DOCUMENT RESUME

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TITLE	Military Curricula for Vocational & Technical Education. Metals Processing Specialist, Block VII, Classroom Course 13-8.
INSTITUTION	Chanute AFB Technical Training Center, Ill.; Ohio State Univ., Columbus. National Center for Research in Vocational Education.
PUB DATE	Sep 75
NOTE	183p.; Not available in paper copy due to light and broken type. For related documents see CE 026 394-396.
EDRS PRICE	MF01 Plus Postage. PC Not Available from EDRS.
DESCRIPTORS	Behavioral Objectives; Course Descriptions; Curriculum Guides; *Finishing; High Schools; Learning Activities; Lesson Plans; *Machine Tools; Metals; *Metal Working; Postsecondary Education; Secondary Education; Skilled Occupations; *Trade and Industrial Education; Units of Study; *Welding
IDENTIFIERS	Military Curriculum Project

ABSTRACT

These curriculum materials are the fourth section of a four-part, secondary-postsecondary-level course in metals processing. The course is one of a number of military-developed curriculum packages selected for adaptation to vocational instruction and curriculum development in a civilian setting. Block VII deals with heat treating, hardness testing, cleaning, and electroplating. It contains six lessons covering fifty-six hours of instruction: Safety and Operation of Heat Treating Furnaces; Identification and Classification of Metals; Hardness Testing; Heat Treatment of Ferrous Metals; Heat Treatment of Heat and Corrosion Resistant Ferrous Alloys, Nickel Base Alloys, Aluminum and Aluminum Alloys, and Titanium Alloys; and Cleaning, Plating, and Corrosion Control. Instructor materials include a course chart, detailed lesson plans, and a plan of instruction containing the units of instruction, criterion objectives, and additional materials needed. Student materials include a study guide which contains objectives, information, review exercises, and references for each lesson. Suggested audiovisuals are not provided. (YLB)

Military Curricula for Vocational & Technical Education

METALS PROCESSING SPECIALIST
BLOCK VII

THE NATIONAL CENTER
FOR RESEARCH IN VOCATIONAL EDUCATION
THE OHIO STATE UNIVERSITY

METALS PROCESSING SPECIALIST, BLOCK VII

Table of Contents

MILITARY CURRICULUM MATERIALS

The military-developed curriculum materials in this course package were selected by the National Center for Research in Vocational Education Military Curriculum Project for dissemination to the six regional Curriculum Coordination Centers and other instructional materials agencies. The purpose of disseminating these courses was to make curriculum materials developed by the military more accessible to vocational educators in the civilian setting.

The course materials were acquired, evaluated by project staff and practitioners in the field, and prepared for dissemination. Materials which were specific to the military were deleted, copyrighted materials were either omitted or approval for their use was obtained. These course packages contain curriculum resource materials which can be adapted to support vocational instruction and curriculum development.

The National Center Mission Statement

The National Center for Research in Vocational Education's mission is to increase the ability of diverse agencies, institutions, and organizations to solve educational problems relating to individual career planning, preparation, and progression. The National Center fulfills its mission by:

- Generating knowledge through research
- Developing educational programs and products
- Evaluating individual program needs and outcomes
- Installing educational programs and products
- Operating information systems and services
- Conducting leadership development and training programs

FOR FURTHER INFORMATION ABOUT
Military Curriculum Materials
WRITE OR CALL

Program Information Office
The National Center for Research in Vocational Education
The Ohio State University
1960 Kenny Road, Columbus, Ohio 43210
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FOR RESEARCH IN VOCATIONAL EDUCATION
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Military Curriculum Materials for Vocational and Technical Education

Information and Field Services Division

The National Center for Research in Vocational Education

Military Curriculum Materials Dissemination Is . . .

an activity to increase the accessibility of military-developed curriculum materials to vocational and technical educators.

This project, funded by the U.S. Office of Education, includes the identification and acquisition of curriculum materials in print form from the Coast Guard, Air Force, Army, Marine Corps and Navy.

Access to military curriculum materials is provided through a "Joint Memorandum of Understanding" between the U.S. Office of Education and the Department of Defense.

The acquired materials are reviewed by staff and subject matter specialists, and courses deemed applicable to vocational and technical education are selected for dissemination.

The National Center for Research in Vocational Education is the U.S. Office of Education's designated representative to acquire the materials and conduct the project activities.

Project Staff:

Wesley E. Budke, Ph.D., Director
National Center Clearinghouse

Shirley A. Chase, Ph.D.
Project Director

What Materials Are Available?

One hundred twenty courses on microfiche (thirteen in paper form) and descriptions of each have been provided to the vocational Curriculum Coordination Centers and other instructional materials agencies for dissemination.

Course materials include programmed instruction, curriculum outlines, instructor guides, student workbooks and technical manuals.

The 120 courses represent the following sixteen vocational subject areas:

Agriculture	Food Service
Aviation	Health
Building & Construction Trades	Heating & Air Conditioning
Clerical Occupations	Machine Shop
Communications	Management & Supervision
Drafting	Meteorology & Navigation
Electronics	Photography
Engine Mechanics	Public Service

The number of courses and the subject areas represented will expand as additional materials with application to vocational and technical education are identified and selected for dissemination.

How Can These Materials Be Obtained?

Contact the Curriculum Coordination Center in your region for information on obtaining materials (e.g., availability and cost). They will respond to your request directly or refer you to an instructional materials agency closer to you.

CURRICULUM COORDINATION CENTERS

EAST CENTRAL
Rebecca S. Douglass
Director
100 North First Street
Springfield, IL 62777
217/782-0759

NORTHWEST
William Daniels
Director
Building 17
Airdustrial Park
Olympia, WA 98504
206/753-0879

MIDWEST
Robert Patton
Director
1515 West Sixth Ave.
Stillwater, OK 74704
405/377-2000

SOUTHEAST
James F. Shill, Ph.D.
Director
Mississippi State University
Drawer DX
Mississippi State, MS 39762
601/325-2510

NORTHEAST
Joseph F. Kelly, Ph.D.
Director
225 West State Street
Trenton, NJ 08625
609/292-6562

WESTERN
Lawrence F. H. Zane, Ph.D.
Director
1776 University Ave.
Honolulu, HI 96822
808/948-7834

	<u>Course Material</u> - <u>UNCLASSIFIED</u> 70 Hours TI BLOCK VII - Heat Treating, Hardness Testing, Cleaning, and Electroplating	10 Hours CTT
14 15	Safety and Operation of Heat Treating Furnaces (4 hrs); Identification and Classification of Metals (8 hrs); Hardness Testing (4 hrs); Heat Treatment of Ferrous Metals (18 hrs); Heat Treatment of Heat and Corrosion Resistant Ferrous Alloys, Nickel Base Alloys, Aluminum and Aluminum Alloys, and Titanium Alloys (12 hrs); Cleaning, Plating, and Corrosion Control (10 hrs); Measurement and Critique (2 hrs); Course Critique and Graduation (2 hrs). (Equipment Hazards and Personnel Safety Integrated with Above Subjects) 60 Hours C/L 13-8	10 Hours RT

ATC FORM APR 73 449A PREVIOUS EDITION OBSOLETE.

73-24978

PLAN OF INSTRUCTION	COURSE TITLE Metals Processing Specialist	
BLOCK TITLE Heat Treating, Hardness Testing, Cleaning, and Electroplating		
UNITS OF INSTRUCTION AND CRITERION OBJECTIVES 1	DURATION (HOURS) 2	SUPPORT MATERIALS AND GUIDANCE 3
1. Safety and Operation of Heat Treating Furnaces a. Without reference, identify types and uses of heat treating furnaces with 75% accuracy. b. Given heat treating equipment and TO 1-1A-9, set up and operate furnaces without error. All shop safety, good housekeeping, and fire prevention measures must be observed. c. Without reference, identify maintenance and repair procedures pertaining to heat treating furnaces with 75% accuracy. d. Without reference, identify fabricating methods and properties of metals with 75% accuracy.	4	<u>Column 1 Reference</u> — <u>STS Reference</u> 1a — <u>19a</u> 1b — 3a, 3b, <u>19b</u> 1c — <u>19d</u> 1d — <u>19e</u> <u>Instructional Materials</u> 3ABR53131-SG-701, Safety and Operation of Heat Treating Furnaces TO 1-1A-9, Aerospace Metals - General Data and Usage Factors <u>Audio Visual Aids</u> Charts: Furnaces <u>Training Equipment</u> Heat Treating Furnace (2) Tongs (1) Quench Tanks (6) <u>Training Methods</u> Discussion/Demonstration (1 hr) Performance (3 hrs) <u>Instructional Environment/Design</u> Classroom (.7 hr) Laboratory (3.3 hrs) <u>Instructional Guidance</u> Emphasize shop safety applicable to heat treating furnaces and the handling of hot metal. Explain and demonstrate the correct methods for operating and cooling down heat treating furnaces. Have each student respond to the written items in the lesson. Make outside assignment to read 3ABR53131-SG-702. Caution students not to mark or write on any training literature as it is to be reused by subsequent classes. Instructor will use AFR 127-101, Ground Accident Prevention Handbook as a reference.

PLAN OF INSTRUCTION (Continued)

1 UNITS OF INSTRUCTION AND CRITERION OBJECTIVES	2 DURATION (HOURS)	3 SUPPORT MATERIALS AND GUIDANCE
2. Identification and Classification of Metals a. Given metal specimens and identification equipment, identify and determine classification of ferrous metals IAW TO 42D-1-3. All shop safety, good housekeeping, and fire prevention measures must be observed. b. Given metal specimens and identification equipment, identify and determine classification of nonferrous metals IAW TO 42D-1-3. All shop safety, good housekeeping, and fire prevention measures must be observed. c. Without reference, identify shop methods of metal identification with 75% accuracy.	10 (8/2) (3.5) (3.5) (1)	Column 1 Reference — STS Reference 2a — 3a, 3b, 19f 2b — 3a, 3b, 19g 2c — 19h Instructional Materials 3ABR53131-SG-702, Identification and Classification of Metals TO 42D-1-3, Methods of Identification of Steels, Aluminum Alloys, and Copper Alloys in Air Force Stock Audio Visual Aids Film: TVL 53-2A and B, Metal Identification, Parts A and B Charts: Metal Identification Training Equipment Grinder (4) Trainer: 4047 Spark Tester (12) Test Kit, Chemical (12) Training Methods Discussion/Demonstration (4 hrs) Performance (4 hrs) Outside Assignment (2 hrs) Instructional Environment/Design Classroom (3.5 hrs) Laboratory (4.5 hrs) Instructional Guidance Have each student respond to all written items in the lesson and perform shop methods of metal identification. Make outside assignment to read 3ABR53131-SG-703. Administer appraisal test upon completion of this assignment. Instructor will use TO 1-1A-1, General Manual for Structural Repair, Section IV, and TO 1-1A-9, Aerospace Metals, as an additional reference. Emphasize use of light pressure on grinding wheels to conserve metal specimens and grinding wheels.

PLAN OF INSTRUCTION (Continued)

1 UNITS OF INSTRUCTION AND CRITERION OBJECTIVES	2 DURATION (HOURS)	3 SUPPORT MATERIALS AND GUIDANCE
3. Hardness Testing a. Without reference, select statements pertaining to purpose, principles, and methods of hardness testing with 75% accuracy. b. Given Rockwell hardness tester and metal specimens, while observing all shop safety, set up and test metal for hardness without error.	4	Column 1 Reference — STS Reference 3a — 20a 3b — 3b, 20b Instructional Materials 3ABR53131-SG-703, Hardness Testing TO 1-1A-9 Audio Visual Aids Charts: Conversion Training Equipment Rockwell Hardness Tester (2) Training Methods Discussion/Demonstration (1 hr) Performance (3 hrs) Instructional Environment/Design Classroom (.5 hr) Laboratory (3.5 hrs) Instructional Guidance Emphasize the importance of proper Rockwell testing and the correct use of penetrators. Explain the use of the hardness conversion chart and have each student respond to the written items in the lesson. Have student read 3ABR53131-SG-704. Instructor will use TO 1-1A-1, Section V, as an additional reference. Emphasize proper use of Rockwell hardness tester to conserve penetrators.

1 UNITS OF INSTRUCTION AND CRITERION OBJECTIVES	2 DURATION (HOURS)
4. Heat Treatment of Ferrous Metals	24 (18/6)
a. Without reference, identify metal alloy compositions and their relation to heat treatment with 75% accuracy.	(1)
b. Without reference, identify basic structures produced by heat treating operations with 75% accuracy.	(1)
c. Given a heat treating furnace and metal specimens, set up and normalize carbon and alloy steels with a Rockwell hardness range of no less than RB-90 and no greater than RC-25. All shop safety, good housekeeping, and fire prevention measures must be observed.	(3)
d. Given a heat treating furnace and metal specimens, set up and harden carbon and alloy steels with a Rockwell hardness of no less than RC-55. All shop safety, good housekeeping, and fire prevention measures must be observed.	(4)
e. Given heat treating furnace and hardened metal specimens, set up and temper carbon and alloy steels to within ± 2 Rockwell hardness points, of that specified by the instructor. All shop safety, good housekeeping, and fire prevention measures must be observed.	(5)
f. Given a heat treating furnace and metal specimens, set up and anneal carbon and alloy steels with a Rockwell hardness no greater than RB-85. All shop safety, good housekeeping, and fire prevention measures must be observed.	(3)

3 SUPPORT MATERIALS AND GUIDANCE

Column 1 Reference	STS Reference
4a	19i
4b	19j
4c	3a, 3b, 19k
4d	3a, 3b, 19l
4e	3a, 3b, 19m
4f	3a, 3b, 19n
4g	19o

Instructional Materials
3ABR53131-SG-704, Heat Treatment of Ferrous Metals
TO 00-25-224, Welding High Pressure and Cyrogenic Systems, Section VI, Heat Treatment
TO 1-1A-9

Audio Visual Aids
Film: TFL-4016, Heat Treating Hints, Parts 1 & 2
Film: TVL 53-11, Heat Treating
Charts: Group Name Phase Diagrams

Training Equipment
Heat Treating Furnace (2)
Tongs (1)
Quench Tanks (6)
Rockwell Hardness Tester (6)

Training Methods
Discussion/Demonstration (4 hrs)
Performance (14 hrs)
Outside Assignment (6 hrs)

Instructional Environment/Design
Classroom (3.5 hrs)
Laboratory (14.5 hrs)

Instructional Guidance
Emphasize safety applicable to a heat treating shop and explain and demonstrate the proper techniques for all the various heat treating operations applicable to carbon and alloy steels. Have each student

1 UNITS OF INSTRUCTION AND CRITERION OBJECTIVES	2 DURATION (HOURS)	3 SUPPORT MATERIALS AND GUIDANCE
g. Without reference, identify methods and procedures for case hardening of metals with 75% accuracy.	(1)	respond to all written items in the lesson. Make outside assignment to read 3ABR53131-SG-705. Administer appraisal test upon completion of this assignment. Instructor will use TO 1-1A-1, Sections IV and V, as additional reference. Instructor will use Rockwell hardness tester to test heat treated specimens. Emphasize importance of proper procedural furnace operation to reduce operating cost.
5. Heat Treatment of Heat and Corrosion Resistant Ferrous Alloys, Nickel Base Alloys, Aluminum and Aluminum Alloys, and Titanium Alloys	14 (12/2)	<u>Column 1 Reference</u> / <u>STS Reference</u> 5a — 3a, 3b, <u>19r</u> 5b — <u>19v</u> 5c — 3a, 3b, <u>19q</u> 5d — <u>19w</u>
a. Given a heat treating furnace and metal specimens, set up and heat treat heat and corrosion resistant ferrous alloys to a tensile strength range of from 150,000 to 180,000 psi. All shop safety, good housekeeping, and fire prevention measures must be observed.	(5)	<u>Instructional Materials</u> 3ABR53131-SG-705, Heat Treatment of Heat and Corrosion Resistant Ferrous Alloys, Nickel Base Alloys, Aluminum and Aluminum Alloys, and Titanium Alloys TO 1-1A-9
b. Without reference, identify procedures for heat treatment of nickel base alloys with 75% accuracy.	(.5)	<u>Audio Visual Aids</u> Film: TF 1-4945, Heat Treatment of Aluminum, Part I Film: TF 1-4946, Heat Treatment of Aluminum, Part II Charts: Phase Diagrams
c. Given a heat treating furnace and metal specimens, set up and heat treat aluminum and aluminum alloys to a tensile strength of 70,000 psi ± 10,000 psi. All shop safety, good housekeeping, and fire prevention measures must be observed.	(6)	<u>Training Equipment</u> Heat Treating Furnace (2) Tongs (1) Quench Tank (6) Tensile Tester (12)
d. Without reference, identify procedures for heat treatment of titanium alloys with 75% accuracy.	(.5)	<u>Training Methods</u> Discussion/Demonstration (2 hrs) Performance (10 hrs) Outside Assignment (2 hrs) <u>Instructional Environment/Design</u> Classroom (1.5 hrs) Laboratory (10.5 hrs)

PLAN OF INSTRUCTION (Continued)

1 UNITS OF INSTRUCTION AND CRITERION OBJECTIVES	2 DURATION (HOURS)	3 SUPPORT MATERIALS AND GUIDANCE
		Instructional Guidance Emphasize safety applicable to a heat treating shop. Have each student respond to all written items in the lesson. Make outside assignments to read 3ABR53131-SG-706. Administer appraisal test upon completion of this assignment. Instructor will use TO 1-1A-1, Sections IV and V, as an additional reference. Instructor will use tensile tester to test heat treated specimens. Emphasize conservation of argon gas used in the controlled atmosphere furnace.
6. Cleaning, Plating, and Corrosion Control	10	Column 1 Reference — STS Reference 6a — 26a 6b, 6c — 3a, 3b, 26b 6d — 26c 6e — 26d 6f — 26e 6g — 26f 6h — 26g 6i — 26h 6j, 6k, 6l, 6m — 26i
a. Without reference, identify the methods for identification and prevention of corrosion with 75% accuracy.	(.3)	
b. Given equipment and metal specimens, set up and perform mechanical cleaning operation without error. All shop safety, good housekeeping, and fire prevention measures must be observed.	(3.2)	
c. Given equipment and metal specimens, set up and perform chemical cleaning operations without error. All shop safety, good housekeeping, and fire prevention measures must be observed.	(4)	Instructional Materials 3ABR53131-SG-706, Cleaning, Plating, and Corrosion Control TO 1-1-1, Cleaning of Aerospace Equipment TO 1-1A-9 TO 42C2-1-7, Process Instructions Metal Treatment
d. Without reference, identify the principles involved in plating operations with 75% accuracy.	(.3)	Audio Visual Aids Film: TF 6656, An Ounce of Prevention Charts: Cleaning and Plating
e. Without reference, determine the proper steps relating to preparing and testing plating solutions with 75% accuracy.	(.2)	Training Equipment Sandblast Machine (12) Metal Cleaning Tanks (12) Electroplating Tanks (12) Analytical Test Kit (12)
f. Without reference, determine the proper steps relating to electroplating aircraft and ground equipment parts with 75% accuracy.	(.3)	Training Methods Discussion/Demonstration (6 hrs) Performance (4 hrs)

PLAN OF INSTRUCTION (Continued)

1 UNITS OF INSTRUCTION AND CRITERION OBJECTIVES	2 DURATION (HOURS)	3 SUPPORT MATERIALS AND GUIDANCE
g. Without reference, determine the proper steps and methods for stripping electroplate from parts prior to replating or nondestructive inspection with 75% accuracy.	(.2)	Instructional Environment/Design Classroom (5.5 hrs) Laboratory (4.5 hrs) Instructional Guidance Emphasize safety in the use of acids and cleaning solutions. Have each student perform cleaning operations by both mechanical and chemical processes and respond to all written items in the lesson. Emphasize conservation of mechanical cleaning materials, acids, and alkalines.
h. Without reference, identify safety precautions pertinent to a plating shop without error.	(.2)	
i. Without reference, identify the proper layout and set-up procedures for electroplating shops with 75% accuracy.	(.3)	
j. Without reference, identify the proper steps and procedures relating to anodizing operations with 75% accuracy.	(.2)	
k. Without reference, identify the proper steps and procedures pertaining to metal spraying operations with 75% accuracy.	(.3)	
l. Without reference, identify the proper steps and procedures relating to metal hot dipping operations with 75% accuracy.	(.2)	
m. Without reference, identify methods of oxide coloring operations with 75% accuracy.	(.3)	
7. Related Training (identified in course chart).	10	
8. Measurement and Critique	2	
9. Course Critique and Graduation	2	

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Developed by:
United States Air Force

Development and Review Dates
September 23, 1975

D.O.T. No.:
812.884

Occupational Area:
Machine Shop

Target Audiences:
Grades 11-adult

Print Pages:
181

Cost:
$3.75

Availability:
Military Curriculum Project, The Center for Vocational Education, 1960 Kenny Rd., Columbus, OH 43210

Contents:	Type of Materials:						Instructional Design:				Type of Instruction:	
	Lesson Plans:	Programmed Text:	Student Workbook:	Handouts:	Text Materials:	Audio-Visuals:	Performance Objectives:	Tests:	Review Exercises:	Additional Materials Required:	Group Instruction:	Individualized:
Block VII – *Heat Treating, Hardness Testing, Cleaning, and Electroplating*								★				
Safety and Operation of Heat Treating Furnaces	•				•	★	•		•	★	•	
Identification and Classification of Metals	•				•	★	•		•	★	•	
Hardness Testing	•				•	★	•		•	★	•	
Heat Treatment of Ferrous Metals	•				•	★	•		•	★	•	
Heat Treatment of Heat & Corrosion Resistant Ferrous Alloys, Nickel Base Alloys, Aluminum & Aluminum Alloys & Titanium Alloys	•				•	★	•		•	★	•	
Cleaning, Plating, and Corrosion Control	•				•	★	•		•	★	•	

★ Materials are recommended but not provided.

Expires July 1, 1978

Course Description:

This is the fourth section of a four-part course on metals processing. Training for the entire course includes fabrication of welded structures and metal weld repairs; principles, techniques and processes of welding, cutting, soldering, brazing, and hard surfacing of various types of metals used in fabrication and repair of equipment; blueprint reading; heat treating, hardness testing, identification and prevention of corrosion, use of hand measuring tools; and operation and maintenance of welding, heat treating, test equipment and power machinery such as grinders, drill presses, power saws, and metal cutting shears. Safety is emphasized throughout the course. This section deals with heat treating, hardness testing, cleaning, and electroplating. It contains one block of instruction covering 56 hours. Students should complete Metals Processing Specialist, Blocks V and VI, (3-7), before beginning this fourth part of the course.

Block VII — *Heat Treating, Hardness Testing, Cleaning, and Electroplating* contains the following six lessons:

Safety and Operation of Heat Treating Furances (4 hours)
Identification and Classification of Metals (8 hours)
Hardness Testing (4 hours)
Heat Treatment of Ferrous Metals (18 hours)
Heat Treatment of Heat and Corrosion Resistant Ferrous Alloys, Nickel Base Alloys, Aluminum and Aluminum Alloys, and Titanium Alloys (12 hours)
Cleaning, Plating, and Corrosion Control (10 hours)

This section contains both teacher and student materials. Printed instructor materials include a course chart; detailed lesson plans; and a plan of instruction including the unit of instruction, criterion objectives, the duration of the lessons, and additional materials needed. Student materials include a study guide for the block which contains objectives, information, review exercises and references for each lesson.

Text materials are provided in the study guides, however, several commercial texts and military technical manuals are referenced throughout the course. Audiovisuals suggested for use in the entire course include 188 slides, 8 films, and 2 videotapes. This course can be used as advance study in a metals, welding, or machine shop course.

LESSON PLAN (Part I, General)

APPROVAL OFFICE AND DATE	INSTRUCTOR
TWSTI 14 ...	13-8
COURSE NUMBER 3ABR53131	**COURSE TITLE** Metals Processing Specialist
BLOCK NUMBER VII	**BLOCK TITLE** Heat Treating, Hardness Testing, Cleaning, and Electroplating

LESSON TITLE
Safety and Operatinn of Heat Treating Furnaces

LESSON DURATION

CLASSROOM/Laboratory	Complementary	TOTAL
D & D 1 hr/Perf 3 hrs	None	4 hrs

POI REFERENCE

PAGE NUMBER	PAGE DATE	PARAGRAPH
49	23 Sep 1975	1

STS/CTS REFERENCE

NUMBER	DATE
STS 531X1	31 May 1975

SUPERVISOR APPROVAL

SIGNATURE	DATE	SIGNATURE	DATE

PRECLASS PREPARATION

EQUIPMENT LOCATED IN LABORATORY	EQUIPMENT FROM SUPPLY	CLASSIFIED MATERIAL	GRAPHIC AIDS AND UNCLASSIFIED MATERIAL
1. Heat Treating Furnace 2. Tongs 3. Quench Tanks	None	None	1. 3ABR53131-SG-701 2. TO 1-1A-9 3. Charts - Furnaces CAFB 52-542

CRITERION OBJECTIVES AND TEACHING STEPS

a. Without reference, identify types and uses of heat treating furnaces with 75% accuracy.

b. Given heat treating equipment and TO 1-1A-9, set up and operate furnaces without error. All shop safety, good housekeeping, and fire prevention measures must be observed.

c. Without reference, identify maintenance and repair procedures pertaining to heat treating furnaces with 75% accuracy.

d. Without reference, identify fabricating methods and properties of metals with 75% accuracy.

Teaching steps are listed in Part II.

ATC FORM 770 AUG 72 — GPO 1972 779-396/23

INTRODUCTION TIME: 10 Min. 4

Attention:

Review: During the past six blocks we have learned the basic welding methods and techniques for various types of metals.

Overview: Todays lesson will cover the safety and operation of heat treating furnaces.

Motivation:

BODY TIME: 3 Hrs. 40 min.

PRESENTATION:
(Refer Objectives 1, 2, & 3)

1. Types and uses of Heat Treating Furnaces

   a. Types

      (1) Type of fuel

      (2) Type of atmosphere

      (3) Condition of the air

   b. Uses

      (1) Generate heat in a confined area

      (2) Develop mechanical properties in metals

      (3) Electric Furnace - most common in the Air Force

2. Furnace Construction

   a. Shell

   b. Asbestos

   c. Fire Bricks — Silicon carbide - very brittle

d. Heating Elements

(1) Electrical resistance

(2) Corrosion resistance

(3) Heat resistance

Nickel-Chrome Alloy - costly to repair or replace

e. Hearth Plate

f. Grind rack

(1) Corrosion resistance

(2) Heat resistance

Uniform Heating and to Avoid Hot Spots

g. Furnace Control

(1) Thermocouple

(2) Extension leads

(3) Pyrometer

Pyrometer -

1. Milivoltmeter

2. Mechanical Potentiometer

3. Electrical Potentiometer

3. Set up and Operate Furnaces

a. Check inside furnace

b. Install grid rack

c. Set furnace control

d. Install part

e. Turn power on

4. Cool-Down Procedure

a. Reset control to lower temperature, or

b. Turn power off

c. Leave furnace door closed.

Possible damage to fire brick and heating elements

5. Fabrication Methods

a. Refining Methods

(1) Blast furnace - iron ore to pig iron	Iron ore, limestone, and coke
(2) Bessemer Converter - pig iron to steel	Hot air forced thru molten metal
(3) Basic oxygen furnace - pig iron to steel	Lanced with oxygen
(4) Open Hearth furnace - pig iron and scrap to steel	Chart: CAFB 52-385
(5) Electric Arc furnace - scrap to alloy steel	Chart: CAFB-52-349
(6) Induction furnace - makes uniform comp. metal	Used for tool, and high alloy steels
(7) Cupola furnace - pig iron and scrap to cast iron	Resembles a small blast furnace
(8) Electrolytic Cell - nonferrous metals	Aluminum and Magnesium
b. Wrought Products	Def. shaped while in the solid state
(1) Rolling - passed bewteen rolls	
(2) Forging - shaped by hammer blows while "hot"	Def. Hot - heated above critical temp.
(3) Drawing - pulling a part through a die	Ex. wire drawing.
(4) Extrusion - pushing metal through a die	Ex. angle iron and simple shapes
(5) Piercing - combination of rolling, piercing, and drawing action	Done to metal in the "hot" condition Used for production of Seamless Tubing
c. Cast Products	Def. Formed from metal in the liquid state
(1) Perminant Mold Casting -	
(a) Simple design	Good for production line
(b) Metal or ceramic mold	Produces white cast iron

(c) Mold reused

(d) Fast cooling

(2) Sand Mold Casting

(a) Intricate designs — Not so good for production line

(b) Sand mold — Produces gray cast iron

(c) Pattern used again

(d) Slow cooling

(3) Die casting

(a) Intricate designs

(b) High quality surface finish

(c) Ceramic (destroyed) or metal (permanant) mold

(d) Metal forced in under pressure

(e) Low melting point metals — Aluminum, Zinc, Magnesium, and Pot Metal

6. Characteristics

a. Wrought products -

(1) Small elongated grains

(2) Improved grain pattern

(3) Inclusions broken up

(4) Welding recasts grains

(5) Cold formed stronger than hot formed

b. Cast products -

(1) Intricate shapes

(2) Large grains

(3) Low impact and tensile strength

(4) High compressive strength

(5) Many inclusions

7. Shop Safety

   a. Avoid contact with live electrical circuits

   b. Avoid hot thermocouples.

   c. Tongs for proper handling of metal.

   d. Keep clear when loading or unloading.

   e. Always assume metal and furnace are hot.

APPLICATION:

1. Student will set up and adjust heat treating furnace.

2. All safety procedures will be observed during the accomplishment of the objectives.

3. Assistance will be given where necessary.

EVALUATION:

1. Student must set up and adjust furnaces without error.

2. Written questions given to students must be answered with 75% accuracy.

   1. What type of heat treating furnaces is the most common in the Air Force? Ans. Electric-Circulating Air

   2. What are two uses of a heat treating furnace? Ans. Generate heat in a confined area and develop mechanical properties in metals.

3. What are heating elements made from?
   Ans. Chrome-Nickel alloy

4. Define a wrought product.
   Ans. Any product formed while in the solid state.

5. What are blast furnaces used for?
   Ans. Refine iron ore into pig iron.

6. What fabrication methos id used in the production of sheet steel?
   Ans. Rolling

7. What method is used to extract Aluminum from its ore?
   Ans. Electrolytic process

CONCLUSION TIME: 10 Min.

Summary: Review the following items covered:

1. Types and uses of heat treating furnaces.
2. Set up and operation of heat treating furnaces.
3. Fabrication and characteristics of metals.
4. Safety in the operation of required tasks.

Remotivation:

Assignment:
1. Read 3ABR53230-SG-702
2. Complete 3ABR53230-WS-702
3. Read Chapter 1, paragraph 2-43 thru 2-57, pages 2-8 to 2-11, and Chapter 2, paragraph 2-1 thru 2-12, pages 2-1 to 2-3, in TO 1-1A-9.

Closure: Make appropriate statement, leaving no doubt that the lesson is completed.

APPROVAL OFFICE AND DATE	INSTRUCTOR
TWSTI 14 Oct 75 Richard	
COURSE NUMBER	COURSE TITLE
3ABR53131	Metals Processing Specialist
BLOCK NUMBER	BLOCK TITLE
VII	Heat Treating, Hardness Testing, Cleaning, and Electroplating

LESSON TITLE

Identification and Classification of Metals

LESSON DURATION		
CLASSROOM /Laboratory	Complementary	TOTAL
D & D 4 hrs/Perf 4 hrs	2 hrs	10 hrs

POI REFERENCE		
PAGE NUMBER	PAGE DATE	PARAGRAPH
50	23 Sep 1975	2

STS/CTS REFERENCE	
NUMBER	DATE
STS 531X1	31 May 1975

SUPERVISOR APPROVAL			
SIGNATURE	DATE	SIGNATURE	DATE

PRECLASS PREPARATION

EQUIPMENT LOCATED IN LABORATORY	EQUIPMENT FROM SUPPLY	CLASSIFIED MATERIAL	GRAPHIC AIDS AND UNCLASSIFIED MATERIAL
1. Grinder 2. Trainer: 4047 Spark Tester 3. Test Kit, Chemical	None	None	1. 3ABR53131-SG-702 2. TO 42D-1-3 3. Film: TVL 53-2A 4. Film: TVL 53-2B 5. Charts - Metal Identification CAFB 52-360

CRITERION OBJECTIVES AND TEACHING STEPS

a. Given metal specimens and identification equipment, identify and determine classification of ferrous metals IAW TO 42D-1-3. All shop safety, good housekeeping, and fire prevention measures must be observed.

b. Given metal specimens and identification equipment, identify and determine classification of nonferrous metals IAW TO 42D-1-3. All shop safety, good housekeeping, and fire prevention measures must be observed.

c. Without reference, identify shop methods of metal identification with 75% accuracy.

