DOCUMENT RESUME

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TITLE	Military Curriculum Materials for Vocational and Technical Education. Welding High and Low Pressure Lines, 3-26.
INSTITUTION	Ohio State Univ., Columbus. National Center for Research in Vocational Education.
SPONS AGENCY	Office of Education (DHEW), Washington, D.C.
PUB DATE	[81]
NOTE	173p.; This course was adapted from original U.S. Air Force curriculum materials.
EDRS PRICE	MF01/PC07 Plus Postage.
DESCRIPTORS	*Construction (Process); Construction Materials; Learning Activities; Lesson Plans; Postsecondary Education; *Repair; Secondary Education; Structural Elements (Construction); *Teaching Methods; Technical Education; Units of Study; *Vocational Education; *Welding
IDENTIFIERS	Military Curriculum Project; *Pipelines

ABSTRACT

This short course in welding high and low pressure lines was adapted from military curriculum materials for use in vocational education. The course is designed to teach safety requirements for work with high and low pressure pipelines; pipe welding requirements and specifications; special pipeline repair welding applications; layout of pipe joints; metallic arc welding of carbon steel pipe; and inert gas shielded arc welding of stainless steel and aluminum pipe. The course consists of nine lessons covering 57.5 hours of instruction. The course contains materials for both student and teacher use. Printed materials for the instructor include a plan of instruction for the course and lesson plans for each lesson. These contain an outline of instruction, objectives, activities, materials and tools needed, text assignments, and references. Student materials consist of a study guide containing objectives, information, questions, and references. (This course was designed for students with experience in basic welding.) (KC)

Military Curriculum Materials for Vocational and Technical Education

WELDING HIGH AND LOW PRESSURE LINES
3-26

THE NATIONAL CENTER
FOR RESEARCH IN VOCATIONAL EDUCATION
THE OHIO STATE UNIVERSITY
1960 KENNY ROAD · COLUMBUS, OHIO 43210

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
Telephone: 614/486-3655 or Toll Free 800/848-4815 within the continental U.S. (except Ohio)

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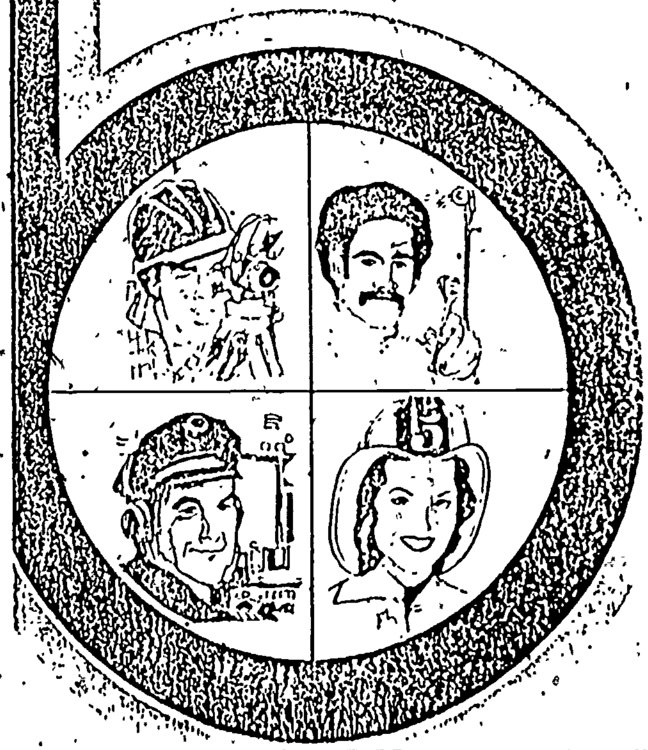
Military Curriculum Materials for Vocational and Technical Education

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

TABLE OF CONTENTS

Developed by:

United States Air Force

Development and Review Dates

June 4, 1975

D.O.T. No.:
812.884

Occupational Area:
Building and Construction

Target Audiences:
Grades 12-adult

Print Pages
157

Cost:
$3.25

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

Contents:	Type of Materials: Lesson Plans:	Programmed Text:	Student Workbook:	Handouts:	Text Materials:	Audio-Visuals:	Instructional Design: Performance Objectives:	Tests:	Review Exercises:	Additional Materials Required:	Type of Instruction: Group Instruction:	Individualized:
Block I								*				
Practice Safety Requirements in the Performance of Required Tasks	•				•		•				•	
Pipe Welding Requirements and Specifications	•				•		•				•	
Special Pipeline Welding Repair Applications	•				•		•			*	•	
Layout and Fit-up of Various Types of Pipe Joints	•				•		•			*	•	
Metallic Arc Welding Machine	•				•		•			*	•	
Prepare Various Types of Pipe Joints for Welding	•				•		•			*	•	
Metallic Arc Welding of Carbon Steel Pipe Joints	•				•		•			*	•	
Inert Gas Shield Arc Welding of Stainless Steel Pipe Joints	•				•		•			*	•	
Inert Gas Shielded Arc Welding of Aluminum Pipe Joints	•				•		•			*	•	

★ Materials are recommended but not provided.

Expires July 1, 1978

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Course Description

This one-block course includes training in safety requirements for work with high and low pressure pipelines, pipe welding requirements and specifications, special pipeline repair welding applications, layout of pipe joints, metallic arc welding of carbon steel pipe, and inert gas shielded arc welding of stainless steel and aluminum pipe. The course consists of nine lessons covering 57.5 hours of instruction. The lesson titles and hours follow:

- Practice Safety Requirements in the Performance of Required Tasks (.5 hour)
- Pipe Welding Requirements and Specifications (2 hours)
- Special Pipeline Welding Repair Applications (5 hours)
- Layout and Fit-up of Various Types of Pipe Joints (3 hours)
- Metallic Arc Welding Machine (1 hour)
- Prepare Various Types of Pipe Joints for Welding (1 hour)
- Metallic Welding of Carbon Steel Pipe Joints (18 hours)
- Inert Gas Shielded Arc Welding of Stainless Steel Pipe Joints (14 hours)
- Inert Gas Shielded Arc Welding of Aluminum Pipe (13 hours)

The course contains materials for both student and teacher use. Printed materials for the instructor include a plan of instruction for the course and lesson plans for each lesson. These contain an outline of instruction, objectives, activities, materials and tools needed, text assignments, and references. Student materials consist of a study guide containing objectives, information, questions, and references. This course was designed for students with experience in basic welding.

