

AIRCRAFT MATERIALS

and PROCESSES

by

GEORGE F. TITTERTON

Assistant Chief Engineer, Grumman Aircraft Engineering Corporation

Formerly Faculty Lecturer, Graduate Division, College of

Engineering, New York University

Fifth Edition



PITMAN PUBLISHING CORPORATION

NEW YORK

TORONTO

LONDON

COPYRIGHT, 1956
BY
PITMAN PUBLISHING CORPORATION

All rights reserved. No part of this book
may be reproduced in any form without
the written permission of the publisher.

5.1

Associated Companies
SIR ISAAC PITMAN & SONS, LTD.
London Melbourne Johannesburg
SIR ISAAC PITMAN & SONS (CANADA), LTD.
Toronto

PRINTED IN THE UNITED STATES OF AMERICA

AIRCRAFT MATERIALS AND PROCESSES

PITMAN AERONAUTICAL PUBLICATIONS

Aeronautical Engineering Series

Teichmann: AIRPLANE DESIGN MANUAL

Titterton: AIRCRAFT MATERIALS AND PROCESSES

Katz: PRINCIPLES OF AIRCRAFT PROPULSION MACHINERY

Pope: AERODYNAMICS OF SUPERSONIC FLIGHT

Dommasch, Sherby, and Connolly: AIRPLANE AERODYNAMICS

Steinbacher and Gerard: AIRCRAFT STRUCTURAL MECHANICS

Dommasch: PRINCIPLES OF AERODYNAMICS

Dommasch: ELEMENTS OF PROPELLER AND HELICOPTER AERODYNAMICS



Grumman Tiger—Navy Supersonic Fighter

PREFACE TO FIFTH EDITION

During the past few years, rapid advancements have been made in aircraft performance, structural materials, and processes. Advances in the quality of new materials such as titanium, high-temperature materials, plastics, and super-strength steels indicate that these new materials should find wide use in the aircraft industries in the near future. Emphasis has been placed on the effects of heat from aerodynamic heating and jet engine heating on aircraft materials in order to help the engineer select the most efficient materials. The author has included all of the latest processes, materials, and specifications.

PREFACE TO THE FOURTH EDITION

The great expansion of the aircraft industry that is currently under way has made it desirable to bring this text right up to date. This will make the latest information on materials and processes readily available to the newcomers as well as the experienced designers, engineers, and mechanics.

PREFACE TO THE THIRD EDITION

During the war years many new materials and processes have been developed. Many of these have been specifically designed for aircraft applications. The author has made an effort to include all the latest materials and processes in the revised text. Many of those described are so new that they have not yet acquired an extensive manufacturing and service background. The basic data on materials that show promise have been included in the revised text to keep this revision up-to-date for as long a time as possible.

PREFACE TO THE SECOND EDITION

The reception this book received during the last four years has indicated its value to students, engineers, designers and shop men. At this time of national emergency, the book has been carefully revised to include the latest materials and processes. It is the author's hope that the revised edition will prove useful in training the new personnel now entering the rapidly expanding aircraft industry.

PREFACE TO THE FIRST EDITION

The author's purpose in writing this book was to present in one coordinated volume the essential information on materials and processes used in the construction of aircraft. Unimportant details have been purposely omitted in the interest of brevity and readability. Within the aircraft field this volume is rather general in scope and should meet the needs of students, engineers, and designers, as well as practical shop men.

This book is based largely upon a series of lectures given by the author at New York University. Similar lectures were also given to a miscellaneous group composed of engineers, shop men, and purchasing department employees of a large aircraft manufacturing corporation. Both in these lectures and the book itself, the author has drawn freely on a fund of information obtained while employed as an engineer in the Naval Inspection Service. As a result, the latest materials and processes used in aircraft construction have been described from a utilitarian point of view. Numerous suggestions have been included on the choice of material for a particular job and on the best way of working, heat treating, and finishing materials for specific applications.

The technical data for a book of this type must, of necessity, be collected from many sources. Government publications have been used to a large extent. These include Army, Navy, and Federal specifications as well as reports of the Forest Products Laboratory. The Handbook of the Society of Automotive Engineers has also been invaluable for reference purposes. The author is also indebted to many persons and companies for their coöperation in supplying data, and for proofreading portions of the text. The following named deserve special mention for their efforts along these lines:

Mr. Frederick C. Pyne of the Aluminum Company of America

Mr. Frank G. Flocke of the International Nickel Company

Mr. Harry A. Goslar of the Naval Inspection Service

The Dow Chemical Company

The author also wishes to thank those who so generously provided illustrations for the text. In so far as possible these contributions have been acknowledged in the title of the illustration.

