4.7.1 Bearing Yield (BYS or F _{bry}) and Ultimate (BUS or F _{bru}) Strength	
.	1-22
1.4.7.2 Bearing Load Orientation	1-22
1.4.8 TEMPERATURE EFFECTS	1-24
1.4.8.1 Low Temperature.	1-24
1.4.8.2 Elevated Temperature	1-24
1.4.9 FATIGUE PROPERTIES	1-26
1.4.9.1 Terminology.	1-26
1.4.9.2 Graphical Display of Fatigue Data	1-26
1.4.10 METALLURGICAL INSTABILITY.	1-28
1.4.11 BIAXIAL PROPERTIES	1-28
1.4.11.1 Biaxial Modulus of Elasticity	1-30
1.4.11.2 Biaxial Yield Stress	1-30
1.4.11.3 Biaxial Ultimate Stress	1-30
1.4.12 FRACTURE TOUGHNESS	1-30
1.4.12.1 Brittle Fracture	1-31
1.4.12.2 Brittle Fracture Analysis	1-31
1.4.12.3 Critical Plane-Strain Fracture Toughness	1-32
1.4.12.4 Fracture in Plane-Stress and Transitional-Stress States.	1-33
1.4.12.5 Apparent Fracture Toughness Values for Plane-Stress and Transitional-Stress States	1-34
.	
1.4.12.6 Crack Resistance (R-Curve)	1-35
1.4.13 FATIGUE CRACK GROWTH	1-39
1.4.13.1 Fatigue Crack Growth Rate Testing	1-39
1.4.13.2 Fatigue Crack Growth Analysis.	1-40
1.4.13.3 Fatigue Crack Growth Data Presentation	1-41
1.4.14. Use of Values for Heat Treat by User Materials	1-42
1.5 TYPES OF FAILURES	1-43
1.5.1 GENERAL	1-43
1.5.2 MATERIAL FAILURES	1-43
1.5.2.1 Direct Tension or Compression	1-43
1.5.2.2 Shear	1-43
1.5.2.3 Bearing.	1-43
1.5.2.4 Bending	1-43
1.5.2.5 Failure Due to Stress Concentrations	1-44
1.5.2.6 Failure From Combined Stresses.	1-44
1.5.3 INSTABILITY FAILURES	1-44
1.5.3.1 Instability Failures Under Compression	1-44

MMPDS-10
1 April 2015

1.5.3.2 Instability Failures Under Bending	1-44
1.5.3.3 Instability Failures Under Torsion	1-44
1.5.3.4 Failure Under Combined Loadings	1-44
1.6 COLUMNS	1-45
1.6.1 GENERAL	1-45
1.6.2 PRIMARY INSTABILITY FAILURES	1-45
1.6.2.1 Columns With Stable Sections.	1-45
1.6.2.2 Columns with Unstable Sections.	1-45
1.6.2.3 Column Stress (F _{co})	1-45
1.6.2.4 Other Considerations	1-45
1.6.3 LOCAL INSTABILITY FAILURES	1-45
1.6.3.1 Crushing or Crippling Stress (F _{cc}).	1-46
1.6.4 CORRECTION OF COLUMN TEST RESULTS	1-46
1.6.4.1 Nature of “Short Column Curve”	1-46
1.6.4.2 Local Failure	1-46
1.6.4.3 Reduction of Column Test Results on Aluminum and Magnesium Alloys to Standard Material	1-46
1.6.4.4 Reduction of Column Test Results to Standard Material-AlternateMethod	1-46
.	1-52
1.7 THIN-WALLED AND STIFFENED THIN-WALLED SECTIONS	1-55
1.8 ALLOWABLES-BASED FLOW STRESS FOR NONLINEAR STATIC ANALYSIS	1-57
.	1-57
1.8.1 INTRODUCTION.	1-57
1.8.2 DETAILED PROCEDURE	1-57
1.8.3 REPORTING REQUIREMENTS.	1-59
1.9 ESTIMATION OF AVERAGE TENSILE PROPERTIES FROM A- AND B-BASIS DESIGN ALLOWABLES	1-61
1.9.1 INTRODUCTION.	1-61
1.9.2 GENERAL TRENDS	1-61
REFERENCES	1-65

Table of Contents

CHAPTER 2 - STEEL	2-1
2.1 GENERAL.	2-1
2.1.1 ALLOY INDEX	2-1
2.1.2 MATERIAL PROPERTIES.	2-2
2.1.2.1 Mechanical Properties.	2-3
2.1.2.2 Physical Properties	2-6
2.1.3 ENVIRONMENTAL CONSIDERATIONS	2-9
2.1.4 OBSOLETE ALLOYS, HEAT TREATMENTS, AND PRODUCT FORMS	
.	2-9
2.2 CARBON STEELS	2-13
2.2.0 COMMENTS ON CARBON STEELS	2-13
2.2.0.1 Metallurgical Considerations	2-13
2.2.0.2 Manufacturing Considerations	2-13
2.2.0.3 Environmental Considerations	2-14
2.2.1 AISI 1025	2-14
2.2.1.0 Comments and Properties	2-14
2.3 LOW-ALLOY STEELS (AISI GRADES AND PROPRIETARY GRADES).	2-17
2.3.0 COMMENTS ON LOW-ALLOY STEELS (AISI AND PROPRIETARY GRADES)	
.	2-17
2.3.0.1 Metallurgical Considerations	2-17
2.3.0.2 Manufacturing Conditions	2-17
2.3.0.3 Environmental Considerations	2-20
2.3.1 SPECIFIC ALLOYS	2-21
2.3.1.0 Comments and Properties	2-21
2.3.1.1 AISI Low-Alloy Steels	2-21
2.3.1.2 AISI 4130 and 8630 Steels	2-21
2.3.1.3 AISI 4340 Steel	2-21
2.3.1.4 300M Steel	2-21
2.3.1.5 D6AC Steel	2-21
2.4 INTERMEDIATE ALLOY STEELS	2-73
2.4.0 Comments on Intermediate Alloy Steels	2-73
2.4.0.1 Metallurgical Considerations	2-73
2.4.1 5CR-Mo-V	2-73
2.4.1.0 Comments and Properties	2-73
2.4.1.1 Heat-Treated Condition	2-77
2.4.2 9Ni-4Co-0.20C	2-81
2.4.2.0 Comments and Properties	2-81
2.4.2.1 Heat-Treated Condition	2-83
2.4.3 9Ni-4Co-0.30C	2-86
2.4.3.0 Comments and Properties	2-86
2.4.3.1 Heat-Treated Condition	2-88