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POI 3AZR53250-4
(PDS Code C65)

PLAN OF INSTRUCTION
(Technical Training)

WELDING HIGH AND LOW PRESSURE LINES

AIR TRAINING COMMAND

CHANUTE TECHNICAL TRAINING CENTER

12 March 1975 - Effective 12 March 1975 with Class 750312

LIST OF CURRENT PAGES

This POI consists of 15 current pages issued as follows:

DISTRIBUTION: ATC/TTMS-1, AULD-1, TWS-40, TTOC-3, TTOT-1, TTOXW-1, TTOR-1, TTE-1, CCAF/AY-2

DEPARTMENT OF THE AIR FORCE — PLAN OF INSTRUCTION 3AZR53250-4
USAF School of Applied Aerospace Sciences (ATC) — (PDS Code C65)
Chanute Air Force Base, Illinois 61868 — 12 March 1975

FOREWORD

1. PURPOSE. This plan of instruction prescribes the qualitative requirements for Course Number 3AZR53250-4, Welding High and Low Pressure Lines, in terms of criterion objectives presented by units/modules of instruction, and shows duration, correlation with the training standard, support materials, and instructional guidance. It was developed under the provisions of ATCR 52-33, Instructional System Development, and ATCR 52-7, Plans of Instruction.

2. COURSE DESCRIPTION. This technical training course trains selected Air Force personnel possessing AFSC 53250/70 or equivalent civilian experience in the skills and knowledges required for welding high and low pressure lines. Training includes safety requirements in performance of required tasks; pipe welding requirements and specifications; special pipeline repair welding applications; layout and fit-up of various types of pipe joints; metallic arc welding machine current setting and electrode selection for carbon steel pipe; preparation of various types of pipe joints; metallic arc welding of carbon steel pipe joints in the fixed vertical, horizontal, and overhead positions; inert gas shielded arc welding machine current setting and gas flow adjustment and filler rod selection for stainless steel pipe welding; inert gas shielded arc welding of stainless steel pipe in the fixed vertical, horizontal, and overhead positions; inert gas shielded arc welding machine current setting, and gas flow adjustment and filler rod selection for aluminum pipe welding; inert gas shielded arc welding of aluminum pipe joints in the fixed vertical and horizontal positions. In addition, related training covers commander's calls/briefings, etc.

NOTE: Trainees entering this course at a level below that specified by AFM 50-5 or other established prerequisites cannot be expected to achieve the levels indicated.

3. EQUIPMENT ALLOWANCE AND AUTHORIZATION. Training equipment required to conduct this course is listed in Equipment Authorization Inventory Data Number 3ABR532300000. Training equipment authorizations for this course are based on the following Tables of Allowance:

TA 781	Machine Shop (Intermediate Maintenance, Civil Engineering) WRAMA
TA 782	Welding, Radiator, and Cooler Shop (Intermediate Maintenance) WRAMA
TA 783	Sheet Metal and Plastic Shops (Intermediate Maintenance) WRAMA
TA 785	Electroplating and Heat Treating Shops (Intermediate Maintenance) WRAMA

NOTE: Group size is shown in parentheses after equipment listed in column 3 of numbered pages of this POI.

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4. MULTIPLE INSTRUCTOR REQUIREMENTS. Not applicable to this POI.

5. REFERENCES. This plan of instruction is based on COURSE TRAINING STANDARD 3AZR53250-4, 26 April 1973, and Course Chart 3AZR53250-4, 9 October 1974.

FOR THE COMMANDER

William R. Mitchell

WILLIAM R. MITCHELL, Colonel, USAF
Chief, Operations Division

Supersedes Plan of Instruction 3AZR53250-4, 13 March 1974
OPR: Department of Weapon Systems Support Training
DISTRIBUTION: Listed on page A

COURSE CHART 7

NUMBER	PDS CODE	DATE
3AZR53151-2	C65	15 April 1975

COURSE TITLE
Welding High and Low Pressure Lines

ATC OPR AND APPROVAL DATE	CENTER OPR	SUPERSEDES COURSE CHART
TTMS, 12 June 1973	Chanute/TTOXW	3AZR53250-4, 9 October 1974

DEPARTMENT OPR Department of Weapon Systems Support Training	APPLICABLE TRAINING STANDARD * (See Remarks)
LOCATION OF TRAINING Chanute AFB, Illinois 61868	COURSE SECURITY CLASSIFICATION UNCLASSIFIED
INSTRUCTIONAL DESIGN Group/Lock Step	TARGET READING GRADE LEVEL FOR PREPARATION OF TRAINING LITERATURE 8

LENGTH OF TRAINING

(2 Weeks, 0 Days)

		Hours
Technical Training (TT)		70
Classroom/Laboratory (C/L)	60	
Complementary Technical Training (CTT) (assigned study)	10	
Related Training (RT)		10
Appointments, End of Course, Predeparture Safety Briefing	10	
TOTAL		80

REMARKS

* CTS CH52-3AZR53151-2, 14 April 1975

Effective Date: 4 June 1975 with class 750604

TABLE I - MAJOR ITEMS OF EQUIPMENT

Training Equipment: Electric Arc Welding Machine, Gas Shielded Arc Welding Equipment, Oxyacetylene Cutting Equipment, Pedestal Grinder and Buffer, Cleaning Equipment, Power Hacksaw.

COURSE CHART – TABLE II – TRAINING CONTENT 3AZR53151-2

NOTE: Include time spent on technical training (TT) (classroom/laboratory (C/L) and complementary technical training (CTT)) and related training (RT). Exclude time spent on individual assistance (remedial instruction). A single entry of time shown for a unit is C/L time. When a double entry is shown, the second entry is CTT time.

WK OF TNG \ HRS PER DAY	1 2 3 4 5 6	7 8
	Course Material - UNCLASSIFIED BLOCK I - 70 Hours TT	10 Hours CTT
1	Orientation (.5 hr)	
	Practice Safety Requirements in the Performance of Required Tasks (.5 hr)	
	Pipe Welding Requirements and Specifications (2 hrs)	
	Special Pipeline Welding Repair Applications (5 hrs)	
	Lay Out and Fit-up of Various Types of Pipe Joints (3 hrs)	
2	Metallic Arc Welding Machine (1 hr)	
	Prepare Various Types of Pipe Joints for Welding (1 hr)	
	Metallic Arc Welding of Carbon Steel Pipe Joints (18 hrs)	
	Inert Gas Shielded Arc Welding of Stainless Steel Pipe Joints (14 hrs)	10 Hours RT
	Inert Gas Shielded Arc Welding of Aluminum Pipe Joints (13 hrs)	
	Measurement Test and Test Critique (1 hr)	
	Course Critique and Graduation (1 hr)	
	(Equipment Hazards and Personnel Safety Integrated with Above Subjects).	
	60 Hours C/L	

ATC FORM APR 73 449A PREVIOUS EDITION OBSOLETE.