Teaching steps are listed in Part II.

GPO 1972 779-398/23

INTRODUCTION Time: 10 min

Attention:

Review: Our last lesson was centered on types and uses of heat treating furnaces, the procedure of operating these furnaces, and the fabricating methods and characteristics of metals.

Overview: Upon completion of this lesson you should have a better understanding of the identification and classification of ferrous and non-ferrous metals by the use of numbering systems and color coding. Also you should perform shop methods of metal identification.

Motivation:

BODY Time: 7 hrs 40 min

Presentation:
(Refer to objectives 1, 2, 3, 4 & 5)

1. Identification and classification of ferrous metals by the numbering systems.

   a. SAE Numbering System

      (1) 1st digit shows type of steel

      (2) 2nd digit shows approximate percentage of main alloying element

      (3) Last 2 or 3 digits show carbon content in hundredths of one percent

   b. AISI Numbering System

      (1) First two digits show the type of steel

      (2) Last two or three digits show carbon content in hundredths of one percent

      (3) For common steels, nos. are same as SAE nos.

2. Identification and classification of ferrous metals by color . code.

FeferTO 42D-1-3

a. Used for identifying metal in storage.

Chart: CAFB 52-360

b. Bands of paint represent numbers

c. Shows metal ID numbers

d. Found on each end and read toward the center

3. Identification and classification of nonferrous metals by the AA numbering system

a. Four digit system with a temper designation

b. Pure Aluminum Example (1000)

(1) First digit -1 - pure Al.

(2) Second digit - no. of impurities under control

(3) Third and fourth digits - purity over 99%, in hundredths of one percent

c. Aluminum Alloy Example (2024)

(1) First digit - type of alloy

(2) Second digit - no. of modifications

(3) Third and fourth digits - no. in a series

d. Temper Designations

(1) O - Annealed

(2) F - As fabricated

(3) H - Strain hardened

(4) W - Unstable temper

(5) T - Solution heat treated

(6

(6) Nos. following H & T tell type of process and hardness

END OF DAY SUMMARY

(Day 1, 2hrs)

Summary:

Review:

1. Identification of ferrous metals by numbering systems.

2. Identification of ferrous metals by color code.

3. Identification of nonferrous metals by numbering system.

Assignment:

1. 3ABR53131-Sg-703

2. Chapter 2, paragraph 2-13 thru 2-42, pages 2-3 to 2-8, TO 1-1A-9.

(Day 2, 6 hrs) INTRODUCTION TO NEW DAY'S INSTRUCTION

CONTINUATION:

Review:

1. Identification of ferrous metals by numbering system.

2. Identification of ferrous metals by color code.

3. Identification of nonferrous metals by numbering system.

Objectives to be covered:

1. Identification of nonferrous metals by color code.

2. Shop method of identification

BODY

Time:

Presentation:

4. Identification and classification of nonferrous metals by use of color code.

   a. Used on metal in storage

   b. Bands of paint represent nos. and letters

   c. Found at each end and read toward the center

5. Shop methods of metals identification

a. Spark test

(1) Separate ferrous from nonferrous

(2) Positive identification of carbon and alloy steels

(a) Known sample compared to unknown sample

(b) Against a dark background

(c) Size, shape, color and quantity of sparks noted

b. Cupric chloride Test - to tell stainless steel from nickel base alloys.

(1) Add one drop to the surface of the metal

(2) Let stand for 2 minutes

(3) Slowly add four drops water

(4) Brown spot - it is stainless steel

(5) White spot - it is nickel base

b. Caustic Soda Test - to tell heat treatable from non-heat treatable aluminum

(1) Submerge a corner of the part in 10% SOLUTION of caustic soda

(2) Black - it is heat treatable

(3) No effect - it is non-heat treatable

(4) Black along edge - clad H/T alloy

d. Flame test

(1) Use to tell Al. from Mg.

(2) Aluminum melts

(3) Magnesium burns violently

(4) Caution: very high temp. flame

e. Chip test

(1) Used on cast iron

(2) White cast - - small broken fragments

(3) Grey cast iron - small, approx. 1/8" long before breaking

(4) Maleable cast iron - - 1/8 to 3/8" long , tends to curl before breaking

f. Heat and Quench test

(1) Used to tell low carbon tubing from alloy steel tubing

(2) Specimen heated to cherry red and quenched in water

(3) Alloy steel - hard and brittle

(4) Low carbon steel - soft and ductile

(5) Checked by - hardness tester, file hardness, or squeezing in a vise

g. Shop Safety

h. Good Housekeeping and fire prevention

Application:

Given adequate materials and equipment the student will identify various metals by using shop methods of metal identification.

Evaluation:

1. Shop methods of metal identification must be done I.A.W. TO 34W4-1-5.

2. Students must answer questions over the following objectives with 75% accuracy:

a. Ferrous numbering systems

b. Coloring coding ferrous metals

c. The AA numbering system

d. Coloring coding non-ferrous metals

3. Questions:

1. What is a ferrous metal?

2. What does the second digit of a SAE number refer to?

3. What do the last two digits of a four digit ferrous no. refer to?

4. What does the first digit of an SAE no. refer to?

5. What TO covers color coding of metals used by the Air Force?

6. What does the color code for a steel represent?

7. Where on a length of bar steel is the color code found?

8. In which direction are color codes read?

9. What two series of aluminums can be hardened by heat treatment?

10. Which series of aluminus is not an alloy series?

11. Which of the aluminum series will respond to cold working?

12. Copper is the main alloying element in which series?

Questiond 13, 14, 15,& 16 use the color code chart:

13. An aluminum alloy colored green, black, green, yellow is?

14. An aluminum alloy colored red, black, red, olive drab, is?

15. An aluminum alloy colored maroon, green, maroon, black, is?

16. An aluminum alloy colored yellow, black, yellow, olive drab, is?

CONCLUSION   Time: 10 min.

Summary:

Review the following:

1. Ferrous numbering system

2. AA numbering system

3. Coloring coding of metals

4. Shop methods of metal identification

Remotivation:

Assignment:

1. Read chapter 703, 3ABR53131-SG-703.

2. Read chapter 2, paragraph 2-13, thru 2-42, pages 2-3 to 2-8, in TO 1-1A-9

LESSON PLAN (Part I, General) 18

APPROVAL OFFICE AND DATE	INSTRUCTOR
TWSTI 14 Oct 75 Bickard	

COURSE NUMBER	COURSE TITLE
3ABR53131	Metals Processing Specialist

BLOCK NUMBER	BLOCK TITLE
VII	Heat Treating, Hardness Testing, Cleaning, and Electroplating

LESSON TITLE
Heat Treatment of Ferrous Metals

LESSON DURATION

CLASSROOM/Laboratory	Complementary	TOTAL
D & D 4 hrs/Perf 14 hrs	6 hrs	24 hrs

POI REFERENCE

PAGE NUMBER	PAGE DATE	PARAGRAPH
52 and 53	23 Sep 1975	3

STS/CTS REFERENCE

NUMBER	DATE
STS 531X1	31 May 1975

SUPERVISOR APPROVAL

SIGNATURE	DATE	SIGNATURE	DATE

PRECLASS PREPARATION

EQUIPMENT LOCATED IN LABORATORY	EQUIPMENT FROM SUPPLY	CLASSIFIED MATERIAL	GRAPHIC AIDS AND UNCLASSIFIED MATERIAL
1. Heat Treating Furnace 2. Tongs 3. Quench Tanks 4. Rockwell Hardness Tester	None	None	1. 3ABR53131-SG-704 2. TO 1-1A-9 3. TO 00-25-224 4. Film: TFL-4016, Part 1 & 2 5. Film TVL 53-11 6. Charts: Group Nam[e] Phase Diagram CAFB 52-361

CRITERION OBJECTIVES AND TEACHING STEPS

a. Without reference, identify metal alloy compositions and their relation to heat treatment with 75% accuracy.

b. Without reference, identify basic structures produced by heat treating operations with 75% accuracy.

c. Given a heat treating furnace and metal specimens, set up and normalize carbon and alloy steels with a Rockwell hardness range of no less than RB-90 and no greater than RC-25. All shop safety, good housekeeping, and fire prevention measures must be observed.

d. Given a heat treating furnace and metal specimens, set up and harden carbon and alloy steels with a Rockwell hardness of no less than RC-55. All shop safety, good housekeeping, and fire prevention measures must be observed.

ATC FORM AUG 72 770

☆ GPO: 1972 770-388/23

CRITERION OBJECTIVES AND TEACHING STEPS (Continued)

e. Given a heat treating furnace and hardened metal specimens, set up and temper carbon and alloy steels to within ± 2 Rockwell hardness points, of that specified by the instructor. All shop safety, good housekeeping, and fire prevention measures must be observed.

f. Given a heat treating furnace and metal specimens, set up and anneal carbon and alloy steels with a Rockwell hardness no greater than RB-85. All shop safety, good housekeeping, and fire prevention measures must be observed.

g. Without references, identify methods and procedures for case hardening of metals with 75% accuracy.

Teaching steps are listed in Part II.

INTRODUCTION Time: 10 nim.

Attention:

Review: During our last lesson we covered the various methods to identify and classify metals and the characteristics, Evaluate CTT assignment.

Overview: Upon completing todays lesson you will be able to determine heat treating effects on carbon steels and alloys to properly perform such heat treating operations as normalizing, hardening, tempering, and annealing.

Motivation:

BODY Time: 17hrs, 40min.

Presentation: (Refer to objectives 4a, 4b, 4c,&4d)

1. Composition of metals and alloys and their relation to heat treatment.

   a. Chemical composition of metal will effect:

      (1) Grain structure

      (2) Properties

      (3) Metal or alloy

   b. Alloys and their relation to heat treatment of ferrous metals

      (1) Carbon - main hardening element

      (2) Molydeneum-gives steel toughness

      (3) Nickel-gives steel toughness and aids in corrosion resistance

      (4) Chromiun-gives depth hardness and corrosion resistance

2. Basic structures produced during heat treating operations.

a. Grain Size

(1) Various from 1 (largest) to 8 (smallest)

(2) Normally 5 to 7 after proper heat treatment

b. Structures

(1) Solid Solution

(a) Interstitial such as carbon, nitrogen and hydrogen

(b) Substitutional such as Ni, Mo, & Cr,

(c) Ferrite-low temp. solid solution of carbon in iron (below 1333 F)

(d) Austenite-hign temp. solid solution of carbon in iron (above 1333 F)

(2) Chemical Compound

(a) Intermetallic such as iron carbide (Cementite)

(b) Has specific chemical composition

(c) Normally hard brittle

(3) Mechanical Mixture

(a) Two or more phases present, and can be physically separated.

(b) Pearlite-alternate layers of ferrite and cementite. (toughest grain structure)

(c) Martensite- afine mixture of iron and carbon (hardest grain structure)

(Day 3, 2hrs)

END OF DAY SUMMARY

Summary:

Review:

1. Composition of metals and alloys and their relation to heat treatment.

2. Basic structures produced during heat treatment operations.

Assignment:

Review:

1. 3ABR53131-SG-704

2. Class notes

INTRODUCTION TO NEW DAY'S INSTRUCTION

CONTINUATION:
(Day 4, 6hrs)

1. Evaluate CTT assignment

2. Attention:

3. Remotivation:

4. Review:

   a. Composition of metals and alloys and their relation to heat treating

   b. Basic structures produced by heat treating operations.

5. Objectives to be covered:

   a. Normalizing of carbon and alloy steels

   b. Hardening of carbon and alloy steels

Presentation:

c. Three steps in all heat-treating operations

   (1) Heat

   (2) Soak

   (3) Cool

d. Five common heat treating operations

(1) Annealing

(2) Normalizing

(3) Hardening

(4) Tempering

(5) Case Hardening

3. Norlize SAE carbon and alloy steels

a. Purpose

(1) Remove internal stress induced by:

(a) Welding

(b) Forging

(c) Heat treating

(d) Forming

(e) Machining

(2) Prepare part for further heat treatment

b. Procedure:

(1) Heat metal above its upper critical point

(2) Soak time varies with thickness

(3) Cool in still air

c. Precautions:

(1) Cooling too fast causes hardening

(2) Cooling too slow causes carbide disburtion

(3) Over soaking causes large grain structure

4. Harden SAE carbon and alloy steel

   a. Purpose:

      (1) Induce hardness

      (2) Increase tensile strength

   b. Considerations:

      (1) Effect of alloying elements

         (a) Amount of carbon

         (b) Alloying elements

      (2) Effect of mass or design

      (3) Effects of quenching

      (4) Preheating

   c. Procedure:

      (1) Preheat if necessary

      (2) Heat

         (a) Below 1080 carbon-
             heat above upper critical

         (b) Above 1080 carbon-
             heat above lower critical

      (3) Soak time varies with thickness

      (4) Cool - rapid cooling

         (a) Water - for carbon steel

         (b) Oil - for alloy steel

         (c) Oil or air for tool steel

Application:

Students will be given applicable equiptment and materials to perform normalizing and hardening of steels,

Evaluation:
Normalizing and hardening nust be done IAW TO 1-1 a-9.

Assistance will be given with the hardest parts.

(Day 4, 6hrs) END OF DAY SUMMARY

Summary:

Review:

1. Composition of metals and alloys and thier relation to heat treatment.

2. Basic structures produced during heat treating operations.

3. Normalizing and of carbon and alloy steels.

4. Hardening of carbon and alloy steels.

Assignment:

1. 3ABR53131-SG-704

2. Review class notes.

(Day 5, 6hrs) INTRODUCTION TO NEW DAY'S INSTRUCTION

Continuation:

1. Evaluate CTT assignment

2. Remotivation

3. Review:

   a. Composition of metals

   b. Basic structures

   c. Normalizing

   d. Hardening

4. Objectives to be covered:

   a. Hardening of carbon and alloy steels.

   b. Tempering of carbon and alloy steels.

PRESENTATION:

5. Temper SAE carbon and alloy steel

   a. Purpose

      (1) Remove brittleness

      (2) Increase toughness

(3) Achieve desired hardness

(4) Relief of stresses

(5) High impact strength

(6) Greater ductility

b. Tempering temperature

(1) Depends on final hardness

(2) Ranges from 212 to just below 1333 F.

(a) Carbon steel 400-800 F

(b) Alloy steel 1100-1250 F

(c) High speed steel 1000-1250F

c. Procedure:

(1) Heat to required temp.

(2) Soak time varies with thickness

(3) Cool

(a) Rate of cooling doesn't effect hardness

(b) Normally cooled in still air

(c) cooling too fast can cause cracking

(4) When in doubt use lowest temp.

Application:

Students will be given applicable equiptment and materials to perform hardening and tempering of steels.

Evaluation:

Hardening and tempering operations must be done IAW TO 1-1A-9.

Assistance will be given with the hardest parts.

(Day 5, 6hrs) END OF DAY SUMMARY

Summary:

Review:

1. Composition of metals and alloys and their relation to heat treatment.

2. Basic structures produced during heat treating operations.

3. Normalizing, hardening, and tempering of carbon and alloy steels.

Assignment:

1. Read 3ABR53131-SG-705 & ans. questions.

2. Review class notes.

INTRODUCTION TO NEW DAY'S INSTRUCTION

(Day 6,4hrs)

Continuation:

1. Evaluate CTT assignment

2. Remotivation:

3. Review:

a. Composition of metals

b. Basic structures of metals

c. Normalizing

d. hardening

e. Tempering

3. Objectives to covered:

a Annealing of carbon and alloy steels.

b. Case hardening of steels.

Presentation:

6. Anneal SAE carbon and alloy steel

a. Purpose

(1) Soften metal for machining

(2) Remove the cold working or heat treatment

(3) Refines the grain structure

(4) Removes the internal stresses

b. Process

(1) Heating temp. same as hardening temp.

(2) Soak time varies with thickness

(3) Cool- slow cool (normally furnace cool

7. Case hardening metals

a. Purpose

(1) Produce a hard, wear resistant surface

(2) Produce a tough inner core

b. Materials used

(1) Carborizing

(a) Pack carborizing part packed in solid charcoal

(b) Liquid carborizing part in liquid salt with high carbon content

(c) Gas carborizing part in a carborizing atmosphere

(2) Nitriding

(3) Carbo-Nitriding

(4) Cyaniding

(5) All methods can be performed in solid, liquid or gas surroundings

c. Process

(1) Requires several heat treating operations

(2) A change of chemical composition of the surface of the part

(3) No change in the core of the part

(4) Surface becomes hardenable

Application:

Students will be given applicable equipment and materials to perform annealing of steels.

Evaluetion:

Annealing must be done IAW TO 1-1A-9

Assistance will be given with the hardest parts.

Students will be administer appraisal test on methods and procedures for case hardening of steels with 75% accuracy.

CONCLUSION Time: 10min.

Summary:

Review the following:

1. Composition of metals and alloys and their relation to heat treating.
2. Basic structures produced during heat treating operations.
3. The setting up and normalizing, hardening, tempering and annealing of carbon and alloy steels.
4. The case hardening of metals

Assignment:

1. Read 3ABR53131-SG-705
2. Read chapter 3, paragraph 3-17 thru 3-69, in TO 1-1A-9

NOTE: Numbers 30-40 have been omitted. However, all materials are included.

LESSON PLAN (Part I, General) 41

APPROVAL OFFICE AND DATE TWSTI 14 Oct 75 Richard	INSTRUCTOR
COURSE NUMBER 3ABR53131	COURSE TITLE Metals Processing Specialist
BLOCK NUMBER VII	BLOCK TITLE Heat Treating, Hardness Testing, Cleaning, and Electroplating

LESSON TITLE Heat Treatment of Heat and Corrosion Resistant Ferrous Alloys, Nickel Base Alloys, Aluminum and Aluminum Alloys, and Titanium Alloys

LESSON DURATION

CLASSROOM/Laboratory	Complementary	TOTAL
D & D 2 hrs/Perf 10 hrs	2 hrs	14 hrs

POI REFERENCE

PAGE NUMBER	PAGE DATE	PARAGRAPH
53 and 54	23 Sep 1975	5

STS-CTS REFERENCE

NUMBER	DATE
STS 531X1	31 May 1975

SUPERVISOR APPROVAL

SIGNATURE	DATE	SIGNATURE	DATE

PRECLASS PREPARATION

EQUIPMENT LOCATED IN LABORATORY	EQUIPMENT FROM SUPPLY	CLASSIFIED MATERIAL	GRAPHIC AIDS AND UNCLASSIFIED MATERIAL
1. Heat Treating Furnace 2. Tongs 3. Quench Tank 4. Tensile Tester	None	None	1. 3ABR53131-SG-705 2. TO 1-1A-9 3. Film: TF 1-4945 4. Film: TF1-4946 5. Charts - Phase Diagrams, CAFB 52-361

CRITERION OBJECTIVES AND TEACHING STEPS

a. Given a heat treating furnace and metal specimens, set up and heat treat heat and corrosion resistant ferrous alloys to a tensile strength range of from 150,000 to 180,000 psi. All shop safety, good housekeeping, and fire prevention measures must be observed.

b. Without reference, identify procedures for heat treatment of nickel base alloys with 75% accuracy.

c. Given a heat treating furnace and metal specimens, set up and heat treat aluminum and aluminum alloys to a tensile strength of 70,000 psi ± 10,000 psi. All shop safety, good housekeeping, and fire prevention measures must be observed.

d. Without reference, identify procedures for heat treatment of titanium alloys with 75% accuracy.

Teaching steps are listed in Part II.

ATC FORM AUG 72 770

GPO: 1972 779-398/2

INTRODUCTION Time: 10min.

Attention:

Review: During our last lesson, we covered various types of heat treating operations and were able to determine their effects on carbon and alloy steel.

Evaluate CTT assignment.

Overview: Upon completing today's lesson, you will be able to perform the heat treatment of non-ferrous metals.

Motivation:

BODY Time:

Presentation:
(Refer to objectives, 5a, 5b, 5c, & 5d)

1. Heat treatment of Heat and Corrosion Resistant Ferrous Alloys.

   a. Purpose

      (1) Soften the metal

      (2) Improve corrosion resistance

      (3) Harden the metal

      (4) Increase tensile strength

   b. Types

      (1) Austenetic

      (2) Ferrictic

      (3) Martensictic

      (4) Precipitation hardening

   c. Heat treatment of stainless steels

      (1) Austenitic and ferritic

         (a) Only hardening- cold worked

         (b) Only heat treating - annealing (Heat and quench)

(2) Martensitic

(a) Hardening - similar to carbon steels (heat and oil quench or air cool)

(b) Annealing

(3) Precipitation Hardening

(a) Hardening - similar to aluminum (solution heat treat, sustinizing and aging)

(b) Annealing

d. Heat treating procedure

(1) Anneal 321 stainless steels
heat 1750 to 1950 degrees
soak for 1 hour
cool - water quench

(2) 17-7 PH

(a) Condition A (solution annealed from factory)

(b) Austenizing
Heat 1400 plus or minus 25 degrees
Soak for 1-1/2 hours
Cool to 32 to 60 degrees
within 1 hour, hold 1/2 hour.

(c) Precipitation hardening
(180,000 psi)
Heat to 1050 plus or minus 10 degrees
Soak 1-1/2 hours
Cool in still air

(Day 6, 2 hrs) END OF DAY SUMMARY

Summary:

Review:

1. Heat treatment of heat and corrosion resistant ferrous alloys.

Assignment:

Review:

1. 3ABR53131-SG-705

2. Class notes

(Day 7, 6 hrs) INTRODUCTION TO NEW DAY'S INSTRUCTION

Continuation:

1. Evaluate CTT assignment
2. Remotivation:
3. Review - Heat treatment of heat and corrosion resistant ferrous alloys.
4. Objectives to be covered:
   a. Heat treatment of stainless steels
   b. Procedures for heat treatment of nickel base alloys
   c. Set up and heat treatment of aluminum and aluminum alloys

Presentation:

2. Heat treating of Nickel base alloys
   a. Purpose
      (1) Soften the metal
      (2) Improve corrosion resistance
      (3) Harden the metal
      (4) Increase tensile strength
   b. Properties
      (1) Most are similar to austenetic stainless steels
      (2) Some heat treating like precipitation hardening stainless steels
   c. Annealing Procedure
      (1) Heat to 1800 to 2200 degrees
      (2) Soak for a short time to prevent grain growth.
      (3) Cool rapidly to prevent age hardening

(4) Alloys vary in heat treating and should be researched in TO 1-1A-9 Before heat treating.

3. Heat treatment of Aluminum and Aluminum alloys

a. Purpose

(1) Develop maximum tensile strenght

(2) Increase hardness

(3) Increase of corrosion resistance of nonclad alloys

(4) Remove hardness due to heat treatment or cold working.

b. Procedure

(1) Solution heat treatment

(a) Heat to specified temperature (900 to 1000 degrees)

(b) Soak time depends on thickness of the part and type of alloy

(c) Quench - water, to retain copper in solution

(d) Done mostly to 2xxx & 7xxx series alloys

Application:

Students will be given applicable equipment and materials to perform heat treatment of stainless steels and aluminum alloys.

Evaluation:

1. Heat treatment of heat and corrosion resistant ferrous metals must be done IAW TO 1-1A-9.

Assistance will be given on the hardest parts.

2. Students be administered an appraisal test on heat treating procedures of Nickel base alloys with 75% accuracy.

3. Heat treatment of Aluminum and aluminum alloys must be done IAW TO 1-1A-9.

   Assistance will be given on the hardest parts.

(Day 7, 6hrs) END OF DAY SUMMARY

Summary:

Review:

1. Heat treatment of heat and corrosion resistant ferrous alloys.
2. Procedures for heat treatment of Nickel base alloys.
3. Heat treatment of aluminum and aluminum alloys.

Assignment:

Review:

1. 3ABR53131-SG-706 and answer questions.
2. Classnotes.

(Day 8, 4hrs) INTRODUCTION TO NEW DAY'S INSTRUCTION

Continuation:

1. Evaluate CTT assigment
2. Remotivation:
3. Review:
   a. Heat treatment of heat and corrosion resistant ferrous alloys.
   b. Procedures for heat treatment of Nickel base alloys.
   c. Heat treatment of Aluminum and aluminum alloys.

4. Objectives to be covered:

a. Heat treatment of Aluminum and aluminum alloys

b. Identify procedures for heat treatment of titanium alloys.

Presentation:

(2) Aging

(a) Natural aging

1 Done at room temperature

2 Requires many hours

3 May be retarded by cooling

(b) Artificial aging

1 Done at elevated temp, in furnace

2 Shorter period of time than natural aging

3 Produces higher strength

4 Cooled by any method

c. Procedure for 2024 alloy aluminum, 0.125" thichness.

(1) Heat - 920± 10 degrees F.

(2) Soak - 40 to 50 min.

(3) Cool - water quench

(4) Naturally age - 96 hrs.

d. Procedure for annealing 2024 alloy aluminum

(1) Heat - 750 to800 degrees F.

(2) Soak - 1 hour

(3) Cool - furnace cool

4. Heat treatment of titanium alloys

   a. Purpose

      (1) Relieve stresses

      (2) Soften the metal

      (3) Increase tensile strength

   b. Procedure

      (1) Stress relieving

         (a) Heat - 900 to 1300 degrees F.

         (b) Soak - 1/4 to 8 hrs.

         (c) Cool - still air

         (d) Treatment varies with specific alloy

      (2) Annealing

         (a) Heat - 1200 to 1650 degrees F.

         (b) Soak - 1/2 to 8 hrs.

         (c) Cool - slow cool or still air

         (d) Treatment varies with specific alloy

      (3) Hardening

         (a) Solution heat treatment

            1 Heat - 1400 to 1850 degrees F.

            2 Soak - up to 1 hr.

            3 Cool - water quench

         (b) Aging

            1 Heat - 900 to 1150 degrees F.

            2 Soak - 2 to 8 hours

            3 Cool - still air

Application:

1. Students will be given applicable equiptment and materials to perform heat treatment of aluminum andalu aluminum alloys.

Evaluation:

1. Heat treatment of aluminum and aluminum alloys must be done IAW TO 1-1A-9.

   Assistance will be given on the hardest parts.

2. Students will be administered an appraisal test on procedures for heat treatment of Titanium and Titanium alloys with 75% accuracy.

CONCLUSION TIME: 10min.

Summary:

Review the following:

1. Heat treatment of heat and corrosion resistant ferrous alloys.
2. Procedures for heat treatment of Nickel base alloys.
3. Heat treatment of aluminum and aluminum alloys.
4. Procedures for heat treatment of titanium alloys.

Remotivation:

Assignment:

1. Read 3ABR53131-SG-706 and answer questions.
2. Read chapters 1 and 7, TO 42C2-1-7.

LESSON PLAN (Part I, General) 50

APPROVAL OFFICE AND DATE TWSTI	INSTRUCTOR	
COURSE NUMBER 3ABR53131	COURSE TITLE Metals Processing Specialist	
BLOCK NUMBER VII	BLOCK TITLE Heat Treating, Hardness Testing, Cleaning, and Electroplating	
LESSON TITLE Cleaning, Plating, and Corrosion Control		

LESSON DURATION

CLASSROOM/Laboratory	Complementary	TOTAL
D & D 6 hrs/Perf 4 hrs	None	10 hrs

POI REFERENCE

PAGE NUMBER	PAGE DATE	PARAGRAPH
54 and 55	23 Sep 1975	6

STS-CTS REFERENCE

NUMBER	DATE
STS 531X1	31 May 1975

SUPERVISOR APPROVAL

SIGNATURE	DATE	SIGNATURE	DATE

PRECLASS PREPARATION

EQUIPMENT LOCATED IN LABORATORY	EQUIPMENT FROM SUPPLY	CLASSIFIED MATERIAL	GRAPHIC AIDS AND UNCLASSIFIED MATERIAL
1. Sandblast Machine 2. Metal Cleaning Tanks 3. Electroplating Tanks 4. Analytical Test Kit	None	None	1. 3ABR53131-SG-706 2. TO 1-1A-9 3. TO 42C2-1-7 4. TO 1-1-1 5. Film: TF 6656 6. Chart: CC74-204

CRITERION OBJECTIVES AND TEACHING STEPS

a. Without reference, identify the methods for identification and prevention of corrosion with 75% accuracy.

b. Given equipment and metal specimens, set up and perform mechanical cleaning operation without error. All shop safety, good housekeeping, and fire prevention measures must be observed.

c. Given equipment and metal specimens, set up and perform chemical cleaning operation without error. All shop safety, good housekeeping, and fire prevention measures must be observed.

d. Without reference, identify the principles involved in plating operations with 75% accuracy.

e. Without reference, determine the proper steps relating to preparing and testing plating solutions with 75% accuracy.

ATC FORM AUG 72 770

CRITERION OBJECTIVES AND TEACHING STEPS (Continued)

f. Without reference, determine the proper steps relating to electroplating aircraft and ground equipment parts with 75% accuracy.

g. Without reference, determine the proper steps and methods for stripping electroplate from parts prior to replating or non-destructive inspection with 75% accuracy.

h. Without reference, identify safety precautions pertinent to a plating shop without error.

i. Without reference, identify the proper layout and set-up procedures for electroplating shops with 75% accuracy.

j. Without reference, identify the proper steps and procedures relating to anodizing operations with 75% accuracy.

k. Without reference, identify the proper steps and procedures pertaining to metal spraying operations with 75% accuracy.

l. Without reference, identify the proper steps and procedures relating to metal hot dipping operations with 75% accuracy.

m. Without reference, identify methods of oxide coloring operations with 75% accuracy.

Teaching steps are listed in Part II.

INTRODUCTION TIME: 10 Min.

ATTENTION:

REVIEW: During the previous lesson we covered the basic procedures and techniques of making hardness test, using the Rockwell tester.

OVERVIEW: Upon completing the lesson you will be able to identify and take precaution for prevention of corrosion, and be able to clean metals and understand the principles of plating.

MOTIVATION:

BODY TIME: 9 hrs 40 min

PRESENTATION:

1. Identification and prevention of corrosion

   a. Identification

      (1) Definition: Corrosion is the deterioration of a metal due to reaction with its environment.

      (2) Types

         (a) Uniform etch corrosion

            1 First seen as a general dulling of the surface

            2 The surface becomes rough and possibly frosted in appearance

         (b) Pitting corrosion

            1 Common on aluminum and magnesium alloys

            2 First as a white or gray powdery deposit

            3 Tiny pits or holes in the surface

         (c) Intergranular corrosion

            1 A form of galvanic corrosion

2 Shows itself by lifting up the surface grains of a metal

(d) Galvanic corrosion

1 Occurs when dissimilar metals are in contact and external circuit is present.

2 Corrosion at the joint between the metals.

(e) Stress corrosion cracking

1 Caused by tensile stress and corrosion

2 Stress may be internal or applied

3 Difficult to recognize before cracks appear

(f) Exfoliation corrosion

1 A form of intergranular corrosion

2 Along the grain boundaries under surface

3 Cause metal to flake like leaves

b. Prevention of corrosion

(1) Proper heat treatment

(2) Scheduled inspection

(3) Preventive maintenance of metals

(a) Aluminum alloys

1 Alclad

2 Anodized

3 Chemically treated

4 Painted

(b) Steel and iron

1 Plated

2 Painted

(c) Magnesium alloys

1 Chemical treatment

2 Painted

2. Selection of cleaning agent

a. Type of contamination

(1) Inorganic soils

(a) Chemical reaction of elements

(b) Rust, scale, oxides

(c) Removal requires removal of some base metal

(2) Organic soils

(a) Mechanically adhered to metal

(b) Paint, oil, grease

(c) Soil lifted away from base metal, no loss of metal

b. Degree of cleanliness

(1) Welding

(2) Plating

(3) Special surface treatments

c. Type of metal to be cleaned

d. Design of part

e. Surface finish to be retained

3. Cleaning Processes

   a. Mechanical cleaning

      (1) Removal of base metal

      (2) Organics should be removed first

      (3) Possible galvanic or intergranular corrosion

APPLICATION:

None

EVALUATION:

Students will be administered appraisal test on identification and prevention of corrosion with 75% accuracy.

