

CONTENTS

PREFACE \

INTRODUCTION 1

Review Questions

1. TESTING 14

1-1. Purchaser's protection. 1-2. Purchase specifications. 1-3. The tension test. 1-4. Elasticity. 1-5. Plasticity. 1-6. The compression test (metallic). 1-7. The compression test (nonmetallic). 1-8. Shear tests. 1-9. Transverse tests. 1-10. Modulus of rupture. 1-11. Specifications governing the quality of gray iron castings. 1-12. Impact tests. 1-13. Repeated stress tests. 1-14. Hardness numbers. 1-15. Brinell numbers. 1-16. The Rockwell hardness numbers. 1-17. Macroscopic examination. 1-18. Microscopic examination. Review Questions.

2. WOOD 36

2-1. Trees. 2-2. The growth of trees. 2-3. Tree types. 2-4. Microstructure of wood. 2-5. White pine. 2-6. Medullary rays in white pine. 2-7. Physical characteristics of white pine. 2-8. Diffuse-porous wood. 2-9. Sugar maple. 2-10. Physical characteristics of sugar maple. 2-11. Red oak. 2-12. Medullary rays in oak. 2-13. Characteristics of red oak. 2-14. Grain vs. figure. 2-15. Grain-strength relation. 2-16. Moisture-strength relation. 2-17. Slash- and rift-sawing. 2-18. Quartersawing. 2-19. Practical considerations. 2-20. Shrinkage. 2-21. Knots. 2-22. Laminated construction. 2-23. Veneer. 2-24. Plywood. Review Questions.

3. STONE **73**

3-1. Geological aspect. **3-2.** The theory of earth formation. **3-3.** Historical aspect. **3-4.** Choice of stone. **3-5.** Strength. **3-6.** Appearance.

3-7. Spalling and splitting. 3-8. Atmospheric abrasion. 3-9. Fire damage. 3-10. Fire resistance. 3-11. Special-purpose stone. 3-12. Granite. 3-13. Marble. 3-14. Slate. 3-15. Asbestos. 3-16. Mica. ROAD METAL AND CONCRETE AGGREGATE. 3-17. Road metal. 3-18. Material to be used in the base. 3-19. Surface courses. 3-20. Water-bound macadam. 3.21. Track ballast.

GRAVEL AND SAND. 3-22. Glacial action. 3-23. Structural sand. 3-24. Concrete aggregate. 3-25. Washed aggregate. Review Questions.

4. BRICK 96

4-1.The first brick. 4-2.Modern bricks. 4-3.Standard sizes. Clay or shale brick. 4-4. Compressive strength. 4-5.Porosity and absorption. 4-6.Durability. 4-7.Color. 4-8.Manufacturing processes. 4-9.Softmud process. 4-10.Stiff-mud process. 4-11.Dry-press process. 4-12.Burning brick. 4-13.Permanent kilns. 4-14.Special-purpose brick. Review Questions.

5. CEMENTING MATERIALS 111

5-1. Calcium. 5-2. Calcination and hydration. 5-3. Gypsum. 5-4. Gypsum plasters. 5-5. High-temperature calcination. 5-6. Gypsum building units. 5-7. Lime. 5-8. Hydration of lime. 5-9. Setting of lime plaster. 5-10. Dolomitic lime. 5-11; Effect of magnesium oxide. 5-12. Popping of plaster. 5-13. Mortar, plaster, and stucco. 5-14. Hydrated lime. 5-15. Lime mortar. Review Ouestions.

6. CEMENT AND CONCRETE 126

6-1. Silicates. 6-2. Natural cements. 6-3. Portland cement. 6-4. Raw materials and manufacture. 6-5. Crushing. 6-6. Calcining. 6-7. Grinding. 6-8. Basic definition of Portland cement. 6-9. Setting and hardening. 6-10. Strength. 6-11. Soundness. 6-12. Concrete. 6-13. Normal changes in volume. 6-14. The design of concrete mixtures. 6-15. Water-cement ratio. 6-16. Aggregate-cement ratio. 6-17. **Age**-strengthening of concrete. 6-18. Use of the graphs. 6-19. Aggregate gradation. Review Questions.

7. PLASTICS 151

7-1. Plastics as a group of engineering materials. 7-2. Reasons for using plastics. 7-3. Resins. 7-4. Synthetic resins. 7-5. Cellulose resins. 7-6. Polymerization and condensation. 7-7, Thermoplastic and thermosetting resins. 7-8. Plasticizers, fillers, and bases. 7-9. General

shaping methods. **7-10.** Polystyrene (TP). **7-11.** Polymethyl methacrylate (TP). **7-12.** Phenol formaldehyde (TS). **7-13.** Urea formaldehyde (TS). **7-14.** Cellulose acetate (TP). **7-15.** The laminates. **7-16.** Mechanical properties and specific gravities. **7-17.** The light weight of plastics. **7-18.** Impact resistance. **7-19.** Wear resistance. **7-20.** Molding of plastics. **7-21.** The principal molding methods. **7-22.** Injection molding. **7-23.** Molding temperature. **7-24.** Molding pressures. **7-25.** Metallic inserts. **7-26.** Compression molding. **7-27.** Heating molds. **7-28.** Mold pressure. **7-29.** Ejection of molded part. **7-30.** Transfer molding. **7-31.** Extrusion. **7-32.** Blow molding. **7-33.** Finishing molded plastics. **7-34.** Applications of nonmolded resins. Review Questions.