2.5 HIGH-ALLOY STEELS	2-97
2.5.0 COMMENTS ON HIGH-ALLOY STEELS	2-97
2.5.0.1 Metallurgical Considerations	2-97
2.5.0.2 Environmental Considerations	2-97
2.5.1 18 Ni MARAGING STEELS	2-99
2.5.1.0 Comments and Properties	2-99
2.5.1.1 Maraged Condition (aged at 900°F)	2-99
2.5.2 AF1410	2-108
2.5.2.0 Comments and Properties	2-108
2.5.2.1 Heat-Treated Condition	2-110
2.5.3 AERMET 100	2-111
2.5.3.0 Comments and Properties	2-111
2.5.3.1 280-300 ksi Heat-Treated Condition	2-113
2.5.3.2 290-310 ksi Heat-Treated Condition	2-115
2.5.4 FERRIUM S53	2-117
2.5.4.0 Comments and Properties	2-117
2.5.4.1 Heat Treated Condition	2-120
2.5.5 FERRIUM M54	2-129
2.5.5.0 Comments and Properties	2-129
2.5.5.1 Aged at 960°F Condition	2-132
2.6 PRECIPITATION- AND TRANSFORMATION-HARDENING STEELS (STAINLESS)	2-135
2.6.0 COMMENTS ON PRECIPITATION AND TRANSFORMATION-HARDENING STEELS (STAINLESS)	2-135
2.6.0.1 Metallurgical Considerations	2-135
2.6.0.2. Manufacturing Considerations	2-135
2.6.0.3 Environmental Considerations	2-135
2.6.1 AM-350	2-135
2.6.1.0 Comments and Properties	2-135
2.6.1.1 SCT 850 Condition	2-138
2.6.2 AM-355	2-142
2.6.2.0 Comments and Properties	2-142
2.6.2.1 SCT Condition	2-146
2.6.3 CUSTOM 450	2-148
2.6.3.0 Comments and Properties	2-148
2.6.3.1 H900 Condition	2-152
2.6.3.2 H1050 Condition	2-156
2.6.4 CUSTOM 455	2-160
2.6.4.0 Comments and Properties	2-160
2.6.4.1 H950 Condition	2-163
2.6.4.2 H1000 Condition	2-168
2.6.5 CUSTOM 465	2-171
2.6.5.0 Comments and Properties	2-171

MMPDS-10
1 April 2015

2.6.5.1 H950 and H1000 Condition	2-174
2.6.6 PH13-8Mo	2-177
2.6.6.0 Comments and Properties	2-177
2.6.6.1 H950 and H1000 Conditions	2-182
2.6.6.2 Extra-High Toughness H1000 Conditions	2-188
2.6.7 15-5PH	2-196
2.6.7.0 Comments and Properties	2-196
2.6.7.1 Various Heat-Treated Conditions	2-201
2.6.7.2 H1025 Condition	2-205
2.6.7.3 H1150 Condition	2-210
2.6.8 PH15-7Mo	2-211
2.6.8.0 Comments and Properties	2-211
2.6.8.1 TH1050 Condition	2-214
2.6.9 17-4PH	2-223
2.6.9.0 Comments and Properties	2-223
2.6.9.1 H900 Condition	2-230
2.6.9.2 Various Heat Treat Conditions	2-235
2.6.9.3 H1000 Condition	2-235
2.6.9.4 H1025 Condition	2-235
2.6.9.5 H1100 Condition	2-235
2.6.9.6 H1150 Condition	2-235
2.6.10 17-7PH	2-241
2.6.10.0 Comments and Properties	2-241
2.6.10.1 TH1050 Condition	2-243
2.6.11 HSL180 (12.5Cr-1.0Ni-15.5Co-2.0Mo)	2-248
2.6.11.0 Comments and Properties	2-248
2.6.11.1 Austenitized and Tempered Condition	2-250
2.6.12 MLX17	2-255
2.6.12.0 Comments and Properties	2-255
2.6.12.1 H950 Condition	2-257
2.6.12.2 H1000 Condition	2-261
2.7 AUSTENITIC STAINLESS STEELS	2-265
2.7.0 COMMENTS ON AUSTENITIC STAINLESS STEEL	2-265
2.7.0.1 Metallurgical Considerations	2-265
2.7.0.2 Manufacturing Considerations	2-265
2.7.0.3 Environmental Considerations	2-266
2.7.1 AISI 301 AND RELATED 300 SERIES STAINLESS STEELS	2-267
2.7.1.0 Comments and Properties	2-267
2.7.1.1 Solution Heat Treated Condition	2-275
2.7.1.2 $\frac{1}{4}$ Hard Condition	2-277
2.7.1.3 $\frac{1}{2}$ Hard Condition	2-278
2.7.1.4 $\frac{3}{4}$ Hard Condition	2-281
2.7.1.5 Full-Hard Condition	2-282

MMPDS-10
1 April 2015

2.8 ELEMENT PROPERTIES	2-287
2.8.1 BEAMS	2-287
2.8.1.1 Simple Beams	2-287
2.8.1.2 Built-Up Beams	2-287
2.8.1.3 Thin-Web Beams	2-287
2.8.2 COLUMNS	2-290
2.8.2.1 General	2-290
2.8.2.2 Effects of Welding	2-290
2.8.3 TORSION	2-291
2.8.3.1 General	2-291
2.8.3.2 Torsion Properties	2-291
REFERENCES	2-297