(Day 8, 2 hrs) END OF DAY SUMMARY

SUMMARY:

REVIEW:

1. Methods for identification and prevention of corrosion.

2. Mechanical cleaning operations

ASSIGNMENT:

REVIEW:

1. 3ABR53131-SG-706

2. Class notes

3. Chapters 1 and 7, TO 4202-1-7

(Day 9, 6 hrs) INTRODUCTION TO NEW DAY'S INSTRUCTION

Continuation:

1. Evaluate CTT assignment

2. Remotivation:

3. Review:

   a. Methods for identification and prevention of corrosion

   b. Mechanical cleaning operations.

4

4. Objectives to be covered:

   a. Mechanical cleaning operations

   b. Chemical cleaning operations

   c. Principles of plating operations

   d. Steps relating to preparation and testing of plating solutions.

PRESENTATION:

b. Chemical Cleaning

(1) Solvent cleaning

(a) Dissolving action solvents, kerosene, naptha or acetone

(b) Emulsifying action hot water, steam or soap

(c) Both remove organic soil

(2) Vapor degreasor

(a) Solvent type cleaner to remove organic soils

( ) Part hung solution

1 Vapor rises heat

2 Condenses on part

3 Runs off

(c) Dissolving and rinsing actions

(3) Alkaline immersion

(a) Reaction with organic soils

(b) Heated to 205-210 degrees F.

(c) Changes soil to soapy residue

(d) Rinses off readily

(e) For organic soils only

(4) Electro-Alkaline Cleaning

(a) Alkaline action - change organic to soap

(b) Scrubbing action - production of hydrogen and oxygen bubbles (electrolysis)

(c) Ionization action - change soil to charged particles and repel from surface

(d) Reverse current for 30 sec to prevent intergranular corrosion

(e) Cleaning power increased when heated (205-210)

4. Preparing and testing Cleaning Solution

a. Solvents

(1) Used full strength

(2) Replaced when contaminated

b. Alkaline solutions

(1) Can be neutralized with acids

(2) Replaced when loss of cleaning power

(3) Neutralized then disposed down drain

(4) Possible explosion when preparing solution of excessive build-up dissolving the caustic soda

c. Acid Solutions

(1) Can be neutralized with alkalines

(2) Replaced when loss of cleaning power

(3) Neutralized then disposed of down drain

(4) Never add water to acid - excessive heat generated possible bubbling and splattering

(5) Always add acid to water

5. Principles involved in Plating

a. Purpose of plating

(1) Corrosion control - cadmium

(2) Base layer for other plating copper or nickel

(3) Decoration or hard surfacing nickel or chromium

b. Plating and electrolytic process

(1) A pure metal and the part placed in the electrolyte

(a) Pure metal as the positive electrode anode

(b) Part as the negative electrode cathode

(2) Current is passed through the electrolyte

(a) Tiny particles of pure metal deposited on the part

(b) Process is continued to required thickness

(3) Test plated deposit

(a) Adhesion

1 Bend test

2 Magnification test

(b) Thickness

1 Micrometer

2 Acid Drop test

c. Equipment used for plating

(1) Source of current-rectified DC

(2) Current controls - amps and volts

(3) Plating tank - corrosion resistant

(4) Solution - electrolyte

6. Prepare and test plating solutions

a. Prepare a cadmium plating solution

(1) Cadmium oxide 3.5 oz per gal of water

(2) Sodium cyanide 16 oz per gal of water

(3) Brighter 1 oz per 25 gal of water

(4) Cadmium balls

b. Testing a cadmium solution

(1) Cadmium determination

(2) Total and free sodium cyanide determination

(3) Sodium carbonate determination

(4) Sodium hydroxide determination

(5) Done weekly or more often if necessary

(6) Always refer to 42C2-1-7

APPLICATION:

1. Students will perform mechanical cleaning operations on various types of metals IAW TO 1-1-1 and 42C2-1-7.

2. Students will perform chemical cleaning operations on various types of metals IAW TO 1-1-1 and 42C2-1-7.

EVALUATION:

1. Students will be administered an appraisal test on methods for identification and prevention of corrosion with 75% accuracy.

2. Students will be administered an appraisal test on principles of plating operations with 75% accuracy.

3. Students will be administered an appraisal test on the steps relating to preparation and testing of plating solutions with 75% accuracy.

(Day 9, 6 hrs) END OF DAY SUMMARY

SUMMARY:

REVIEW:

1. Methods for identification and prevention of corrosion
2. Mechanical cleaning operations
3. Chemical cleaning operations
4. Principles of plating operations
5. Steps relating to preparation and testing of plating solutions.

ASSIGNMENT:

REVIEW:

1. Class notes
2. 3ABR53131-SG-706
3. Chapters I and VII of TO 42C2-1-7

(Day 10, 2 hrs) INTRODUCTION TO NEW DAY'S INSTRUCTION

CONTINUATION:

1. Remotivation:
2. Review
   a. Methods for identification and prevention of corrosio

b. Mechanical cleaning operations

c. Chemical cleaning operations

d. Principles of plating operations

e. Steps relating to preparation and testing of plating solutions.

3. Objectives to be covered

a. Determine steps relating to electroplating aircraft and age parts.

b. Determine steps and methods for stripping plated parts.

c. Identify safety precautions pertinent to a plating shop.

d. Identify proper layout and setup procedures for plating shop.

e. Identify steps and procedures for anodizing.

f. Identify steps and procedures for metal spraying.

g. Identify steps and procedures for hot dipping.

h. Identify methods of oxide coloring.

PRESENTATION:

7. Electroplate aircraft and ground equipment parts (consult Tech Order)

a. Cadmium plating tank temperature 80 to 90 degrees

b. Voltage 1 to 4 volts

c. Current density 15 to 45 amperes per square ft, surface area of part.

d. Plating time according to thickness of plating

e. Rinsed in cold water (room temp)

f. Immersed in chromic acid solution for one or two minutes, brightner

g. Final rinse should be in water heated 180 to 190 degrees

h. Heat treatment to remove hydrogen embrittlement of high strength steels

8. Strip plating from parts prior to replating or non-destructive inspection

a. Use of acids (cadmium plating)

b. Nitrates (Ammonium 1 lb per gal of water)

c. Off plating (Chromium and copper)

d. Always refer to 42C2-1-7

9. Practice safety precaution pertinent to a plating shop

a. Cyanide can kill three ways

(1) Breath in fumes

(2) Enter skin through cut and pores

(3) Enter system through mouth

b. Store flammables in cool dark place

c. Don't smoke within 50 ft of flammables

d. Provide adequate ventilation as protection from fumes

e. Never handle a part until it is rinsed and dried

f. Wear protective clothing and eye protection

g. Never mix acid and cyanide, this causes toxic hydrocanic gas

h. Clean up spilled chemicals immediately.

10. Plan, lay out and set up electroplating shop

a. Type and volume of plating

b. Safety

(1) Exhaust system

(2) Safety showers

(3) Eye wash fountain

(4) Warning signs

c. Equipment

(1) Adequate rinse tanks

(2) Non corrosive tanks

(3) Current source

(4) Current controls

(5) Grinders and buffers

(6) Type of plating

d. Supplies and storage

(1) Plating chemicals

(2) Acids and caustic sodas

(3) Solvents

(4) Proper storage areas

(5) Separate storage for cyanides

e. Refer to 42C2-1-7

11. Perform miscellaneous surface treatment such as:

a. Anodizing

(1) Electrochemical treatment

(2) Done to aluminum and aluminum alloys

(3) Forms a layer of aluminum oxide on surface

(4) Must be sealed with hot water

(5) Helps prevent further corrosion

(6) Refer to 52C2-1-7

b. Metal spray

(1) Sometimes called metalizing

(2) Metal sprayed on the surface of a part

(3) Used for corrosion resistance

(4) Metals used - copper, aluminum, brass, nickel, lead, tin and zinc. Also carbon and stainless steels.

(5) Process

(a) Metal in form of wire or powder

(b) Melted by high temperature flame

(c) Formed into spray by compressed air or other gas

c. Hot dipping

(1) Metal dipped into lower melting metal

(2) Done for corrosion resistance

(3) Normally performed to steel parts

(4) Zinc and tin and lead are commonly applied this way

d. Oxide coloring

(1) Process of adding oxide film to steel

(2) Done for corrosion resistance

(3) Performed by immersing in a concentrated solution of basic salt (caustic soda)

(4) Must be sealed with oil

(5) Produces a black or blue-black color

(6) Refer to 42C2-1-7

APPLICATION:

None

EVALUATION:

1. Students will be administered an appraisal test covering the following with 75% accuracy.

   a. Steps relating to electroplating aircraft and age parts.

   b. Steps and methods for stripping plated parts.

   c. Safety precautions pertinent to a plating shop.

   d. Proper layout and set up procedures for a plating shop

   e. Steps and procedures for anodizing

   f. Steps and procedures for metal spraying

   g. Steps and procedures for hot dipping.

   h. Methods of oxide coloring.

CONCLUSIÓN TIME: 10 Min.

SUMMARY: Review the following:

1. Methods for identification and prevention of corrosion.
2. Set up and performance of mechanical cleaning operations.
3. Set up and performance of chemical cleaning operations.
4. Principles involved in plating operations.
5. Proper steps relating to preparing and testing plating solutions.
6. Proper steps relating to electroplating aircraft and ground equipment parts.
7. Proper steps and methos for stripping plated parts.
8. Safety precautions pertinent to a plating shop
9. Proper layout and set up procedures for electroplating shops
10. Proper steps and procedures relating to anodizing operations.
11. Proper steps and procedures pertaining to metal spraying operations.
12. Proper steps and procedures relating to metal hot dipping operations.
13. Methods of oxide color operations.

REMOTIVATION:

ASSIGNMENT: Review for block test

CLOSURE:

PREPARE THE MAN

STUDY GUIDE 3ABR53131-SG-700

Technical Training

Metals Processing Specialist

BLOCK VII
HEAT TREATING, HARDNESS TESTING, CLEANING, AND ELECTROPLATING

13-8

7 February 1975

AIR TRAINING COMMAND

CHANUTE TECHNICAL TRAINING CENTER (ATC)

This supersedes 3ABR53230-SG-700, 25 July 1973.
OPR: TWS
DISTRIBUTION: X
TWS - 100; TTOC - 2

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CONTENTS

SAFETY AND OPERATION OF HEAT TREATING FURNACES

OBJECTIVES

After completing this study guide and your classroom instruction, applying shop safety, good housekeeping, and fire prevention measures you will:

1. Identify types and uses of heat treating furnaces.

2. Set up and operate heat treating furnaces.

3. Identify maintenance and repair procedures pertaining to heat treating furnaces.

4. Identify fabricating methods and characteristics of metals.

INTRODUCTION

The heat treating furnace is an important tool which the welder uses in his routine tasks. His ability to use it properly will determine the quality of his skill as a metals processing specialist.

Furnaces have been employed since the first use of metals, and, in the beginning, were crude and often unreliable. As a result, mechanical properties of a metal varied from time to time. There were few alloys then, and the operations were fairly simple.

Today, with more complex alloys and new types of metals being used, we must have very accurate furnaces and controls to be able to keep the metals and alloys within the close specifications necessary.

INFORMATION

MANAGEMENT OF DEFENSE ENERGY AND RESOURCES

While you are in Block VII, there is to be no writing in training literature provided you. This is due to redistribution to subsequent classes. Also, while you are on regular scheduled breaks, you will leave lights on in the classroom unless you will be out of the classroom for 20 minutes or more.

During clean-up of classroom and other areas, use of cleaning materials will be kept to a minimum in order to reduce cost. These procedures will be followed throughout Block VII.

FURNACE REQUIREMENTS

Successful heat treating requires close control over all factors affecting the heating and cooling of metals. Such control is possible only when the proper equipment is available and the equipment is selected to fit the particular job. Thus, the furnace must be of the proper size, type, and be controlled so that temperatures are kept within the limits prescribed for each operation. Even the atmosphere within the furnace affects the condition of the part being treated, and the quenching media must be selected to fit the metal and the heat treating operation. Finally, there must be equipment for handling parts, cleaning parts, and for straightening parts.

A heat treating furnace is designed to generate a high temperature in a confined area. It is nothing more than an insulated box into which parts may be placed and heated to a desired temperature. To ensure the desired temperature is obtained, some method of temperature indication and control is necessary.

TYPES OF FURNACES

Heat treating furnaces are classified into various types, according to three main variables:

1. Type of fuel.

2. Condition of the air.

3. Type of atmosphere.

Types of Fuel

ELECTRICITY. This is the most commonly used fuel, since it is clean, efficient, automatic, and the furnace requires very little maintenance. The operating principle is the same as that of a toaster, grill, or electric stove. An electric current is passed through a conductor that has a high electrical resistance. This creates heat which radiates throughout the surrounding air and heats metal parts which have been placed in the furnace.

GAS AND OIL. These fuels are commonly used in industry and not used in the Air Force. Their principle of operation is the burning of a combustible material to generate heat. They lack several of the advantages that electricity has to offer: less efficient due to the heat carried away with the exhaust gases; not as clean, due to often less than total combustion; and require more frequent maintenance to ensure maximum efficiency.

Condition of the Air

STILL AIR. In this type of furnace, the air is nearly motionless. It is probably used more in Air Force shops than any other type of furnace. The heating medium is ordinary still air and is capable of being used for very high temperature applications.

CIRCULATING. This type of furnace has a built-in fan for circulating the air inside the furnace. Again, the heating medium is commonly air. Although this type is normally limited to lower temperature applications, it offers the advantages of more accurate and closer control of temperature.

Type of Atmosphere

OXIDIZING. This type of atmosphere is the most commonly used due to cost. The oxygen comes from the air and costs nothing, so it is the most often used. It has one disadvantage in that it will cause oxidation of the metal parts heat treated.

CARBURIZING. This type of atmosphere has an excess of carbon of carbon gas. The hot steel absorbs the carbon from the carburizing atmosphere, and increases the carbon content of the metal near the surface. A small amount of carbon is added to the metal, but this is less harmful than scaling. A carburizing atmosphere in a furnace is produced by adding a few pieces of charcoal with the metal being heat treated.

NEUTRAL. This type of atmosphere is a balance between oxidizing and carburizing, and is closely related to a carburizing atmosphere. It also is mostly found with gas or oil fired furnaces. This type of atmosphere is very hard to maintain and therefore, is not used often.

INERT. This type of atmosphere offers the same basic protection from oxidation that a neutral one does, but does so through the use of inert gases such as argon and helium. Electric furnaces are often designed to allow the use of inert atmospheres.

VACUUM. More and more, vacuum furnaces are being used. With the advantage of no contamination during heat treatment and no atmosphere to purchase, this type is preferred in many cases. The biggest single disadvantage is the initial cost of the furnace itself.

FURNACE CONSTRUCTION

Electric Furnace

The electric heat treating furnace, shown in figure 1, is similar in construction to the oven of an electric kitchen stove. The furnace is a steel box, lined with firebrick separated from the steel box by a layer of magnesia or ground asbestos. The layer serves as a flexible insulator. Along with its insulating value, it allows the firebrick, which is also an insulator to expand and contract without cracking and/or breaking.

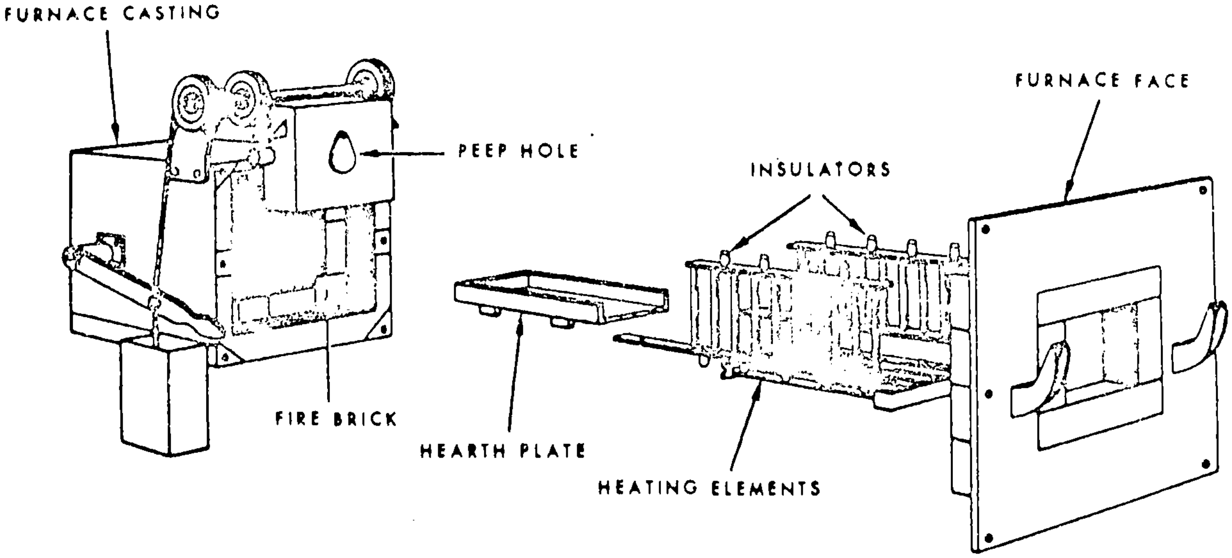


Figure 1. Heat Treating Furnace.

HEATING ELEMENTS. The heating elements, figure 1, are located along the sides of the furnace, and under the hearth plate. Larger furnaces also have heating elements in the top and the door to provide a more even temperature throughout the furnace. Chrome-nickel alloy, called Ni-Chrome, is generally used for the heating elements. The heating elements must have a high resistance to the flow of electricity, hold their shape, and not corrode or oxidize at high temperatures.

HEARTH PLATE. The hearth plate, figure 1, is a flat carbide plate which covers the lower heating elements, and services as the floor of the furnace on which the parts are to be set. Parts should be placed on a grid, whenever possible, as the lower heating elements may cause the hearth plate to overheat, resulting in the part being heated to a higher temperature than that indicated.

GRIDS. A grid, figure 2, is a device made of a corrosion resistant alloy or of a refractory material that may be used in the furnace to hold the part. This allows more uniform heating and makes it easier to handle the part.

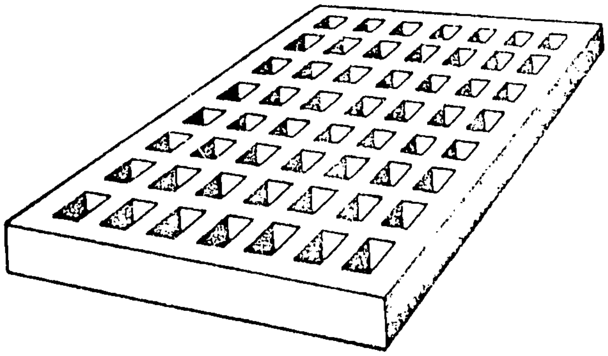


Figure 2. Furnace Grid.

MATERIAL HANDLING DEVICES

The equipment used for handling parts during heating and quenching includes a wide variety of tongs, hooks, baskets, and trays. Tongs designed for handling pieces of average design and shape are shown in figure 3. In addition to these, there are tongs of special sizes and shapes for handling extremely light and heavy sections and for intricately shaped parts. Average sized tongs usually range from 36 to 44 inches in length and are made from round 3/8-inch medium carbon steel. The jaws or lips vary in width from 3/8 to 1 inch. Standard shaped tongs are usually available in three or more sizes, and meet the requirements of 90 percent of all heat treating jobs.

Types of Tongs

STRAIGHT LIPPED. Straight lipped, flat jawed tongs are used for handling parts with flat surfaces. These tongs are not satisfactory for handling round parts.

PICKUP. These tongs are designed for handling round parts such as reamers, broaches, drills, mandrels, arbors, and tubin. With these tongs, gripping the part at the point of balance is particularly important.

INSIDE. Inside tongs are used for quenching sections with inside holes large enough to accommodate the jaws of the tongs. The jaws of the inside tongs are opened by applying pressure to the handles. Flat milling cutters, collars, gears, cylinders, and similar parts are handled with inside tongs.

ROUNDNOSE. These tongs can be either the single jawed type, shown in figure 3, or of the double jawed type. Both types are used for handling flat parts; however, the double jawed tongs will accomodate larger and heavier parts than the single jawed type.

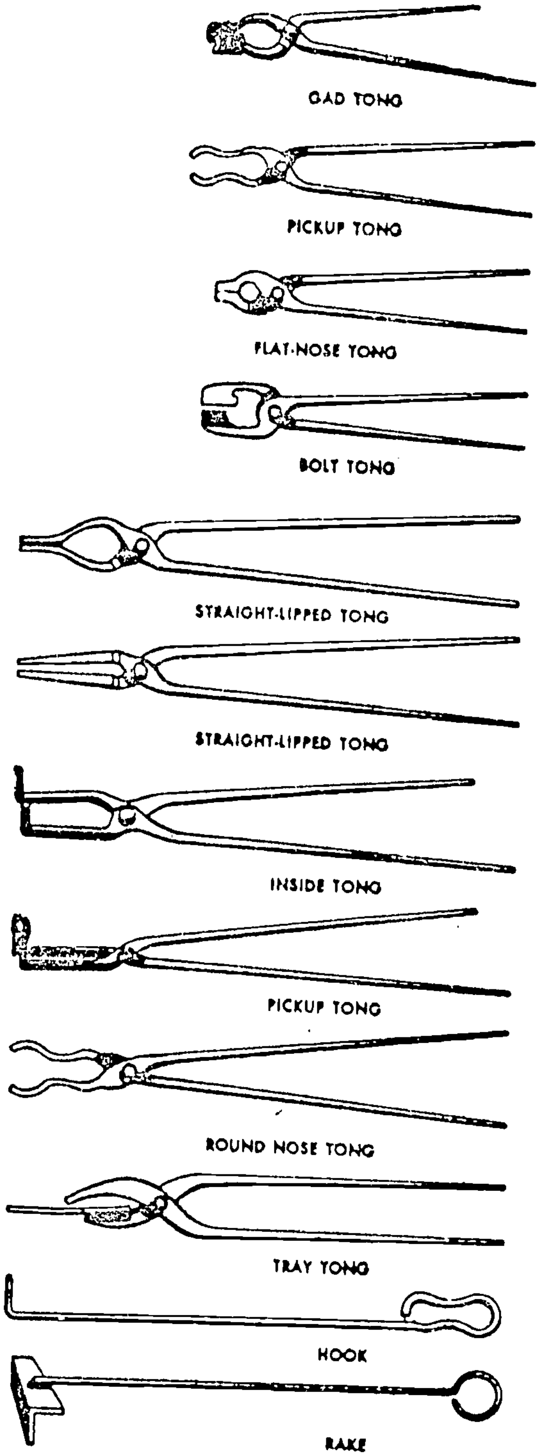


Figure 3. Heat-Treating Tongs.

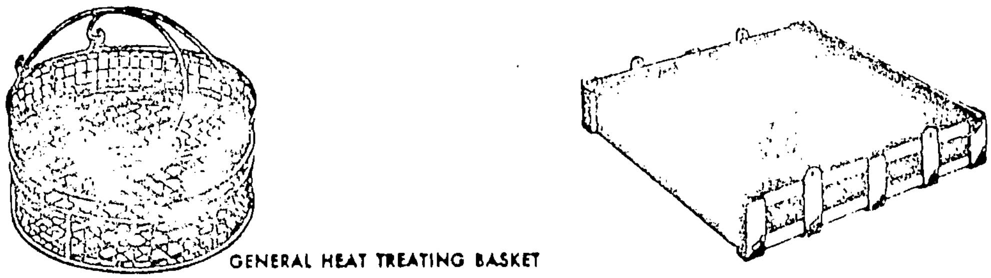


Figure 4. Baskets Used for Heat Treating.

An annealing basket, in addition to its construction of woven wire and rod, has a removable plate. With the plate removed, the basket can be used for other heat treating operations. Specifically designed baskets are necessary for cyaniding so that the heat treater will not be unnecessarily exposed to furnace heat and toxic fumes.

When high temperatures and long soaking are required, racks and trays, similar to those shown in figure 5, are more suitable than baskets. Racks for normalizing and general heat treating are so designed that parts can be handled easily and separators can be used when necessary. Trays help in the handling of large quantities of small parts, make larger furnace loads possible, and speed the heat treating operations.

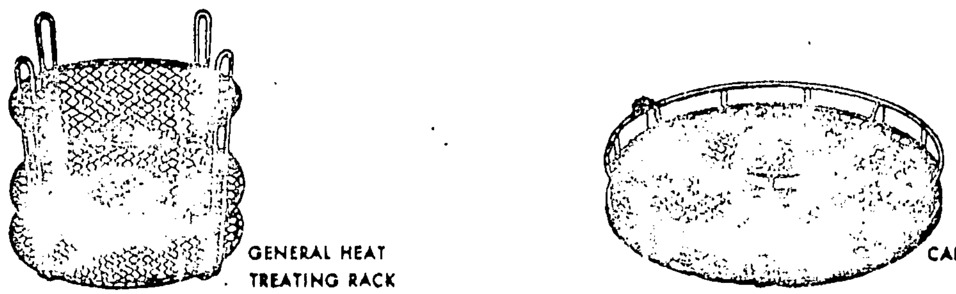


Figure 5. Trays Used for Heat Treating.

TRAY. These tongs are used for handling baskets, trays, racks, crates, separators, and other fixtures. With these tongs, a firm grip is essential to prevent slipping.

HOOK. Although the hook is not a tong, it is used for much the same purpose. Light and medium weight parts may be handled with a hook, provided that the part contains a hole through which the hook can be inserted. For quenching, the hole must be located so that the part hangs from the hook in a balanced position and is not quenched at an angle. If the part is too heavy to be handled with a hook, or if satisfactory balance cannot be obtained, an inside tong should be used.

Selection of Tongs

The improper choice of tongs may cause complete failure of a hardening job. Tongs with large, heavy jaws, cause excessive cooling when they are used on small or thin sections. On the other hand, heavy pieces cannot be satisfactorily handled with small tongs because of improper balance and the possibility of slipping. In selecting tongs, choose a pair that is properly balanced and of the correct length. Choose a jaw shape to fit the part to be handled. While the part is cold, grip it with the tongs to locate the point of balance and to test for ease of handling. Go through the motions of moving each part in and out of the furnace and to the quench tank to make sure that the tongs will not slip. Testing the tongs is particularly important when parts are long or irregular in shape.

Immediately after using a pair of tongs, quench the jaws in water and place them in the proper rack. If a pair of tongs has been dipped in a quench tank containing oil, wipe the oil from the jaws before returning them to the rack or placing them in the furnace. Do not allow tongs to touch the heating elements of electric furnaces. Touching the heating elements may cause serious shock and it is certain to damage the elements and the tongs. Never touch a fellow workman with a pair of tongs. They may be hot enough to cause a serious burn.

Baskets and Trays

Baskets and trays designed for use in heat treating shops are usually fabricated from wire, rod, and plate of special composition. Woven wire screen is very practical because of the large open area, important for uniform heating and quenching. The parts must be separated when placed in the basket or tray. The basket or tray must be highly resistant to corrosion and abrasion, must hold their shape at high temperatures, and must not become brittle with repeated heating and cooling. The baskets, shown in figure 4, and other types similar in design, are used to hold small parts during quenching, annealing, and general heat treating operations. Quenching baskets may also be submerged in a quench tank to catch and hold small parts during a continuous quenching operation.

QUENCH TANKS

A typical quench tank of the portable type is shown in figure 6. This type of tank can be moved to various locations in the heat treating shop. Such tanks may have one or more compartments. If one compartment contains oil and another water, the partition must be thoroughly sealed to prevent mixing. Each compartment is equipped with a drain plug, a screen in the bottom to catch scale and other foreign matter, and a mesh basket to hold the parts being quenched. The mesh basket and wire screen are suspended in the tank and held in position with clips which fit over the rim of the tank. A portable electric pump may be attached to the rim of the tank to circulate the liquid. This mechanical agitation aids in uniform cooling. An exhaust system of proper design should be provided to remove toxic vapors and fumes when other than a water quench is used.

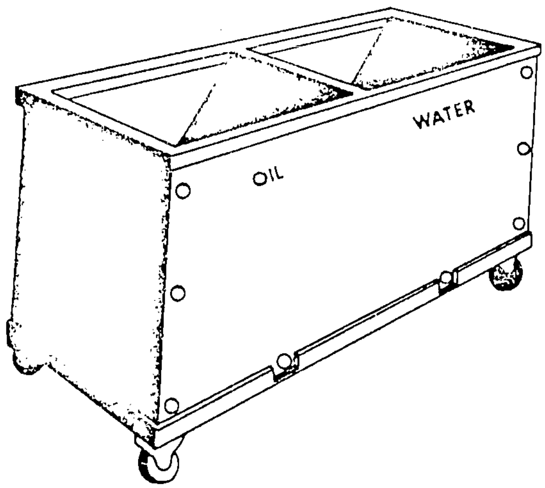


Figure 6. Quenching Tank.

Stationary quench tanks usually contain only one liquid. The mesh basket is raised and lowered by air pressure and controlled by a three-way air valve. The basket can be positioned at any level and can be raised above the liquid to allow the parts to drain after cooling. Parts too heavy for manual agitation may be placed in the basket and alternately raised and lowered in the liquid by operating the three-way valve. Stationary quench tanks usually have built-in electric pumps for agitating the liquid.

SAFETY IN OPERATING HEAT TREATING FURNACES

In any shop, you are as safe as your most careless act. For years, you may work in the shop without having the slightest accident. Then, one day, because of some careless act on your part, you may be injured so badly that permanent disability, even loss of life may occur. Furthermore, this careless act may result in injury to others, or may put expensive machinery out of operation for a considerable length of time. Too many times the attitude of the heat treater is, "I know this isn't exactly the safe way to do it, but more than likely nothing will happen if I do it this way," instead of, "The chances are that nothing will happen if I do it this way, but I had better do it the other way just to be safe." Usually, the safest way turns out to be the easiest way. You should always plan to do your work the safe way. The following safety precautions should be observed in the heat treating shop:

1. Avoid contact with live electrical circuits. Severe electrical shock may result.

2. Avoid contact with hot furnace parts. Anyone coming in contact with them can be severely burned.

3. Stand back at a safe distance when a furnace is being loaded or unloaded. When a part is being quenched, transfer the part from the furnace to the tank in a minimum of time. In trying to hold this time to a minimum, the heat treater sometimes forgets to look behind him to see if another person is standing there, exposing him to danger of the handle end of the tongs.

4. Open and close the furnace doors gently to avoid cracking the firebrick.

5. When the furnace is hot, do not leave the door open any longer than necessary. The cold air rushing in can scale the parts and warp the hearth plate and heating elements.

6. Shut off the power while you load and unload the furnace. The part or tongs may come in contact with the heating elements, resulting in a short circuit, severe shock, or burns.

7. Use suitable tongs in handling all metal.

8. Never put your hands inside the furnace. Shock and burns may result.

9. If the furnace is not operating properly, shut it off and notify your instructor.

OPERATING PROCEDURES

General procedures to be followed in operation of a heat treating furnace are as follows:

1. Check the inside of the furnace to be sure there is nothing inside.

2. Close the switches and allow the pyrometer to show the actual furnace temperature.

3. Check to see that the power input controller is on. Adjust if necessary.

4. During the cool-down, use the following steps:

a. Leave furnace door shut to prevent possible damage to firebrick and heating elements.

b. Reset pyrometer to lower temperature.

c. If finished with the furnace, shut the power off.

Note: When a furnace is to be reset from a higher to a lower temperature, the current should be shut off and the furnace allowed to cool down slowly 200°F below the new lower temperature. This is necessary to keep the furnace from going past the desired temperature when it is turned on again. Keep the furnace door closed during the cooling down period.

QUESTIONS

Note: Answer the questions at the end of this chapter on a separate sheet of paper. DO NOT WRITE IN THIS STUDY GUIDE.

1. Name some common safety hazards around heat treating furnaces.

2. Why do you avoid contact with electrical circuits?

3. What instrument controls and measures the heat inside the furnace?

4. What is a heat treating furnace designed to generate?

5. What are the three requirements of a heating element?

a.
b.
c.