It is, of course, improbable that a book such as this is wholly free of errors. The author will appreciate having errors brought to his attention to insure their correction in future revisions of this volume.

GEORGE F. TITTERTON.

CONTENTS

| | PAGE |
|--|------|
| PREFACES | v |
| ILLUSTRATIONS | xv |
| TABLES | xvii |
| CHAPTER I. DEFINITIONS | 1 |
| <i>Physical terms:</i> Hardness; Brittleness; Malleability; Ductility; Elasticity; Density; Fusibility; Conductivity; Contraction and Expansion. | |
| <i>Heat-treatment Terms:</i> Critical Range; Annealing; Normalizing; Heat Treatment; Hardening; Quenching; Tempering; Car- burizing; Casehardening. | |
| <i>Physical-test Terms:</i> Strain; Stress; Tensile Strength; Elastic Limit; Proportional Limit; Proof Stress; Yield Strength; Yield Point; Elongation (Percentage); Reduction of Area (Percentage); Modulus of Elasticity. | |
| CHAPTER II. TESTING AIRCRAFT MATERIALS | 5 |
| <i>Tension Testing:</i> Elastic-limit Determination; Proof-stress Determination; Yield-strength Determination; Yield-point Determination. | |
| <i>Hardness Testing:</i> Brinell Hardness; Rockwell Hardness; Diamond Pyramid (Vickers) Hardness; Shore Scleroscope Hardness. | |
| <i>Bending Tests:</i> Reverse Bend Test; Flattening Test. | |
| <i>Impact Tests:</i> Izod Test; Charpy Test. | |
| <i>Crushing Tests</i> | |
| <i>Hydrostatic Test</i> | |
| <i>Torsion Test</i> | |
| <i>Fatigue Testing</i> | |
| <i>Inspection Methods:</i> Radiography; Magnaflux. | |
| CHAPTER III. STEEL AND ITS ALLOYS | 22 |
| <i>Plain Carbon Steels</i> | |
| <i>Alloy Steels</i> | |
| <i>Effect of Individual Elements:</i> Carbon; Manganese; Silicon; Sulphur; Phosphorus; Nickel; Chromium; Molybdenum; Vanadium; Tungsten; Titanium. | |
| <i>S.A.E. Steel Numbering System</i> | |
| <i>Army-Navy Aeronautical Specifications, Military specifications</i> | |

| | PAGE |
|---|------|
| CHAPTER IV. AIRCRAFT STEELS—PROPERTIES AND USES | 29 |
| <i>Carbon Steels:</i> S.A.E. 1015; S.A.E. 1020; S.A.E. 1025; S.A.E. 1035; S.A.E. 1045; S.A.E. 1095. | |
| <i>Nickel Steels:</i> S.A.E. 2320; S.A.E. 2330; S.A.E. 2515. | |
| <i>Nickel-chromium Steels:</i> S.A.E. 3115; S.A.E. 3140; S.A.E. 3250; S.A.E. 3312. | |
| <i>Molybdenum Steels:</i> S.A.E. 4037; S.A.E. 4130; S.A.E. 4135; S.A.E. 4140; S.A.E. 4340; S.A.E. 4615. | |
| <i>Chrome-vanadium Steels:</i> S.A.E. 6115; S.A.E. 6135; S.A.E. 6150; S.A.E. 6195; S.A.E. 8620; S.A.E. 8630; S.A.E. 8735; S.A.E. 8740; S.A.E. 9260. | |
| <i>Special Steels:</i> Silicon-chromium Steel; Nitriding Steel; Austenitic Manganese Steel. | |
| CHAPTER V. HEAT TREATMENT OF STEEL | 43 |
| <i>Critical Range</i> | |
| <i>Internal Structure of Steel</i> | |
| <i>Theory of Heat Treatment:</i> Annealing; Normalizing; Hardening; Drawing (Tempering). | |
| <i>Practical Heat Treatment:</i> Heating; Soaking; Quenching. | |
| <i>Heat Treatments for Aircraft Steels</i> | |
| S.A.E. 1025— <i>Mild-carbon Steel:</i> Normalizing; Heat Treatment. | |
| S.A.E. 1035— <i>Medium-carbon Steel:</i> Heat Treatment. | |
| S.A.E. 1045— <i>Medium-carbon Steel:</i> Heat Treatment. | |
| S.A.E. 1095— <i>High-carbon Steel:</i> Heat Treatment. | |
| S.A.E. 2330— <i>Nickel Steel:</i> Heat Treatment. | |
| S.A.E. 3140— <i>Chrome-nickel Steel:</i> Heat Treatment. | |
| S.A.E. 3047— <i>Molybdenum Steel:</i> Heat Treatment. | |
| S.A.E. 4130— <i>Chrome-molybdenum Steel:</i> Annealing; Normalizing; Heat Treatment. | |
| S.A.E. 4140— <i>Chrome-molybdenum Steel (High Carbon)</i> | |
| S.A.E. 4340— <i>Chrome-nickel-molybdenum Steel:</i> Heat Treatment. | |
| S.A.E. 6135— <i>Chrome-vanadium Steel (Medium Carbon):</i> Heat Treatment. | |
| S.A.E. 6150— <i>Chrome-vanadium Steel (Springs):</i> Heat Treatment. | |
| S.A.E. 8630, 8735, 8740 | |
| <i>Interrupted Quenching:</i> Cycle Annealing; Austempering; Martempering. | |
| <i>Hardenability</i> | |
| CHAPTER VI. SURFACE HARDENING | 70 |
| <i>Casehardening:</i> Carburizing; Solid Carburizing; Liquid Car- | |