PLAN OF INSTRUCTION	COURSE TITLE Welding High and Low Pressure Lines	
BLOCK TITLE Welding High and Low Pressure Lines		
UNITS OF INSTRUCTION AND CRITERION OBJECTIVES	DURATION (HOURS) 2	SUPPORT MATERIALS AND GUIDANCE 3
	.5	**Column 1 Reference** 1a **CTS Reference** None **Instructional Materials** 3AZR53250-4-SG-101, Orientation 3AZR53250-4-HO-101, Bibliography **Training Methods** Discussion (.5 hr) **Instructional Environment/Design** Classroom (.5 hr) Group/Lock Step **Instructional Guidance** Explain the course objective, student responsibility, course content, and grading methods. Explain the school policies and the student critique program. Have student study 3AZR53250-4-SG-101. Review the Bibliography Handout. NOTE: This will apply to every lesson throughout this POI. Emphasize conservation of classroom lighting, metal specimens, electrical power and all expendable materials.
2. Practice Safety Requirements in the Performance of Required Tasks a. Without reference, describe welding protective equipment and its use without error. b. Without reference, describe welding equipment safety procedures without error.	.5	**Column 1 Reference** 2a, 2b **CTS Reference** 1 **Instructional Materials** 3AZR53250-4-SG-102, Practice Shop Safety ~~in~~ the Performance of Required Tasks **Training Methods** Discussion (.5 hr)

PLAN OF INSTRUCTION NO. 3AZR53250-4	DATE 12 March 1975	BLOCK NO. I	PAGE NO. 1

PLAN OF INSTRUCTION (Continued)

1 UNITS OF INSTRUCTION AND CRITERION OBJECTIVES	2 DURATION (HOURS)	3 SUPPORT MATERIALS AND GUIDANCE
		Instructional Environment/Design Classroom (.5 hr) Group/Lock Step **Instructional Guidance** Explain that protective equipment will be worn at all times during a performance in the laboratory and that all students will conform to all required tasks, in accordance with AFM 127-101. Have student complete 3AZR53250-4-SG-102. Instructor will use AFM 127-101, Industrial Safety Accident Prevention Handbook, as reference.
3. Pipe Welding Requirements and Specifications a. Using a list, determine requirements pertaining to pipe welding operations with 80% accuracy. b. Without reference, identify and describe pipe welding specifications with 80% accuracy.	4 (2/2)	**Column 1 Reference** 3a, 3b **CTS Reference** 2 **Instructional Materials** 3AZR53250-4-SG-103, Pipe Welding Requirements and Specifications TO 00-25-224, Welding High Pressure and Cryogenic Systems **Training Methods** Discussion (2 hrs) Outside Assignment (2 hrs) **Instructional Environment/Design** Classroom (2 hrs) Group/Lock Step **Instructional Guidance** Discuss pipe welding requirements and specifications. Have each student study TO 00-25-224 and make outside assignment (completion of 3AZR53250-4-SG-103).

PLAN OF INSTRUCTION NO. 3AZR53250-4	DATE 12 March 1975	BLOCK NO. I	PAGE NO. 2

PLAN OF INSTRUCTION (Continued)

1 UNITS OF INSTRUCTION AND CRITERION OBJECTIVES	2 DURATION (HOURS)	3 SUPPORT MATERIALS AND GUIDANCE
4. Special Pipeline Welding Repair Applications a. Without reference, describe special pipeline welding repair applications with 80% accuracy. b. Given a list of statements, identify procedures pertaining to special pipeline welding repair applications with 80% accuracy. c. Without reference, describe operator qualifications for special pipeline welding applications with 80% accuracy. d. Without reference, describe welding techniques relating to special pipeline repair applications with 80% accuracy.	7 (5/2)	<u>Column 1 Reference</u> 4a, 4b, 4c, 4d — <u>CTS Reference</u> 3 <u>Instructional Materials</u> 3AZR53250-4-SG-104, Special Pipeline Welding Repair Applications TO 00-25-224 <u>Training Methods</u> Discussion (5 hrs) Outside Assignment (2 hrs) <u>Instructional Environment/Design</u> Classroom (5 hrs) Group/Lock Step <u>Instructional Guidance</u> Explain specifications for special pipeline welding repair applications and instruct each student on the proper preparation procedures prior to welding. Discuss operator qualifications for welding of high pressure and cryogenic systems and special welding techniques applicable to pipeline welding repair. Have each student respond to all written items in the lesson. Have students study TO 00-25-224. Assign completion of 3AZR53250-4-SG-104 as outside assignment.
5. Layout and Fit-Up of Various Types of Pipe Joints a. Given applicable equipment and pipe specimens, while observing all shop safety measures, lay out and fit up various types of pipe joints. Joints must be beveled to 37-1/2 degree angles with 1/32 inch land face, clean, and free of burrs.	3	<u>Column 1 Reference</u> 5a — <u>CTS Reference</u> 1, 4 <u>Instructional Materials</u> 3AZR53250-4-SG-105, Layout and Fit-Up of Various Types of Pipe Joints TO 00-25-224 <u>Training Equipment</u> Portable oxyacetylene cutting equipment consisting of 1 cart, 1 oxygen cylinder, 1 acetylene cylinder, torch complete with cutting tips, regulators, and hoses (1) Pedestal Grinder (1) Power Hacksaw (1) Toolkit (8) Drawing Table and Stool (1)

PLAN OF INSTRUCTION NO.	DATE	BLOCK NO.	PAGE NO.
3AZR53250-4	12 March 1975	I	3

PLAN OF INSTRUCTION (Continued)