6. What are the types of atmospheres used in a heat treating furnace?

7. Which tongs are designed for handling round parts?

8. Which tongs are used for handling baskets, trays, or racks?

9. What is the purpose of mechanically agitating a quench medium?

10. Why is the door left closed in cooling down a furnace?

11. What is the most common type of furnace?

12. Why should you use a grid in the heat treating furnace?

13. The temperature reading shall be within what percent of the calibrating equipment reading?

14. How often should surveys be conducted on furnace control equipment?

15. When performing maintenance checks on furnace controls how often should their accuracy be checked?

REFERENCES

1. AFR 127-101, Ground Accident Prevention Handbook.

2. TO 1-1A-9, Aerospace Metals-General Data and Usage Factors.

IDENTIFICATION AND CLASSIFICATION OF METALS

OBJECTIVES

After completing this study guide, your classroom instruction, and assigned study, while observing all shop safety, good housekeeping, and fire prevention measures, you will:

1. Identify and determine classification of ferrous metals.

2. Identify and determine classification of nonferrous metals.

3. Identify shop methods of metal identification.

INTRODUCTION

The more you know about metals, the better you will be able to do your job. It is not enough just to perform the welding and heat treating operation; you must know why these operations are performed and what effect they have on the metal. In order to do this, you must be able to identify the different types of metal.

INFORMATION

MANAGEMENT OF DEFENSE ENERGY AND RESOURCES

Use light pressure on grinding wheels to conserve metal specimens and grinding wheels. Return metal specimens to instructor for reissue to subsequent class. Turn off equipment after completion of task.

PURPOSE OF ELEMENTS

Very few metals or alloys are found in a usable form in nature. They are usually combined with other elements in the form of compounds. Some refining process must be used to reduce, or remove, these other elements and impurities before the metal can be used. In most cases, additional alloying elements must be added so that certain desirable properties can be developed in the metal.

In all refining processes, the refined metal comes out as molten metal. The metal must then be changed into a usable shape. The methods used in shaping any metal have a direct effect on the properties of the metal. Knowing how a part is made and what changes fabricating may cause in that part will help you to be a better welder.

Blast Furnace

The first step in changing iron ore to steel takes place in the blast furnace. The blast furnace, shown in figure 7, is a tall, round, furnace lined with firebrick. In the blast furnace, the iron ore is separated from most of the impurities. The furnace is charged, or filled, with layers of coke, ore, and limestone. Compressed air heated to 1200°F is forced into the lower part of the furnace. The air burns the coke causing the mixture of ore and limestone to melt. This causes a chemical reaction between the gases, ore, and limestone. The gases from the burning coke take much of the oxygen out of the ore. The limestone melts, collects many other impurities, and forms slag. The hot gases rise up through the charge of the furnace, heat it, and carry many impurities along. Some of the carbon from the gases unites with the molten iron. This gives the molten iron a carbon content of 2.5 to 6 percent. The molten slag and iron settle to the bottom of the furnace where they can be tapped off. Before tapping, the slag floats on the surface of the molten iron and protects it from the air and combustion just as the flux or slag does in welding. The molten iron is called pig iron. As the slag and pig iron are tapped off, the upper layers of the charge work down to the melting area. More coke, ore, and limestone are added at the top. The pig iron may be poured into a ladle and taken to other furnaces for further refining, or it may be cast into bars.

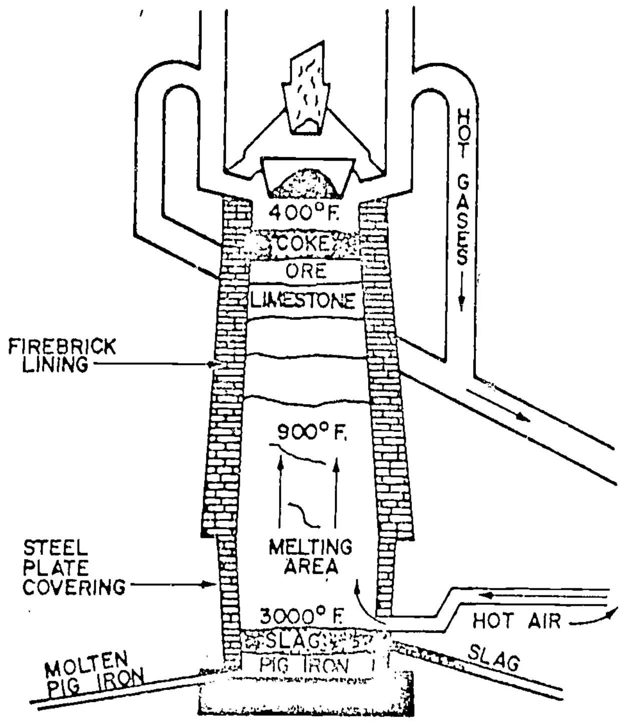


Figure 7. Blast Furnace.

Open Hearth Furnace

During the late 1960s and early 1970s, this furnace has lost some of the prestige that it enjoyed as a steel maker. From the 1940s thru the 1960s this furnace produced approximately 90% of steel made in this country. Most of the SAE-AISI steels were produced in this furnace. A charge of pig iron, scrap, and limestone went into this furnace. The pig iron was generally taken directly from the blast furnace, in the molten state, and poured into the open hearth. Figure 8 shows the open hearth furnace and how it operates.

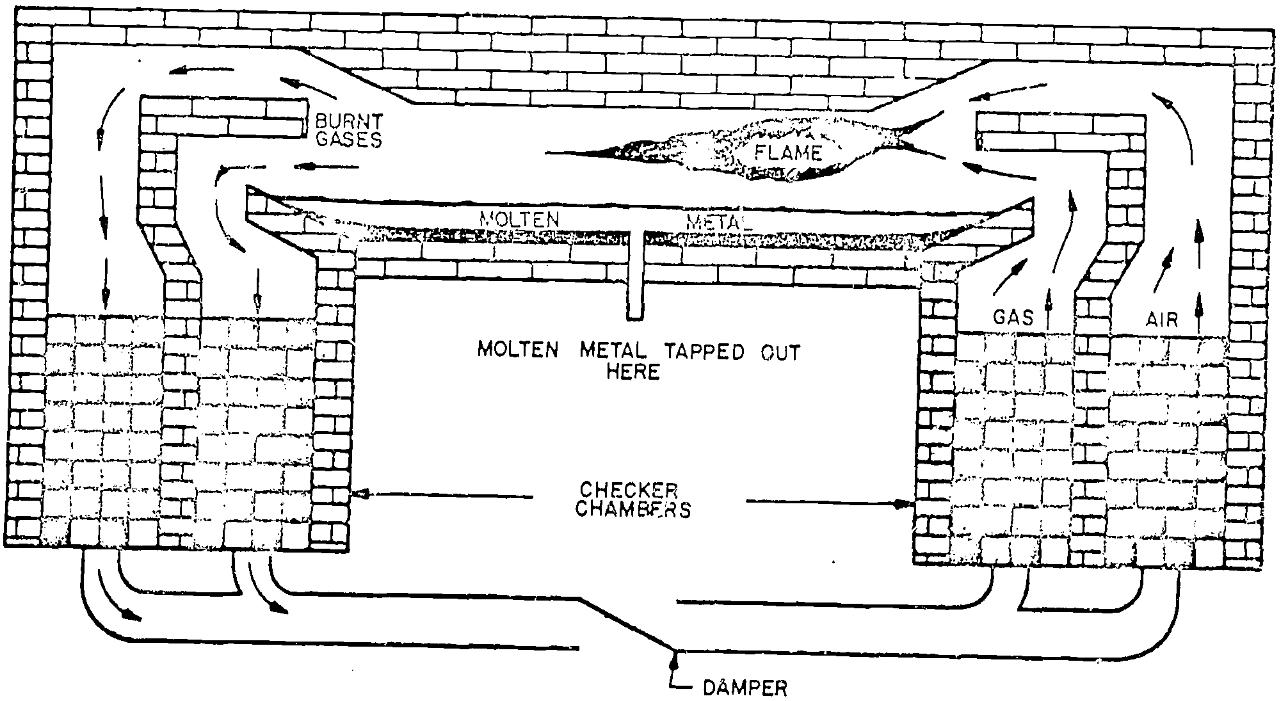


Figure 8. Open Hearth Furnace.

Preheated gases and air are fed into the furnace and burned over the charge to melt it. The process resembles the action of a huge welding flame. The limestone melts and floats on top of the steel. The limestone serves two purposes. It collects more of the impurities from the steel and it protects the steel from the flame. While the steel is being heated, many tests are made to determine its chemical analysis. Other materials may be added to react with certain impurities and cause them to burn out or form slag. Alloying elements, such as chromium, nickel, molybdenum, etc., may be added. When the composition is just right, the molten steel is poured into a ladle. Any slag floating on top will overflow. The molten steel is then poured from the ladle into a large rectangular mold where it solidifies. These large blocks are called ingots. The steps in forming this ingot into shapes such as plates, rods, bars, and wire will be taken up in a later section.

Basic Oxygen Process

During the mid 1950s, a new process was introduced to the steel industry from Germany. It was a modification of the Bessemer converter, and was referred to as the basic oxygen process. The main advantages to this process includes steels with lower hydrogen content and less pollution to the environment. During the 1950s, it was considered too costly to switch over from the open hearth furnaces to this process. Today, faced with the problem of endangering the environment by pollution, and the fact that industry must comply with strict pollution regulations, the changeover is being made. The cost of pollution control equipment for the open-hearth furnaces would exceed the cost of the new basic oxygen process. The basic oxygen process is pollution free, produces a getter grade steel, and in larger tonnages.

This process is simply a modification of the older Bessemer process. Instead of air being forced through the bottom of the charge, as with the Bessemer converter, the basic oxygen process incorporates the use of a water-cooled pipe (lance) that is lowered into the furnace. The lance is not lowered into the pig iron, but is maintained at a level just above the pig iron. Oxygen at a rate of 20,000 cfm is blown into the furnace through the lance. When the pig iron has been converted to steel, usually approximately 18 minutes after the start of the oxygen flow, alloying elements can be added to make the desired carbon and alloy steels. The smoke that is generated is drawn off, cooled, and particles filtered out. Thus, this furnace will fulfill the role of high production in the steel industry, with minimum effect on the environment.

Electric Furnace

High grade alloy steels, tool steels, and stainless steels are produced in the electric furnace, shown in figure 9. Selected alloy scraps and alloying elements are added to the molten steel in the furnace. Carbon electrodes, when they are lowered to just above the surface of the metal, create an electric arc to heat the metal to its melting temperature. Some steel may be taken from the open hearth furnace to the electrical furnace. No oxygen is necessary in the electric furnace. A controlled atmosphere is used in the furnace to keep the oxygen from reacting with the molten metal and burning out some of the alloying elements. Many checks are made on the steel in the electric furnace to determine its composition. Alloying elements are added to remove impurities and to insure that the steel is within the desired specifications. The steel is then poured into ingot molds to harden.

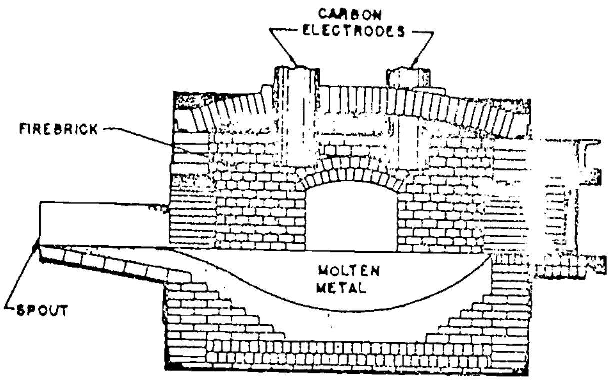


Figure 9. Electric Furnace.

Induction Furnace

The induction furnace, shown in figure 10, is another type of electric furnace. It is used when the steel must have a uniform composition throughout. The induction furnace makes use of a high frequency, alternating current which passes through a coil wound around the furnace. The magnetic flux lines formed around the coil collapse many thousands of times per second as the current reverses. These flux lines passing through the melt heat it by their collapsing action. The main advantage of the induction furnace is the action of the magnetic flux lines which stir the melt, insuring that the melt becomes thoroughly mixed. After proper melting and mixing, the melt is cast. Some of the finest quality tool steels are made in this manner. The charge for this furnace must be high grade steel and high grade alloys. Very little slag is formed in this furnace.

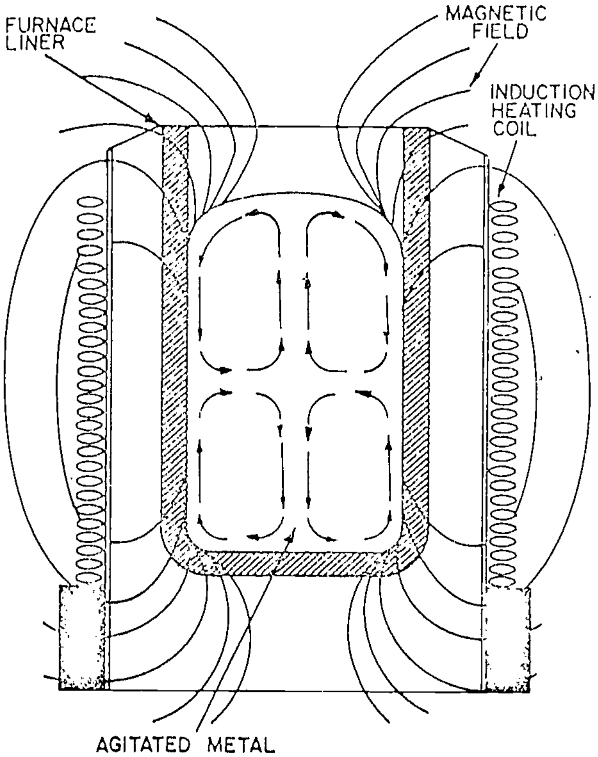


Figure 10. Schematic Cross Section of a Small Induction Furnace.

Cupola Furnace

The cupola furnace, figure 11, is used in making cast iron from pig iron. The furnace is charged with charcoal and billets of pig iron. Hot air is forced into the bottom of the furnace which causes the charcoal to burn, melting the pig iron. The burning charcoal and gases also burn many of the impurities out of the pig iron. The molten iron drops to the bottom of the furnace where it is tapped off. This iron still contains many impurities and has a high carbon content. The molten iron is then poured into molds where it takes the shape of the mold and hardens. The mold is then removed.

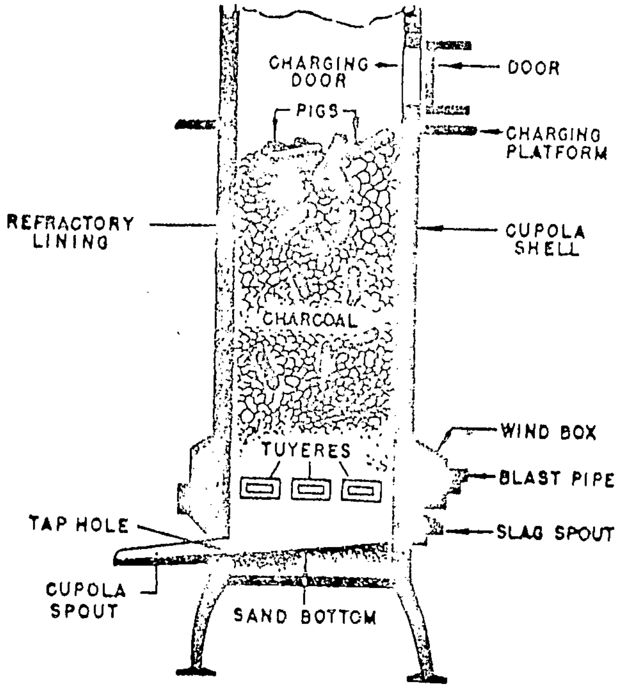


Figure 11. Cupola.

Electrolytic Cell

Many of the nonferrous metals are refined electrolytically. In this process, an electric current is used to separate the metals from their ores. The process varies in detail with different metals, but is essentially as follows:

1. The ore of the metal is dissolved in an electrolyte.

2. Electrodes are placed in the solution containing the electrolyte and the ore.

3. The current is turned on. This causes the metal to move to one of the electrodes. As the metal collects, it is tapped off. Figure 12 illustrates the electrolyte cell for separating aluminum from its ore.

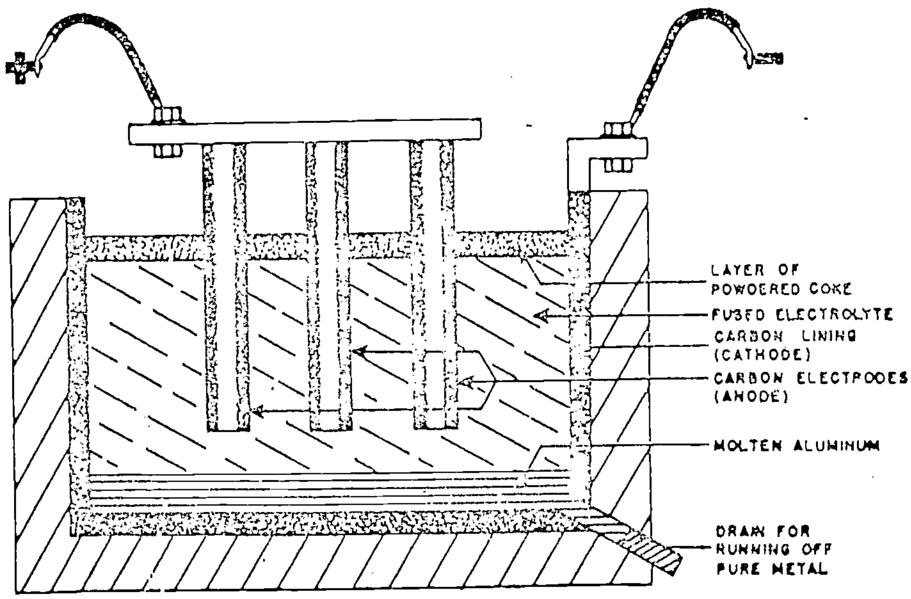


Figure 12. Electrolytic Cell for Refining Aluminum.

4. After the metal is separated from its ore, it may be further refined, alloyed, and cast. Nonferrous metals are often used in the as cast condition. However, higher strength properties are often obtained by the use of a wrought product. Nonferrous metals may be shaped either hot or cold.

METHODS OF SHAPING METAL

The next step, after refining metal, is to get it into a shape we can use, figure 13. All methods of shaping a metal may be classified as either casting or wrought. Wrought means worked. All metals, ferrous or nonferrous, are shaped in one or both of these two ways. The molten metal is cast into an ingot. The ingot is then rolled into shape. The rolled shapes are wrought products, as they have been worked into shape by force.

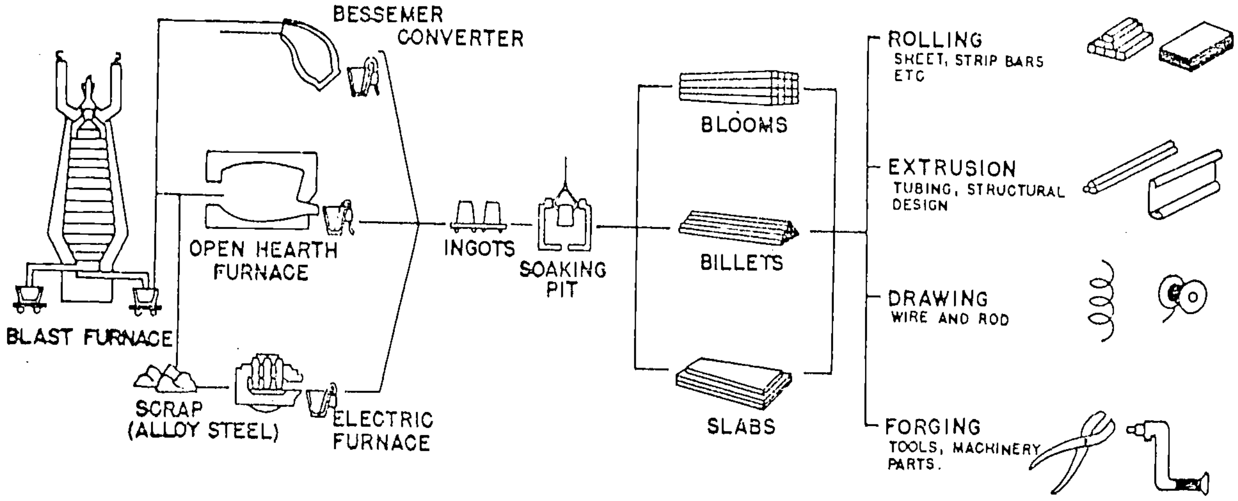


Figure 13. Flow of Steel During Mfg.

Castings

A casting is a metal part that has been formed by pouring or forcing molten metal into a mold. The liquid metal solidifies in the shape of the mold. The mold is then removed. Casting is the only way that some parts can be formed. It is also a relatively cheap process. Castings may be easily machined, but are usually not as strong as wrought parts. In a casting, the grains are large and there may also be inclusions of slag or impurities which weaken the part, as shown in figure 14. Working the metal to form the wrought part causes the grains to become smaller and elongated, as shown in figure 15. The working gives a grain pattern to the steel something like the grains of wood. These long grains help to strengthen the part. Any inclusions are broken up so that they will not be as harmful. During welding these long grains are melted and recast. This will tend to reduce the strength if the parts are not properly heat treated after welding. There are three types of castings.

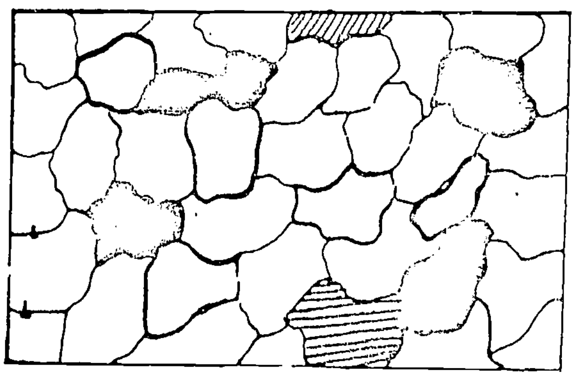


Figure 14. Grain Structure in a Casting.

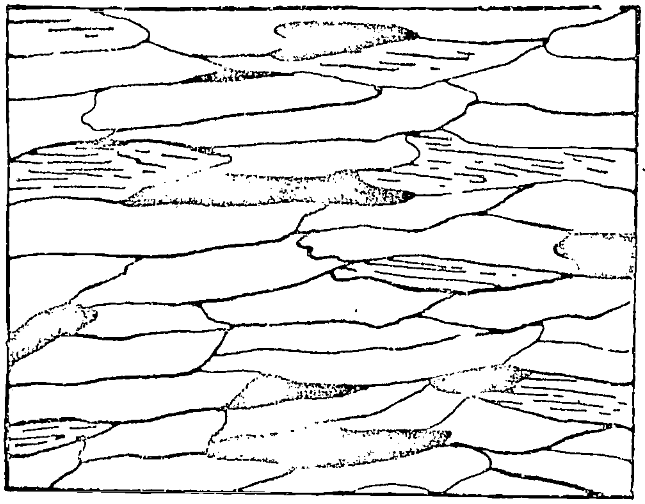


Figure 15. Grain Structure After Being Worked.

PERMANENT MOLD CASTINGS. A permanent mold is used for parts of fairly simple design. This is usually a metal or ceramic mold. After the molten metal has solidified, the mold is removed, cleaned, and reused. The molten metal will harden and cool fairly fast in a permanent mold. White cast iron is formed in a permanent mold.

SAND MOLD. A mold may be made of sand which has been packed to hold its shape. The sand is either formed around a pattern or in sections. The sections are put together and molten metal poured into the openings. After the metal solidifies, the sand is shaken off the part. Very complicated shapes may be made by sand castings. Motor blocks for cars are sand castings. Gray cast iron is made by sand casting. The sand holds the heat in and allows the metal to cool slowly. This is in contrast to a permanent mold, which allows the molten metal to cool faster.

DIE CAST. Die casting is usually used for low melting point metals. In a permanent mold or a sand mold "pot metal", zinc, aluminum, or magnesium would cool and solidify before getting to all areas of the mold. The metal would not flow into thin sections. In die casting the molten metal is forced into the mold under pressure. This completely fills the mold before the metal solidifies.

Wrought Products

A wrought metal part is any metal part that has been shaped by force while it is in the solid form. Some of the advantages of wrought parts were listed in the preceding section. Most metals may be worked into shape while either hot or cold. The temperature of the metal while it is being worked will directly affect the properties of the finished part.

HOT FORMING. Recrystallization takes place in metal when it is heated to certain known temperatures. The temperatures where these changes take place are known as recrystallization temperatures. Above the recrystallization temperature the grains of metal are able to reform themselves. Below the recrystallization temperature the grains cannot reform and will remain in the condition into which they are forced. Hot working is any forming or working performed above the recrystallization temperature. Cold working is any forming or working of the metal that is performed below the recrystallization temperature. Each metal has its own recrystallization temperature. The purpose of hot working and cold working is the same for all metals. Hot worked metal will be soft and almost stress free, because the metal will recrystallize after working and before it cools. Hot worked metal will not be as strong as the same metal would be if it were cold worked. Hot worked steel has a hard scale on the surface and is not rolled to accurate dimensions.

COLD FORMING. Cold forming is any forming or working of the metal that is performed below the critical temperatures. Cold working will increase the strength and hardness of the metal. The structure of the metal is forced into shape and cannot recrystallize after the working operation is complete as is the case with hot working. Cold worked steel will have a smooth, even finish and have dimensions within $\pm$ .005. The amount of strength and hardness that may be developed by cold working will depend upon the particular metal and the cold working method used. Cold working is the only way that any pure metal and some alloys may be hardened. A metal may be cold worked only so much. Cold working a metal beyond its limit will cause the metal to fracture. During severe cold forming operations the metal should be partially formed, annealed (to allow the metal to recrystallize), and then formed to final shape. Intricate parts may have to be annealed several times. In many manufacturing processes, the metal is first hot worked and then cold worked to final shape. This makes the forming easier, yet results in the strength properties gained by cold working.

FIVE METHODS OF FORMING WROUGHT PRODUCTS

Most of the wrought products are formed by one or more of the following methods: rolling, forging, drawing, piercing, or extruding. All parts start as a casting when the metal is cast as an ingot. The next step is hot rolling when the ingot is first rolled into large bars or billets. These bars or billets are then further reduced by rolling or other forming methods, either hot or cold.

Rolling

In rolling the metal is passed between two rolls to reduce the metal to a designated thickness. Special shapes may be rolled with rolls made for this purpose. Figure 16 shows some of the shapes that may be made by rolling. Figure 17 shows the steps of rolling a part to final shape.

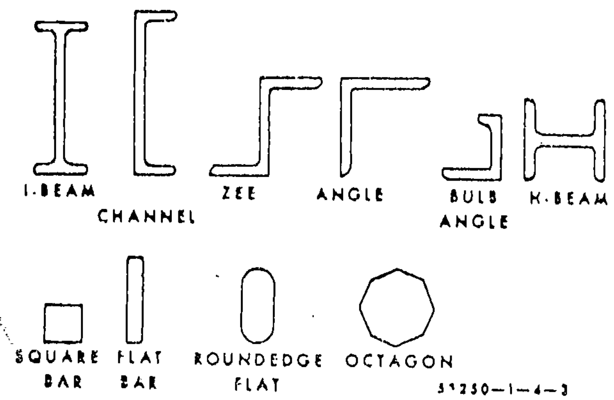


Figure 16. Rolled Steel Shapes.

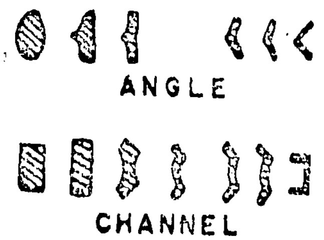


Figure 17. Steps in Rolling.

Forging

Forging is done by heating the metal until it is soft, or plastic, and then forming it with one or more blows. This may be done by a huge machine or with a hammer and anvil. The metal may be hammered into a die to get the proper shape. Figure 18 shows some forged parts.

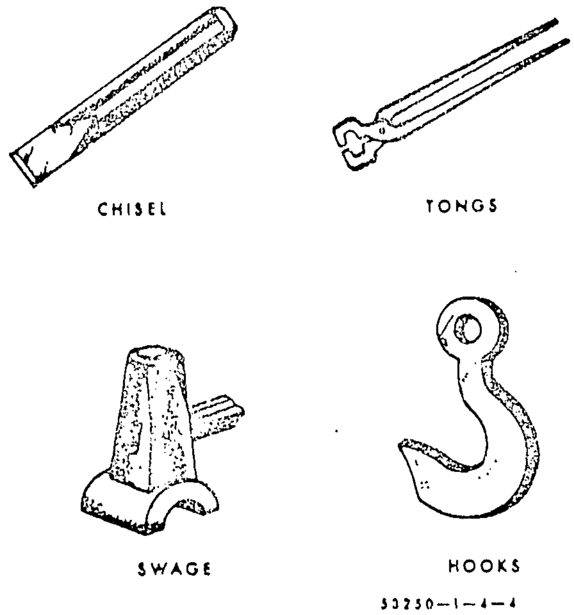


Figure 18. Forged Parts.

Drawing

Drawing is a method of forming a part by pulling it through a die so that the part takes the cross sectional shape of the die. A series of dies may be used, each one smaller than the last. The metal may start out hot but cools during the drawing. The last die or dies may be cold working the metal. Wire is made in this manner. Figure 19 shows how wire is drawn.

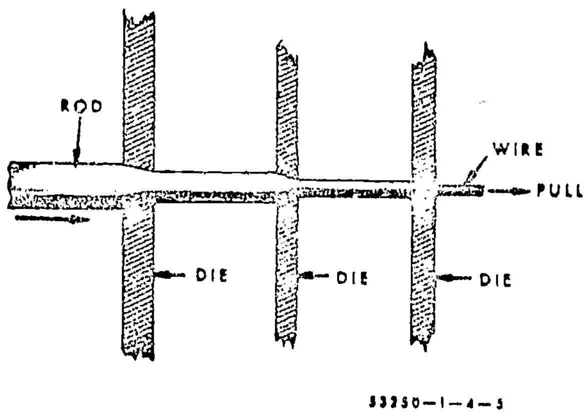


Figure 19. Drawing.

Extruding

Extruded parts are made by pushing metal through a die. The metal is shaped in a manner similar to toothpaste being forced out of a tube. The metal takes the cross sectional shape of the opening. Very complex shapes may be made in this way. Some of these shapes cannot be made in any other way. Aluminum, copper, and magnesium are often extrusion. Some extruded shapes are shown in figure 20.

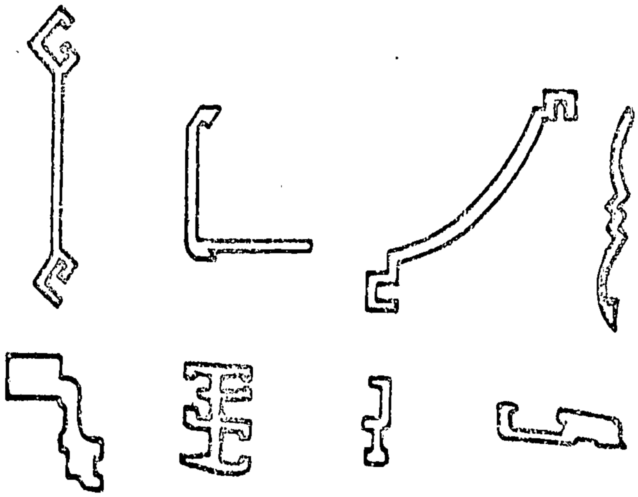


Figure 20. Extruded Shapes.

Piercing

A bar of hot metal may be rolled lengthwise between rolls so that the center opens up. As the center opens up, the bar is fed over a mandrel. The mandrel opens up the center to a given diameter to form tubing. This tubing is then drawn through a die to give it the proper size and smoothness. Figure 21 illustrates the making of seamless tubing.