8. IRONS, STEELS, AND CAST IRONS 176

IRONS. 8-1. Commercially pure iron. 8-2. Ingot iron. 8-3. Electrolytic iron. 8-4. The mechanical properties of commercially pure iron. 8-5. The microstructure. 8-6. Wrought iron. 8-7. The modem process for the manufacture of wrought iron. 8-8. The microstructure of wrought iron. 8-9. Mechanical properties of wrought iron. 8-10. Alloy effect. 8-11. Slag effect. 8-12. Summary.

STEEL. 8-13. Steelmaking. 8-14. The basic open-hearth. 8-15. The Bessemer process. 8-16. The electric process. 8-17. Comparison of methods. 8-18. Processing ingots. 8-19. Wire, rods, shafting tubing, and sheet. 8-20. Generalizations. 8-21. Chemical composition of steel. 8-22. Plain carbon steels. 8-23. Structure and mechanical properties. 8-24. Ferrite and cementite. 8-25. Uses of plain carbon steels. 8-26. The structural steels. 8-27. Machinery steels. 8-28. Spring and tool steels. 8-29. Steel castings.

CAST IRONS. 8-30. The cast irons.
8-31. Cast-iron production.
8-32. Gray iron, structure and properties.
8-33. Alloy cast irons.
8-34. White cast iron.
8-36. Malleable iron.
8-37. Ductile cast iron.
8-38. Malleable iron, structure and properties.
8-39. Pearlitic malleable cast iron.
8-40. Uses of ferritic malleable cast iron.

9. HEAT-TREATMENT OF STEEL 227

9-1. Thesis. **9-2.** Heat-treatment. **9-3.** Allotropy. **9-4.** Austenite.

9-5. Austenite transformation. **9-6.** Austenitization. **9-7.** Diffusion.

9-8. Effects of cooling rate. **9-9.** Full annealing and normalizing. **9-10.** Spheroidizing. **9-11.** Process annealing. **9-12.** Stress-relief an-

nealing. 9-13. The hardening of steel. 9-14. Split transformation.

9-15. Hardenability.
9-16. Factors influencing hardenability.
9-17. Practical significance of hardenability.
9-18. The Jominy hardenability test.
9-19. Tempering of martensite.
9-20. Structure of tempered steel.
9-21. Bainite.
9-22. Austempering.
9-23. Case hardening.
9-24. Carburizing and hardening.
9-25. Austenite grain size.
9-26. Cyaniding.
9-27. Induction and flame hardening.
9-28. Nitriding.
9-29. Carbonitriding.
9-30. General aspects. Review Questions.

10. MECHANICAL FORMING 270

10-1. Mechanical working.
10-2. Cold-work strengthening.
10-3. Deformation mechanism.
10-4. Work-strengthening theories.
10-5. Effect of cold working on mechanical properties.
10-6. Commercially cold-worked metals and alloys.
10-7. Annealing.
10-8. Recrystallization.
10-12. Mechanics and metallurgy.
10-13. Hot-working temperatures.
10-14. Finishing temperatures.
10-15. Generalization. Review Questions.

11. CASTING AND WELDING 288

11-1. The casting of metals and alloys. 11-2. The melting practice. 11-3. Solidification phenomena. 11-4. Shrinkage. 11-5. Directional solidification. 11-6. Dendritic segregation. 11-7. Macrosegregation. 11-8. Gas porosity. 11-9. Radiography. 11-10. Sand casting. 11-11. Die casting. 11-12. Permanent-mold castings. 11-13. Plaster of Paris molds. 11-14. Centrifugal castings. 11-15. Precision casting. 11-16. Common castings. 11-17. Powder metallurgy. 11-18. Welding. 11-19. Fusion welding. 11-20. Metallurgy of welding. 11-21. Metallic arc welding. 11-22. Gas-shielded arc welding. 11-23. Atomic hydrogen welding. 11-24. Carbon-arc welding. 11-25. Gas welding. 11-26. Flame cutting. 11-27. Thermit welding. 11-28. Pressure welding. 11-29. Resistance butt welding. 11-30. Flash welding. 11-31. Spot and seam welding. 11-32. Brazing. 11-33. Cold welding. 11-34. Special joining processes. Review Questions.

12. ALLOY STEELS 312

12-1. Alloy steels.