Table of Contents

CHAPTER 3 - ALUMINUM	3-1
3.1 GENERAL	3-1
3.1.1 ALUMINUM ALLOY INDEX	3-1
3.1.2 MATERIAL PROPERTIES	3-2
3.1.2.1 Mechanical Properties.	3-7
3.1.2.1.1 Edgewise Bearing	3-7
3.1.2.1.2 Clad Sheet and Plate.	3-8
3.1.2.1.3 Fatigue	3-8
3.1.2.1.4 Fracture Toughness	3-8
3.1.2.1.5 Cryogenic Temperatures	3-29
3.1.2.1.6 Elevated Temperatures	3-29
3.1.2.1.7 Stress-Strain Relationships	3-29
3.1.2.2 Physical Properties.	3-40
3.1.2.3 Corrosion Resistance	3-40
3.1.2.3.1 Resistance to Stress-Corrosion Cracking	3-40
3.1.2.3.2 Resistance to Exfoliation	3-48
3.1.3 MANUFACTURING CONSIDERATIONS	3-48
3.1.3.1 Avoiding Stress Corrosion Cracking	3-48
3.1.3.2 Cold-Formed, Heat-Treatable Aluminum Alloys	3-48
3.1.3.3 Dimensional Changes.	3-48
3.1.3.4 Welding	3-49
3.1.4 OBSOLETE ALLOYS, TEMPERS, AND PRODUCT FORMS	3-53
3.1.5 STABILIZED SPECIFICATIONS	3-57
3.2 2000 SERIES WROUGHT ALLOYS	3-59
3.2.1 2013 ALLOY	3-59
3.2.1.0 Comments and Properties	3-59
3.2.1.1 T6511 Temper	3-61
3.2.2 2014 ALLOY	3-76
3.2.2.0 Comments and Properties	3-76
3.2.2.1 T6, T62, T651, T652, T6510, and T6511 Temper.	3-86
3.2.3 2017 Alloy	3-110
3.2.3.0 Comments and Properties	3-110
3.2.3.1 T4, T451, and T42 Temper	3-113
3.2.4 2024 Alloy	3-114
3.2.4.0 Comments and Properties	3-114
3.2.4.1 T3, T351, T3510, T3511, T4, and T42 Temper.	3-134
3.2.4.2 T361 (Supersedes T36) Temper.	3-168
3.2.4.3 T62 and T72 Temper	3-168
3.2.4.4 T81, T851, T852, T8510, and T8511 Temper	3-175
3.2.4.5 T861 (supersedes T86) Temper	3-188
3.2.5 2025 Alloy	3-197

MMPDS-10
1 April 2015

3.2.5.0 Comments and Properties	3-197
3.2.6 2026 Alloy	3-200
3.2.6.0 Comments and Properties	3-200
3.2.7 2027 Alloy	3-202
3.2.7.0 Comments and Properties	3-202
3.2.7.1 T351 Temper	3-202
3.2.7.2 T3511 Temper	3-209
3.2.8 2050 Alloy	3-211
3.2.8.0 Comments and Properties	3-211
3.2.8.1 T84 Temper	3-216
3.2.9 Clad 2056 Alloy	3-226
3.2.9.0 Comments and Properties	3-226
3.2.10 2090 Alloy	3-232
3.2.10.0 Comments and Properties.	3-232
3.2.10.1 T83 Temper	3-234
3.2.11 2098 ALLOY	3-235
3.2.11.0 Comments and Properties	3-235
3.2.11.1 T82P Temper.	3-239
3.2.12 2099 ALLOY	3-245
3.2.12.0 Comments and Properties	3-245
3.2.12.1 T86 Temper	3-249
3.2.12.2 T83 Temper	3-251
3.2.12.3 T81 Temper	3-257
3.2.13 2124 ALLOY	3-259
3.2.13.0 Comments and Properties	3-259
3.2.13.1 T851 Temper.	3-261
3.2.14 2195 ALLOY	3-277
3.2.14.0 Comments and Properties	3-277
3.2.14.1 T8, T82 Temper	3-283
3.2.15 2196 ALLOY	3-289
3.2.15.0 Comments and Properties	3-289
3.2.15.1 T8511 Temper	3-291
3.2.16 2198 ALLOY	3-293
3.2.16.0 Comments and Properties	3-293
3.2.16.1 T8 Temper.	3-296
3.2.17 2219 ALLOY	3-306
3.2.17.0 Comments and Properties	3-306
3.2.17.1 T62 Temper	3-313
3.2.17.2 T81 and T851X Tempers	3-317
3.2.17.3 T852 Temper.	3-325
3.2.17.4 T87 Temper	3-328
3.2.18 2297 ALLOY	3-334
3.2.18.0 Comments and Properties	3-334

MMPDS-10
1 April 2015

3.2.18.1 T87 Temper	3-337
3.2.19 2397 ALLOY	3-343
3.2.19.0 Comments and Properties	3-343
3.2.20 2424 ALLOY	3-346
3.2.20.0 Comments and Properties	3-346
3.2.21 2519 ALLOY	3-349
3.2.21.0 Comments and Properties	3-349
3.2.21.1 T87 Temper	3-351
3.2.22 2524 ALLOY	3-352
3.2.22.0 Comments and Properties	3-352
3.2.22.1 T3 Temper	3-354
3.2.23 2618 ALLOY	3-356
3.2.23.0 Comments and Properties	3-356
3.2.23.1 T61 Temper	3-360
3.2.24 2624 ALLOY	3-366
3.2.24.0 Comments and Properties	3-366
3.2.24.1 T39 Temper	3-369
3.2.24.2 T351 Temper	3-371
3.2.25 2055 ALLOY	3-375
3.2.25.0 Comments and Properties	3-375
3.2.25.1 T84 Temper	3-377
3.2.26 2824 ALLOY	3-382
3.2.26.0 Comments and Properties	3-382
3.3 3000 SERIES WROUGHT ALLOYS	3-385
3.4 4000 SERIES WROUGHT ALLOYS	3-385
3.5 5000 SERIES WROUGHT ALLOYS	3-385
3.5.1 5052 ALLOY	3-385
3.5.1.0 Comments and Properties	3-385
3.5.1.1 O-Temper	3-389
3.5.1.2 H32 Temper	3-391
3.5.1.3 H34 Temper	3-391
3.5.1.4 H36 Temper	3-395
3.5.1.5 H38 Temper	3-395
3.5.2 5083 ALLOY	3-398
3.5.2.0 Comments and Properties	3-398
3.5.2.1 O Temper	3-403
3.5.3 5086 ALLOY	3-405
3.5.3.0 Comments and Properties	3-405
3.5.3.1 O Temper	3-408
3.5.3.2 H32 Temper	3-410
3.5.3.3 H34 Temper	3-412
3.5.3.4 H36 Temper	3-414
3.5.3.5 H38 Temper	3-414