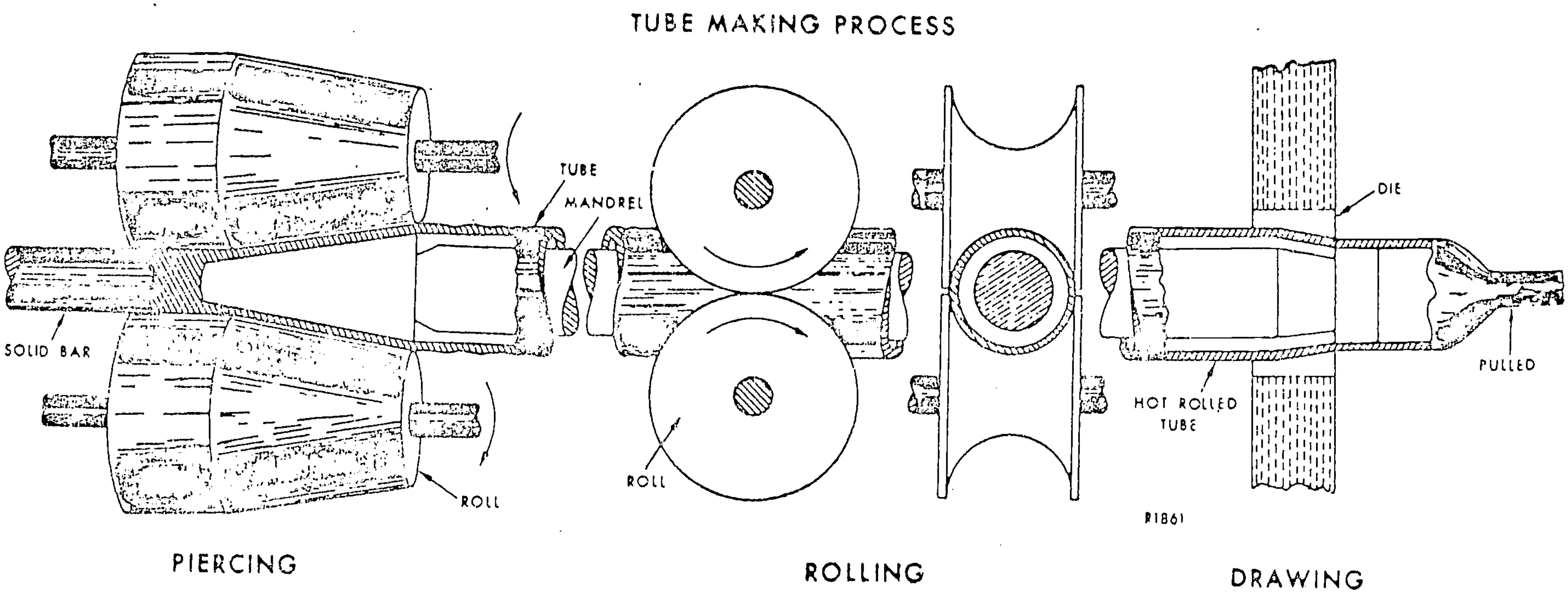


Figure 21. Making Seamless Tubing by Piercing, Rolling and Drawing.

IDENTIFICATION OF METALS

Identification of metals is important to the specialist since he must know what material he is working with before he heat treats a part or tool. Most metals cannot be accurately identified by visual inspection alone. It is possible to distinguish between aluminum alloys and steel but, all steels appear the same, as do all aluminum alloys. Several corrosion-resistant alloys such as inconel, monel, and stainless steel all look alike. Although a complete chemical analysis can be made in a chemical laboratory by a well trained, technician, it is possible for you, as a metal worker, to identify metals with reasonable accuracy in the shop. There are several quick tests you can use for this purpose.

Ferrous and Nonferrous Metals

When the weight and color of two or more metals are similar, a quick method of separating them is to touch each one to a grinding wheel. Ferrous metals will give off sparks, but most nonferrous metals will not. The exceptions being nickel-based alloys and titanium. Further identification can sometimes be made with a magnet. At room temperature, most ferrous metals are magnetic. However, certain types of stainless steel are nonmagnetic at room temperature. There are also certain nickel-based alloys that are magnetic at room temperature. As a result, the magnet test should be regarded with caution.

Low Carbon or Alloy Steel Tube Test

Alloy steel tubes look exactly like carbon steel tubes. To distinguish between the two, cut a specimen 1 to 2 inches long from the tube. Heat it to a bright red and quench it rapidly in water. Place the specimen in a vise and apply pressure. If it is low carbon steel, it will deform considerably before it breaks, while an alloy tube will break more easily and with less deformation.

Plain Carbon or Alloy Steel Test

The spark test is used to identify the various carbon steels and alloy steels. Because of the different chemical analysis, each metal has a characteristic spark stream. To perform the spark test, the unknown specimen is placed against the grinding wheel and the size, shape, color, quantity, mass, and arrangement of the sparks are noted. A known specimen may be compared to an unknown. Experience and practice are necessary to become proficient in spark testing. Observing the spark stream against a dark background helps you to see the spark stream better.

The grinding equipment used for spark testing may be any pedestal or bench-type grinder. The grinding wheel should turn at a speed of at least 3,500 feet per minute. The wheel should be fairly coarse and very hard.

Steels produce spark streams that vary in length, shape, and color. The lengths may be as short as 10 inches or as long as 2 feet. The color will vary from a dull red to nearly white. The spark stream is made up of shafts, forks, springs, dashes, appendages, and bud break arrows, as shown in figure 22. Each stream may have few, many, or no sprigs. The length of the shaft may vary, it may not have any forks, bud break arrows, nor appendages. By observing the individual characteristics of the stream and comparing it with the spark stream of the known specimen, the metal can be identified quite accurately.

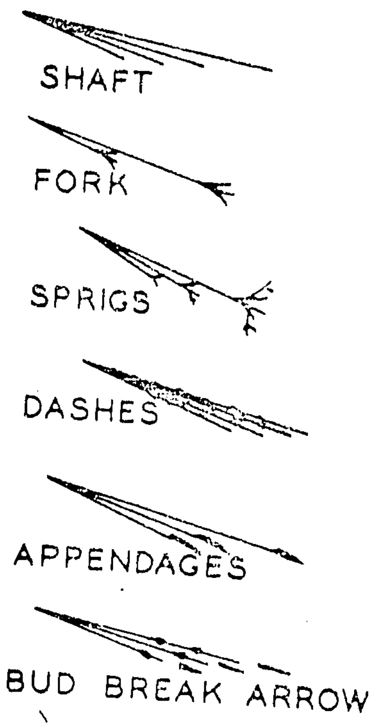


Figure 22. Spark Testing Terms.

Low carbon steels produce long straight shafts, and the carbon content is high enough to produce a few sprigs at the wheel. Along the shafts a few forks will be formed and the shafts will swell to the bursting point at the end to form appendages, as shown in figure 23.

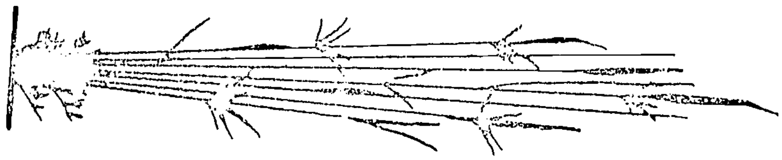


Figure 23. Low Carbon Steel Spark Stream.

High carbon steels produce a spark stream of average length. The high carbon content causes an enormous amount of sprigs and forks to form along the entire length of the shafts as shown in figure 24. Many shafts are formed and the spark stream appears dull red in color.

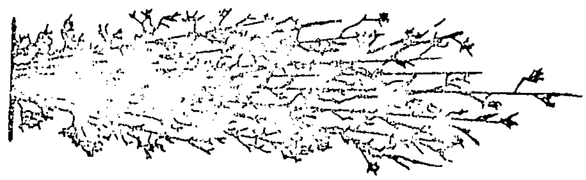


Figure 24. High Carbon Steel.

Wrought iron produces a few long shafts and because of the extremely low carbon content, there are practically no sprigs or dashes. On nearly all the shafts there appears an appendage that bursts at the end as in figure 25. Each of these appendages start from the fork.

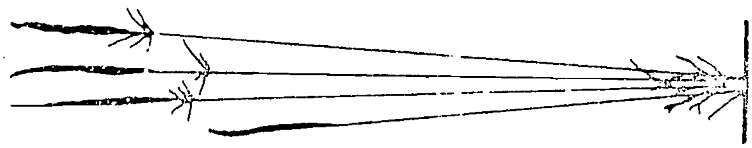


Figure 25. Wrought Iron.

99

Chromium-molybdenum steel is principally characterized by its color and formation of detached arrows. A few sprigs are seen along the spark stream and detached arrows appear at the end of the shafts illustrated in figure 26. The detached arrows are light orange in color. A swelling in the shaft line is an indication that nickel is also present.

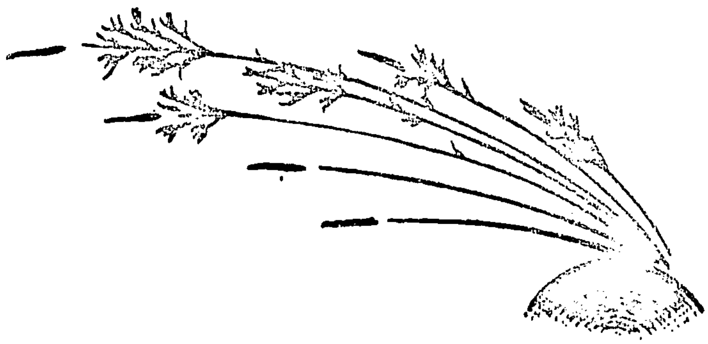


Figure 26. Chrome-Molybdenum Spark Stream.

Stainless steel, being an iron base alloy, has a spark stream similar to carbon steel. Depending upon the type of stainless steel, the spark stream is only affected by the chromium content. The amount of chromium determines the length of the spark stream which may be from 1/3 to 1/2 the length of a carbon steel spark stream.

Steel containing normal amounts of manganese produce a spark stream very similar to a carbon steel spark stream. If the manganese content is increased, the volume of the spark stream and intensity of the bursts are increased. Those steels that contain more than normal amounts of manganese produce a spark almost identical to that of high carbon steel. Manganese also has a tendency to cause the spark stream to have a light orange color.

Identifying Gas Welding Rod

The same identification methods are used for welding rod as for any other metal form. Special checks may be made to make a positive identification.

CARBON STEEL ROD. Some carbon steel rods may be coated with copper. This is done to protect the rod from corrosion and to add toughness to the weld. Check with a magnet to see that it is steel and then check for carbon content using the spark test.

CAST IRON ROD. The cast iron rod is very brittle and when broken has a gray color. It usually has a rough, sandy surface and it is magnetic.

ALUMINUM AND MAGNESIUM. The flame or bend test gives a quick check. Magnesium rods sometimes have spiral lines around them from forming.

STAINLESS STEEL AND INCONEL. These rods usually have the drawing scratches, and are fairly stiff, heavy, and nonmagnetic. For a final test, the spark test or acid test must be used.

Color

Color is dependent and directly based or determined upon the chemical composition of the metal. For example, copper has its own distinguishable color, as well as brass. It is, by the same token, easy to identify copper from aluminum. However, color cannot always be a sole judging factor, since aluminum and magnesium have the same color, but are obviously different.

Weight

In metal identification, if color gives little indication to chemical composition as in aluminum and magnesium, weight can be sometimes used as the deciding factor. However, it must be remembered that it is weight unit volume (density) that is important. In the case of aluminum versus magnesium, identification of the magnesium from the aluminum can be successfully accomplished only if the pieces of metal are to be identified are approximately the same physical dimensions.

Flame Test

There are a small number of metals which will burn readily. Examples of this could be sodium, phosphorous, magnesium, and titanium. The most common use of this test is to distinguish aluminum from magnesium. Using a file to make fine filings, and a torch for a heat source, the magnesium filings will burn with a brilliant white glow. The aluminum will not burn, but simply melt away.

Chip Test

Since the three common forms of cast iron appear similar to the eye, they may be distinguished from each other by the chip test. A sharp, cold chisel and hammer are used to perform this test. Raise a chip from the surface of the metal with the hammer and chisel. If the metal is white cast iron, the chip will come off in small broken fragments because of the brittleness of the metal. If it is gray cast iron, a small chip approximately 1/8 inch long can be raised before it breaks off. A malleable iron chip will be 1/8 to 3/8 inches long and tends to curl up before it breaks off.

Heat Treating Test

The heat treating tests which may be performed for identifying metal is limited only by the knowledge and ingenuity of the men performing the tests. All of them, however, follow the same lines of reasoning which is, "If it is this type of metal it will respond to this heat treatment in this manner and if it isn't, it is some other type." It may be necessary to perform many heat treating operations to positively identify the metal. By following the heat treatment chart in TO 1-1A-9, you should be able to identify the metal rather quickly.

Chemical Tests

For the purposes of this study guide, the chemical tests listed are by no means complete, yet are of the common ones that can be performed in any shop with a few simple chemicals. With a combined knowledge of other methods of identification, the following chart will be a great asset in identification. See table 1.

TYPE METAL	CHEMICAL	REACTION	MAGNETIC	NONMAGNETIC
Aluminum	Silver Nitrate	None-White Spot		X
Magnesium	10%	Black Spot		X
Inconel	Cupric Chloride	None-White Spot		X
Stainless Steel		Copper Spot	X	X
Aluminums	Caustic Soda			
Series 2xxx		Black		X
6xxx		Black		X
7xxx		Black		X
Series 1xxx		None-White		X
3xxx		None-White		X
4xxx		None-White		X
5xxx		None-White		X
Aluminum	Cadmium Chloride			
Series 2xxx		Gray 15 min.		X
6xxx		Black 10 min.		X
7xxx		Black 2 min.		X
Monel	Nitric Acid	Green	X	
K-Monel		Green		X
Inconel		None-White		X

Table 1. Chemical Tests.

STEEL CLASSIFICATION SYSTEMS

The Air Force uses both the SAE and AISI code number systems to identify steels in storage. The code numbers for all common AF steels are the same in both systems. TO 42D-1-3 outlines the visual identification systems for steel aluminum sheet, bar, rod, and strip. The title of this technical order is Method of Identifying Steel, Aluminum, and Copper Alloys in Air Force Stock.

SAE and AISI Numbering Systems

In these two coding systems, four or five digits are used to identify a specific steel. The second digit shows the approximate percentage of the main alloying elements. The last two, or sometimes three digits, indicate the carbon content in hundredths of one percent. In the AISI system, the first two digits indicate the type of steel when more than one alloying element is present. The code numbers for the common types of steel are listed in table 2.

TYPES OF STEEL	CODE NO.
Carbon Steels	1XXX
Plain Carbon	10XX
Free Cutting, Screw Stock	11XX
Free Cutting, Manganese	13XX
Nickel Steels	2XXX
Nickel Steel, 3.50% Nickel	23XX
Molybdenum Steel	4XXX
Chromium Molybdenum	41XX
Chromium-Nickel-Molybdenum	43XX
Chromium Steels	5XXX
.60% to 1.10% Chromium	51XXX
1.20% to 1.5% Chromium	53XXX
Chromium-Vanadium Steels	6XXX
Tungsten Steels	7XXX or 7XXXX
Chromium-Nickel-Molybdenum	8XXX
Silicon-Manganese	9XXX

Table 2. SAE, AISI Number Coding System.

Tool Steel Numbering System

Tool steel may not be described by the SAE or AISI numbering systems. Many tool steels have a high alloy content which cannot be described by the SAE system. A special numbering system for tool steels is used in the Air Force. This system consists of a letter and a number such as: A-3, B-4, or F-4.

USAF Color Code

For ease of identifying metals in storage, the Air Force uses bands of various colored paint to represent the SAE or AISI code number. These bands are placed in the center and near each end of the metal. Table 3 shows the colors, numbers, and letters they represent. This color code is always read from the end of the bar toward the middle.

First Digits, Steel No	
1	Blue
2	Green
3	Olive Drab
4	Yellow
5	Orange
6	Red
7	Maroon
8	White
9	Gray
0	Black

Table 3. Color Code, Steel.

ALUMINUM ASSOCIATION ALLOY NUMBERING SYSTEM

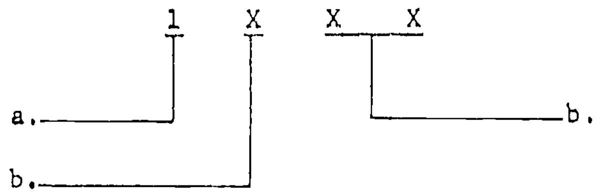
The Aluminum Association has devised a standard which provides a system for the identification of aluminum and its various alloys. This system divides aluminums into two main categories, Commercially Pure Aluminums (1XXX) and Aluminum Alloys (2XXX-7XXX) as shown in table 4. This system consists of a four-digit numerical designation, used to identify wrought products. This four-digit number, in all cases, is broken down into three main parts, each having its own specific meaning. There is, however, some difference in meaning of these parts depending upon which main category (Commercially Pure Aluminum or Aluminum Alloy) is referred to. Because of this, each category must be observed individually when discussing the breakdown and meaning of these four-digit numbers.

Aluminum - 99.00% minimum and greater	1XXX
<u>Major Alloying Element</u>	
Copper	2XXX
Manganese	3XXX
Silicon	4XXX
Magnesium	5XXX
Magnesium and Silicon	6XXX
Zinc	7XXX

Table 4. Designations for Alloy Groups.

The first category of Aluminum, Commercially Pure Aluminum, are those aluminums that contain a minimum of 99% aluminum. However, this does not include the Electrical Conductor Aluminum (EC Aluminums) which contain a minimum of 99.45% aluminum, and are to be used only for certain applications requiring electrical conductance and reflective properties.

The breakdown and the resulting meaning of the number is relatively simple. This first category, Commercially Pure, contains but one series which always is labeled by the number 1 followed by three other numbers, making up the four-digit number. The breakdown and meaning are as follows:

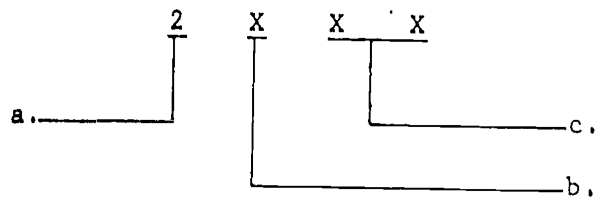


a. The first digit is read by itself and identifies the composition as commercially pure aluminum with a content of 99% minimum aluminum;

b. The second digit, also read by itself, lists the number of impurities that are under control. It does not identify what the impurities are or might be or what process or processes were used to control them. It gives the quantitive value of impurities that were controlled during refinement.

c. The last two digits are read together, and list the degree of purity above 99%.

The second category of aluminums, aluminum alloys, are those aluminums that contain one or more alloying elements. The four-digit designations range from 2XXX to and including 7XXX with the first digit identifying the alloy group of a particular series. All the alloy series are identical in breakdown, except for the different alloying element for each series. The breakdown is as follows:



a. The first digit is read by itself and identifies the main alloying element or elements. The main alloying element or elements are as follows:

Copper	2XXX
Manganese	3XXX
Silicon	4XXX
Magnesium	5XXX
Magnesium and Silicon	6XXX
Zinc	7XXX

b. The second digit is also read by itself, and lists the number of main modifications to the original alloy. If the second digit is zero, it is the original alloy. Numbers ranging from 1 through 9, assigned consecutively, indicate alloy modifications.

c. The last two digits are read together and have no special significance but serve only to identify the different alloys within the particular series referred to.

The complete AA numbering system runs from 1XXX through 9XXX. The 1XXX through 7XXX series has already been discussed, but something must be said for the last two series to make the numbering system complete. The 8XXX series is entitled "other elements" and means exactly what it implies. Industry is now in the process of experimenting with new alloying elements to see if desired properties can be obtained with the use of other elements than have already been proven. Some common elements now being alloyed with aluminum are nickel, boron, bismuth, lead, sodium, and titanium. Where one of these is the dominant alloy, then the alloy would be designated with the number eight (8XXX). The 9XXX series is entitled "unused series" and serves no purpose at the present time.

Aluminum and Aluminum Alloy Temper Designations

The Aluminum and Aluminum Alloy Temper Designation System is used for all products of aluminum and aluminum alloys. This system is based on the sequences of basic operations performed on aluminum and aluminum alloys to produce various conditions. The temper designation follows the basic four-digit number and is separated from it by a dash (-). Temper designations consist of a letter indicating one of the five basic temper conditions. Subdivision of the basic tempers, when required, are indicated by one or more numbers immediately following the letter. The five basic temper designations for aluminums and aluminum alloys are as follows:

F - As Fabricated. This temper designation applies to products that come in the condition resulting from normal manufacturing procedures, without special control over the degree of cold working and/or heat treatment. This temper designation can be applied to all aluminums and aluminum alloys.

O - Annealed. This temper designation applies to wrought products only, which are fully annealed to obtain maximum ductility and malleability.

H - Strain Hardened. This temper designation applies to products which have their hardness and strength increased by a modification of the crystal structure due to cold working (strain hardening) only, with or without additional heat treatment to produce some reduction in strength. This temper designation is reserved for those aluminums and aluminum alloys which can be hardened by cold working only: Series 1, 3, 4, and 5.

The "H" is always followed by two or more digits. The first digit following the "H" indicates the specific combination of basic operations, as follows:

H1 - Strain Hardened Only. This temper designation applies to products which are strain hardened to obtain the desired hardness and strength without additional heat treatment.

H2 - Strain Hardened and Partially Annealed. This temper designation applies to products which are strain-hardened more than the desired final amount and then partially annealed to reduce the strength to the desired level.

H3 - Strain Hardened and Stabilized. This temper designation applies to products which are strain hardened and whose mechanical properties are then stabilized by a low temperature heat treatment which results in slightly lower strength and improved ductility. It is applicable only to those alloys which, unless stabilized, gradually age-soften at room temperature. Examples of common alloys put in H3 condition are: 3004, and most of the 5XXX series. This temper is to prevent age-softening of these alloys.

The second digit following the "H" designation indicates the degree of hardness resulting from strain hardening. The number 8 has been assigned to indicate tempers having an ultimate hardness and strength, and is sometimes referred to as "Full Hard." Tempers between 0 (annealed) and 8 are identified by numerals 1 through 7. Aluminums having an ultimate strength about midway between 0 and 8 is designated by the number 4, commonly referred to as "half hard." Also, there are those having strength midway between 0 and 4, which are represented by a 2, commonly called "1/4 hard." Lastly, there are those having strength midway between 4 and 8, being represented by a 6, referred to as "3/4 hard." These (2, 4, 6, and 8) are the common digits found following H1, H2, or H3. There are also odd numbers, including 9, which could be used but they are not standard and generally will not be seen in normal applications. The odd numbers (1, 3, 5, and 7) would represent strengths midway between the adjacent even numbers and 9 would represent "extra hard." There may also be a third digit following the "H" designation, but it simply indicates a variation of the standard two-digit temper. It is not standard, thus it will not be covered in this text.

W - Unstable Condition. This temper designation applies to those aluminum alloys which have been solution heat treated but not aged. This designation is reserved for those aluminum alloys which are hardenable by solution heat treatment - Series 2, 6, and 7.

T - Thermally created to produce stable tempers other than F, O, or H. This temper designation applies to products which are heat treated, with or without additional strain hardening to produce stable tempers. This designation is reserved for those aluminum alloys which are hardenable by heat treatment; series 2, 6, and 7. The "T" designation is always followed by one or more digits. The first digit or digits indicate specific sequences of basic operation, as follows:

T1. Cooled from an elevated temperature shaping process and then naturally aged. This temper designation generally applies to cast products which are naturally aged only after proper solidification.

T2. Annealed. This temper designation applies to cast products only which are annealed to obtain maximum ductility and malleability.

T3. Solution Heat Treated and Cold Worked. This temper designation applies to wrought products which are cold worked after solution heat treating to improve their strength.

T4. Solution Heat Treated and Naturally Aged. This temper designation applies to products which are hardened by solution heat treating and natural aged, without any appreciable cold working to improve hardness and strength.

T5. Cooled from an elevated temperature shaping process and then aritficially aged. This temper designation generally applies to cast products which are artificially aged only, after proper solidification.

T6. Solution Heat Treated and Artificially Aged. This temper designation applies to products which are hardened by solution heat treating and an artificial age without any appreciable cold working to improve hardness and strength.

T7. Solution Heated and Stabilized. This temper designation applies to products that are solution heat treated and then stabilized to reduce stresses caused by heat treating.

T8. Solution Heat Treated, Cold Worked, and Artificially Aged. This temper designation applies to products which are solution heat treated and cold worked an appreciable amount to improve strength, and artificially aged.

T9. Solution Heat Treated, Artificially Aged, and then Cold Worked. This temper designation applies to products which are solution heat treated, artificially aged, and then cold worked and appreciable amount to improve strength.

T10. Cooled from an elevated temperature shaping process, artifically aged and then cold worked. This temper designation generally applies to cast products which are artificially aged and then cold worked after proper solidification.

In addition to the first digit following the "T" designation, there may also be a second digit following this designation in the case of T3, T8, or T9. These three temper designations apply mainly to wrought products and contain a cold working operation in addition to any solution heat treating and aging which may have been applied. This cold working operation is generally a stretching procedure to improve the final hardness and strength. This stretching is expressed in percentage of elongation, with the range being a maximum of 6%. This basically means that the part is stretched a certain percentage (1% - 6%) of its length. Probably the most common example would be T86 - which would be read - solution heated, cold worked, and artificially aged with 6% elongation.

Color Code

As with ferrous metals, color coding can be used to identify nonferrous metals in storage. Again, bands of paint represent various numbers, but they can also represent various letters. When reading a color coded metal, the color represents either a number or a letter and is determined by its position in the coding. For further information, refer to TO 42D-1-3.

Properties and Uses of Aluminum and Its Alloys

COMMERCIALLY PURE ALUMINUM - 1000 SERIES. Aluminum containing no more than one percent of other elements (99% commercially pure) has many applications, especially in the electrical and chemical fields. Formability, weldability, and the ability to take a finish are good to excellent. Alloys in this group are characterized by excellent corrosion-resistance and high thermal and electrical conductivity. The strength of this group is limited, and only moderate increases in hardness and strength are obtainable by cold working. Typical uses of these aluminums include chemical equipment, reflectors, heat exchangers, architectural components, and decorative trim.

ALUMINUM-COPPER ALLOYS - 2000 SERIES. Copper is the main alloying element in this group and it makes these alloys hardenable by heat treatment. Copper also increases hardness and strength to the point where, when in the heat treated condition, the alloy's mechanical properties are similar to, and sometimes exceed, those of mild steel. The corrosion resistance and weldability of this group are limited while most alloys exhibit superior machinability. Members of this series are particularly suited for parts and structures demanding a high strength-to-weight ratio and are commonly used to make truck-trailer panels and for aircraft structural parts requiring good strength at elevated temperatures up to 300°F.

ALUMINUM-MANGANESE ALLOYS - 3000 SERIES. Manganese is the main alloying element in this group and yields aluminum alloys that are about 20% higher in strength than commercially pure aluminum, but retain formability almost equal to that of the 1000 series. Because of these properties and good corrosion resistance, alloy 3003 is called the "workhorse of the industry" with typical applications being cooking utensils, heat exchangers, storage tanks, awnings, furniture, highway signs, roofing, siding, and many architectural uses.

ALUMINUM-SILICON ALLOYS - 4000 SERIES. The chief alloying element in this series is silicon, which can be added in sufficient quantities to cause substantial lowering of the melting temperature. This property makes the 4000 series particularly suited for use as filler material for welding and brazing because their melting point is lower than that of the parent metal. Silicon also greatly improves castability making it invaluable for cast products requiring high fluidity. Most alloys in this series are not hardenable by heat treatment, but when used in welding alloys that are heat-treatable they acquire some of the constituents of the parent metal and so respond to heat treatment to a limited extent.

ALUMINUM-MAGNESIUM ALLOYS - 5000 SERIES. Magnesium is the major alloying element of this group, and is one of the most effective and widely used alloying elements for aluminum. Alloys in this series exhibit moderate to high strength, good weldability, and good resistance to corrosion in marine atmospheres. Uses of this series include decorative trim, aircraft fuel and oil lines, sheet metal work, appliances, cryogenic tanks, gun mounts, and ship construction.

ALUMINUM-MAGNESIUM-SILICON ALLOYS - 6000 SERIES. Alloys in this series contain silicon and magnesium as their main alloying elements. Most aluminums and aluminum alloys contain these two elements, but in the case of the 6000 series, they are present in substantial proportions to make these alloys hardenable by heat treatment. Members of the group have good formability, high resistance to corrosion, good weldability, excellent machinability, and can be finished in may ways. Typical applications include architectural installations, transportation equipment, bridge railings, aircraft landing mats, canoes, and welded constructions.

ALUMINUM-ZINC ALLOYS - 7000 SERIES. Zinc is the main alloying element of this series and when coupled with a small percentage of magnesium, results in alloys which are hardenable by heat treatment. In the heat treated and aged condition, these alloys possess very high strength and hardness. Corrosion resistance and weldability are fair, but limited. These alloys find application in aircraft structures, mobile equipment, and equipment or components requiring high strength-to-weight ratio.

Cladding of Aluminum Alloys

Cladding is defined as a metallurgically bonded coating of aluminum, consisting of chemical composition of a more pure aluminum than the alloy it is applied to. The purpose of such cladding is to improve corrosion resistance, surface appearance, or electrical conductance. The heat-treatable alloys which contain copper or zinc as main alloying elements are less corrosive resistant than the majority of nonheat treatable alloys. To increase the corrosion resistance of these alloys, they are often clad with a more pure aluminum, a low magnesium-silicon alloy, or an aluminum alloy containing approximately 1% zinc. The cladding, which usually is 2-1/2 to 5 percent of the total thickness of the part, not only increases corrosion resistance but enhances the galvanic properties of the part. An aluminum, which is clad, is identified by the term "alclad" preceding the alloy number. Table 5 lists some common alloys and the aluminum or aluminum alloy used as the clad surface.

ALLOY-(CORE)	ALLOY USED FOR CLAD SURFACE
2014	6003
2024	1230
2219	7072
3003	7072
5056	6253
7075	7072

Table 5. Clad Surfaces.

QUESTIONS

Note: Answer the questions at the end of this chapter on a separate sheet of paper. DO NOT WRITE IN THIS STUDY GUIDE.

1. How can you distinguish carbon steel tubing from alloy tubing?

2. What is the purpose of the spark test?

3. How is the acid test performed? (Cupric chloride test)

4. What three tests are used to distinguish one type of cast iron from another?

5. What is the purpose of the flame test?

6. The silver nitrate test is used to distinguish between what two metals?

7. What test is used to distinguish between weldable and nonweldable aluminum?

8. Is 1020 carbon steel a high or low carbon steel?

9. What are the three types of casting?

10. What is cold working?

11. What effect does welding have on cold worked metal?

12. Explain what each digit means in a four-digit SAE number for a ferrous metal.

13. Explain what each digit means in a four-digit AA number for pure aluminum.

REFERENCES

1. TO 1-1A-9, Aerospace Metals-General Data and Usage Factors.

2. TO 34W4-1-5, Welding Theory and Application.

3. TO 42D-1-3, Methods of Identification of Steels, Aluminum Alloys, and Copper Alloys in Air Force Stock.

4. Althouse/Turnquist/Bowditch, Modern Welding, Goodheart-Wilcox Co. Inc., 1967.

HEAT TREATMENT OF FERROUS METALS

OBJECTIVES

After completing this study guide, classroom instruction, and assigned study, while observing all shop safety, good housekeeping and fire prevention measures, you will:

1. Identify metal compositions and their relation to heat treatment.

2. Identify basic structures produced by heat treating operations.

3. Set up and normalize carbon and alloy steels.

4. Set up and harden carbon and alloy steels.

5. Set up and temper carbon and alloy steels.

6. Set up and anneal carbon and alloy steels.

7. Identify methods and procedures pertaining to case hardening of metals.

INTRODUCTION

Heat treating is a series of operations involving the heating, soaking, and cooling of a metal or an alloy, while in the solid state, for the purpose of obtaining certain desirable mechanical properties. Some of the mechanical properties that can be controlled by heating, soaking, and cooling the metal are hardness, ductility, impact strength, wear resistance, and tensile strength. No one heat treating operation can give all these properties. Many times one property must be sacrificed to gain another.

INFORMATION

MANAGEMENT OF DEFENSE ENERGY AND RESOURCES

It is essential that you follow proper procedures in the operation of heat treating furnaces to reduce operating costs. All material will be used to its fullest extent.