burizing; Gas Carburizing; Refining the Core; Hardening the Case; Tempering.

Selective Casehardening: Warpage and Cracking; Carburizing Steels.

Cyaniding

Nitriding

Induction Hardening

Shot Peening

CHAPTER VII. SHAPING OF METAL 82

Mechanical Treatment

Hot Working: Hot Rolling; Forging; Drop Forging.

Pressed Powdered-metal Parts

Cold Working: Cold Rolling; Cold Drawing.

Casting: Static Casting; Centrifugal Casting; Precision Casting.

Defects in Steel: Defects in Ingots; Defects Caused by Rolling; Defects in Cold-drawn Seamless Tubes.

CHAPTER VIII. CORROSION-RESISTING STEELS 97

Corrosion

Intergranular Corrosion: Embrittlement Test; Metallographic Examination.

Heat Treatment: Annealing; Stabilizing; Hardening.

Salt-spray Corrosion Test: Rating Salt-spray Test Specimens.

Pickling

Polishing

Passivating

Working Properties: Forging; Forming and Drawing; Machining.

Welding and Soldering: Gas Welding; Electric Arc Welding; Spot Welding; Soldering.

Properties of Corrosion-resisting Steels

Corrosion-resisting Steel for Exhaust Collectors: Chemical Composition; Physical Properties; Heat Treatment; Working Properties; Welding; Corrosion; Available Shapes; Uses.

Corrosion-resisting Steel for Hydraulic Systems

Corrosion-resisting Steel for Structural Purposes: Chemical Composition; Physical Properties; Heat Treatment; Working Properties; Welding; Corrosion; Available Shapes; Uses.

Corrosion-resisting Steel for Machined Parts: Chemical Composition; Physical Properties; Heat Treatment; Working Properties; Welding; Corrosion; Available Shapes; Uses.

Corrosion-resisting Steel for Springs: Chemical Composition; Physical Properties; Heat Treatment; Working Properties; Corrosion; Available Shapes; Uses.

CORROSION-RESISTING STEELS (Continued)

Corrosion-resisting Castings: Chemical Composition; Physical Properties; Heat Treatment; Welding; Working Properties; Corrosion & Heat Resistant Steel for Jet Tail Pipes.

CHAPTER IX. NICKEL ALLOYS 123

Inconel: Chemical Properties; Physical Properties; Annealing and Stress Relieving; Working Properties; Welding; Soldering and Brazing; Corrosion Resistance; Available Shapes; Uses.

Monel: Chemical Properties; Physical Properties; Annealing; Working Properties; Welding; Soldering.

K Monel: Chemical Properties; Physical Properties; Heat Treatment; Working Properties; Welding; Brazing; Corrosion; Available Shapes; Uses.

Specifications: Inconel; Monel; K Monel.

CHAPTER X. COPPER AND ITS ALLOYS 137

Copper: Copper Tubing; Copper-Silicon-Bronze Tubing; Copper Wire; Beryllium Copper.