1 UNITS OF INSTRUCTION AND CRITERION OBJECTIVES	2 DURATION (HOURS)	3 SUPPORT MATERIALS AND GUIDANCE
		<u>Training Methods</u> Discussion/Demonstration (1 hr) Performance (2 hrs) <u>Instructional Environment/Design</u> Classroom (.5 hr) Laboratory (2.5 hrs) Group/Lock Step <u>Instructional Guidance</u> Emphasize the importance of proper layout and fit-up of pipe joints. Demonstrate the correct use of all equipment and supervise each student in the safe operation of all equipment required in layout and fit-up procedures. Have student study TO 00-25-224, and complete 3AZR53250-4-SG-105. Emphasize conservation of cleaning materials.
6. Metallic Arc Welding Machine	1	<u>Column 1 Reference</u> / <u>CTS Reference</u> 6a / <u>5a</u> 6b / <u>5b</u>
a. Given a metallic arc welding machine, set up and make current adjustments for welding carbon steel pipe joints. Settings are to be made within the range of 80 to 120 amperes.	(.5)	<u>Instructional Materials</u> 3AZR53250-4-SG-106, Metallic Arc Welding Machine TO 00-25-224 <u>Audio Visual Aids</u> Chart: Color Code Classification of Electrodes
b. Given arc welding electrodes, select the proper electrodes for welding carbon steel pipe joints in the vertical, overhead, and horizontal positions. Each electrode selected must be equal to AWS E-6010.	(.5)	<u>Training Equipment</u> Metallic Arc Welding Equipment consisting of 1 welding machine, welding table, cables and electrode holder (1) <u>Training Methods</u> Discussion/Demonstration (.5 hr) Performance (.5 hr) <u>Instructional Environment/Design</u> Classroom (.5 hr) Laboratory (.5 hr) Group/Lock Step

PLAN OF INSTRUCTION NO. 3AZR53250-4	DATE 12 March 1975	BLOCK NO. I	PAGE NO. 4

PLAN OF INSTRUCTION (Continued)

1 UNITS OF INSTRUCTION AND CRITERION OBJECTIVES	2 DURATION (HOURS)	3 SUPPORT MATERIALS AND GUIDANCE
		<u>Instructional Guidance</u> Demonstrate the correct current settings for carbon steel pipe welding. Have each student set up the equipment and select the proper welding electrode for welding carbon steel pipe joints in the vertical, overhead, and horizontal positions. Have each student study TO 00-25-224, and complete 3AZR53250-4-SG-106. Emphasize proper fit-up to conserve electrodes.
7. Prepare Various Types of Pipe Joints for Welding	3	<u>Column 1 Reference</u> 7a <u>CTS Reference</u> 1, 6
a. Given the applicable equipment and various types of pipe specimens, while observing all shop safety requirements, set up and prepare joints for welding. Specimens must be free of burrs and all organic matter.	(1/2)	<u>Instructional Materials</u> 3AZR53250-4-SW-107, Prepare Various Types of Pipe Joints for Welding TO 00-25-224 <u>Training Equipment</u> Vapor Degreaser (8) Sandblast Machine (8) <u>Training Methods</u> Discussion/Demonstration (.5 hr) Performance (.5 hr) Outside Assignment (2 hrs) <u>Instructional Environment/Design</u> Classroom (.5 hr) Laboratory (.5 hr) Group/Lock Step <u>Instructional Guidance</u> Emphasize the importance of proper preparation prior to welding. Have each student prepare various types of pipe joints for welding while observing all safety measures applicable to the equipment. Have students study TO 00-25-224, and assign completion of 3AZR53250-4-SG-107 as outside assignment.

PLAN OF INSTRUCTION (Continued)

1 UNITS OF INSTRUCTION AND CRITERION OBJECTIVES	2 DURATION (HOURS)	3 SUPPORT MATERIALS AND GUIDANCE
8. Metallic Arc Welding of Carbon Steel Pipe Joints a. Given metallic arc welding equipment and carbon steel pipe specimens, while observing all shop safety measures, set up and weld butt joints in the fixed vertical position. Joints must have 100% penetration and be free of overlap, undercut, and slag inclusions for the entire length of the weld. b. Given metallic arc welding equipment and carbon steel pipe specimens, while observing all shop safety measures, set up and weld angle joints in the fixed vertical position. Joints must have 100% penetration and be free of overlap, undercut, and slag inclusions for the entire length of the weld. c. Given metallic arc welding equipment and carbon steel pipe specimens, while observing all shop safety measures, set up and weld tee joints in the fixed vertical position. Joints must have 30 to 80% penetration and be free of overlap, undercut, and slag inclusions for the entire length of the weld. d. Given metallic arc welding equipment and carbon steel pipe specimens, while observing all shop safety measures, set up and weld butt joints in the fixed horizontal position. Joints must have 100% penetration and be free of overlap, undercut, and slag inclusions for the entire length of the weld. e. Given metallic arc welding equipment and carbon steel pipe specimens, while observing all shop safety measures, set up and weld	22 (18/4) (2) (2) (2) (2)	<u>Column 1 Reference</u> — <u>CTS Reference</u> 8a — 1, <u>7a</u> 8b — 1, <u>7b</u> 8c — 1, <u>7c</u> 8d — 1, <u>7d</u> 8e — 1, <u>7e</u> 8f — 1, <u>7f</u> 8g — 1, <u>7g</u> 8h — 1, <u>7h</u> 8i — 1, <u>7i</u> <u>Instructional Materials</u> 3AZR53250-4-SG-108, Metallic Arc Welding of Carbon Steel Pipe Joints TO 00-25-224 <u>Training Equipment</u> Metallic Arc Welding Machine (1) Pedestal Grinder and Buffer (1) Sandblast Machine (8) <u>Training Methods</u> Discussion/Demonstration (1 hr) Performance (17 hrs) Outside Assignment (4 hrs) <u>Instructional Environment/Design</u> Laboratory (18 hrs) Group/Lock Step <u>Instructional Guidance</u> Emphasize all shop safety applicable to position welding. Make sure students use all the required protective equipment during all laboratory performance. Inspect all welds after the first pass and recommend improvements needed to complete a joint IAW TO 00-25-224. Have student study TO 00-25-224, and complete 3AZR53250-4-SG-108. Assign completion of 3AZR53250-4-SG-108 as outside assignment. Emphasize conservation of carbon steel pipe specimens by recutting and re-use. Conserve electrodes by using to maximum of 2" stubs.