MMPDS-10
1 April 2015

3.5.3.6 H111 Temper	3-414
3.5.3.7 H112 Temper	3-414
3.5.4 5454 ALLOY	3-415
3.5.4.0 Comments and Properties	3-415
3.5.4.1 O Temper	3-418
3.5.4.2 H32 Temper	3-418
3.5.4.3 H34 Temper	3-419
3.5.5 5456 ALLOY	3-420
3.5.5.0 Comments and Properties	3-420
3.5.5.1 O Temper	3-424
3.5.5.2 H111 Temper	3-425
3.5.5.3 H112 Temper	3-425
3.5.5.4 H321 Temper	3-425
3.6 6000 SERIES WROUGHT ALLOYS	3-427
3.6.1 6013 ALLOY	3-427
3.6.1.0 Comments and Properties	3-427
3.6.1.1 T6 Temper	3-429
3.6.2 6061 ALLOY	3-431
3.6.2.0 Comments and Properties	3-431
3.6.2.1 T4, T42, T451, T4510, and T4511 Tempers	3-444
3.6.2.2 T6, T62, T651, T652, T6510, and T6511 Tempers	3-444
3.6.3 6151 ALLOY	3-460
3.6.3.0 Comments and Properties	3-460
3.6.3.1 T6 Temper	3-460
3.6.4 6156 ALLOY	3-463
3.6.4.0 Comments and Properties	3-463
3.6.4.1 T62 Temper	3-465
3.7 7000 SERIES WROUGHT ALLOYS	3-469
3.7.1 7010 ALLOY	3-469
3.7.1.0 Comments and Properties	3-469
3.7.1.1 T7451 Temper	3-472
3.7.1.2 T7651 Temper	3-475
3.7.2 7037 ALLOY	3-477
3.7.2.0 Comments and Properties	3-477
3.7.2.1 T7452 Temper	3-480
3.7.3 7040 ALLOY	3-486
3.7.3.0 Comments and Properties	3-486
3.7.4 7049/7149 ALLOY	3-490
3.7.4.0 Comments and Properties	3-490
3.7.4.1 T73 and T73511 Tempers	3-495
3.7.5 7050 ALLOY	3-507
3.7.5.0 Comments and Properties	3-507
3.7.5.1 T73510 and T73511 Tempers	3-517

MMPDS-10
1 April 2015

3.7.5.2 T74, T7451, and T7452 Tempers	3-525
3.7.5.3 T76510 and T76511 Tempers	3-554
3.7.6 7055 ALLOY	3-559
3.7.6.0 Comments and Properties	3-559
3.7.6.1 T74511 Temper	3-564
3.7.6.2 T76511 Temper	3-571
3.7.6.3 T7751 and T77511 Tempers	3-571
3.7.7 7056 ALLOY	3-574
3.7.7.0 Comments and Properties	3-574
3.7.7.1 T7651 Temper.	3-577
3.7.8 7068 ALLOY	3-581
3.7.8.0 Comments and Properties	3-581
3.7.8.1 T6511 Temper.	3-583
3.7.9 7075 ALLOY	3-588
3.7.9.0 Comments and Properties	3-588
3.7.9.1 T6, T651, T652, T6510, T6511 Temper.	3-610
3.7.9.2 T73, T7351, T7352, T73510, T73511 Tempers	3-643
3.7.10 7085 ALLOY	3-660
3.7.10.0 Comments and Properties	3-660
3.7.10.1 T7451 Temper	3-668
3.7.10.2 T7651 Temper	3-670
3.7.10.3 T7452 Temper	3-672
3.7.11. 7136 ALLOY.	3-692
3.7.11.0. Comments and Properties.	3-692
3.7.11.1. T76511 Temper	3-694
3.7.12 7140 ALLOY	3-697
3.7.12.0 Comments and Properties	3-697
3.7.12.1 T7451 Temper	3-701
3.7.12.2 T7651 Temper	3-704
3.7.13 7150 ALLOY	3-710
3.7.13.0 Comments and Properties	3-710
3.7.13.1 T6151 and T61511 Tempers	3-716
3.7.13.2 T7751 and T77511 Tempers	3-718
3.7.14 7175 ALLOY	3-723
3.7.14.0 Comments and Properties	3-723
3.7.14.1 T73511 Temper.	3-728
3.7.14.2 T74 and T7452 Tempers	3-733
3.7.15 7249 ALLOY	3-738
3.7.15.0 Comments and Properties	3-738
3.7.15.1 T7452 Temper	3-742
3.7.15.2 T76511 Temper.	3-744
3.7.16 7255 ALLOY	3-746
3.7.16.0 Comments and Properties	3-746

MMPDS-10
1 April 2015

3.7.16.1 T7751 Temper	3-748
3.7.17 7349 ALLOY	3-750
3.7.17.0 Comments and Properties	3-750
3.7.17.1 T76511 Temper	3-752
3.7.18 7449 ALLOY	3-754
3.7.18.0 Comments and Properties	3-754
3.7.18.1 T7651 Temper	3-761
3.7.18.2 T7951 Temper	3-764
3.7.18.3 T79511 Temper	3-767
3.7.19 7475 ALLOY	3-770
3.7.19.0 Comments and Properties	3-770
3.7.19.1 T61 and T651 Tempers	3-774
3.7.19.2 T7351 Temper	3-783
3.7.19.3 T761 and T7651 Tempers	3-791
3.7.20 7065 ALLOY	3-799
3.7.20.0 Comments and Properties	3-799
3.7.20.1 T7451 Temper	3-804
3.7.20.2 T7651 Temper	3-811
3.8 200.0 SERIES CAST ALLOYS	3-819
3.8.1 A201.0 ALLOY	3-819
3.8.1.0 Comments and Properties	3-819
3.8.1.1 T7 Temper	3-822
3.8.2 205/TIB2/3P ALLOY	3-829
3.8.2.0 Comments and Properties	3-829
3.8.2.1. Investment Casting	3-831
3.8.2.2. Sand Casting	3-836
3.9 300.0 SERIES CAST ALLOYS	3-841
3.9.1 354.0 ALLOY	3-841
3.9.1.0 Comments and Properties	3-841
3.9.2 355.0 ALLOY	3-843
3.9.2.0 Comments and Properties	3-843
3.9.3 C355.0 ALLOY	3-846
3.9.3.0 Comments and Properties	3-846
3.9.4 356.0 ALLOY	3-848
3.9.4.0 Comments and Properties	3-848
3.9.5 A356.0 ALLOY	3-851
3.9.5.0 Comments and Properties	3-851
3.9.5.1 T6 Temper	3-854
3.9.6 A357.0/F357.0 ALLOY	3-855
3.9.6.0 Comments and Properties	3-855
3.9.6.1 T6 Temper	3-858
3.9.7 D357.0/E357.0 ALLOY	3-859
3.9.7.0 Comments and Properties	3-859

MMPDS-10
1 April 2015

3.9.7.1 T6 Temper	3-862
3.9.8 359.0 ALLOY	3-865
3.9.8.0 Comments and Properties	3-865
3.10 ELEMENT PROPERTIES	3-867
3.10.1 BEAMS	3-867
3.10.1.1 Simple Beams	3-867
3.10.1.2 Built-Up Beams.	3-868
3.10.1.3 Thin-Web Beams	3-868
3.10.2 COLUMNS.	3-869
3.10.2.1 Primary Failure	3-869
3.10.2.2 Local Failure	3-869
3.10.2.3 Column Properties.	3-869
3.10.3 TORSION	3-871
3.10.3.1 General	3-871
3.10.3.2 Torsion Properties.	3-871
REFERENCES	3-875