THE CONSTRUCTIONAL ALLOY STEELS. 12-2. Hardenability. 12-3. Alloying elements. 12-4. Behavior of alloying elements. 12-5. Hardenability results. 12-6. Strengthening by alloying. 12-7. Alloying elements. 12-8. Behavior of alloying elements. 12-9. Results of strengthening by alloying. 12-10. Toughening by alloying. 12-11.

Alloying elements. 12-12. Results of toughening by alloying. 12-13. Machinability. 12-14. Alloying elements. 12-15. Behavior of alloying elements. 12-16. Results of alloying for machinability.

THE ALLOY TOOL STEELS. 12-17. The service requirements of tool steels. 12-18. Distortion and cracking during hardening. 12-19. Effects of alloying elements. 12-20. Cutting capacity and wear resistance. 12-21. High-temperature hardness. 12-22. Hot-work tool steel. 12-23. Alloying elements. 12-24. Behavior of alloying elements. 12-25. The heat-treatment of the high alloy tool steels. 12-26. Results of alloying for hot hardness. 12-27. The sintered carbides.

THE SPECIAL ALLOY STEELS. 12-28. Thesis. 12-29. Corrosionand heat-resistant steels. 12-30. Behavior of chromium. 12-31. Results of alloying for corrosion and heat resistance. 12-32. Classification. 12-33. Intergranular corrosion of stainless steel. 12-34. Stabilization. 12-35. Alloying for high-temperature strength. 12-36. Classification. 12-37. Alloy elements and their behavior in low-alloy steels. 12-38. Results of alloying for high-temperature strength. 12-39. The high-alloy steels. 12-40. Behavior of alloying elements. 12-41. The superhigh-temperature-strength alloys. 12-42. Magnetic properties. 12-43. Coefficient of expansion. 12-44. Hardening and strengthening during service. 12-45. Results of alloying for service hardening. 12-46. Generalization. Review Questions.

13. THE LIGHT METALS AND THEIR ALLOYS 346

13-1. Basic considerations.

ALUMINUM. 13-2. Density. 13-3. Corrosion resistance. 13-4. Highpurity aluminum. 13-5. Commercially pure aluminum. 13-6. The stiffness of aluminum. 13-7. Work strengthening of aluminum. 13-8. Alloying of aluminum. 13-9. Precipitation heat-treatment. 13-10. The aging or precipitation process. 13-11. Overaging. 13-12. Dur-**13-13.** Strengthening by heat-treatment. alumin alloys. High-strength aluminum alloy. 13-15. Alclad. 13-16. Age hardening and cold working. 13-17. Age hardening of casting alloys. Strengthening by alloying. 13-19. Alloying to increase high-tempera-**13-20.** Machinability. 13-21. Castability. ture strength. Aluminum-silicon casting alloys. 13-23. Fabrication of aluminum alloys. **13-24.** Density. **13-25.** Mechanical Properties. MAGNESIUM. 26. Machinability. 13-27. Casting of magnesium alloys. 13-28. Corrosion resistance. 13-29. Alloying of magnesium. 13-30. Welding magnesium alloys. 13-31. Applications.

TITANIUM. 13-32. Commercially pure titanium and titanium alloys. 13-33. Physical properties. 13-34. Utility. Review Questions.

14. COPPER AND ITS ALLOYS 368

xii

14-1. Utility. 14-2. Electrolytic tough-pitch copper. 14-3. OFHC copper. 14-4. Deoxidized copper. 14-5. Continuous casting. 14-6. Mechanical properties of copper. 14-7. Fabrication of commercially pure copper. 14-8. The corrosion resistance of copper. 14-9. General applications of copper alloys. 14-10. Copper alloys of the solid-solution type. 14-11. Copper alloys possessing two or more microconstituents. 14-12. Fabrication of copper alloys. 14-13. Commercial copper alloys. 14-14. The brasses. 14-15. Muntz metal. 14-16. Mechanical properties of the brasses. 14-17. Forging brass. 14-18. Season cracking of brass. 14-19. Dezincification. 14-20. The phosphor bronzes. 14-21. The silicon bronzes. 14-22. The aluminum bronzes. 14-23. Heat-treatable aluminum bronzes. 14-24. The copper-beryllium alloy. 14-25. The casting alloys of copper. Review Questions.

15. THE SPECIAL-PURPOSE NONFERROUS ALLOYS 391

15-1. Definition of special alloys.
15-2. Die castings.
15-3. Mechanical properties of die-casting alloys.
15-4. Sleeve-bearing alloys.
15-5. The type metals.
15-6. The common solders.
15-7. Brazing alloys.
15-8. The fusible alloys.
15-9. Corrosion-resistant alloys.
15-10. Alloys for electrical heating elements.
15-11. Hard-facing alloys.
15-12. High-temperature alloys.
Review Questions.

SUGGESTED READING 403

MOTION PICTURES AND FILMSTRIPS 407

INDEX 415

*