ELEMENTS AND METALS

Elements

Everything on earth is made up of elements. Some elements may be found in a pure state, while others are found in combination with one or more other elements. Some common elements are copper, gold, oxygen, iron, carbon, aluminum, sulphur, hydrogen, titanium, nitrogen, and calcium. Water is broken down into sodium and chlorine. Steel is an alloy of iron and carbon. One or more other elements may be added to make it a better steel. An element is a substance that cannot be separated into other substances. Any element can be a solid, liquid, or a gas.

Metals

Metal is a general term which includes both pure metals and alloys. Most of the metals we use today are alloys. An alloy is a substance that has metallic properties and is made up of two or more elements, one of which is a metal. To be an alloy, the substance must fill all of these requirements. Some common alloys are brass, steel, aluminum alloys, and stainless steel. These alloys have been developed to meet special needs. Each of these alloys was designed for a specific purpose and meet these needs better than any other alloy. Some alloys can be heat treated to increase their strength, while others cannot.

Metals which have iron as their base metal are ferrous metals. Metals which have any element other than iron as their base metal are nonferrous metals. Some nonferrous metals are aluminum, copper, nickel, lead, and magnesium.

Metals are made up of millions of small particles or grains, such as a block of concrete or a piece of wood. The arrangement of these grains is known as the grain structure of the metal. This grain structure determines the properties of the metal. Grain structures can be changed and controlled by heating and cooling.

BASIC GRAIN STRUCTURES

All grain structures that are found in steel can be classified as being one of three basic structures; chemical compounds, solid solutions, or mechanical mixtures. In most practical cases, metals contain more than one of these three basic structures. However, temperature plays as important part in determining grain structure as does chemical composition.

Chemical Compounds

Chemical compounds are defined as: Two or more elements, chemically combined at a definite ratio. The molecules of compounds contain at least two different kinds of atoms. A compound always has the same chemical composition. This study guide is not intended to cover the formation by discussion of the valence in formation of ionic compounds. If further information is desired, consult any basic chemistry book.

However, there are a few things to make mention of on chemical compounds:

1. Chemical compounds are usually hard and brittle. As a result, alloys in which they are found are hard and brittle. An example of a chemical compound is cementite (Fe_3C), which is found in steel. Cementite, if present in excessively large particles, makes steel very brittle. Steels having these large cementite particles are called abnormal steels.

2. Chemical compounds can usually be done away with by causing them to go into the unit cells of a metal and form a solid solution. This is usually accomplished by heating to a high temperature, and then quenching. Heating to a high temperature causes the compounds to go into solution. Quenching traps them there.

3. All chemical compounds are homogeneous.

Solid Solutions

Solid solutions are formed when one or more elements go into solution within the unit cells of another element. Even though the unit cell is a solid material, there is still a lot of space between the atoms. This space between these atoms is referred to as space lattice. When an element dissolves other elements within its unit cells, one type of solid solution is formed. This type of solid solution occurs between iron-carbon and iron-hydrogen. The main deciding factor is that of the diameter of the atoms involved. Atoms of different materials having different sizes go into solid solution interstitually. The absorbed atoms go into the space lattice of the unit cell they are absorbed into. Such is the case with carbon and hydrogen being dissolved into iron in solid solution.

When an element dissolves other elements into its unit cell by some of its atoms swapping places with other atoms, substitutional solid solution is formed. The one prerequisite for this, however, is that atoms must be of similar size that are substituting. Most all metallic elements go into solid solution substitutionally. Metallic materials such as chromium, molybdenum, and vanadium combine with iron substitutionally. Aluminum and copper combine substitutionally to form $CU\ Al_2$. All solid solutions are homogeneous.

It must be pointed out that there are some pecularities common to alloys which contain crystalline structures of solid solutions at room temperature. For example, ferrous alloys in the austenitic steel family fit this description. As a result of this, they are nonmagnetic at room temperature. Alloys containing solid solutions at room temperature can be hardened only by cold working. The effects of cold working can be removed by a stress-relief anneal.

Mechanical Mixtures

A mechanical mixture is defined as a mixture consisting of two or more substances, which retain their own properties. For example, gun powder is a mixture of sulfur, potassium nitrate, and carbon. Mechanical mixtures are heterogeneous, variable in composition, separable into their constituents by mechanical means, and composed of substances that retain their own energy contents. An example of a mechanical mixture in metals is that of iron carbides located in iron. The iron carbides can readily be distinguished from the iron. The same is true of identification of copper aluminide ($CU\ Al_2$) and aluminum, in the case of annealed 2024-0 aluminum.

THE THREE HEAT TREATING STEPS

Heating

The metal is heated to a given temperature. Certain changes take place within the metal at known temperatures. The metal must be heated until it is hot enough for the changes we want to take place. In any heat treating operation, the metal is never heated until it melts.

Soaking

The piece of metal is allowed to remain in the furnace until the heat soaks into the metal. The bigger the piece, the longer it takes the heat to soak all the way through. The piece must be heated uniformly throughout.

Cooling

The metal must be cooled down to room temperature after it has been heated. This may be done by several methods. The substance in which the metal is cooled is known as the cooling medium. The common cooling media listed in order from the fastest to the slowest cooling rate are salt water, water, oil, room temperature, and furnace cooling. Most parts should be cooled slowly at room temperature after welding.

THE FIVE HEAT TREATING OPERATIONS

Each of the five operations is performed by heating, soaking, and cooling. They may be performed by heating with a welding torch, in a forge, or in a heat treating furnace.

Annealing

Annealing is the process of softening metals. Any pure metal or alloy that may be hardened either by cold working or heat treating can be softened by annealing. This is the only heat treating operation that may be performed on pure metals. Annealing is usually performed to make metals softer for easier machining or forming operations.

Normalizing

Normalizing is used to refine the grain structure and to relieve the stresses induced by the welding, forming, or manufacturing processes. An abnormal grain structure may result from these operations. Normalizing gives a uniform grain structure throughout the metal.

Hardening

Hardening causes metal to become hard so that it can resist deformation and penetration. Some alloys cannot be hardened by heat treatment. Most of them, however, respond to some form of heat treatment that makes them much harder and stronger. The tool steels are a good example of the hardenable ferrous alloys. Most aluminum, magnesium, and titanium alloys can be hardened by heat treatment. Pure metals can be hardened by cold working only. A few pure metals cannot be hardened by any method.

Tempering

Tempering follows the hardening operation on steel. Tempering is performed to develop certain desirable characteristics, such as elasticity, toughness, and impact strength. It also reduces the hardness to the desired degree.

Case Hardening

Case hardening is performed on steels with a low carbon content. In this process, carbon or nitrogen is induced into the surface of a part. This makes a hard, wear-resistant case around a soft, tough core.

PHYSICAL AND MECHANICAL PROPERTIES

The characteristics of a metal that enable it to resist deformation by some external force are known as its physical or mechanical properties. It is the internal changes that take place within the metal during heating and cooling which make possible changes in the mechanical properties. By properly regulating the heating and cooling, the desired properties can be obtained through heat treatment.

Hardness

Hardness is the ability of a metal to resist penetration and indentation by another metal or substance. A gain in hardness is often accompanied by a gain in other properties.

Wear Resistance

Wear resistance is the ability of a metal to withstand the cutting or abrasive action of a sliding motion between two surfaces under pressure. This is one of the many properties gained by the hardening operation.

Tensile Strength

Tensile strength is the maximum stress that a metal will develop under a slowly applied load. It is usually stated in pounds per square inch (psi). This property is also gained in the hardening operation. It increases up to a Rockwell hardness of C-53. Beyond this point, any tensile test becomes inaccurate.

Corrosion Resistance

Corrosion resistance is the ability of a metal to resist a chemical or electrochemical attack by atmosphere, moisture, or other agents. Proper quenching procedures help to maintain this property after heat treating.

Stress

Stress is the reaction within a metal to an externally applied force. This force can be a hardness test, a machining operation, or a welding operation. Each mark made from one of these operations becomes a stress riser and can set up either pitting corrosion or stress corrosion. This is why the normalizing operation is required after forming or repairing of a part.

Strain

Strain is the change in length per unit of length within a metal that is subjected to stress.

Shear Strength

Shear strength is the resistance to a force applied at a right angle to the metal which causes the particles of the metal to slide over each other.

Brittleness

Brittleness is the tendency of a metal to fracture with little deformation. Brittleness increases as hardness increases. Tempering reduces the brittleness to an acceptable level while maintaining the required degree of hardness.

Toughness

Toughness is the property of a metal which permits it to absorb considerable energy before it fractures. This property is induced into steel by adding small amounts of nickel.

Ductility

Ductility is the property of a metal which permits it to be a drawn out in wire form or to make forming possible. Maximum ductility is achieved in the annealing process.

Malleability

Malleability is the property of a metal which permits it to be hammered or rolled into thin sheets. Gold is an example of a malleable metal. It is one of the pure metals that cannot be hardened by any method. It can be hammered into very thin sheets. These thin sheets are known as gold leaf and are used for various decorative purposes.

Coefficient of Thermal Conductivity

The coefficient of thermal conductivity is a number which tells how fast a material will transfer heat from one part to another. Aluminum has a high thermal conductivity. That is why you need a larger torch tip to weld it.

Coefficient of Thermal Expansion

The coefficient of the thermal expansion is a number which tells how much a metal expands when it is heated. Stainless steel has a high rate of thermal expansion. Jigs and fixtures are required to weld stainless steel to control this expansion.

ALLOY STEELS

The term alloy steel normally refers to a steel containing iron and carbon plus one or more other alloying elements, such as manganese, nickel, chromium, or silicon. The properties of a steel may be greatly changed by increasing or decreasing the percentage of one or more elements. These elements are of great importance in determining the use and treatment of metal. The melting point, formation of gas pockets, hardenability, tensile strength, ductility, toughness, elastic limit, corrosion resistance, and thermal expansion are some of the factors that may be affected by these elements.

Commercial steel always contains at least five elements besides iron. They are carbon, silicon, sulphur, phosporous, and manganese. These elements get into the steel from the ore and the refining processes. The percentage of such elements must be controlled so that the different steels will possess the desired properties for the job they are designed to do. The percentage of these elements also determines whether the steel is classed as a carbon or an alloy steel.

1. Carbon is not normally an impurity but may become one if it is present in excess of the desired amount. This carbon may be added by an excess of carbon in the atmosphere surrounding the hot metal during heat treating.

2. Silicon is found in steel in small amounts. Silicon unites readily with oxygen and forms a slag during the manufacturing process. The silicon uses up the oxygen and does not allow the metal to scale. Three to four percent silicon improves the magnetic properties of steel. A high silicon content (13 to 15%) gives high corrosion resistance. Silicon in low carbon steel makes it brittle.

3. The sulphur content is never allowed to exceed 0.10% as it will make the steel very weak and brittle while it is hot. The addition of manganese and sulphur together increase the machinability of steel.

4. The phosphorous content is not allowed to exceed 0.10%. Higher percentages make the steel brittle while not lowering its tensile strength. A higher phosphorous content in combination with a high sulphur content will produce free machining steel.

5. Manganese is added to steel during the manufacturing process to take out other impurities. It also increases hardenability at less cost than chromium. Manganese is generally present in quantities of about 0.40%. When 1 to 7% manganese is present, it makes the steel very brittle. Higher percentages make steel very hard, wear resistant, and able to withstand severe shock and abrasion. Manganese steels are used in some hard surfacing applications.

The reaction of alloy steels to heat treatment is very similar to that of carbon steel. The soaking times for alloy steels are approximately one and one half times longer than for carbon steel because the alloys slow down the change. The temperature required for heat treating may be higher or lower according to the alloy, but they are usually higher. Alloy steels may harden during air cooling. They are usually quenched in oil, if a quench is necessary. In most cases it is necessary to preheat alloy steels, or heat them by steps to the higher temperatures to prevent stresses and cracking. Charts and tables for determining these temperatures are found in Military Specification H-6875.

ANNEALING CARBON AND ALLOY STEEL

The purpose of annealing is to soften metal for machining or fabrication processes and to refine the grain structure. Before any structural change can occur, the upper critical point must be exceeded slightly. Regardless of the grain size of the previous structure, a new grain size is formed at the upper critical temperature. It is the smallest grain size possible. The grains shrink in size at the upper critical temperature to the smallest possible size and still retain hardening qualities. As the temperature increases above this point, the grains increase in size. The highest temperature reached and the soaking time involved determine the resulting grain size of the metal. The rate of cooling has no appreciable effect on the grain size. To produce the finest grain size, heat no higher than necessary and soak no longer than needed.

The resulting tensile strength of annealed carbon and alloy steel will be nearly minimum. However, the hardest of all annealed steels should be machinable. When cold rolled steels are annealed, the elongated grains are refined. The temperature is slightly lower for the annealing process due to strain effects in metals causing lower points of recrystallization. Other ferrous metals may be annealed by applying a certain temperature and cooling slowly. If time is an important factor, the hot metal may be removed from the furnace at 1000°F. and air cooled. Welded steel sections should be stress relieved by using a temperature that is just slightly lower than the critical temperature and cooling in still air.

NORMALIZING CARBON AND ALLOY STEEL

The purpose of normalizing is to remove internal stresses from ferrous metals and to produce a normal structure within the metal. Forging, welding, fabricating, heat treating, and machining cause stresses to be set up. Stresses, when highly concentrated, cause failure by cracking, so, most steels should be normalized immediately before the hardening operation. Parts that have been normalized should have a tensile strength of from 90,000 to 120,000 psi.

To control the carbide dispersion, the cooling rate must be faster than that used for the annealing operation. Still air is required to properly control the grain structure when red hot steel is cooled. If air drafts contact the metal when it is cooling, stresses may develop again. If the cooling rate is too fast, hardness may develop. If the cooling rate is too slow, carbide precipitates into the grain boundary and causes problems in the hardening operation.

Properly normalized parts have a fine grain structure which is the toughest of all structures. The metal deforms before fracturing if it is overloaded and it is much stronger than a coarse grain structure. Aircraft parts which encounter sudden loads and vibrations are frequently normalized.

Caution must be observed in normalizing hypereutectoid steels. The finest grain size is formed at the upper critical temperature. Normalizing operations cause a slightly larger grain size. Therefore, temperatures should be held as low as possible to develop a stress free structure. If it becomes necessary to heat hypereutectoid steels to their normalizing temperatures, an annealing or hardening operation must follow to refine the grain structure. In this class of steel, the carbon is equally dispersed. However, some operations involving high-carbon content require a refining treatment. Soaking at the proper temperature is essential to ensure a homogeneous mass. Oversoaking causes an enlargement of the grain, just as overheating does.

HARDENING CARBON AND ALLOY STEEL

In this text we discuss hardening and tempering separately to promote a better understanding of the two operations, although in practice, an understanding of how they are related is necessary to perform them satisfactorily. Hardening induces the initial hardness and tensile strength in a steel part necessary for it to perform its job. Tempering is necessary to remove stresses and brittleness after hardening. Carbon and alloy steel used in fabricating aircraft parts are usually received in the annealed or normalized condition. Most hardening heat treatment is performed after other necessary fabrication operations have been completed. On most steel parts, there is a direct relationship between hardness, tensile strength, wear resistance, and other properties.

Effect of Alloying Elements on Hardness

Carbon is the primary hardening element in all steels. If the mass remains constant as carbon content increases through the steel range, the capability of a steel part to be hardened increases. Other alloying elements may combine with the carbon to produce additional hardness. These other alloying or carbide forming elements tend to increase hardness only if a sufficient amount of carbon is present to combine with them. Without a sufficient amount of carbon in a steel, it is difficult to produce any great degree of hardness.

Effect of Mass or Design on Hardness

There is a tendency on the part of inexperienced personnel to place a great deal of emphasis on carbon or alloying elements in alloy steel and disregard the effect that mass or design has on a part as far as total hardness is concerned. No matter what heat treating procedure is used, parts with extremely large mass present a problem when a high degree of hardness is required. Parts with extremely small cross sectional areas present a problem in the prevention of warping or cracking during heat treatment. It is not difficult to obtain maximum hardness in parts of small cross section.

Effects of Quenching on Hardness

After considering the effect of the various alloying elements on steel, the method or procedure to be used for hardening is the next consideration. Generally speaking, the faster the quench, the greater will be the hardness up to the point at which full hardness is acquired for a specific steel. Beyond this point, any increase in the speed of

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the quench produces no additional hardness. Hardness is also determined by the mass, as previously mentioned. If the part is of fairly large mass, even the fastest quench may not produce full hardness unless the part is designed to allow the quench to cool all portions of the part very rapidly.

When parts of extremely small cross section are being hardened, full hardness may be acquired by quenching in oil. Plain carbon steels are quenched in water, and unless specified otherwise, most alloy steels are quenched in oil. There are few special alloy steels that are air hardened and require none of the various liquid quenches to gain full hardness.

Preheating Prior to Hardening

Preheating parts of medium to high carbon content is necessary to prevent warping or cracking. Approximately 800°F is adequate for parts of ordinary design. 1100°F to 1200°F is recommended after the 800°F preheat for parts of complex design, especially where thick and thin sections are involved.

TEMPERING CARBON AND ALLOY STEEL

Tempering

The purpose of tempering steel parts is to remove brittleness induced during hardening operations. Other advantages or properties gained during tempering operations are as follows:

1. Relief of stresses.
2. Increased toughness.
3. Greater elasticity.
4. Higher impact strength.
5. Greater ductility.
6. Required hardness.

During tempering operations, all of these properties are not gained. The final properties gained are a result of a compromise between the hardness and brittleness produced during hardening operations and the amount of ductility and decreased hardness produced during tempering operations. An example of this is the cutting edge of a reamer. It must retain enough of the original hardness to be able to cut steel after being tempered, but still be tough enough and wear resistant enough to maintain its cutting edge without undue wear or chipping. A properly tempered aircraft bolt does not have the tensile strength or hardness of the reamer cutting edge, but it must be tempered to produce elasticity and ductility so that it can stand up under bending, shearing, and twisting stresses. Another example of the varied demands of properly tempered steel is an ordinary cold chisel. The cutting edge of the chisel must be hard enough to cut into moderately soft steel but still tough and high enough in impact strength so that it does not shatter when it is hammered. If it is too hard, the cutting edge may break. If it is too soft, the cutting edge may be peened over and not cut.

The tempering range for steel is from 212°F to 1250°F. The tempering range of steel depends upon the specific class of the steel. Most carbon steels are tempered between 400°F and 800°F, alloy steels from 700°F to 1250°F, and high speed steels from 1000°F to 1250°F.

The hardness and tensile strength of a steel are directly related. As one increases, the other increases; as one decreases, the other decreases. This holds true up to the point where the steel becomes brittle (above R55) on the Rockwell Tester. Tensile strength above this hardness falls off rapidly due to brittleness.

The main factor in determining the tempering temperature to be used is the final hardness desired. The higher the tempering temperature used, the lower the final hardness.

Because tempering is performed below the critical temperature (transformation temperature), the rate of cooling after tempering has no effect on final hardness. Caution should be taken, however, not to warp or crack the part by uneven or too rapid cooling.

Case Hardening

Case hardening is a process of changing the chemical composition on the surface of a piece of steel. This hardens the surface of the steel without changing the soft, ductile properties of the core.

The most common process is carborizing; the addition of carbon to the surface layer of low carbon steel. This is accomplished by heating the steel while in a carbon bearing environment. The environment may be either solid, liquid, or gas.

An example is the addition of carbon to .030 inch thick steel which increases to 0.050 inch; obtained in 4 hours, at 1700°F. The case depth varies with time, temperature, and composition of the carborizing material.

Case hardening may be accomplished by nitriding carbo-nitriding, and cyaniding. The rates of application and properties of the case will vary from process to process. These cases may be applied from either liquid or gaseous environments.

In all cases, the mere application of the case does not induce hardness, but further heat treatment is required to achieve the desired hardness of case and core.

Case hardening is a process whereby the chemical composition in the surface of the material is changed.

QUESTIONS

Note: Answer the questions at the end of this chapter on a separate sheet of paper. DO NOT WRITE IN THIS STUDY GUIDE.

1. What is the purpose of annealing metal?

2. What effect does the cooling rate have on the grain size of an annealed part?

3. How is the tensile strength of steel affected by annealing?

4. Why are soaking periods necessary in heat treating?

5. What is the main hardening element in steel?

6. List five methods of quenching a part after heat treatment.

7. Why is a part that has a cross section of less than 1/4" quenched in oil?

8. List the quenching methods in the order of their cooling rate.

9. What is the most important purpose of tempering?

10. What are the five heat treating operations?

11. What are the three steps of any heat treating operation?

12. What is a ferrous metal?

13. What is a nonferrous metal?

14. What is the relationship between hardness and tensile strength?

15. Why is cooling in still air or its equivalent essential in normalizing?

16. What effect does tempering temperature have on the hardness of a steel?

17. When does the soaking period begin in heat treating?

18. What possible damage may result due to improper cooling after tempering?

19. What cooling media is commonly used on carbon steels to obtain maximum hardness; on alloy steels?

REFERENCES

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2. TO 1-1A-9, Aerospace Metals-General Data and Usage Factors.

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HEAT TREATMENT OF HEAT AND CORROSION RESISTANT FERROUS ALLOYS, NICKEL BASE ALLOYS, ALUMINUM AND ALUMINUM ALLOYS AND TITANIUM ALLOYS

OBJECTIVES

After completing this study guide, your classroom instruction, and assigned study, while observing all shop safety, good housekeeping, and fire prevention measures, you will:

1. Set up and heat treat heat and corrosion resistant ferrous alloys.

2. Identify procedures pertaining to heat treatment of nickel base alloys.

3. Set up and heat treat aluminum and aluminum alloys.

4. Identify procedures pertaining to heat treatment of titanium alloys.

INTRODUCTION

Heat treatment of ferrous heat and corrosion resistant alloys can serve to increase hardness and tensile strength or to increase ductility and corrosion resistance, depending upon the type of alloy and the heat treating operation.

Solution heat treating may be applied to nonferrous alloys such as aluminum, nickel, and titanium. Ferrous alloys may also be annealed.

INFORMATION

MANAGEMENT OF DEFENSE ENERGY AND RESOURCES

It is essential that you follow proper procedures in the operation of heat treating furnaces to reduce operating costs. All material will be used to its fullest extent.

HEAT AND CORROSION RESISTANT FERROUS ALLOYS

There are many variations to stainless steels, yet they all can be classified into four families: (1) austenitic; (2) ferritic; (3) martensitic; and (4) semi-austenitic, or precipitation hardening stainless steels. All stainless steels contain chromium; some contain nickel. The carbon content of stainless steels can vary from a very low to a high percentage.

All four families of stainless steels can be hardened by cold working or softened by annealing, but only two families (martensitic and semi-austenitic) can be hardened by heat treatment.

The heat treatment of martensitic stainless steel is very similar to the heat treatment of plain carbon steels, and the heat treatment of semi-austenitic stainless steels is similar to the hardening of some aluminum alloys.

This study guide will deal mainly with the austenitic family of stainless steels, since this type is the one most commonly used in the aircraft industry. This family of stainless steel will not harden as a result of heat treating. However, it is necessary from time to time to give this stainless steel an annealing treatment. There are two common types of austenitic stainless steel that are frequently encountered in the field; 321 and 347. Both 321 and 347 are stabilized stainless steel.

Carbide Precipitation

Between 800°F and 1650°F carbon unites with iron and chromium to precipitate out of the solid solution. This precipitation causes the carbide to form at the grain boundaries. In 321 and 347 austenitic stainless steel stabilizers are added to prevent the carbides from forming and precipitating out of solution. 321 stainless steel has titanium added as a stabilizer. This stabilization occurs as a result of titanium's high activity with carbon, the principle element involved with carbide precipitation. Columbium is used in 347 stainless steel to accomplish the same thing. As a result of adding these stabilizers the carbon remains in solid solution through the carbide precipitation range. However, there are times when even stabilized austenitic stainless steels will undergo precipitation caused by welding temperatures overheating during heat treatment operations.

Annealing Treatment

Annealing is most often associated with reducing the hardness of a hardened piece of metal, greatly enhancing ductility, and malleability. In the instance of the austenitic stainless steel family, annealing accomplishes a twofold purpose. First of all, annealing will remove the effects of cold working. Secondly, and probably more important, annealing will restore the corrosion resistance lost as a result of carbide precipitation. The corrosion resistance is restored as a result of redissolving the carbides that have precipitated out of solid solution. After annealing, the grain structure has returned to a 100% solid solution, accompanied with maximum ductility and malleability for the alloy.

Full Annealing Procedure

Stabilized austenitic stainless steel -

Heat - 1700 - 1900°F temperature range depending upon type of austenitic stainless steel.

Soak - 1 hour per inch of part thickness.

Quench - Air cool parts of 1/16" thickness or less. Water quench parts of over 1/16" in thickness. Allowing a slow cool down through the carbide precipitation range will result in the reoccurance of carbide precipitation.

Hardening of Semi-Austenitic Stainless Steels

These alloys differ from austenitic stainless steel by having a lower nickel content and by the addition of small amounts of aluminum, copper, molybdenum, or columbium. These alloys may be precipitation hardened and are designated so by a "PH" after the number.

The hardening from precipitation hardening of stainless steels occurs with two basic heat treating operations. The first, an austenite conditioning, transforms the structure to a solid solution. The second, a precipitation hardening treatment, causes precipitation of alloy products out of solution to cause hardness.

Heat Treatment of 17-7PH

Austenite Conditioning - Heat to 1400 ± 25°F and soak for 1-1/2 hours.

Cool - Cool within one hour to between 32 and 60°F, and hold 1/2 hour.

Precipitation Hardening - Heat to 1050° ± 10°F and soak for 1-1/2 hours.

NICKEL BASED ALLOYS

Nickel is one of the most dense common metals used today. Its density is greater than that of iron. It is slightly magnetic at room temperature, with a melting point approximately 200° - 300°F below that of iron. Nickel and its alloys are considered heat and corrosion resistant.

The corrosion resistance in nickel based alloys can be altered by the addition of such alloying elements as magnesium, aluminum, silicon, copper, beryllium, and molybdenum. As a result of adding these elements, certain alloys will respond to solution heat treatment and aging. All these elements have different effects upon the properties of the alloys.

Monel

This nickel based metal has small amounts of copper added. The alloy designated as monel will not respond to hardening by heat treating, but will harden only as a result of cold working. This alloy contains 67% nickel and 30% copper. When heat treating any nickel based alloy, a sulfur-free atmosphere must be used. Monel is found used in valve bodies, pumps, pump impellers, oil cooler shells, and magneto parts.

K-Monel

This alloy, a version of monel, contains 65% nickel, 30% copper, and 3% aluminum. It also has the presence of copper and aluminum in a hardening compound of copper aluminide ($CU\ AL_2$), which is formed as a result of solution heat treating and aging. The heat treatment of K-Monel is similar to that of 7075 aluminum, except accomplished at higher temperatures. This alloy, like all alloys, can be annealed. High quality heat and corrosion resistant springs are made of K-Monel.

Inconel

The nickel based alloy containing chromium and iron is inconel. The normal composition range is 72 - 83% nickel, 14 - 17% chromium, and 6 - 10% iron. The inconel alloys are corrosion resistant, heat resistant, and are exceptionally tough. Sub-zero temperatures have no harmful influence on the strength, hardness, toughness, or corrosion resistance. Only some inconel alloys can be hardened by solution heat treating and aging, but all alloys will respond to annealing. Wide application of inconel and its alloys have been found in the construction of hot section components for jet engines.

Hastelloy Alloys

Hastelloy alloys are similar in composition to inconel, except that molybdenum has been added. The hastelloy alloys will respond to solution heat treating and aging. This group of alloys has similar properties to the other nickel based alloys, with the exception of high temperature corrosion resistance. Coupled with this is the ability to maintain its high strength at high temperatures.

This group of nickel based alloys is widely used for wire in welding of high corrosion resistant alloys.

ALUMINUM AND ALUMINUM ALLOYS

This heat treatment of aluminum alloys is a process where the alloying elements enter into solid solution in the aluminum at critical temperatures. The alloying elements that increase strength and hardness are more soluble at high temperatures than low ones. It is necessary, during solution heat treatment, that the temperature used be as high as possible, but not high enough to cause any melting of the alloying elements. This is necessary to insure that all the alloying elements have entered into solid solution with the aluminum. It is a fact that all of the alloying elements must be evenly dispersed throughout the matrix of aluminum. If the maximum temperature is exceeded, eutectric melting will occur. When this condition exists, a severe loss in strength and corrosion resistance will develop, rendering the alloy useless. If the solution heat treatment temperature is too low, maximum strength cannot be developed in the alloy.

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Solution heat treating is a must in developing a major increase in strength and hardness. However, this treatment by itself is by no means an end in itself toward accomplishing this change in the mechanical properties. A precipitation treatment must follow, before any increase in hardness and tensile strength can be recorded.

PRINCIPLES OF SOLUTION HEAT TREATING

After the discussion of the purposes of solution heat treating, an examination of the principles of solution heat treating, using copper and aluminum as an example will be made.

The equilibrium diagram for aluminum-copper, figure 27, shows that aluminum will hold more copper in solid solution at 900 to 1000°F than it will at room temperature. Successful solution heat treatment depends upon putting the copper into solid solution and then trapping it there. A further aging treatment must be given this alloy before it will develop maximum tensile strength.

When an aluminum-copper alloy is in the annealed condition, the copper in it is in the form of round balls or globules of copper aluminide. This permits severe forming operations. During solution heat treatment, the copper aluminide particles are dissolved, and the copper goes into solution in the aluminum. Quenching in water traps it there. Aging then causes the copper to precipitate out as very fine particles of copper aluminide. These tiny particles act like keys which prevent the metal from taking a severe forming operation. Aging treatments are sometimes referred to as precipitation heat treatments.

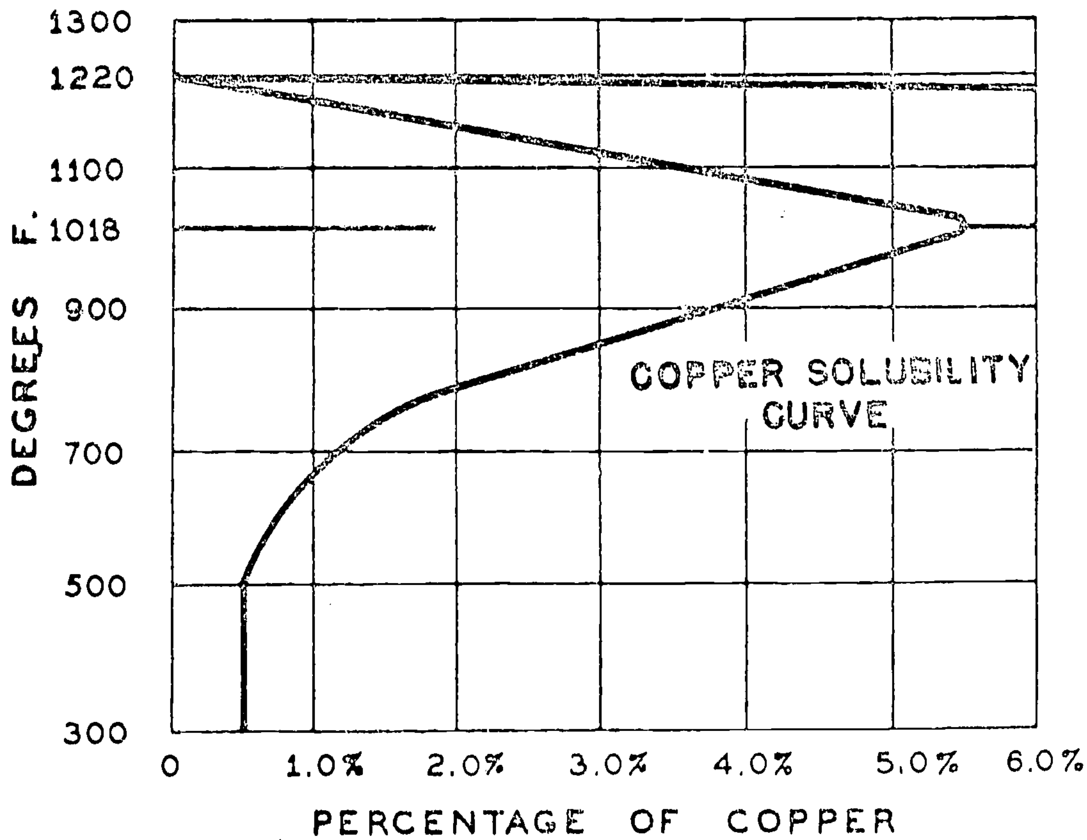

Figure 27. Aluminum-Copper Equilibrium Diagram.