Table of Contents

CHAPTER 4 - MAGNESIUM ALLOYS	4-1
4.1 GENERAL.	4-1
4.1.1 ALLOY INDEX	4-1
4.1.2 MATERIAL PROPERTIES.	4-1
4.1.2.1 Mechanical Properties.	4-1
4.1.3 PHYSICAL PROPERTIES	4-4
4.1.4 ENVIRONMENTAL CONSIDERATIONS	4-4
4.1.5 ALLOY AND TEMPER DESIGNATIONS	4-4
4.1.6 JOINING METHODS	4-6
4.1.7 OBSOLETE ALLOYS, TEMPERS, AND PRODUCT FORMS	4-6
4.2 MAGNESIUM-WROUGHT ALLOYS	4-9
4.2.1 AZ31B	4-9
4.2.1.0 Comments and Properties	4-9
4.2.1.1 AZ31B-O Temper	4-15
4.2.1.2 AZ31B-H24 Temper	4-16
4.2.1.4 AZ31B-F Temper	4-19
4.2.2 AZ61A	4-21
4.2.2.0 Comments and Properties	4-21
4.2.3 WE43C (Elektron 43)	4-23
4.2.3.0 Comments and Properties	4-23
4.2.3.1 WE43C-T5 Temper	4-27
4.2.4 ZK60A	4-35
4.2.4.0 Comments and Properties	4-35
4.2.4.1 ZK60A-F Temper	4-35
4.2.4.2 ZK60A-T5 Temper	4-39
4.3 MAGNESIUM CAST ALLOYS	4-43
4.3.1 AM100A	4-43
4.3.1.0 Comments and Properties	4-43
4.3.2 AZ91C/AZ91E	4-45
4.3.2.0 Comments and Properties	4-45
4.3.2.1 T6 Temper	4-48
4.3.3 AZ92A	4-49
4.3.3.0 Comments and Properties	4-49
4.3.3.1 AZ92A-T6 Temper	4-52
4.3.4 EV31A (ELEKTRON 21) ALLOY	4-55
4.3.4.0 Comments and Properties	4-55
4.3.4.1. T6 Temper	4-57
4.3.5 EZ33A	4-61
4.3.5.0 Comments and Properties	4-61
4.3.5.1 EZ33A-T5 Temper	4-64
4.3.6 QE22A	4-66

MMPDS-10
1 April 2015

4.3.6.0 Comments and Properties	4-66
4.3.6.1 QE22A-T6 Temper	4-68
4.3.7 ZE41A	4-70
4.3.7.0 Comments and Properties	4-70
4.3.7.1 T5 Temper	4-73
4.4 ELEMENT PROPERTIES	4-75
4.4.1 BEAMS	4-75
4.4.1.1 Simple Beams	4-75
4.4.1.2 Built-Up Beams	4-75
4.4.1.3 Thin-Web Beams	4-75
4.4.2 COLUMNS	4-75
4.4.2.1 Primary Failure	4-75
4.4.2.2 Local Failure	4-76
4.4.2.3 Column Properties	4-76
4.4.3 TORSION	4-78
4.4.3.1 General	4-78
4.4.3.2 Torsion Properties	4-78
REFERENCES	4-79

Table of Contents

CHAPTER 5 - TITANIUM	5-1
5.1 GENERAL	5-1
5.1.1 TITANIUM INDEX	5-1
5.1.2 MATERIAL PROPERTIES	5-1
5.1.2.1 Mechanical Properties	5-2
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
5.2.1.0 Comments and Properties	5-7
5.2.1.1 Annealed Condition	5-12
5.3 ALPHA AND NEAR-ALPHA TITANIUM ALLOYS.	5-17
5.3.1 Ti-5Al-2.5Sn	5-17
5.3.1.0 Comments and Properties	5-17
5.3.1.1 Annealed Condition	5-23
5.3.2 Ti-8Al-1Mo-1V	5-32
5.3.2.0 Comments and Properties	5-32
5.3.2.1 Single-Annealed Condition.	5-37
5.3.2.2 Duplex-Annealed Condition	5-40
5.3.3 Ti-6Al-2Sn-4Zr-2Mo	5-48
5.3.3.0 Comments and Properties	5-48
5.3.3.1 Single, Duplex, and Triplex Annealed	5-53
5.4 ALPHA-BETA TITANIUM ALLOYS.	5-57
5.4.1 Ti-6Al-4V	5-57
5.4.1.0 Comments and Properties	5-57
5.4.1.1 Annealed Condition	5-71
5.4.1.2 Solution-Treated and Aged Condition	5-104
5.4.2 Ti-6Al-6V-2SN	5-123
5.4.2.0 Comments and Properties	5-123
5.4.2.1 Annealed Condition	5-129
5.4.2.2 Solution-Treated and Aged Condition	5-139
5.4.3 Ti-4.5Al-3V-2FE-2Mo	5-140
5.4.3.0 Comments and Properties	5-140
5.4.3.1 Anneal Condition	5-140
5.4.4 Ti-4Al-2.5V-1.5FE	5-149
5.4.4.0 Comments and Properties	5-149
5.4.4.1 Cold Rolled Sheet, Annealed Condition.	5-155
5.4.4.2 Hot Rolled Sheet and Plate, Annealed Condition	5-163
5.5 BETA, NEAR-BETA, AND METASTABLE-BETA TITANIUM ALLOYS.	5-171
5.5.1 Ti-13V-11Cr-3Al	5-171

MMPDS-10
1 April 2015

5.5.1.0 Comments and Properties	5-171
5.5.1.1 Annealed Condition	5-175
5.5.1.2 Solution-Treated and Aged Condition	5-182
5.5.2 Ti-15V-3CR-3SN-3AL (Ti-15-3)	5-188
5.5.2.0 Comments	5-188
5.5.2.1 Solution-Treated and Aged (1000°F) Condition	5-191
5.5.3 Ti-10V-2FE-3AL (Ti-10-2-3)	5-192
5.5.3.0 Comments and Properties	5-192
5.5.3.1 Solution Treated and Aged (900° to 950°F) Condition	5-195
5.5.3.2 Solution Treated and Aged (950° to 1000°F) Condition	5-196
5.6 ELEMENT PROPERTIES.	5-197
5.6.1 BEAMS.	5-197
5.6.1.1 Simple Beams	5-197
REFERENCES	5-199