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PLAN OF INSTRUCTION (Continued)

UNITS OF INSTRUCTION AND CRITERION OBJECTIVES 1	DURATION (HOURS) 2	SUPPORT MATERIALS AND GUIDANCE 3
angles in the fixed horizontal position. Joints must have 100% penetration and be free of overlap, undercut, and slag inclusions for the entire length of the weld.	(2)	
f. Given metallic arc welding equipment and carbon steel pipe specimens, while observing all shop safety measures, set up and weld tee joints in the fixed horizontal position. Joints must have 30 to 80% penetration and be free of overlap, undercut, and slag inclusions for the entire length of the weld.	(2)	
g. Given metallic arc welding equipment and carbon steel pipe specimens, while observing all shop safety measures, set up and weld butt joints in the fixed overhead position. Joints must have 100% penetration and be free of overlap, undercut, and slag inclusions for the entire length of the weld.	(2)	
h. Given metallic arc welding equipment and carbon steel pipe specimens, while observing all shop safety measures, set up and weld angle joints in the fixed overhead position. Joints must have 100% penetration and be free of overlap, undercut, and slag inclusions for the entire length of the weld.	(2)	
i. Given metallic arc welding equipment and carbon steel pipe specimens, while observing all shop safety measures, set up and weld tee joints in the fixed overhead position. Joints must have 30 to 80% penetration and be free of overlap, undercut, and slag inclusions for the entire length of the weld.	(2)	

PLAN OF INSTRUCTION (Continued)

1 UNITS OF INSTRUCTION AND CRITERION OBJECTIVES	2 DURATION (HOURS)	3 SUPPORT MATERIALS AND GUIDANCE
9. Inert Gas Shielded Arc Welding of Stainless Steel Pipe a. Given inert gas shielded arc welding equipment, set up and make current adjustments for welding stainless steel pipe joints. Settings must be made within the range of 60 to 80 amperes. b. Given inert gas shielded arc welding equipment, set up and make correct gas flow adjustments for welding stainless steel pipe joints. Settings must be made within the range of from 10 to 15 cubic feet per hour. c. Given stainless steel filler rods, select the correct filler rod for welding stainless steel pipe joints in the overhead, vertical, and horizontal positions. Each filler rod must be correctly selected. d. Given inert gas shielded arc welding equipment and stainless steel pipe specimens, while observing all shop safety measures, set up and weld butt joints in the fixed vertical position. Joints must have 100% penetration and be free of overlap, undercut, and surface oxidation for the entire length of the weld. e. Given inert gas shielded arc welding equipment and stainless steel pipe specimens, while observing all shop safety measures, set up and weld angle joints in the fixed vertical position. Joints must have 100% penetration and be free of overlap, undercut, and surface oxidation for the entire length of the weld.	14 (.3) (.2) (.3) (1.5) (1.5)	Column 1 Reference — CTS Reference 9a — 8a 9b — 8b 9c — 1, 8c 9d — 1, 8d 9e — 1, 8e 9f — 1, 8f 9g — 1, 8g 9h — 1, 8h 9i — 1, 8i 9j — 1, 8j 9k — 1, 8k 9l — 1, 8l Instructional Materials 3AZR53250-4-SG-109, Inert Gas Shielded Arc Welding of Stainless Steel Pipe TO 00-25-224 Training Equipment Inert Gas Shielded Arc Welding Equipment (1) Pedestal Grinder and Buffer (1) Training Methods Discussion/Demonstration (2 hrs) Performance (12 hrs) Instructional Environment/Design Classroom (1 hr) Laboratory (13 hrs) Group/Lock Step Instructional Guidance Discuss machine current settings and gas flow requirements for welding stainless steel pipe joints. Emphasize safety requirements for welding in the overhead, horizontal, and vertical positions. Inspect all welds after the first pass and recommend improvements needed to complete a joint IAW TO 00-25-224. Have student study TO 00-25-224, and complete

PLAN OF INSTRUCTION (Continued)

1 UNITS OF INSTRUCTION AND CRITERION OBJECTIVES	2 DURATION (HOURS)	3 SUPPORT MATERIALS AND GUIDANCE
f. Given inert gas shielded arc welding equipment and stainless steel pipe specimens, while observing all shop safety measures, set up and weld tee joints in the fixed vertical position. Joints must have 30 to 80% penetration and be free of overlap, undercut, and surface oxidation for the entire length of the weld.	(1.5)	3AZR53250-4-SG-109. Emphasize conservation of argon shielding and back-up gas by proper flowmeter adjustment. Recut and re-use pipe specimens when possible.
g. Given inert gas shielded arc welding equipment and stainless steel pipe specimens, while observing all shop safety measures, set up and weld butt joints in the fixed horizontal position. Joints must have 100% penetration and be free of overlap, undercut, and surface oxidation for the entire length of the weld.	(1.5)	
h. Given inert gas shielded arc welding equipment and stainless steel pipe specimens, while observing all shop safety measures, set up and weld angle joints in the fixed horizontal position. Joints must have 100% penetration and be free of overlap, undercut, and surface oxidation for the entire length of the weld.	(1.5)	
i. Given inert gas shielded arc welding equipment and stainless steel pipe specimens, while observing all shop safety measures, set up and weld tee joints in the fixed horizontal position. Joints must have 30 to 80% penetration and be free of overlap, undercut, and surface oxidation for the entire length of the weld.	(1.5)	
j. Given inert gas shielded arc welding equipment and stainless steel pipe specimens, while observing all shop safety measures, set up and weld butt joints in the fixed overhead position. Joints must have 100% penetration and be free of overlap, undercut, and surface oxidation for the entire length of the weld.	(1.5)	

PLAN OF INSTRUCTION (Continued)

1 UNITS OF INSTRUCTION AND CRITERION OBJECTIVES	2 DURATION (HOURS)	3 SUPPORT MATERIALS AND GUIDANCE
k. Given inert gas shielded arc welding equipment and stainless steel pipe specimens, while observing all shop safety measures, set up and weld angle joints in the fixed overhead position. Joints must have 100% penetration and be free of overlap, undercut, and surface oxidation for the entire length of the weld.	(1.5)	
l. Given inert gas shielded arc welding equipment and stainless steel pipe specimens, while observing all shop safety measures, set up and weld tee joints in the fixed overhead position. Joints must have 30 to 80% penetration and be free of overlap, undercut, and surface oxidation for the entire length of the weld.	(1.2)	
10. Inert Gas Shielded Arc Welding of Aluminum Pipe Joints	13	<u>Column 1 Reference</u> / <u>CTS Reference</u> 10a — <u>9a</u> 10b — <u>9b</u> 10c — <u>9c</u> 10d — 1, <u>9d</u> 10e — 1, <u>9e</u> 10f — 1, <u>9f</u> 10g — 1, <u>9g</u> 10h — 1, <u>9h</u> 10i — <u>1</u>, <u>9i</u>
a. Given an inert gas shielded arc welding machine, while observing all shop safety measures, set up and make correct current adjustments for welding aluminum pipe joints. Settings must be made within the range of 110 to 130 amperes.	(.3)	
b. Given an inert gas shielded arc welding machine, while observing all shop safety measures, set up and make correct gas flow adjustments for welding aluminum pipe joints. Settings must be made within the range of 10 to 15 cubic feet per hour.	(.2)	<u>Instructional Materials</u> 3AZR53250-4-SG-110, Inert Gas Shielded Arc Welding of Aluminum Pipe Joints TO 00-25-224 <u>Training Equipment</u> Inert Gas Shielded Arc Welding Machine (1) Pedestal Grinder and Buffer (1)
c. Given aluminum and aluminum alloy filler rods, select the correct filler rod for welding aluminum or aluminum alloy pipe joints. Filler rod selected must be of the same chemical composition as the joint being welded.	(.5)	<u>Training Methods</u> Discussion/Demonstration (1 hr) Performance (12 hrs)