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This is due to the fact that, during aging, copper aluminide precipitates out of the solution. Before it can be severely formed it must be annealed to put the copper aluminide back in the form of small balls or globules. The number of reheat treatments which can be performed is limited by the thickness of the material and whether or not it is clad. Always consult TO 1-1A-9 and Specification MIL-H-6088 before performing any operations requiring reheat treatment.

SPECIFIC HEAT TREATMENTS

There are several heat treatable aluminum alloys. Each requires a slightly different heat treating procedure. Also, there are alternate aging methods which may be used for certain alloys. Table 6 lists heat treating procedures for heat treatable aluminum alloys.

Notice in table 6 that many of the temperature ranges listed are quite narrow. This is necessary to insure that the temperature is high enough to put the hardening compounds into solid solution, yet low enough to prevent eutectic melting. If the hardening compounds don't go into solution, maximum hardness and tensile strength cannot be obtained. If eutectic melting occurs, the grain structure will be weakened at the grain boundaries. This results in low strength and poor corrosion resistance. It is very important to stay within the temperature limits given. Therefore, it is best to use a circulating air furnace or a salt bath when solution heat treating aluminum alloys to insure that parts are heated evenly with no "hot spots" present.

PRECIPITATION TREATMENT

Table 6 lists the common aging times and temperatures for aluminum alloys. Aging may be done naturally or artificially. Natural aging is accomplished at room temperature. Artificial aging is done at temperatures higher than room temperature. The following are modifications of standard aging procedures listed in table 6.

Natural Aging

This treatment is a precipitation process, accomplished at room temperature. This treatment may be used on the 2 and 6 series aluminum alloys. This treatment follows the solution heat treatment and subsequent quench. The heat of room temperature on the solution heat treated alloy causes the hardening constituents of the alloy to precipitate out of solid solution in the form of a hardening compound. These fine precipitate particles precipitate to the space lattices within the unit cells of aluminum. Since movement during deformation occurs along the planes of the space lattice, anything that would interrupt the movement of the different planes of space lattice would increase the yield and tensile strengths of the alloy. Since the precipitate precipitates to the space lattice, and indeed interrupts the movement of the planes of movement, a dramatic increase in yield and tensile strengths occurs.

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Commercial Designation	Soaking Temperature (Degrees F)	*Soaking Time For Various Thicknesses (Minutes)				Aging Temperature (Degrees F)	Aging Time (Hours)
		Up to 0.032 Inches	Over 0.032 to 0.125 Inches	Over 0.125 to 0.250 Inches	Over 0.250 Inches		
2014	925-950	20	20	30	60	345-355 355-365	8 5
2017	925-950	20	20	30	60	Room Temperature	96
2024	910-930	30	30	40	60	Room Temperature	96
6053	960-1010	20	30	40	60	315-325 345-353	**12 to 20 6 to 10
6061	960-1010	20	30	40	60	315-325 345-355	**12 to 20 6 to 10
7075	860-960	25	30	40	60	245-255	24

*Soaking time begins after the part has reached temperature.

** Thicker material requires a longer time at temperature.

Table 6. Solution Heat Treating and Aging Times and Temperatures.

It should be noted that if the temperature were to be substantially dropped below room temperature, the precipitation herein described would slow down to such a rate as to being minutely detectable. Such is a practice in the use and handling of "D" or "DD" aluminum aircraft rivets.

In the case of the alloy 2024 when a solution heat treatment has been applied and a natural aging treatment follows, maximum hardness and tensile strength is not immediate. Natural aging will start approximately 30 minutes after the water quench, if the alloy is not refrigerated. At the end of the first 24 hours, exposed at room temperature, the alloy will assume 90% of its strength and may then be called 2024.T4. Complete hardness and strength will develop at the end of 96 hours.

By consulting TO 1-1A-9, it can be seen through the same development of strength in "D" and "DD" rivets, since they are essentially composition 2017 and 2024, respectively.

Artificial Aging

All alloys that respond to hardening as a result of solution heat treating and precipitation hardening can be artificially aged. Artificial aging is the precipitation treatment applied to the solution treated alloy at temperatures above room temperature. It must be noted that artificially aged alloys are somewhat higher in hardness and tensile strength than those that are naturally aged. However, artificial aging should be limited to those aluminums that respond only to artificial aging. For all alloys that respond to natural aging, artificial aging should be limited to clad materials, since artificial aging lowers the corrosion resistance of the alloy.

Since aging times, temperatures, and procedures vary from one alloy to another, consult TO 1-1A-9 or MIL-H-6088 for further information and explanation and solution heat treating and aging treatment. The following are examples of typical alternate precipitation treatments.

Typical Interrupted Aging Treatment

1. Soak three to four hours 230° - 350°F.

2. Air cooling to below 100°F.

3. Soaking three to four hours at 315° - 355°F.

4. Air cooling to room temperature.

Typical Progressive Treatment

1. Soaking at 190° - 205°F for four hours.

2. Increasing the temperature to 245° - 255°F and soaking four hours.

3. Increasing the temperature to 295° - 305°F and soaking four hours.

4. Air cooling to room temperature.

HEAT TREATING TROUBLES

As may be seen from the above discussion, the heat treatment of aluminum alloys is a rather complicated process. Table 6 shows, too, that soaking times and temperatures must be closely controlled. In order to help prevent faulty heat treatment of aluminum alloys, some of the factors commonly causing failures are listed on the following pages.

Overheating

If the maximum specified temperature is exceeded during solution heat treating, eutectic melting WILL occur. Eutectic melting within an alloy is a result of overheating, causing the alloying elements to separate from the aluminide compound. After separation, these elements precipitate to the grain boundary and melt. When melting occurs of this element within the metal at the grain boundaries gas is released, causing a blister to form on the surface of the alloy. Any alloy having this condition is to be scrapped. Consult figure 28 for an example of physical appearance.

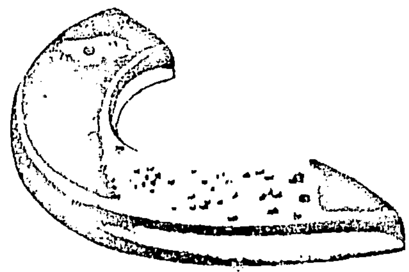

Figure 28. Blistered Aluminum Alloy Nose Rib.

Underheating

The soluability of different hardening elements into solid solution in aluminum depends directly upon the temperature reached up to the saturation point. Since the degree of strength developed depends directly on the amount of hardening compound precipitated out of solution, it is a must that the maximum amount of the hardening element be put into solution. If the alloy is underheated during solution heat treating, the alloy will not develop its maximum strength as a result. Undersoaking at the correct temperature will cause the same problem.

Oversoaking

Oversoaking cuts down the corrosion resistance of clad products. A clad product is one which has a very thin coating of a more pure aluminum on all surfaces. Pure aluminum has good corrosion resistance and protects the alloy which it covers. During extended soaking periods, alloying elements move from the core composition out into the cladding. Oversoaking thus lowers corrosion resistance by changing the chemical composition of the cladding from a more pure aluminum to an aluminum alloy. Soaking periods depend on the type of furnace used, initial condition of the metal, and the size and shape of the parts being heat treated. Soaking periods begin only after the part has reached the desired temperature.

Reheat Treatment

Reheat treatment has the same effect as oversoaking. Corrosion resistance of clad products is lost if they are reheated more than two or three times.

Overaging

Overaging causes a loss of strength and corrosion resistance. It occurs when an aluminum alloy is aged at too high a temperature or for too long a time. The copper aluminide particles become quite large overaging. This causes low strength and corrosion resistance.

Delay on Quench

Too much time taken in getting from the furnace to the quench tank causes a loss of corrosion resistance for both clad and nonclad alloys. This is due to the condition of the alloying elements as they come out of a solid solution. When the cooling rate is too slow the alloying elements collect at the boundaries of the grains of the metal. This makes an ideal setup for one of the most severe forms of corrosion (intergranular corrosion) to occur. A maximum time of seven seconds should be spent in getting the part from the furnace into the quench.

Hot Quench

The quenching medium becomes too hot when many parts have been quenched. The water quench should never be allowed to become greater than 100°F. Parts quenched in water at a higher temperature will have poor corrosion resistance, but will develop approximately the same strength as one that was done correctly.

METHODS OF ANNEALING ALUMINUM ALLOYS

Stress Relief Annealing

Stress relief annealing is accomplished to remove the effects of any cold working operation performed on aluminum or aluminum alloys. This treatment consists of heating the metal to approximately 650°F ± 15°F (750°F ± 15°F for alloy 3003) and then cooling at an even rate to room temperature. The soaking time at this temperature has no strict requirement, however, it is important to make sure that the entire part has reached the specified temperature. For this reason, it is common to require a soaking period of at least one hour. For stress relief annealing, the maximum temperature is moderately critical, and should not exceed 775°F to prevent the possibility of oxidation and grain growth. Cooling from this temperature should be relatively slow. Cooling in still air or even in the furnace is recommended for all alloys to prevent distortion and avoid partial solution heat treatment.

When aluminum alloys are cold worked, their grains become elongated and severely stressed. Stress-relieve annealing aluminum alloys recrystallizes the grain into a uniform, normal size. The structure within the grain, or the structure produced by solution heat treatment is not sufficiently altered. For the aluminum or aluminum alloys that harden by cold working only, this procedure produces maximum ductility and malleability. For the aluminum alloys that harden as a result of solution heat treatment, stress relieve annealing will remove the effects of cold working, which has been employed in conjunction with a solution treatment, such as 7075T86.

Full Annealing

Full annealing is a heat treatment operation which removes the effects of any cold working operation and the effects of a solution heat treating operation. As discussed in the previous study guide, the aluminum alloys which are hardenable by solution heat treating gain their hardness and strength by having their hardening compounds distributed within the space lattice structure. Full annealing immediately removes the effects of cold working, since the temperature used is above the recrystallization temperature of the alloy. But this procedure, because of a very slow cool down, causes overprecipitation allows the hardening compounds to precipitate out of the space lattice structure into large sphreres or globules. This structure formed which resembles spherodized steel, renders the alloy to a "dead soft" condition with maximum ductility and malleability.

Full annealing consists of heating an alloy at 775°F to 825°F, soaking 1 to 3 hours, and furnace cooling slowly to room temperature. This procedure looks similar to stress relief annealing, but because of the method of furnace cooling, full annealing is quite different. In this case, the cooling down of the alloy is critical. The part must be cooled at a maximum rate of 50°F per hour until 500°F has been reached. After the part has cooled to 500°F, it can be quenched as desired, since all transformation has been completed. To keep stresses or warpage to a minimum, air quenching is normally used. This procedure produces maximum ductility and malleability in the alloys of the 2000 and 6000 series. In the case of the 7000 series, this treatment causes partial annealing and must be followed by a second treatment to insure maximum ductility and malleability. This second treatment consists of soaking at 450°F ± 10°F for 2 hours and cooling in the same manner as before down to 450°F. For exact procedures for either stress relief annealing or full annealing on particular alloys, consult TO 1-1A-9 or MIL-H-6088E.

Annealing Alclad Products

Whenever clad products are subjected to full annealing, precautions must be observed to avoid diffusion of any of the alloying elements into the cladding. Those precautions consist of limiting the soaking time to the minimum, and limiting the number of repeated treatments to the minimum necessary to obtain desired properties.

TITANIUM AND TITANIUM ALLOYS

Titanium and its alloys are primarily found in the aircraft and missile fields. The main concerns at the time of its development were: temperature, loading, time at temperature, and part configuration. Due to high performance aircraft coming into development, a lightweight, heat and corrosion resistant alloy was needed. This lead to the development of titanium. It is only 57% the weight of steel. Titanium alloys available are capable of sustained operation at temperatures of approximately 1000°F.

Titanium is a very active metal, and readily dissolves and absorbs carbon, oxygen, hydrogen, and nitrogen. For this reason, layout lines on titanium alloys should not be made with lead pencils or markers containing carbon. Any heating operations performed should be accomplished in a controlled atmosphere, so that there will be no reaction with these elements. These elements cause embrittlement of the metal, as hydrogen does to steel As a result, most titanium alloys have a maximum operating temperature of 800°F.

Titanium Classification

There are four types or classes of titanium and titanium alloys, consisting of the following: Type I - Commercially Pure (weldable); Type II - Alpha Titanium (weldable); Type III - Alpha-Beta Titanium (nonweldable but heat treatable); and Type IV - Beta Titanium (weldable in annealed condition only).

Weldability

Three of the four types of titaniums are weldable. Types I and II will not respond to solution heat treating and as a result, they may be welded in any condition. Type IV (beta titanium) is also weldable, but responds to solution heat treating. Therefore, beta titanium can only be welded in the annealed condition since alpha-beta titanium (Type III) is a complex group of titanium alloys, they are considered nonweldable, in any condition.

Welding temperatures cause precipitation of the hardening compound (titanium carbide). This is similar to carbide precipitation found in austenitic stainless steels. The precipitation of titanium carbides would cause a decrease in strength and corrosion resistance. This compound is not found in the annealed Type IV titanium alloys, so this is why they can be welded. Welding this group of titanium alloys in the solution heat treated and aged condition would destroy the strength of the alloy in the weld area.

Heat Treatment

All titanium alloys will respond to annealing. However, only two types, III and IV, will respond to hardening by solution heat treating and aging. Types I and II titanium and titanium alloys harden only as a result of cold working.

Type III (Alpha-Beta)

This type differs from Type I and II titaniums in that aluminum, chromium, iron, molybdenum, and vanadium are added. These elements influence the titanium, giving it a dual structure at room temperature. Possessing this characteristic enables this type of titanium to respond to solution heat treating and aging, as well as causing an increase in hardness.

Type IV (Beta)

This titanium alloy is composed of aluminum, iron, molybdenum, and vanadium in amounts similar to those in type III. Beta titanium has approximately ten times the chromium content which permits a greater formation of the titanium carbide T_1CR_2 (titanium chromium). The formation of this compound is accomplished by aging of this alloy after solution heat treating. With the aging treatment, besides precipitation of T_1CR_2, alpha phase titanium will precipitate out of the beta phase, causing an increase in tensile strength. Both precipitants, alpha phase and T_1CR_2, raise the tensile strength. It has been proven that the strength of titanium alloys will increase at subcritical temperatures. This makes the use of titanium in subzero applications ideal, such as in missiles and space vehicles. Titanium has a theoretical tensile strength of 500,000 psi at near absolute zero temperatures. A metal that weighs a little over half as much as steel, has twice the tensile strength of most steels, and has corrosion resistance can be and is very valuable to man and his need for better metals for the future.

QUESTIONS

Note: Answer the questions at the end of this chapter on a separate sheet of paper. DO NOT WRITE IN THIS STUDY GUIDE.

*1. What are the four basic families of stainless steels?

2. Which of the four families of stainless steels will harden by heat treatment?

3. How are austenitic stainless steels hardened?

4. What does the term "carbide precipitation" mean in relation to stainless steels?

5. What are the reasons for heat treating austenitic stainless steels?

6. What heat treatment can be performed on all metals?

7. How is Monel hardened?

8. What two ways is K-Monel hardened?

9. What are two desirable properties of titanium?

10. What are the names of the four types of titanium?

11. Which types of titanium are hardenable by heat treatment?

12. What effect on hardness and strength does welding have on solution heat treated and aged titanium alloy?

*13. How are the effects of cold working removed from aluminum?

14. What is the effect of overheating in heat treating aluminum?

*15. Why should too much time not be taken to quench clad and nonclad aluminum alloys?

16. How can an aluminum alloy develop maximum hardness and tensile strength?

*17. How is the corrosion resistance of a nonclad aluminum alloy improved?

18. What factors limit the number of reheat treatments for aluminum alloys?

19. How is natural aging accomplished?

20. How does oversoaking lower the corrosion resistance of a clad alloy?

21. What is the result when the maximum time allowed for 2024 aluminum alloy to get from the furnace to the quench tank is exceeded?

22. What happens to 2024 aluminum alloy when the quench temperature exceeds 100°F?

23. What is the effect on heat treated aluminum if the part is undersoaked?

24. What is the approximate annealing temperature of 2025 aluminum alloy?

25. What is the temperature used to obtain a full anneal in 7075 aluminum alloy?

REFERENCES

1. TO 1-1A-9, Aerospace Metals-General Data and Usage Factors.

2. Althouse/Turnquist/Bowditch, Modern Welding, Goodheart-Wilcox Co, Inc., 1967.

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HARDNESS TESTING

OBJECTIVES

After completing this study guide, your classrom instruction, and assigned study, while observing all shop safety, good housekeeping, and fire prevention measures, you will:

1. Identify the purpose, principles, and methods of hardness testing.

2. Set up and test metal for hardness using the Rockwell Hardness Tester.

INTRODUCTION

Hardness testing is performed to determine an approximate tensile strength value, the results of heat treatment, and the condition of the metal before metal treatment.

INFORMATION

MANAGEMENT OF DEFENSE ENERGY AND RESOURCES

You will exercise extreme care in the handling and use of the diamond and ball type penetrators, though small, they are costly to replace. All material will be used to its fullest extent.

STANDARD ROCKWELL HARDNESS TESTER

The Rockwell Hardness Tester uses penetrators which are either commercial diamonds or hardened steel balls. The steel ball penetractor is used to test annealed steel or nonferrous metals. The diamond penetrator is used to test hardened steel. The Rockwell Hardness Tester applies a known force through these penetrators, causing actual penetration of the metal surface. The harder the metal, the less the penetration.

The Rockwell Hardness Tester is ideal for testing tools, jigs, bolts, sheet and plate stock, and similar parts. It is not satisfactory for testing materials that are so thin that the penetrator makes an impression on the opposite surface. In such cases, the influence of the anvil causes an error in the reading.

Certain difficulties are involved in testing metal objects of different sizes and shapes. In order to consistently take accurate hardness tests, it is necessary to recognize these special problems and take corrective action in each specific case.

The proper scale must be selected for the type of material to be tested. After selecting the proper scale, you must select the proper penetrator. The dial should then be adjusted to zero and the minor load of 10Kg applied. Apply the major load and read the dial.

The correct anvil must be used so that the specimen being tested is seated properly under the penetrator. The shoulders and the seat of the anvil and the seat of the penetrator must be free of dirt, grit, or oil. The diamond penetrators must be unchipped and the ball penetrators must be free from any flattened areas due to improper use. The improper results that may be obtained by disregarding these precautions as follows:

1. Using the improper scale results in an inaccurate and meaningless dial reading.

2. Using an improper anvil results in an inaccurate reading and may cause a bent or sprung penetrator chuck.

3. A penetrator or an anvil with any dirt, grit, or oil on them results in inaccurate hardness readings.

4. Defective penetrators also result in inaccurate hardness readings.

Precautions

A part to be tested on a Rockwell Tester must have a smooth, level surface on the bottom so that it can seat solidly on the anvil without rocking. All burrs and roughness must be removed from the edges so they will not give or cave in when the major load is applied. The top surface must be level and smooth so that the penetrator sinks into the metal evenly. Uneven hacksaw marks on the surface or a surface that is not level may cause the reading to be too high or too low, as shown in figures 29 and 30.

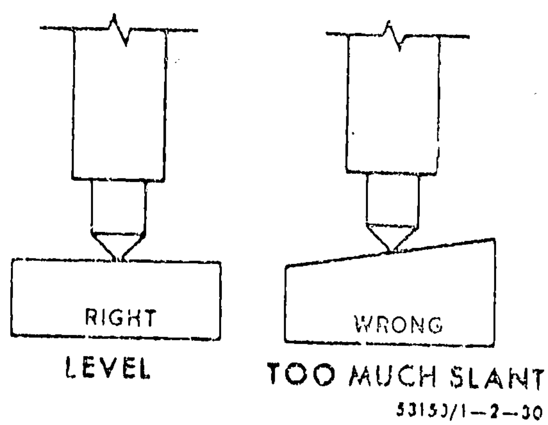

Figure 29. Testing of Surfaces.

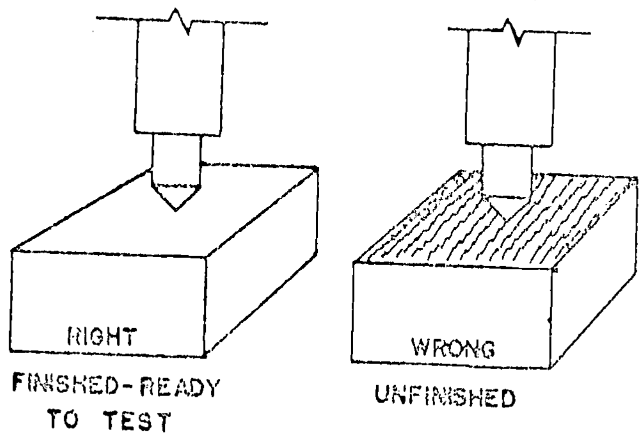

Figure 30. Testing Uneven Flat Surfaces.

Parts that are round in shape tend to produce readings that are too low. The smaller the diameter and the softer the metal, the lower the readings on the round surface. Since it is necessary to test some round specimens, a greater degree of accuracy is obtained by grinding a small, flat surface on the part. In all cases, a crotch type anvil of the proper size must be used to center the piece directly beneath the penetrator, as shown in figure 31.

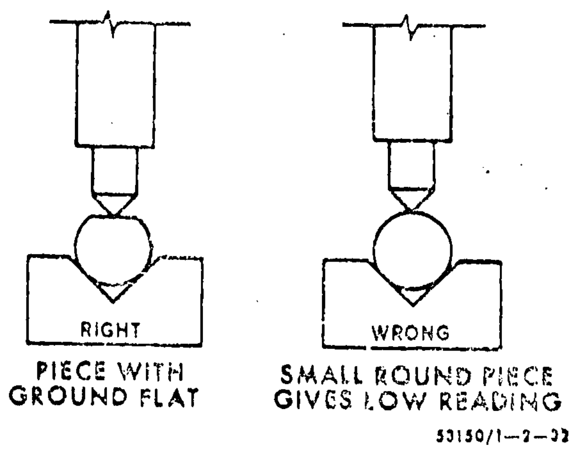

Figure 31. Testing Round Surfaces.

Long pieces that must be tested near the end have a tendency to produce low readings because of excessive overhang. This error can be eliminated by supporting the overhanging section, as shown in figure 32.

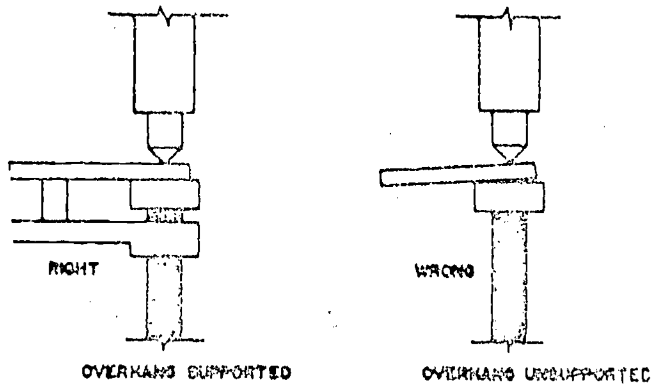

Figure 32. Testing Long Pieces.

When you test extremely thin sections on a Rockwell Tester, there is a tendency for the penetrator to push entirely through the piece or to compress the metal down upon the anvil. In either case, a false high reading is given. To correct this, use a superficial Rockwell Tester or some other method of testing that does not cause a deep penetration of the material being tested to get a hardness reading that is more accurate, as shown in figure 33.

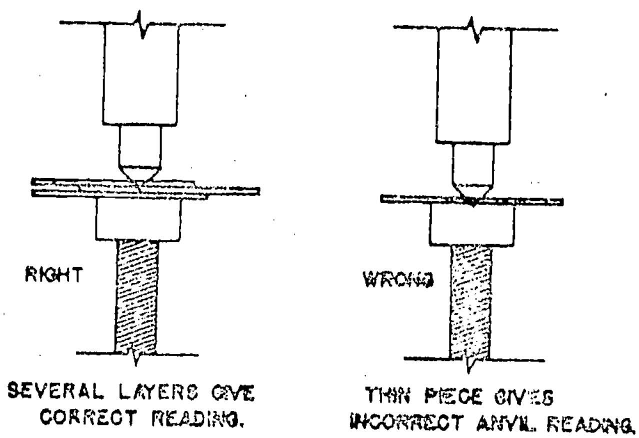

Figure 33. Testing Extremely Thin Sections.

When a piece is given a hardness test, care must be taken not to test it too near the edge. This causes a low reading. When the major load is applied in testing too close to the edge, the metal tends to give way or bulge out on the outside of the piece and cause the penetrator to go too far into the metal. To prevent this condition, metal parts should not be tested closer than 1/8 of an inch from the edge, as illustrated in figure 34.

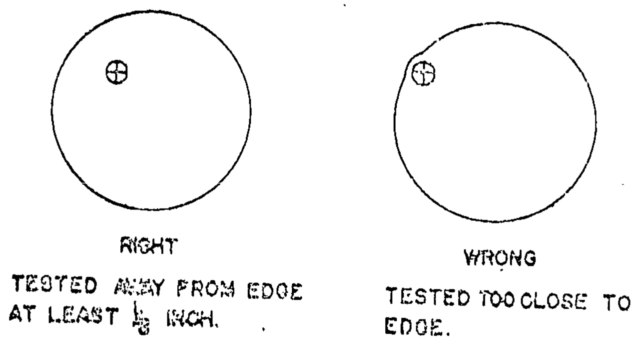

Figure 34. Proper Spot For Testing.

During heat treating operations on some steel parts, a certain amount of decarburization occurs, especially if the soaking time is too long at high temperatures. Testing the decarburized surface for hardness gives a false low reading. To prevent this, a sufficient amount of the metal should be ground off so that the test may be made on the decarburized surface, as shown in figure 35.

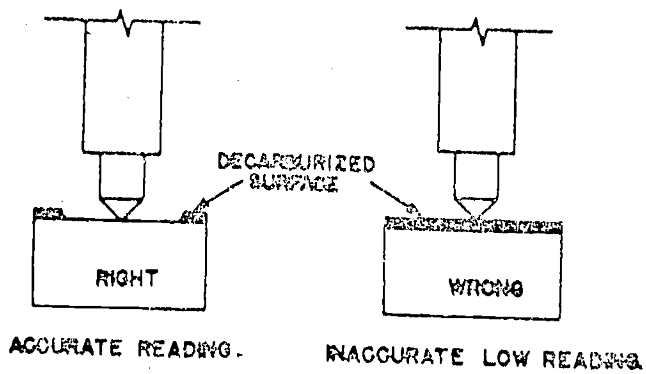

Figure 35. Testing Decarburized Surfaces.

In testing case-hardened parts, shown in figure 36, especially nitrided or cyanided parts, there is a tendency for the penetrator to cave in or push through the case and give a false low reading. The A scale, which is recommended for case hardened materials, usually gives satisfactory results. If the A scale reading is too low, the Superficial Hardness Tester can be used. In ordinary shop practices, a file hardness test would be sufficient to tell if the case was hard enough. Most cyanided and nitrided causes test file hard. Most carburized parts have a case of sufficient thickness so that the C scale can be used to test the hardness.

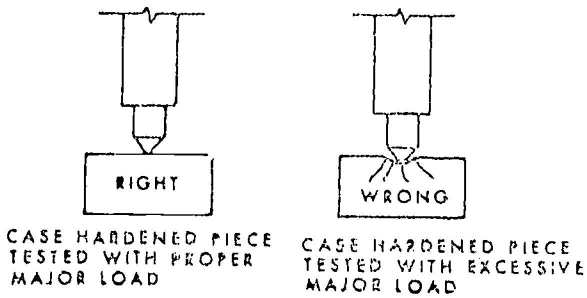

Figure 36. Testing Case-Hardened Parts.

Because metal parts are not exactly uniform hardness throughout, it is necessary that several tests be made on a part and the average of the readings should be taken. This eliminates any possibility of judging the hardness of the piece on a false high or low reading.

Recommended Procedures for Making Standard Rockwell Hardness Tests

Practically all tests on metal parts to be performed on a Rockwell Tester in the average shop can be performed on one of the five scales listed below.

1. The C scale is used for testing hardened steel. It is set up and used as follows:

a. Major load - 150 Kg.

b. Penetrator - Diamond (Brale).

c. Range of Accuracy - C-20 to C-70.

d. If the steel tests less than C-20 or more than C-70, disregard the dial reading and test on the B scale.

Note: Always test steel of unknown hardness on the C scale first to prevent possible damage to the 1/16 inch ball penetrator used in testing soft steel.

2. The B scale is used for testing soft steel or steel that is annealed and some harder types of nonferrous metals and alloys. It is set up and used as follows:

a. Major load - 100 Kg.

b. Penetrator - 1/16 inch steel ball.

c. Range of accuracy - B-0 to B-100.

3. The A scale is used to test the hardness of thin cases on pieces of case-hardened steel. This scale is used because the base is hard, requiring a diamond penetrator, and the case is thin, requiring a small major load to prevent the penetrator from caving in the case. The scale is set up as follows:

a. Major load - 60 Kg.

b. Penetrator - Diamond (Brale).

c. Range of accuracy - A-60 to A-87.

4. The E scale is used for general nonferrous hardness testing when the alloys are soft to moderately soft. It is used in testing heat treatable aluminum alloys in both the annealed and heat treated condition. The scale is set up as follows:

a. Major load - 100 Kg.

b. Penetrator - 1/8 inch steel ball.

c. Range of accuracy - E-0 to E-100.

5. The H scale is used in testing very soft materials, such as pure copper, tin, or aluminum. The scale is set up as follows:

a. Major load - 60 Kg.

b. Penetrator - 1/8 inch steel ball.

c. Range of accuracy - H-0 to H-100.

THE SUPERFICIAL ROCKWELL HARDNESS TESTER

The Superficial Rockwell Hardness Tester is designed especially for determining surface hardness. It is very useful in testing the hardness of material too thin to test on a regular tester because of the sensitivity gained through the use of small major loads. The operation of the Superficial Tester is similar to that of the Standard Rockwell Hardness Tester except that there is a greater range of sensitivity. The setup is as follows:

1. Minor load - 3 Kg.

2. Major load - 15, 30, or 45 Kg.

3. Penetrators - Diamond and 1/16 inch steel ball.

4. Scales - N with diamond penetrator and T with the 1/16 inch steel ball.

a. The scales are broken down as follows:

(1) 15 N scale - Diamond penetrator with 15 Kg major load.

(2) 30 N scale - Diamond penetrator with a 30 Kg major load.

(3) 45 N scale - Diamond penetrator with a 45 Kg major load.

(4) 15 T scale - 1/16" steel ball with a 15 Kg major load.

(5) 30 T scale - 1/16" steel ball with a 30 Kg major load.

(6) 45 T scale - 1/16" steel ball with a 45 Kg major load.

b. The range of accuracy for the scales are as follows:

(1) 15 N - 69 to 94.

(2) 30 N - 41 to 86.

(3) 45 N - 19.5 to 87.

(4) 15 T - 0 to 93.

(5) 30 T - 15 to 82.

(6) 45 T - 1 to 72.

In reading the dial and recording a Superficial Rockwell Hardness Tester reading, the prefix consisting of the major load used and the letter designating the penetrator used along with the dial reading make up the entire reading. For example, if you are using a 30 Kg load with the diamond penetrator and you get a reading of 52, you would record your reading as 30N-52. Without the 30N preceding the dial reading, such a reading would be meaningless.

Never test steel that would normally be tested on the C scale of the Standard Rockwell Hardness Tester on the T scale of the Superficial Rockwell Tester to prevent damage to the 1/16" steel ball penetrator.

QUESTIONS

Note: Answer the questions at the end of this chapter on a separate sheet of paper. DO NOT WRITE IN THIS STUDY GUIDE.