Brass: Muntz Metal; Manganese Bronze (Brass); Hy-Ten-SI Bronze; Naval Brass (Tobin Bronze); Red Brass.

Bronze: Gun Metal; Phosphor Bronze; Phosphor Bronze Casting Alloy; Aluminum Bronze; Aluminum Bronze Casting Alloy; Bronze Cable.

Season Cracking

CHAPTER XI. WROUGHT ALUMINUM ALLOYS 145

Nomenclature

Classification of Wrought Alloys

Corrosion

Alclad Aluminum Alloys

Extrusions

Forgings

Spot-welding Aluminum Alloys

Heat Treatment: Heat Treatment of Aluminum-Alloy Rivets; Annealing.

Strain-hardened Alloys: Chemical Composition; Physical Properties; Annealing; Working Properties; Welding; Corrosion; Available Shapes; Uses.

Heat-treatable Alloys: Chemical Composition; Physical Properties; Heat Treatment; Working Properties; Welding; Riveting; Corrosion; Available Shapes; Uses.

CHAPTER XII. ALUMINUM-ALLOY CASTINGS 185

Sand Casting: Applications

CONTENTS

xi
PAGE

Permanent-mold Castings: Applications
Die Casting
Design of Castings: Heat-treated Castings

CHAPTER XIII. MAGNESIUM ALLOYS 193

Pure Magnesium: Production Methods; Physical Properties.
Magnesium Alloys: Chemical Composition.
Magnesium-alloy Castings: Heat Treatment of Castings; Sand Castings; Permanent-mold Castings; Die Castings.
Wrought Magnesium Alloys: Extrusions; Forgings; Sheet, Plate, Strip.
Shop Fabrication Processes: Machining; Shearing; Blanking and Punching; Routing; Forming Magnesium Alloys.
Joining Methods: Riveting; Gas Welding; Arc Welding; Spot Welding.
Corrosion Resistance

CHAPTER XIV. METAL-JOINING PROCESSES 234

Gas Welding
Electric Arc Welding: Metallic Arc Welding; Carbon Arc Welding; Atomic-hydrogen Welding; Inert arc Welding (heliarc); Multiarc Welding.
Electric Resistance Welding: Butt Welding; Spot Welding; Seam Welding.
Welding Considerations
Brazing: Brazing (Copper); Silver Brazing; Aluminum Brazing.
Soft Soldering
Adhesive Bonding

CHAPTER XV. CORROSION AND ITS PREVENTION 252

Corrosion of Dissimilar Metals: Carbon steel and Aluminum-alloy Joint; Stainless steel and Aluminum-alloy Joint; Copper, Brass, Bronze, and Aluminum-alloy Joints.
Corrosion Protection
Cleaning Operations: Sandblasting; Pickling Steel; Pickling Aluminum Alloy; Pickling Corrosion-resisting Steel.
Plating Operations: Cadmium Plating; Galvanizing (Zinc Plating); Sherardizing; Parkerizing; Bonderizing; Parco Lubrizing; Coslettizing; Granodizing; Metal Spraying; Chromium Plating.
Anodic Oxidation, Chromatizing, Alrok, Alodizing Processes.
Treatments for Magnesium-alloy Parts: Chrome-pickle Treatment; Sealed Chrome-pickled Treatment; Dichromate Treatment; Galvanic Anodizing Treatment.

CORROSION AND ITS PREVENTION (Continued)

Paints: Paint; Primer; Lacquer; Varnish; Enamel; Acid-resistant Paint; Bituminous Paint; Soya-bean-Oil Compound; Marine Glue; Rust-preventive Compound; Beeswax and Grease; Paralketone.

Finish of Detail Parts

CHAPTER XVI. WOOD AND GLUE 277

General Uses of Wood: Naming Wood; Classification of Trees and Woods.

Structure of Wood: Sawing Wood; Grain.

Strength of Wood: Specific Gravity *vs.* Strength; Locality of Growth *vs.* Strength; Rate of Growth *vs.* Strength; Moisture Content *vs.* Strength; Defects *vs.* Strength.