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PLAN OF INSTRUCTION (Continued)

1 UNITS OF INSTRUCTION AND CRITERION OBJECTIVES	DURATION (HOURS) 2	3 SUPPORT MATERIALS AND GUIDANCE
d. Given inert gas shielded arc welding equipment and aluminum or aluminum alloy pipe specimens, while observing all shop safety measures, set up and weld butt joints in the fixed vertical position. Joints must have 100% penetration and be free of overlap, under-cut, and surface oxidation for the entire length of the weld.	(2)	Instructional Environment/Design Classroom (.5 hr) Laboratory (12.5 hrs) Group/Lock Step Instructional Guidance Emphasize all shop safety applicable to position welding. Make sure all students use all the required protective equipment during all laboratory performance. Inspect all welds after the first pass and recommend improvements needed to complete a joint IAW TO 00-25-224. Have each student study TO 00-25-224, and complete 3AZR53250-4-SG-110. Emphasize conservation of aluminum and aluminum alloy pipe specimens, welding rod and argon gas.
e. Given inert gas shielded arc welding equipment and aluminum or aluminum alloy pipe specimens, while observing all shop safety measures, set up and weld angle joints in the fixed vertical position. Joints must have 100% penetration and be free of overlap, undercut, and surface oxidation for the entire length of the weld.	(2)	
f. Given inert gas shielded arc welding equipment and aluminum or aluminum alloy pipe specimens, while observing all shop safety measures, set up and weld tee joints in the fixed vertical position. Joints must have 30 to 80% penetration and be free of overlap, undercut, and surface oxidation for the entire length of the weld.	(2)	
g. Given inert gas shielded arc welding equipment and aluminum or aluminum alloy pipe specimens, while observing all shop safety measures, set up and weld butt joints in the fixed horizontal position. Joints must have 100% penetration and be free of overlap, undercut, and surface oxidation for the entire length of the weld.	(2)	

PLAN OF INSTRUCTION (Continued)

1 UNITS OF INSTRUCTION AND CRITERION OBJECTIVES	2 DURATION (HOURS)	3 SUPPORT MATERIALS AND GUIDANCE
h. Given inert gas shielded arc welding equipment and aluminum or aluminum alloy pipe specimens, while observing all shop safety measures, set up and weld angle joints in the fixed horizontal position. Joints must have 100% penetration and be free of overlap, undercut, and surface oxidation for the entire length of the weld.	(2)	
i. Given inert gas shielded arc welding equipment and aluminum or aluminum alloy pipe specimens, while observing all shop safety measures, set up and weld tee joints in the fixed horizontal position. Joints must have 30 to 80% penetration and be free of overlap, undercut, and surface oxidation for the entire length of the weld.	(2)	
11. Related Training (identified in course chart)	10	
12. Measurement Test and Test Critique	1	
13. Course Critique and Graduation	1	

LESSON PLAN (Part I, General) 21

APPROVAL OFFICE AND DATE	INSTRUCTOR	
TWSTI		
COURSE NUMBER: 3AZR53151-2	COURSE TITLE: Welding High and Low Pressure Lines	
BLOCK NUMBER: I	BLOCK TITLE: Welding High and Low Pressure Lines	
LESSON TITLE: Orientation		

CLASSROOM/Laboratory	LESSON DURATION: Complementary	TOTAL
D&D .5 hr/ Perf None	None	.5 hr

POI REFERENCE

PAGE NUMBER	PAGE DATE	PARAGRAPH
1	12 Mar 75	1

STS/CTS REFERENCE

NUMBER	DATE
CH52-3AZR53151-2	14 April 75

SUPERVISOR APPROVAL

SIGNATURE	DATE	SIGNATURE	DATE

PRECLASS PREPARATION

EQUIPMENT LOCATED IN LABORATORY	EQUIPMENT FROM SUPPLY	CLASSIFIED MATERIAL	GRAPHIC AIDS AND UNCLASSIFIED MATERIAL
None	None	None	1. 3AZR53151-2-SG-101 2. 3AZR53151-2-HO-101

CRITERION OBJECTIVES AND TEACHING STEPS

a. School Orientation Conducted IAW Sch. Reg. 50-18 Attachment 3 Outline

b. To prepare the advanced course students with knowledge of the purpose and operation of the Graduate Evaluation Program so that they may effectively use the system.

Teaching steps are listed in Part II.

INTRODUCTION TIME: 5 MIN.

1. Attention:

2. Review:

3. Overview:

4. Motivation:

BODY TIME: 20 MIN.

Presentation:

1. Course objectives and mission.

   a. Increase knowledge and skill in welding operations.

   b. Train Air Force welders in class A welding operations.

2. Course responsibilities.

   a. Provide training materials, equipment and supervision.

   b. Provide for remedial instruction when necessary.

   c. Supervise welding operations for proper safety procedures.