Table of Contents

CHAPTER 6 - HEAT-RESISTANT ALLOYS	6-1
6.1 GENERAL	6-1
6.1.1 MATERIAL PROPERTIES	6-1
6.1.1.1 Mechanical Properties	6-1
6.1.1.2 Physical Properties	6-3
6.1.2 Obsolete Alloys, Tempers, and Product Forms	6-3
6.2 IRON-CHROMIUM-NICKEL-BASE ALLOYS	6-5
6.2.0 GENERAL COMMENTS	6-5
6.2.0.1 Metallurgical Considerations	6-5
6.2.0.2 Manufacturing Considerations	6-5
6.2.1 A-286	6-5
6.2.1.0 Comments and Properties	6-5
6.2.1.1 Solution-Treated and Aged Condition	6-8
6.2.2 N-155	6-16
6.2.2.0 Comments and Properties	6-16
6.2.2.1 Solution-Treated Condition	6-18
6.3 NICKEL-BASE ALLOYS	6-21
6.3.0 GENERAL COMMENTS	6-21
6.3.0.1 Metallurgical Considerations	6-21
6.3.0.2 Manufacturing Considerations	6-21
6.3.1 HASTELLOY X	6-23
6.3.1.0 Comments and Properties	6-23
6.3.1.1 Solution Treated Condition	6-26
6.3.2 INCONEL 600	6-29
6.3.2.0 Comments and Properties	6-29
6.3.2.1 Annealed Condition	6-34
6.3.3 INCONEL 625	6-36
6.3.3.0 Comments and Properties	6-36
6.3.3.1 Annealed Condition	6-39
6.3.4 INCONEL 706	6-47
6.3.4.0 Comments and Properties	6-47
6.3.4.1 Solution-Treated and Aged Condition (Creep Rupture Heat Treatment)	6-50
6.3.5 718 ALLOY	6-54
6.3.5.0 Comments and Properties	6-54
6.3.5.1 Solution-Treated and Aged Condition	6-60
6.3.6 INCONEL X-750	6-93
6.3.6.0 Comments and Properties	6-93
6.3.6.1 Annealed and Aged	6-95
6.3.6.2 Equalized and Aged	6-97
6.3.7 RENÉ 41	6-99

MMPDS-10
1 April 2015

6.3.7.0 Comments and Properties	6-99
6.3.7.1 Solution Treated at 1975° F and Aged at 1400° F Condition	6-102
6.3.8 WASPALOY	6-122
6.3.8.0 Comments and Properties	6-122
6.3.8.1 Aged Condition	6-124
6.3.9. 230 ALLOY.	6-128
6.3.9.0. Comments and Properties	6-128
6.3.9.1. Annealed Condition	6-132
6.3.10 HR-120 ALLOY.	6-141
6.3.10.0 Comments and Properties	6-141
6.3.10.1 Annealed Condition	6-141
6.3.11 HAYNES 282 ALLOY	6-147
6.3.11.0 Comments and Properties	6-147
6.3.11.1 Precipitation Hardened Condition.	6-148
6.4 COBALT-BASE ALLOYS	6-161
6.4.0 GENERAL COMMENTS	6-161
6.4.0.1 Metallurgical Considerations	6-161
6.4.0.2 Manufacturing Considerations	6-161
6.4.0.3 Special Precautions	6-161
6.4.1 L-605 (25 alloy)	6-162
6.4.1.0 Comments and Properties	6-162
6.4.1.1 Solution Treated Condition.	6-165
6.4.2 188 ALLOY	6-185
6.4.2.0 Comments and Properties	6-185
6.4.2.1 Solution-Treated Condition.	6-187
REFERENCES	6-201

Table of Contents

CHAPTER 7 - 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
7.2.1.0 Comments and Properties	7-3
7.2.1.1 Hot-Pressed Condition	7-8
7.2.1.2 HIP'd Condition	7-12
7.3 COPPER AND COPPER ALLOYS	7-13
7.3.0 GENERAL	7-13
7.3.1 MANGANESE BRONZES	7-14
7.3.1.0 Comments and Properties	7-14
7.3.2 COPPER BERYLLIUM	7-17
7.3.2.0 Comments and Properties	7-17
7.3.2.1 TF00 Temper	7-24
7.3.2.2 TH04 Temper	7-25
7.3.3 COPPER-NICKEL-TIN (SPINODAL ALLOY)	7-26
7.3.3.0 Comments and Properties	7-26
7.3.3.1 TX00 Temper	7-30
7.3.3.2 TX TS Temper	7-32
7.3.4 ALUMINUM BRONZES	7-35
7.3.4.0 Comments and Properties	7-35
7.4 MULTIPHASE ALLOYS	7-37
7.4.0 GENERAL	7-37
7.4.1 MP35N ALLOY	7-37
7.4.1.0 Comments and Properties	7-37
7.4.1.1 Cold Worked and Aged Condition	7-39
7.4.2 MP159 ALLOY	7-42
7.4.2.0 Comments and Properties	7-42
7.4.2.1 Cold Worked and Aged Condition	7-44
7.5 ALUMINUM ALLOY SHEET LAMINATES	7-47
7.5.0 GENERAL	7-47
7.5.1 2024-T3 ARAMID FIBER REINFORCED SHEET LAMINATE	7-47
7.5.1.0 Comments and Properties	7-47
7.5.1.1 T3 Temper	7-49
7.5.2 7475-T761 ARAMID FIBER REINFORCED SHEET LAMINATE	7-55
7.5.2.0 Comments and Properties	7-55
7.5.2.1 T761 Temper	7-57
7.6 ALUMINUM-BERYLLIUM HYBRIDS	7-65
7.6.0 GENERAL	7-65