Strength Properties

Aircraft Woods and Their Uses: Ash, White; Basswood (*Tilia americana*); Beech (*Fagus atropunicea*); Birch; Cherry, Black (*Prunus serotina*); Elm, Cork (*Ulmus racemosa*); Gum, Red (*Liquidambar styraciflua*); Hickory; Mahogany, African (*Khaya senegalensis*); Mahogany, True (*Swietenia mahagoni*); Maple, Sugar (*Acer saccharum*); Oak; Poplar, Yellow (*Liriodendron tulipifera*); Walnut, Black (*Juglans nigra*); Cedar, Port Orford (*Chamaecyparis lawsoniana*); Cypress, Bald (*Taxodium distichum*); Douglas Fir (*Pseudotsuga taxifolia*); Pine, White (*Pinus strobus*); Spruce.

Seasoning of Wood: Air Seasoning of Wood; Kiln Drying of Wood.

Bending of Wood:

Glues and Gluing: Urea Formaldehyde Resin Glues; Resorcinol Phenolic Glues; Alkaline Phenolic Glues; Casein Glues; Blood Albumin Glues; Animal Glues; Gluing Wood.

Plywood: Waterproof Plywood; Superpressed Resin Plywood; Molded Airplane Parts.

CHAPTER XVII. FABRICS AND DOPE 304

Airplane Fabric: Surface Tape; Reinforcing Tape; Sewing Thread; Rib Lacing Cord.

Application of Cloth Surfaces: Wing Covering; Fuselage Covering.

Dopes and Doping: Cellulose-Nitrate Dope; Cellulose-Acetate-Butyrate Dope.

CHAPTER XVIII. PLASTICS 313

Classification: Synthetic Resin Plastics; Natural Resins; Cellulose; Protein Plastics; Thermoplastics; Thermosetting Plastics.

Manufacturing Processes: Molding; Casting; Extruding; Laminating.

Physical Properties

Fiberglass

Working Properties: Joining; Machining; Forming.

Uses

CHAPTER XIX. TRANSPARENT MATERIALS 326

Glass: Physical Properties; Testing Nonscatterable Glass.

Tempered Glass

*Transparent Plastics: Pyralin; Plastecele; Vinylite; Plexiglas
and Lucite; Gafite; Sierracin 611*

CHAPTER XX. RUBBER AND SYNTHETIC RUBBER 336

Natural Rubber

Synthetic Rubber: Buna S.; Buna N.; Neoprene; Butyl; Thiokol.

Manufacturing Processes

Vulcanizing

CHAPTER XXI. TITANIUM AND ITS ALLOYS 342

*Physical Properties: Metallurgy; Chemical Compositions; Spec-
ifications; Mechanical Properties; Elevated Temperature
Properties.*

Forging; Spotwelding; Flashwelding.

Hydrogen Embrittlement

Descaling and Pickling

Casting

Machining

CHAPTER XXII. HIGH TEMPERATURE PROBLEMS 354

Creep: Creep Limits; Creep Strength; Stress Rupture.

Aerodynamic Heating

Heat Storage Sinks

Design Considerations

Ceramic Coatings

*High Temperature Materials: A-286, S.A.E. 4340, HS-25,
AM 350, 17-7 PH, 19-9 DL, Inconel X*

S.A.E. 304—Stainless Steel

S.A.E. 347—Stainless Steel

S.A.E. 310—Stainless Steel

CHAPTER XXIII. SELECTION OF MATERIALS 372

Considerations: Economic; Engineering.

*Specific Material Applications: Propeller Blades; Propeller Hubs;
Cowl Ring; Exhaust Collector; Cowling; Engine Mount;*

SELECTION OF MATERIALS (Continued)

Firewall; Oil Tank; Oil Lines; Engine Controls; Fuel Tanks;
 Fuel Lines; Hydraulic Systems; Landing Gear; Fuselage;
 Hulls and Floats; Wings; Wing Leading Edge; Wing Ribs;
 Wing Covering; Wing-tip Bow; Wing Beams; Wing Fittings;
 Wing Supporting Struts; Wing Wires; Ailerons; Wing Flaps;
 Windshield; Instrument Board; Instrument Tubing; Seats;
 Flooring; Controls; Tail Surfaces; Tail-wheel Structure;
 Bushings; Bearings; Bolts; Rivets; Springs.

Conclusion

APPENDICES 387

Weights of Common Aircraft Materials.

Standard Gage.

Standard Sizes, Weights, and Tolerances of Round Steel Tubing.

Standard Sizes, Weights, and Tolerances of Round Aluminum-
 alloy Tubing.

Streamline Tubing.