1. Why is it necessary to follow hardness testing procedures accurately?

2. What precaution should you take in testing a thin specimen?

3. What scale should you use first when testing steels on the Rockwell Tester?

4. What are the three different types or sizes of penetrators which are used with the regular Rockwell Tester?

5. What precaution must you take in testing a long specimen on the regular Rockwell Tester?

6. What is the range of accuracy of the C scale?

7. How do you prepare small round specimens for testing on the Rockwell Tester?

8. Which penetrator is used to test nonferrous metals?

9. What may cause a bent or sprung penetrator chuck?

10. Which anvil is used to test round specimens?

11. What scale is used to test case-hardened parts?

12. What is the purpose of taking more than one reading on a part?

REFERENCES

1. TO 1-1A-9, Aerospace Metals-General Data and Usage Factors.

Metal and NDI Branch
Chanute AFB, Illinois

CLEANING, PLATING, AND CORROSION CONTROL

OBJECTIVES

After completing this study guide, your classroom instruction, and assigned study, while observing all shop safety, good housekeeping, and fire prevention measures, you will:

1. Identify the methods for the identification and prevention of corrosion.

2. Set up and perform mechanical cleaning operation.

3. Set up and perform chemical cleaning operation.

4. Identify the principles involved in plating operations.

5. Identify the proper steps relating to preparing and testing plating solutions.

6. Identify the proper steps relating to electroplating aircraft and ground equipment parts.

7. Identify the proper steps and methods for stripping electroplate from parts prior to replating or nondestructive inspection.

8. Identify safety precautions pertinent to a plating shop.

9. Identify the proper layout and set up procedures for electroplating shops.

10. Identify the proper steps and procedures relating to anodizing operations.

11. Identify the proper steps and procedures pertaining to metal spraying operations.

12. Identify the proper steps and procedures relating to metal hot dipping operations.

13. Identify methods of oxide coloring operations.

INTRODUCTION

Corrosion is the deterioration of a metal by reaction to its environment. The corrosion occurs because of the tendency for most metals to return to their natural state; for example, iron in the presence of moist air reverts to its natural state, iron oxide. Pure metals, such as gold and platinum, do not corrode since they are chemically uncombined in their natural state. Metals can also be corroded by the direct reaction of the metal to a chemical.

INFORMATION

MANAGEMENT OF DEFENSE ENERGY AND RESOURCES

To help conserve material you will clean and electroplate one of your previous welding projects. You will clean and electroplate your part in a manner conducive to maximum efficiency and economy.

CORROSION CONTROL

Corrosion is of major importance to all Air Force maintenance personnel. Most metals are subject to corrosion, but corrosion can be minimized by the use of corrosion resistant metals and finishes.

Identification of Corrosion

Since corrosion always starts on the surface of a metal, you can often detect it visually. To assist you in the interpretation of corrosion, we will list some of the most common types; each has its own visual characteristics.

Pitting corrosion, the most common type found on aluminum and magnesium, results in a white or gray powdery deposit; when it is removed, small holes or pits are visible on the s rface.

Intergranular corrosion is usually caused by imperfect heat treatment and attacks at the grain boundaries of a metal. All metal alloys are composed of minute grains, each having a different composition at the center than at the grain boundary. A small corrosion cell is established when an electrolyte is in contact with the metal surface, causing rapid corrosion at the grain boundaries. The intergranular corrosion appears as a bulky mass.

Exfoliation corrosion is a form of intergranular corrosion. It starts at the surface and progresses along the grain boundaries under the surface of the metal. The expanding corrosion causes the surface of the metal to "lift up."

Galvanic corrosion occurs when dissimilar metals are in contact. The electrical potential difference between the metals are in the presence of an electrolyte establishes an electrochemical cell and corrosion occurs. This type may be recognized by the presence of a buildup of corrosion at the joint between the metals. The greater the electrical potential difference between the metals, the greater the resulting corrosion.

Stress corrosion cracking is caused by the simultaneous effects of tensile stress and corrosion. When a metal is stressed to a degree within the critical stress range for that particular metal, corrosion will occur at the point of stress concentration. The combination of the corrosion and the concentrated stress causes the metal to crack.

Prevention of Corrosion

Scheduled inspection and preventive maintenance are essential for the early correction of corrosion. The principal corrosion preventive which is used in airframe structures is aluminum alloy sheet coated with a more pure aluminum (alclad). Alclad is more corrosion resistant than the nonclad high strength alloys. Other metals commonly used in airframe structures, such as nonclad high-strength aluminum alloys, steel, and magnesium alloys, require special preventive measures to guard against corrosion. Aluminum alloys, for example, are usually anodized or chemically treated and painted. Steel, except most stainless steels, and other metals, such as brass and bronze, require cadmium or zinc plating, conversion coating, paint, or all three, for protection. Magnesium alloys are highly susceptible to corrosion attack, especially in marine environment. These materials require special chemical treatment and paint finishes.

Since corrosion of most metals require the presence of moisture or various types of aqueous solutions, it can be seen that the most vital factor to control corrosion would be the control of moisture. In most common language to a metal, moisture is referred to as an electrolyte. The term electrolyte may be defined as "A liquid media capable of carrying a flow of electrons." An example is found in the lead-acid car battery. In this example, the electrolyte is comprised of sulphuric acid and water.

The amount of corrosion to a piece of metal will be determined by the amount of electrolyte in contact with the metal, the temperature of metal and electrolyte, composition of the electrolyte, and composition of the metal or metals. Soils such as grease, mud, dirt, and others hold the electrolyte against the surface of the metals. By constant cleaning of the metal, the corrosion could be lessened, or if the metal is coated with a corrosion resistant coating, the corrosion would cease or be greatly arrested.

Since a pure metal has a higher resistance to corrosion, than compared to any of its alloys, plating with pure metals is an effective way to ward off corrosion. By depositing a pure metal in electrical bond to the surface of an alloy, such as SAE 1095, the pure metal will subsequently resist corroding attack by an electrolyte.

METAL CLEANING METHODS

There is no single cleaning agent or process that will clean all metal surfaces. A cleaning agent that will clean one metal surface will not clean another surface or it will attack the alloys. In selecting a cleaning agent, you must consider whether it will attack the metal chemically and whether it will leave a residue that will cause corrosion. Use the cleaning method that produces the required degree of cleanliness. Avoid over-cleaning or an excessive amount of metal will be removed. The method depends upon a type of contamination to be removed, the composition and design of the part to be cleaned, and the quality of the surface finish to be retained. Here are some pointers to remember when you are trying to do a better job of cleaning:

1. Use mechanical cleaning when excessive amounts of easy-to-remove dirt is present in any form.

2. Never use solvents or chemical baths unless you observe the safety and fire regulations.

3. Use solvent cleaning to remove grease and oil contamination that you cannot eliminate by chemical cleaning alone. You can use a combination of mechanical and solvent cleaning.

4. When you use oil-base solvents, such as kerosene, naptha, and distiliate, alkaline cleaning is usually necessary to remove oily film left by the solvent cleaning agent, except when you use a non-oily base solvent like trichloroethylene.

5. Alkaline cleaning is usually necessary to remove the final traces of an oily or greasy contamination. It is also necessary to remove other types of organic surface contamination not affected by solvent cleaning.

6. Acid cleaning should always follow alkaline cleaning to remove any traces of rust, scale, or invisible oxide film. Acid cleaning is usually the last cleaning prior to electroplating.

TYPES OF CLEANING

All cleaning accomplished in preparation for electroplating can be divided into five categories:

1. Mechanical cleaning.
2. Solvent cleaning.
3. Acid cleaning.
4. Alkaline cleaning.
5. Ultrasonic cleaning.

The cleaning method will be selected depending upon the type and amount of soils present, metal composition, and part design.

Mechanical Cleaning

Mechanical cleaning is used to remove heavy surface contamination that is readily removed and when it is necessary to prevent contamination of other cleaning tanks. Wire brushing, hand sanding, steel wool, and scraping are some of the methods you may use to remove light coats of paints and primers, natural oxide films, and light coats of corrosion. The severity of the cleaning required, the composition of the metal, and the required methods may be or to what extent they may be used. If the parts are of soft metal or if the dimensions of the parts are critical, these methods may be too harsh. Be careful to prevent the plastic flow of soft ferrous and nonferrous metals. If possible, use a more suitable cleaning method. Cloth wheel buffing is satisfactory if you keep the cloth wheel free from any imbedded dirt. Dirty wheels may actually make a partially clean part dirtier. This method is not considered satisfactory for cleaning operations unless the part has had a previous cleaning and has a relatively smooth surface.

AIR BLAST CLEANING. Air blast cleaning is done with shot, sand, or metal grit and should not be done prior to nondestructive testing. Parts with a Rockwell hardness of C-40 or higher may be blast-cleaned with nut shells, soft grit, or seeds. Under no circumstances should shot or grit blast, using hard-cutting grit, aluminum oxide, and soft organic grit may be used only when it is necessary to remove brittle contaminants, such as rust, scale, and carbon deposits.

VAPOR BLASTING. Vapor blasting uses abrasives suspended in slurry water propelled at high pressure to erode away oxide films. Parts to be liquid-honed must be free of grease and oil. Cover the part numbers and other markings with masking tape. Keep the nozzle in motion at all times when wet abrasives are in contact with the surface parts being liquid-honed. The distance between the nozzle and the parts must not be less than 2 inches. The angle between the nozzle and the part should be greater than 60°. After liquid-honing, coat the parts with a preservative compound to prevent corrosion. Rinse and dry the parts and individually wrap them in Kraft paper or an equivalent.

Safety During Mechanical Cleaning

The following safety precautions will be adhered to when accomplishing certain mechanical cleaning operations.

1. Always wear eye protection when using a grinder.

2. Inspect grinding wheel for imbedded nonferrous metals before using.

3. Do not grind on the side of the wheel.

4. When operating buffers or wire brushes, goggles or face-shields will be worn.

5. Personnel operating buffers, grinders, or power wire brushes will wear tight-fitting gloves to prevent injury.

6. All jewelry will be removed before operating any power equipment.

Solvent Cleaning

Solvent cleaning includes the use of all cleaning fluids that provide a dissolving and emulsifying, rather than a chemical action, to remove the various types of contamination from a part. The following is a list of some of the principal ingredients used for solvent cleaning:

1. Kerosene or distillate.

2. Carbon tetrachloride.

3. Naptha.

4. Trichloroethylene or perchlorethylene.

5. Steam or hot water.

VAPOR DEGREASING. Vapor degreasing is a solvent type of cleaning operation in which a degrease liquid, such as trichloroethylene, is heated to a temperature between 180° and 196°F., depending upon the degree of contamination to be removed. As the vapors rise from the liquid, they contact a section which is cooled by water circulating in the walls in the upper portion of the degreaser unit. This section, because of rapid condensation, prevents the vapors from rising into the atmosphere, causing the condensate to return to the reservoir. Place the part to be cleaned in the vapor area. As the vapor comes into contact with the comparatively cool part, the vapor condenses and runs down the part, dissolving and washing away the organic contamination. After the part has reached the vapor temperature, remove it and cool it if more vapor cleaning is necessary. This type of solvent cleaning is more suitable than other types for the following reasons:

1. It leaves the part relatively dry and cleaner than other solvent cleaning methods.

2. The liquid is nonflammable and nonexplosive.

3. The method is faster.

PETROLEUM SOLVENTS. Petroleum solvents should conform to Federal specification P-D-680 and may be used in a dip tank or as a spray. The spray booth must have a positive ventilation to the outside. Although the flash point of these solvents is relatively high, you should observe proper fire precautions.

Alkaline Immersion

Alkaline cleaning of parts is done by using a mixture of various basic chemicals in water. Caustic soda is one of the main ingredients of many alkaline cleaning solutions. The reaction that causes the cleaning is such that the caustic or alkaline portion of the solution combines with the contamination and chemically turns it into soap which readily rinses off. Do not use this type of cleaning on most alloys of zinc, aluminum, magnesium, brass, or on any other metal or alloy that will respond chemically to alkaline solutions. An operating temperature of 205° to 210°F is suitable for most alkaline cleaning operations. An alkaline cleaning solution at room temperature is rather ineffective for most cleaning operations. The length of time a part soaks in the alkaline immersion tank usually depends upon the amount and type of contamination.

Whether you use alkaline immersion, spray, or electroalkaline cleaning, the main objective is to remove organic contamination such as grease, oil, or dirt from the metal. Alkaline cleaning will remove the residue of oily base solvent cleaning operations. Alkaline cleaning ordinarily precedes acid cleaning. The removal of the organic contamination leaves a clean surface for the removal of the other types of contamination that acid cleaning agents attack more readily. For general cleaning, alkaline immersion or electroalkaline cleaning is desirable. You can use alkaline spray cleaning when the mechanical action of the spray is necessary to help remove the contamination.

Electrocleaning

Electrocleaning uses the principles of cleaning by chemical reaction of the alkaline solution, the electrochemical action caused by an electric current passing through the part suspended in the solution, and the mechanical action of bubbling off into the solution. The flow of current and the action of the chemicals clean the part. The metal tank may serve as the cathode or negative terminal in the circuit. The parts hang on an insulated bar, which becomes the anode or positive terminal. This terminal completes the circuit when the parts are suspended in the solution. When the current is on, the bubbling action at the anode helps the alkaline solution to remove the contamination. The part usually cleans on the anode terminal for 1 to 5 minutes and then cleans on the cathode terminal. The control switch is reversed for 15 to 30 seconds for cleaning on the cathode terminal. The short cleaning time permitted on the cathode prevents the development of intergranular corrosion.

Acid Cleaning

Acid cleaning is used to remove inorganic soils. That is, soils of metallic origin, such as rust, mill scale, and oxides. All of these originate in the base metal and appear on its surface.

Safety practices must be adhered to when working with acids. Contact with the skin will cause acid burns. Secondly, acid cleaning of a metal gives off hydrogen gas, which can be deadly. This requires special observance of strict safety regulations and proper ventilation. Failure to follow safety precautions can cause injury to you and your fellow workers.

ACID PICKLING. Acid pickling is the chemical stripping of surface oxides (scales) from the metal. Examples of scales include mill scale on hot rolled steel, heat treating scale, and scale formed as a result of welding temperatures. There are several common pickling solutions. One of the most common is sulfuric acid. Sulfuric acid is very effective in stripping scale, but one of the main disadvantages of using sulfuric acid is that it causes darkening (smutting) of the surface on high carbon steels.

HYDROCHLORIC ACID. Hydrochloric acid is used for removal of mill scale from hot rolled steel. It is weaker than sulfuric acid and this can be an advantage since sulfuric acid can cause over-pickling with this scale.

HYDROFLUORIC ACID. This is the acid to use after the sandblasting of a part. During sandblasting sand is usually embedded in the metal surface and must be removed before plating takes place. This type of acid will dissolve silicates, which includes sand, glass, and some stones. This type of acid will leave the surface of the part clean and free from sand. Care must be taken when handling this acid, since it readily attacks the skin. This acid will dissolve glass, so some means of storing it must be provided, usually this is a plastic container.

Precautions for Solutions

When a cleaning solution becomes contaminated or loses its cleaning power, it must be disposed of and replaced. Care must be taken while dispensing and preparing these solutions, due to their various hazards.

SOLVENTS. These should be used full strength. Care must be taken to avoid a buildup of explosive vapors or an excessive breathing of their fumes.

CAUSTIC SODAS. These react with grease and oil and turns them to soap. It will effect your skin oil the same way. Excessive contact could severly burn your skin. Another hazard is that of explosion when preparing a solution. DO NOT allow large amounts of caustic soda to build up on the bottom of the tank when preparing a new solution. This can cause an explosion. To prevent this, add the agent slowly, keep stirring, and make sure it is completely dissolved.

ACIDS. If, when preparing an acid solution the water is added to concentrated acid, much heat is generated, causing the solution to bubble, splatter, or boil. To avoid this, REMEMBER - "ALWAYS ADD ACID TO WATER, NEVER ADD WATER TO ACID."

Ultrasonic Cleaning

Cleaning can be improved by the use of ultrasonic sound ranges. This method of cleaning will do the job that most other methods of cleaning cannot accomplish. The only limitation of this method is the size of the tank connected to the unit.

Note: This is used as a final cleaning step only, since heavy soils will rapidly contaminate the cleaning solution.

During the past ten years, ultrasonic cleaning has grown from a laboratory curiosity to a vital cleaning method for industry. Most of this progress has taken place in the last five years and has come about through a better understanding of the problems of ultrasonic cleaning, through development of more reliable equipment, and through a steady reduction of cost.

Ultrasonic cleaning is the use of high-frequency sound waves to remove foreign matter from metals, plastic, ceramics, and glass. A generator produces high-frequency electrical energy, which the transducer converts to high-frequency sound waves that travel through the liquid cleaning agent. These waves cause "cavitation," the formation of countless microscopic bubbles that grow in size and then collapse, thus setting up a scrubbing action that blasts the contaminant from the substance being cleaned.

ELECTROPLATING OF METALS

All electroplating operations are based on the same basic principle. A good plating job cannot be accomplished without a knowledge of these principles.

This knowledge will also enable you to correct malfunctions of the equipment and make up and maintain plating solutions in accordance with safety rules and regulations. Electroplating is performed in a chemical solution, made up of water, oxides of the metal and in some types of plating, sodium cyanide and other chemicals that can be deadly when not properly handled.

Purpose of Electroplating

In the Air Force, cadmium plating is the most used process for the purpose of corrosion resistance; however, it cannot be used in applications where the temperature exceeds 450°F and must not be used on any food or drink containers. Copper plating finds its applications as a base for other types of plating. Nickel is used as a base for decorative chromium and as a decorative plate itself. Chromium plating is used both for decorative purposes and for buildup of worn parts.

Electroplating Principles

In electrodisposition, metal particles (ions) are transferred from a soluble anode through a plating solution onto the item being plated, which acts as a cathode. When a insoluble anode is used, the metal required in the disposition is furnished from the dissolved metal compound or compounds in the plating solution. Electrodisposition is made possible by applying DC voltage great enough to overcome the resistance of the system and furnish additional energy sufficient to electrochemically transfer metal to the part being plated. The resistance of the circuit includes such things as circuit connections, solution, anode, and cathode.

The voltage required for the plating process usually falls within six to twenty-eight volts. All plating solutions contain various chemicals to produce acidic or alkaline solutions, depending upon type to be plated. Electrodisposition forms metallic crystals on the item being plated. The control of solution concentrations, temperature, and current density, are factors which affect brittleness, ductility, and size of these crystals. Small crystal size is desirable for satisfactorily plating a part. An example of this would be cadmium plating where a salt of the metal is dissolved in the plating solution from the metal anode balls hung on the anode or positive terminal located on the sides of the tank, or the salt already compounded is dissolved in the tank by adding a saturated amount to the tank. In the case where cadmium plating is necessary, the cadmium metal is dissolved from the cadmium balls which hang on the positive terminal into the plating solution. When the circuit is turned on, the sodium cyanide which is also dissolved in the solution assists in conducting the current and causing the chemical reaction to take place, which causes the metal to be dissolved into the solution. This solution is referred to an an ionized solution because of the following reasons.

The substances that form the solution break up onto ions which are either negatively or positively charged matter. The ions of the cadmium are released into the solution as the current passes through it by first being changed to cadmium oxide, which, in turn, is soluable in the solution and as the current flows, is released into the solution. Immediately, the cadmium oxide breaks down into its ions of cadmium and oxygen. The cadmium goes into solution with the other chemicals, and as the plating process proceeds, is attracted to the negative pole, or the part that is hung from the negative pole to be plated, which is referred to as the cathode. The cadmium is attracted to the negatively charged terminal or cathode because the cadmium, as in most metals, is positively charged and opposite charges or opposite charged particles attract each other. As the cadmium is released from the solution and plated out at the cathode, the oxygen, which is negatively released at the anode, forms more cadmium oxide. This oxide is again ionized and the process continues as before as long as the current is flowing and as long as there is sufficient ingredients to continue the plating operation. Most of the other plating operations work in the same manner; the only difference is the chemicals used.

Equipment

A plating tank of the required size and construction for the type of plating to be accomplished. Tank should be constructed of corrosion resistant alloy. A power source of direct current (DC) with an amperage range from 0 to 500 amperes and a control panel to control the plating current in accordance with size and number of parts being plated.

Supplies

Anodes of the metal, to keep up the strength of the solution and to serve the positive electrode to complete the circuit in the solution. Oxide of the metal to be used in the makeup of the solution and to be added as required. Some plating solutions also require a brightener added to the solution.

Plating Solutions

In the process of electrode position, metal particles (ions) are transferred from a soluable anode through a plating solution onto the item being plated, which acts as a cathode. Careful make-up and control of the solution is necessary to obtain acceptable plating results. The following is a list of some of the common plating solutions and how they are made up.

CADMIUM. To one quart of distilled or deionized water for each gallon of solution, add and dissolve one pound of sodium cyanide and 3.5 ounces of cadmium oxide military specification MIL-C-6151. Stir thoroughly and filter into plating tank. Add a brightener, one ounce per gallon, of tank operating level. Stir and fill plating tank to required level with distilled or deionized water. Then determine the solution strength and correct if necessary. See TO 42C2-1-7.

COPPER. Using one quart of distilled or deionized water for each gallon of solution, being prepared, add and dissolve five ounces of sodium cyanide and four ounces of copper cyanide. Filter into plating tanks and add four ounces of Rochelle salt and .5 ounce of sodium hydroxide for each gallon of plating solution being prepared. Determine solution strength and correct, if necessary. See TO 42C2-1-7.

CHROMIUM. Fill plating tanks two-thirds full of tap water. Add 33 ounces of Chromic Acid Flakes, Federal specification O-C-303 for each gallon of tank capacity, spread Chromic Acid Flakes over the tank area, and stir to dissolve. Add 0.33 ounces of sulfuric acid per gallon of solution, then fill the plating tank to operating capacity.

NICKEL. Fill plating tank one-half full with distilled water and heat to 140°F (60°C). Add and dissolve 44 ounces of nickel sulfate and five ounces of boric acid for each gallon of solution being prepared.

Raise the PH factor to at least 5.2 by adding powdered nickel carbonate.

Add 0.25 ounces per gallon of activated carbon which is 200 mesh or finer, then stir for one-half hour. Add 0.75 percent by volume of XXXD wetting agent. Udlite non-pitter number 22 may be substituted for XXXD wetting agent. Fill tank to operating level with distilled water.

Electroplating Vocabulary

In talking about plating, it is necessary to understand some of the terms used in a plating shop. Following is a list of some of the terms used:

1. ION: An electrically charged particle, usually an atom or molecule of the substance.

2. IONIC (IONIZED) SOLUTION: A solution in which a substance breaks up into positively and negatively charged ions. The type of solution necessary to conduct the current necessary for electroplating.

3. CATION: An ion with a positive charge.

4. ANION: An ion with a negative charge.

5. ANODE: The positive terminal in the plating circuit to which the anions are attracted in the plating solution.

6. CATHODE: The negative terminal in the plating circuit to which the parts to be plated are attached.

7. ELECTRODE: Either one of the conductors or terminals used to carry current in the plating process; i.e., the anode is the positive electrode and the cathode is the negative electrode.

8. SALT: A compound of a metal and an acid which, when ionized, will yield positive metal ions and negative acid ions.

PURPOSES OF THE DIFFERENT TYPES OF PLATING

Each type of plating process used is for a specific reason. Following are some of the most common types of plating solutions and their uses.

Cadmium

Cadmium is used primarily as a protection against corrosion but can also be utilized as a sacrificial host to prevent corrosion between two other types of metals. An example would be the cadmium plating on a steel bolt that is used to hold an aircraft magnesium wheel together. It must also be noted that cadmium plating has no resistance to chemicals and offers no wear resistance.

Copper

Copper plate has a wide use as an under plate where several plate coatings are put on a part. Copper is also a good conductor, so some parts that are used as conductors are copper plated to increase their efficiency. Copper is relatively corrosion resistant, however, tarnishes rapidly, and stains easily.

Nickel

Nickel plate is primarily used as a protective and decorative plate. Nickel by itself will tarnish easily and is very soft and has no wear resistance.

Chromium Plating

There are two types of chromium plating, bright and hard chrome. Bright chrome is used to provide a protective coating against corrosion. An example of this would be bright chrome over nickel to prevent the nickel from tarnishing.

Hard chrome, as the name implies, is hard; therefore, it is used to build up worn parts, and to provide wear and scuff resistance.

It goes without saying that anytime you have to handle any of the plating solutions, you must exercise caution. If, at any time, you are in doubt about any procedures, consult AFM 127-101.

TOXICITY OF CADMIUM PLATING

When you handle cadmium plating, poisioning can occur in two ways: ingestion and inhalation. You must never use cooking utensils that have been cadmium plated, as any foods that are acidic in nature will pick up cadmium salts when they are heated.

Inhalation of cadmium vapor usually occurs when someone is welding a cadmium plated part. Cadmium will break down and start to burn at 430°F.

Testing Plating Solutions

It is mandatory to control plating solutions to ensure the production of a deposit of proper thickness and quality. It is necessary to analyze a solution regularly to determine the true chemical composition. Variations can cause poor cathode efficiency, inadequate thickness, improper coverage, and a burned or dull deposit. Plating solutions should be analyzed once a week, or more often if necessary.

The following are the various determinations made when analyzing the four common plating solutions. For the exact procedure on each, refer to TO 42C2-1-7.

1. Cadium Solution:

   a. CD.

   b. Total and free sodium cyanide.

   c. Sodium carbonate.

   d. Sodium hydroxide.

2. Chromium Solution:

   a. Chromic acid.

   b. Trivalent chromium.

   c. Sulfate.

3. Copper Solution:

   a. Copper.

   b. pH.

   c. Rochelle salt.

   d. Sodium carbonate.

   e. Free cyanide.

4. Nickel Solution:

   a. Nickel.

   b. Nickel chloride.

   c. Boric acid.

   d. pH.

Cadmium Plating Procedure

After cleaning, the part will be plated as follows:

1. Current density - 15 to 45 amperes per square foot surface area.
2. Solution temperature - 80° - 95°F.
3. Voltage - 1 to 4 volts.
4. Time - Will vary with desired thickness.

After plating, the part will be rinsed and immersed in a chromic acid dip, used as a brightener.

High strength steels will become embrittled from absorbing hydrogen during plating. This effect can be removed by heat treatment. Bake at approximately 375°F for up to 23 hours.

Stripping Plating

It is often necessary to remove or strip old plating prior to replating. This can be accomplished in various ways depending upon what type of plating is being removed.

1. Strip off old cadmium plate by immersing in a solution composed of one pound of technical grade ammonium nitrate for each gallon of solution.

2. Strip worn chromium plating using one of the following methods.

   a. Strip parts anodically at 20 to 50 amperes per square foot in a solution of 6 to 8 ounces per gallon sodium carbonate.

   b. Strip parts anodically at 60 to 75 amperes per square foot in a solution containing 10 to 15 ounces per gallon of sodium hydroxide.

3. Strip off old copper plating by attaching electrical contacts and making parts anodic in an agitated caustic cyanide stripping solution composed of 12 ounces of sodium cyanide and 2 ounces of sodium hydroxide; use an anode current density of 50 amperes per square foot.

4. Nickel is stripped using a stripping agent, Enstrip A or Metex Strip Aid, and following manufacturer's instructions.

Plating Shop Safety

An electroplating shop is a hazardous environment to work in. Personal protective equipment, safe working conditions, and intelligent action on the part of each person must be strictly enforced.

Personal protective equipment includes face shield, rubber gloves, and apron. Safe working conditions include rapid action, deluge type safety showers, eye wash fountains, and washing facilities.

Cyanide is a deadly poison, and where cyanide is present, the following rules shall be strictly adhered to:

1. Wear rubber gloves when handling cyanide or anything exposed to it.

2. Do not allow cyanide to contact cuts or scratches in skin.

3. Wash hands thoroughly after handling cyanide.

4. Do not store, handle, or eat food, or chew gum or tobacco where cyanide is present.

Adequate ventilation is among the most important of shop safety devices. Highly poisonous hydrocyanic gas can be given off when acid and any form of cyanide are mixed.

Any tank producing toxic gases or containing a cyanide solution must be equipped with a lateral exhaust slot type ventilating system, capable of removing at least 150 cubic feet of air per minute per square feet of tank surface area.

REMEMBER - NEVER MIX ACIDS AND CYANIDES.

Plating Shop

In the event that you should ever be placed in the position of having to set up a plating shop, there are several things to take into consideration.

Of course the first requirements will be set by the type and volume of plating to be done; but there are three other considerations which are more general: (1) Safety, (2) Equipment, and (3) Supplies and Storage.

Remember, when laying out a plating shop, rinse tanks should be between cleaning and plating tanks to prevent drag-out from one tank contaminating another tank. It is also preferrable to have tanks in a straight line whenever possible, to keep chemicals off the floors when transferring from one tank to another. The equipment must be adequate for the volume of plating to be done. No work can get done if you don't have the supplies and, if stored improperly, plating supplies are dangerous.

ANODIZING

Anodizing is the process of forming a thin oxide film on the surface of a metal by an electrochemical reaction. This film acts as a protective layer, greatly reducing further oxidation. This treatment is done primarily to aluminum and its alloys, because of the fact that they can form a dense protective covering.

One characteristic of the anodized film is that it is porous and will stain or color easily as it comes from the bath. Therefore, it requires asealing treatment to convert the surface oxide to aluminum monohydrate, which is denser and seals the surface.

The anodizing process is performed two ways; the chromic acid process and the sulfuric acid process.

With either process, the part is immersed in the electrolytic solution and made anodic with a voltage up to 40 volts.

METAL SPRAYING

This is a relatively new process of applying a protective or special metal surface to another metal.

The metal to be applied may come in either wire, rod, or powder form. This metal is heated to a molten or semimolten state by a high temperature flame and then atomized and applied by compressed air or other gas.

Metals commonly sprayed by the oxyacetylene wire gun are aluminum, copper, bronze, lead, molybdenum, nickel, tin, zinc, low, medium, and hi-carbon steels; and stainless steels.

Metals commonly applied using an oxyacetylene powder gun are hard, corrosion resistant alloys; usually nickel-based or cobalt-based containing chromium, boron, and silicon.

This process requires a clean, slightly roughened surface for good adhesion to the base metal, but due to the ease of application, it is becoming more popular.

Another advantage is that a high temperature metal, like steel, can be applied to a low temperature metal, such as aluminum, without damaging effects to the base metal.

HOT DIPPING

This is an old but reliable process of applying a protective metal covering to iron or steel. Also known as galvanizing, which is the application of zinc by hot dipping, this is used for the prevention of corrosion. Other metals which can be applied in this manner are tin and lead, also applied to iron or steel for corrosion prevention.

The basic principle of this process is the application of a low melting metal to the surface of another, higher melting metal.

OXIDE COATING

A black oxide coating is formed by immersing a cleaned iron or steel part into a highly concentrated, heated solution of basic salts. Unless a rust-inhibiting oil is applied, this process gives only very limited protection due to the fact that the oxide formed is porous and won't stop corrosion of the metal beneath it.

Because the buildup is less than 0.0001 inch, this treatment is particularly suited to moving parts where a greater buildup could not be allowed. This process is well suited for wrought iron, cast iron, and carbon and low alloy steels.

QUESTIONS

Note: Answer the questions at the end of this chapter on a separate sheet of paper. DO NOT WRITE IN THIS STUDY GUIDE.

1. What is corrosion?

2. What are some types of corrosion?

3. Which type of corrosion is the most common?

4. Which type of corrosion is the most destructive?

5. Where is galvanic corrosion found?

6. How can many of the problems of intergranular corrosion be eliminated?

7. What must you consider when selecting a cleaning agent?

8. Why must overcleaning be avoided?

9. What cleaning method always follows alkaline cleaning?

10. When should air blast cleaning not be done?

11. What should be used to clean parts having a Rockwell hardness of C-40 or higher?

12. What is the operating temperature of trichlorethylene in a vapor degreaser?

13. What is one of the main ingredients of many alkaline cleaning solutions?

14. How does caustic soda react with contamination to remove it?

15. What is the suitable operating temperature of an alkaline cleaning solution?

16. In the electrocleaning process, what cleans the part?

17. What acts as the negative pole in the electrocleaning process?

18. What is the purpose of reversing the control switch for 15 to 30 seconds in electrocleaning?

19. What type of exhaust system is used in an electroplating shop and why?

20. What is meant by mechanical cleaning?

21. How does acid pickling clean a part?

22. When is hydrofluoric acid used?

23. How does "ultrasonic cleaning" clean a part?

24. What equipment is needed for electroplating?

25. List the chemicals needed to prepare the following plating solutions:

a. Cadmium -

b. Copper -

c. Chromium -

d. Nickel -

REFERENCES

1. TO 1-1-1, Cleaning of Aerospace Equipment.

2. TO 1-1A-9, Aerospace Metals-General Data and Usage Factors.

3. TO 42C2-1-7, Process Instructions Metal Treatments.