MMPDS-10
1 April 2015

7.6.1 AL-62BE	7-65
7.6.1.0 Comments and Properties	7-65
7.6.1.1 Hot Isostatic Pressed Condition	7-67
REFERENCES	7-79

Table of Contents

CHAPTER 8 - STRUCTURAL JOINTS.	8-1
8.1 MECHANICALLY FASTENED JOINTS	8-2
8.1.1 INTRODUCTION AND FASTENER INDEXES	8-2
8.1.1.1 Data Sources	8-12
8.1.1.2 Fastener Shear Strengths.	8-12
8.1.1.3 Edge Distance Requirements	8-12
8.1.2 SOLID RIVETS	8-27
8.1.2.1 Protruding-Head Solid Rivet Joints.	8-27
8.1.2.2 Flush-Head Solid Rivet Joints.	8-27
8.1.3 BLIND FASTENERS	8-38
8.1.3.1 Protruding-Head Blind Fasteners	8-38
8.1.3.2 Flush-Head Blind Fasteners	8-38
8.1.4 SWAGED COLLAR/UPSET-PIN FASTENERS	8-81
8.1.4.1 Protruding-Head Swaged Collar Fastener Joints.	8-81
8.1.4.2 Flush-Head Swaged Collar Fastener Joints.	8-82
8.1.5 THREADED FASTENERS	8-92
8.1.5.1 Protruding-Head Threaded Fastener Joints.	8-92
8.1.5.2 Flush-Head Threaded Fastener Joints.	8-93
8.1.6 SPECIAL FASTENERS	8-100
8.1.6.1 Fastener Sleeves	8-100
8.1.6.2 Sleeve Bolts.	8-100
8.2 METALLURGICAL JOINTS	8-103
8.2.1 INTRODUCTION AND DEFINITIONS.	8-103
8.2.2 WELDED JOINTS	8-103
8.2.2.1 Fusion Welding—Arc and Gas	8-104
8.2.2.2 Flash and Pressure Welding	8-105
8.2.2.3 Spot and Seam Welding	8-105
8.3 BEARINGS, PULLEYS, AND WIRE ROPE	8-125
REFERENCES	8-127

Table of Contents

CHAPTER 9 - GUIDELINES FOR THE PRESENTATION OF DATA

9.1 GENERAL INFORMATION	9-1
9.1.1 INTRODUCTION	9-1
9.1.2 CROSS INDEX	9-1
9.1.3 APPLICABILITY	9-1
9.1.4 APPROVAL PROCEDURES	9-1
9.1.5 DOCUMENTATION REQUIREMENTS	9-1
9.1.6 SUMMARY	9-4
9.1.7 Data Basis	9-6
9.1.7.1 Data Basis for Mechanical Properties (Chapters 2-7)	9-6
9.1.7.2 Data Basis for Mechanically Fastened Joint Allowables (Chapters 8)	9-8
9.1.8 Rounding Procedures	9-9
9.1.9 Applicable Analysis Methods	9-9
9.2 MATERIAL, SPECIFICATION, TESTING, AND DATA REQUIREMENTS	9-11
9.2.1 MATERIAL REQUIREMENTS	9-11
9.2.2 SPECIFICATION REQUIREMENTS	9-11
9.2.3 REQUIRED TEST METHODS/PROCEDURES	9-11
9.2.3.1 Mechanical-Property Terms	9-14
9.2.3.2 Testing Direction and Specimen Location	9-14
9.2.3.3 Tension, Compression, Shear and Bearing	9-16
9.2.3.4 Other Static Properties	9-16
9.2.3.5 Required Test Methods to Determine Dynamic and Time Dependent Properties	9-17
9.2.3.6 Mechanically Fastened Joints	9-23
9.2.3.7 Fusion-Welded Joints	9-24
9.2.4 DATA REQUIREMENTS	9-25
9.2.4.1 S-Basis Values	9-25
9.2.4.2 A- and B-Basis Values	9-26
9.2.4.3 Derived Property Values	9-31
9.2.4.4 Other Static Properties	9-32
9.2.4.5 Data Requirements for Determination of Dynamic and Time Dependent Properties	9-36
9.2.4.6 Mechanically Fastened Joints	9-40
9.2.4.7 Fastener Strength Table Sunset Clause	9-44
9.2.4.8 Fusion-Welded Joints	9-51
9.2.5 EXPERIMENTAL DESIGN	9-51
9.2.5.1 Uniformity of Sample Size across Thickness Range	9-51
9.2.5.2 Fatigue	9-52
9.2.5.3 Creep-Rupture	9-58
9.2.5.4 Fusion-Welded Joints	9-60

9.3 SUBMISSION OF DATA	9-63
9.3.1 RECOMMENDED PROCEDURES	9-63
9.3.2 COMPUTER SOFTWARE	9-63
9.3.3 INTRODUCTORY SECTION.	9-63
9.3.4 GENERAL DATA FORMATS	9-63
9.3.4.1 Data Format for the Computation of T99 and T90 Values	9-64
9.3.4.2 Data Format for Derived Properties	9-64
9.3.4.3 Data Format for the Construction of Typical Stress-Strain Curves	9-68
9.3.4.4 Data Format for Fasteners	9-68
9.3.4.5 Data Format for Other Properties	9-69
9.4 SUBSTANTIATION OF PROPERTIES	9-73
9.4.1 S-BASIS MINIMUM PROPERTIES	9-73
9.4.2 VALIDATING DESIGN PROPERTIES FOR EXISTING MATERIALS (WHEN A CHANGE INPROCESSING HAS OCCURRED)	9-74
9.4.3 CONFIRMATION OF DESIGN PROPERTIES FOR LEGACY ALLOYS	9-75
9.4.3.1 Initial Steps and Analysis	9-75
9.4.3.2 Increase in Design Properties	9-75
9.4.3.3 Decrease in Design Properties.	9-76
9.4.3.4 Derived Properties	9-76
9.5 ANALYSIS PROCEDURES FOR STATISTICALLY COMPUTED MINIMUM STATICPROPERTIES	9-81
9.5.1 SPECIFYING THE POPULATION	9-81
9.5.1.1 Deciding Between Direct and Indirect Computation	9-81
9.5.1.2 Testing for Regression Effects and Homogeneity	9-84
9.5.1.3 Data Transformation	9-88
9.5.2 REGRESSION ANALYSIS.	9-96
9.5.2.1 Linear Regression	9-96
9.5.2.2 Quadratic Regression	9-98
9.5.2.3 Tests for Adequacy of a Regression	9-101
9.5.2.4 Testing for Equality of Several Regressions	9-103
9.5.3 COMBINABILITY OF DATA	9-106
9.5.3.1 The k-Sample Anderson-Darling Test	9-106
9.5.3.2 The F Test	9-108
9.5.3.3 The t Test	9-109
9.5.4 DETERMINING THE FORM OF DISTRIBUTION	9-111
9.5.4.1 “Anderson-Darling” Test for Normality.	9-111
9.5.4.2 Normal Probability Plot	9-112
9.5.4.3 Three-Parameter Weibull Acceptability Test	9-112
9.5.4.4 Modified Anderson-Darling Test for Pearsonality	9-114
9.5.4.5 The Pearson Backoff Option	9-115
9.5.4.6 Pearson Probability Plot	9-115