Strength of Steel Cable

Tie-rods

INDEX 392

ILLUSTRATIONS

| FIGURE | PAGE |
|---|---------------------|
| Grumman Tiger—Navy Supersonic Fighter | <i>Frontispiece</i> |
| 1. Round Tension-test Specimen | 6 |
| 2. Flat Tension-test Specimen | 6 |
| 3. Flat Tension-test Specimen | 6 |
| 4. Subsize Round Tension-test Specimen | 7 |
| 5. Flat Tension-test Specimen | 7 |
| 6. Set Method of Yield-strength Determination | 9 |
| 7. Izod Impact-test Specimen | 17 |
| 8. Charpy Impact Specimen | 17 |
| 9. Engine Mount | 37 |
| 10. Fatigue Properties of Hy-Tuf | 41 |
| 11. Critical Points of Steel | 44 |
| 12. Grumman Retractable Landing Gear | 50 |
| 13. Typical Isothermal Transformation Diagram | 64 |
| 13a. Hardenability Band 8630 H | 69 |
| 14. Correct and Incorrect Directions of Grain in Forgings | 85 |
| 15. Wire-drawing Die | 88 |
| 16. Cold Drawing of Tubing | 89 |
| 17. Hull and Body Covering | 99 |
| 18. Hull Framing | 106 |
| 19. Skeleton Tail Assembly | 109 |
| 20. Body-panel Construction | 110 |
| 21. Fleetwings Amphibian | 111 |
| 22. Exhaust Stacks | 113 |
| 23. Skeleton Fuselage | 115 |
| 24. Aileron Construction | 117 |
| 25. Wing Construction | 118 |
| 26. High-temperature Properties of Inconel | 125 |
| 27. Jet Tail Pipe | 128 |
| 28. K. Monel Arresting Hook "A" Frame | 129 |
| 29. Grumman Amphibian | 147 |
| 30. Corrugated Double-skin Construction | 149 |
| 31. Bow of Mallard Hull | 151 |
| 32. Edo Seaplane Float | 152 |
| 33. Modern Wing Construction | 153 |
| 34. Aluminum-alloy Forgings | 155 |
| 35. Large Aircraft Forging | 157 |

ILLUSTRATIONS

| | |
|--|-----|
| 36. Hull Bulkhead and Bottom | 158 |
| 37. Honeycomb Cored Rudder Construction | 160 |
| 38. Low Drag Fuel Tank | 162 |
| 39. Engine Ring Cowl | 164 |
| 40. Oil Tank | 167 |
| 41. Wing Ribs | 171 |
| 42. Wing-tip Float | 176 |
| 43. Retractable Landing Gear | 179 |
| 44. Jet-fighter Wing Showing Fuel Cell | 182 |
| 45. Sand-cast Cylinder Head | 187 |
| 46. Aluminum-alloy Die Castings | 190 |
| 47. Stratosphere Gondola | 197 |
| 48. Sand-cast Magnesium Parts | 202 |
| 49. Permanent-mold Cast Magnesium Aircraft Wheels | 205 |
| 50. Miscellaneous Magnesium Extruded Shapes | 209 |
| 51. Press-forged Magnesium Hydraulic Parts | 212 |
| 52. Hammer- and Press-forged Magnesium Control Parts | 213 |
| 53. Assembly of Magnesium SNJ-2 Wings | 215 |
| 54. Hot forming Magnesium Sheet—Gas Heating Dies | 218 |
| 55. Drawn Magnesium Parts | 222 |
| 56. Magnesium Propeller Spinner | 224 |
| 57. Magnesium-alloy Aircraft Doors Assembled by Riveting and Spot Welding | 226 |
| 58. Torch Welding a Magnesium Aircraft Oil Tank | 229 |
| 59. Galvanic-cell Action | 254 |
| 60. Methods of Sawing Logs | 280 |
| 61. Relations between Strength and Moisture Content | 283 |
| 62. Atmospheric Humidity <i>vs.</i> Wood Moisture Control | 294 |
| 63. Windshield—Bullet-proof Glass Pane | 328 |
| 64. Cabin Enclosure—Plexiglas | 332 |
| 65. Bullet-proof Fuel Tank—Synthetic Rubber | 340 |
| 66. Simplified Phase Diagram for Titanium | 344 |
| 67. Titanium Alloy Forging | 350 |
| 68. Schematic Creep Curve | 355 |
| 69. Tensile Strength <i>vs.</i> Temperature for Aluminum Alloys | 356 |
| 70. Aerodynamic Heating | 358 |