3. Student responsibilities

   a. Personal conduct

      (1) Classroom or lab attendance

      (2) No absence except emergency or sickness

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(3) Safety procedures must be followed

(a) No horseplay

b. Cleanup

(1) Immediate area

(2) Classroom

(3) Area used (booths, tables, etc.)

c. Conserve equipment and materials

(1) Put scrap metal in proper containers

4. Course content

a. Orientation

b. Shop safety

c. Pipe welding requirements and specifications

d. Special pipe line welding repair applications

e. Layout and fit-up of various types of pipe joints

f. Metallic arc welding machines

g. Prepare various types of pipe joints for welding

h. Metallic arc welding of carbon steel pipe joints

i. Inert gas shielded arc welding of stainless steel pipe

j. Inert gas shielded arc welding of aluminum pipe joints

5. Grading methods

   a. Criterion test

   b. Work projects

   c. Written test

6. School policies

   a. Uniform and appearance

   b. Driving cars to school

   c. School hours

   d. Smoking

   e. Breaks

   f. Military courtesy

7. Student critique

   a. Base critique during mid-course

   b. Course critique during last week

CONCLUSION TIME:

1. Summary

2. Remotivation

3. Assignment: Students will read 3AZR53250-XWS-102

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LESSON PLAN (Part I, General)

APPROVAL OFFICE AND DATE WSTI 6 Aug 75 [illegible]	INSTRUCTOR
COURSE NUMBER 3ABR53151-2	COURSE TITLE Welding High and Low Pressure Lines
BLOCK NUMBER I	BLOCK TITLE Welding High and Low Pressure Lines

LESSON TITLE

Practice Shop Safety in the Performance of Required Tasks

LESSON DURATION		
Classroom/Laboratory D&D .5 hr/Perf None	Complementary None	TOTAL .5 hr

POI REFERENCE		
PAGE NUMBER 1 & 2	PAGE DATE 12 MAR 75	PARAGRAPH 26

STS/CTS REFERENCE	
NUMBER CHS2 · 3ABR53151-2	DATE 14 APRIL 75

SUPERVISOR APPROVAL

SIGNATURE	DATE	SIGNATURE	DATE

PRECLASS PREPARATION

EQUIPMENT LOCATED IN LABORATORY	EQUIPMENT FROM SUPPLY	CLASSIFIED MATERIAL	GRAPHIC AIDS AND UNCLASSIFIED MATERIAL
None	None	None	1. 3ABR53151-2-SG-102

CRITERION OBJECTIVES AND TEACHING STEPS

a. Without reference, describe welding protective equipment and its use without error.

b. Without reference, describe welding equipment safety procedures without error.

Teaching steps are listed in Part II.

INTRODUCTION TIME:

1. Attention:

2. Review:

3. Overview:

4. Motivation:

BODY TIME:

Presentation:

1. Safety

   a. General housekeeping

      (1) Cleanliness of work area

         (a) No books or paper in welding area

         (b) Store combustible waste in self closing containers

      (2) Mark hot metal when left unattended

         (a) Chalk mark time you stopped welding

   b. Personal equipment

      (1) Remove jewelry prior to entering welding area

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(2) Wear appropriate clothing and safety equipment

(a) No loose clothing or cuffs on trousers

(b) Leather or asbestos gloves

(c) Leather aprons and jackets

(d) High top shoes

(e) Eye protection

1 Approved welders helmet and eye goggles

2 Full face shield (clear) when grinding metal

(3) Use extreme caution when operating equipment

(a) Power shears

1 Only one man may operate at any time

(b) Welding machines

1 Use appropriate safety precautions for operating electrical equipment

2 Shield the area around the welding operations to prevent spectators and nearby personnel from receiving eye damage

c. Mechanical and chemical cleaning of equipment

(1) Grinders and buffers

(a) Face shield required

(b) Use caution to avoid cuts and burns

(2) Chemical cleaning

(a) Flammable

(b) Caustic

(c) Toxic

(d) Use only in well ventilated area

Application: Given a series of questions concerning protective equipment and welding equipment safety, each student will select the correct response for 80% of the questions.

Evaluation: Instructor will check students safety test for 80% accuracy.

CONCLUSION TIME:

1. Summary

2. Remotivation

3. Assignment: Have students read 3AZR53250-X-WS-103

LESSON PLAN (Part I, General)

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APPROVAL OFFICE AND DATE	INSTRUCTOR
TWSTI 6 AUG 75	
COURSE NUMBER	**COURSE TITLE**
3ARZR53151-2	Welding High and Low Pressure Lines
BLOCK NUMBER	**BLOCK TITLE**
I	Welding High and Low Pressure Lines

LESSON TITLE
Pipe Welding Requirements and Specifications

LESSON DURATION		
Classroom/Laboratory D&D 2 hrs/Perf None	Complementary 2 hrs	TOTAL 4 hrs

POI REFERENCE		
PAGE NUMBER 2	PAGE DATE 12 MAR 75	PARAGRAPH 3

STS/CTS REFERENCE	
NUMBER CH52-3AZR53151-2	DATE 14 APRIL 75

SUPERVISOR APPROVAL			
SIGNATURE	DATE	SIGNATURE	DATE

PRECLASS PREPARATION			
EQUIPMENT LOCATED IN LABORATORY	EQUIPMENT FROM SUPPLY	CLASSIFIED MATERIAL	GRAPHIC AIDS AND UNCLASSIFIED MATERIAL
None	None	None	1. 3AZR53151-2-SG-103 2. TO CC 35 274

CRITERION OBJECTIVES AND TEACHING STEPS

a. Using a list, determine requirements pertaining to pipe welding operations with 80% accuracy.

b. Without reference, identify and describe pipe welding specifications with 80% accuracy.

Teaching steps are listed in Part II.

INTRODUCTION TIME:

1. Attention:

2. Review:

3. Overview:

4. Motivation:

BODY TIME:

Presentation

1. Welding requirements

   a. Demonstration of proficiency

      (1) To achieve qualified status the operator shall demonstrate his skill or proficiency by welding joints as specified in MIL-T-5021D, Aircraft and Missile Welding Operator's Qualifications.

         (a) Butt, angle and tee pipe joints of carbon steel, stainless steel, and aluminum in the fixed vertical, horizontal, and overhead positions.

2. Welding specifications

   a. Welding process

      (1) Metallic arc

      (2) Tungsten inert gas (TIG)

   b. Preheat treatment

   c. Post heat treatment

   d. Type of electrode and flux

      (1) The composition of the electrode or filler rod will conform to that of the metal being welded

   e. Mechanical properties of test speciment

Application:

1. Given a series of questions concerning pipe welding requirements and specifications select the correct response for 80% of the questions.

Evaluation:

1. Instructor will check students test results for 80% accuracy.

CONCLUSION TIME:

1. Summary

2. Remotivation

3. Assignment: have students read 3AZR53150-X-WS-104.

LESSON PLAN (Part I, General)

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APPROVAL OFFICE AND DATE: TWSTI 6 Oct 75 [signature]	INSTRUCTOR
COURSE NUMBER: 3AZR53151-2	COURSE TITLE: Welding High and Low Pressure Lines
BLOCK NUMBER: I	BLOCK TITLE: Welding High and Low Pressure Lines

LESSON TITLE: Special Pipe Line Welding Repair Applications.