9.5.4.7 Modified “Anderson-Darling” Test for Weibullness	9-118
9.5.4.8 The Weibull Backoff Option	9-120
9.5.4.9 Weibull Probability Plots	9-121
9.5.4.10 Detection of Lower-Tail Truncation	9-123
9.5.5 DIRECT COMPUTATION WITHOUT REGRESSION	9-125
9.5.5.1 Sequential Pearson Procedure	9-130
9.5.5.2. Sequential Weibull Procedure	9-131
9.5.5.3 Nonparametric Procedure	9-132
9.5.5.4 Censored Normal Procedure	9-133
9.5.6 DIRECT COMPUTATION BY REGRESSION ANALYSIS	9-134
9.5.6.1 Performing the Regression	9-134
9.5.7 INDIRECT COMPUTATION WITHOUT REGRESSION (REDUCED RATIOS/ DERIVED PROPERTIES)	9-135
9.5.7.1 Treatment of Grain Direction	9-136
9.5.7.2 Treatment of Test Specimen Location	9-137
9.5.7.3 Treatment of Clad Aluminum Alloy Plate	9-137
9.5.7.4 Computational Procedure	9-138
9.5.8 INDIRECT COMPUTATION USING REGRESSION	9-139
9.5.9 Handling of Derived Property Test Results Below Estimated Design Allowable	9-140
9.5.10 INDIRECT COMPUTATION OF EDGEWISE BEARING REDUCTIONS	9-142
9.6 ANALYSIS PROCEDURES FOR DYNAMIC AND TIME DEPENDENT PROPERTIES	9-143
9.6.1 LOAD AND STRAIN CONTROL FATIGUE DATA	9-143
9.6.1.1 Data Collection and Interpretation	9-146
9.6.1.2 Analysis of Data	9-147
9.6.1.3 Fatigue Life Models	9-148
9.6.1.4 Evaluation of Mean Stress and Strain Effects	9-150
9.6.1.5 Estimation of Fatigue-Life Model Parameters	9-151
9.6.1.6 Treatment of Outliers	9-157
9.6.1.7 Assessment of the Fatigue Life Model	9-158
9.6.1.8 Data Set Combination	9-160
9.6.1.9 Treatment of Runouts	9-161
9.6.1.10 Recognition of Time Dependent Effects	9-162
9.6.1.11 Estimation of Lower Tolerance Bounds for Fatigue Data	9-163
9.6.2 FATIGUE CRACK GROWTH DATA	9-163
9.6.2.1 Data Collection and Interpretation	9-164
9.6.3 FRACTURE TOUGHNESS DATA	9-166
9.6.3.1 Plane-Strain Fracture Toughness Data	9-166
9.6.3.2 Plane Stress and Transitional Fracture Toughness	9-167
9.6.3.3 Crack Resistance (R-Curve)	9-168
9.6.4 CREEP AND CREEP-RUPTURE DATA	9-174

9.6.4.1 Data Collection and Interpretation	9-174
9.6.4.2 Analysis of Data	9-176
9.7 ANALYSIS PROCEDURES FOR STRUCTURAL JOINT PROPERTIES	9-181
9.7.1 MECHANICALLY FASTENED JOINTS	9-181
9.7.1.1 Definitions	9-182
9.7.1.2 Yield Load Determination	9-183
9.7.1.3 Shear Strength of Fastener	9-188
9.7.1.4 Sheet Critical and Transition Critical Strengths	9-189
9.7.1.5 Calculation of Allowable Loads	9-208
9.7.2 FUSION-WELDED JOINT DATA	9-210
9.7.2.1 Data Collection and Interpretation	9-210
9.7.2.2 Data Analysis	9-212
9.8 Examples of Data Analysis and Data Presentation For StaticProperties	9-213
9.8.1 DIRECT ANALYSES OF MECHANICAL PROPERTIES	9-213
9.8.2 INDIRECT ANALYSES OF MECHANICAL PROPERTIES	9-226
9.8.3 TABULAR DATA PRESENTATION	9-230
9.8.3.1 Mechanical Properties	9-230
9.8.3.2 Modulus of Elasticity and Poisson's Ratio	9-235
9.8.3.3 Physical Properties	9-236
9.8.4 ROOM TEMPERATURE GRAPHICAL MECHANICAL PROPERTY DATA	9-236
9.8.4.1 Typical Stress-Strain	9-236
9.8.4.2 Compression-Tangent-Modulus Curves	9-247
9.8.4.3 Full-Range Tensile Stress-Strain Curves	9-250
9.8.4.4 Minimum Stress-Strain and Stress Tangent-Modulus Curves	9-255
9.8.4.5 Biaxial Stress-Strain Behavior	9-255
9.8.4.6 Mathematical Representation of Stress-Strain Curves	9-256
9.8.5 ELEVATED TEMPERATURE GRAPHICAL MECHANICAL PROPERTIES	9-259
9.8.5.1 Strength Properties	9-259
9.8.5.2 Elongation and Reduction of Area	9-271
9.8.5.3 Modulus of Elasticity	9-271
9.8.5.4 Physical Properties	9-272
9.8.5.5 Effect of Thermal Exposure on Room Temperature Strength	9-273
9.8.5.6 Effect of Thermal Exposure on Elevated Temperature Strength	9-274
9.8.5.7 Simple Exposure	9-275
9.8.5.8 Complex Exposure	9-276
9.9 EXAMPLES OF DATA FOR DYNAMIC AND TIME DEPENDANT PROPERTIES	9-279
9.9.1 FATIGUE	9-279

9.9.1.2 Strain Control	9-293
9.9.2 FATIGUE CRACK GROWTH	9-296
9.9.3 FRACTURE TOUGHNESS	9-303
9.9.3.1 Plane Strain	9-303
9.9.3.2 Plane Stress	9-303
9.9.4 CREEP AND CREEP RUPTURE	9-304
9.9.4.1 Creep-Rupture Example Problem	9-305
9.9.5 Mechanically Fastened Joints	9-311
9.9.5.1 Example Analysis Problem for Three Diameter Blind Fastener Dataset	9-317
9.9.6 Fusion-Welded Joints	9-354
9.9.6.1 Additional Information	9-354
9.9.6.2 Room-Temperature Properties	9-354
9.9.6.3 Data on Effect of Temperature	9-355
9.9.6.4 Use of Design Data	9-356
9.10 STATISTICAL TABLES	9-357
REFERENCES	9-379