LESSON DURATION		
Classroom/Laboratory D&D - 5 hrs/Perf None	Complementary 2 hrs	TOTAL 7 hrs

POI REFERENCE		
PAGE NUMBER: 3	PAGE DATE: 12 MAR 75	PARAGRAPH: 4

STS/CTS REFERENCE	
NUMBER: CH52-3AZR53151-2	DATE: 19 APRIL 75

SUPERVISOR APPROVAL			
SIGNATURE	DATE	SIGNATURE	DATE

PRECLASS PREPARATION			
EQUIPMENT LOCATED IN LABORATORY	EQUIPMENT FROM SUPPLY	CLASSIFIED MATERIAL	GRAPHIC AIDS AND UNCLASSIFIED MATERIAL
None	None	None	1. 3AZR53151-2-SG-104 2. TO 00-25-224

CRITERION OBJECTIVES AND TEACHING STEPS

a. Without reference, describe special pipeline welding repair applications with 80% accuracy.

b. Given a list of statements, identify procedures pertaining to special pipeline welding repair applications with 80% accuracy.

c. Without reference, describe operator qualifications for special pipeline welding applications with 80% accuracy.

d. Without reference, describe welding techniques relating to special pipeline repair applications with 80% accuracy.

Teaching steps are listed in Part II.

ATC FORM AUG 72 770

INTRODUCTION TIME:

1. Attention

2. Review

3. Overview

4. Motivation

BODY TIME:

Presentation

1. Welding repair applications
   a. Refrigeration
   b. Chemical
   c. Petroleum systems
   d. Industrial gas and air systems and plants
   e. Missiles (Cryogenics)
   f. Advantages
      (1) Neatness
      (2) Compactness
      (3) Rigidity
      (4) Low cost

2. Preparations for welding

a. Cleaning

(1) Rust

(2) Scale

(3) Oil and grease

b. Butt joint

(1) Most common joint

(2) Where wall of pipe is less than 3/16"

(a) Bevel 37 $1/2^{\circ}$

(b) Root face land 1/16"

(c) Light materials bevel on grinder

c. Pipe of large diameter wall thickness

(1) Bevel 20 - 37 $1/2^{\circ}$

(2) Usually supplied with V bevel

(a) Use oxyacetylene torch

d. Alignment of pipe ends

(1) Channel, angle iron

(2) Clamps

(3) Backing ring

(a) Ring shaped strap

(b) Used in assisting operator

1 Secure penetration

2 Alignment of pipe ends

3 Check globules and slag

(4) Tack welds

(a) Minimum of four

d. Tee, angle joints

(1) Same preparations as butt joint

(2) More difficult to fit up

(a) Use template

3. Operator qualifications

a. TO 00-25-224 Welding High Pressure and Cryogenic Systems

(1) Class A welders

(2) Class B welders

b. Certification

(1) Requirements

(2) Procedures

4. Welding techniques

a. Vertical position

(1) Hold electrode perpendicular to plate

(2) Point electrode down to start

(3) Build shelf

(4) Point electrode upward to continue the weld

(5) Control flow of metal

(a) Use electrode manipulation

1 Allow metal to solidify

2 Arc never broken

(b) Hold short arc

(c) Lower current setting

(d) Smaller electrode

(e) Reverse polarity

(f) E 6010 electrode 3/16" maximum size

b. Overhead position

(1) Hardest position

(a) Overcome forces

1 Cravity

2 Surface tension of electrode

(2) Weld metal transfer

(a) Forces in electric arc

(b) Expansion of gases

(c) electrode

1 E 6010

2 Size 3/16"

(d) Short arc

(e) Angle of electrode

(f) Also helped by

1 Adhesion

2 Surface tension

END OF DAY SUMMARY

Summary

Assignment: have students review 3AZR53250-X-WS-104, notes taken in class.

INTRODUCTION TO NEW DAY'S INSTRUCTION

Continuation.

1. Remotivation

2. Review

Presentation

Application:

1. Given a series of questions concerning special pipe line welding repair, preparation procedures, operator qualifications and welding techniques, select the correct response for 80% of the questions.

Evaluation:

1. Instructor will check students' tests for 80% accuracy.

CONCLUSION TIME:

1. Summary

2. Remotivation

3. Assignment: have students read 3AZR53250-X-WS-105

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LESSON PLAN (Part I, General)

APPROVAL OFFICE AND DATE STI 6 NOV 75	INSTRUCTOR
COURSE NUMBER 3AZR53151-2	COURSE TITLE Welding High and Low Pressure Lines
BLOCK NUMBER I	BLOCK TITLE Welding High and Low Pressure Lines
LESSON TITLE Layout and Fit-up of Various Types of Pipe Joints	

LESSON DURATION

Classroom/Laboratory	Complementary	TOTAL
D&D 1 hr/Perf 2 hrs	None	3 hrs

POI REFERENCE

PAGE NUMBER	PAGE DATE	PARAGRAPH
~~X~~ 3 + 4	12 MAR 75	5

STS/CTS REFERENCE

NUMBER	DATE
CH52-3AZR53151-2	14 APRIL 75

SUPERVISOR APPROVAL

SIGNATURE	DATE	SIGNATURE	DATE

PRECLASS PREPARATION

EQUIPMENT LOCATED IN LABORATORY	EQUIPMENT FROM SUPPLY	CLASSIFIED MATERIAL	GRAPHIC AIDS AND UNCLASSIFIED MATERIAL
1. Portable Oxyacetylene Cutting Equipment consisting of 1 cart, 1 oxygen cylinder, 1 acetylene cylinder, torch complete with cutting tips, regulators and hoses (1)		None	1. 3AZR53151-~~2~~-SG-105 2. TO 00-25-224

(cont on reverse)

CRITERION OBJECTIVES AND TEACHING STEPS

a. Given applicable equipment and pipe specimens, while observing all shop safety measures, lay out and fit up various types of pipe joints. Joints must be beveled to 37 1/2 degree angles with 1/32 inch land face, clean, and free of burrs.

Teaching steps are listed in Part II.

INTRODUCTION TIME:

1. Attention:

2. Review:

3. Overview: During this lesson you will learn layout and fit up of various types of pipe joints for welding.

4. Motivation:

BODY TIME:

Presentation:

1. Layout and fit up of pipe joints for welding

NOTE: Draw joints on chalkboard and layout of each

   a. Butt joint using pipe

      (1) Most common joint

      (2) Where wall of pipe is less than 3/16"

         (a) Bevel 20 to 37 1/2°

      (3) Pipe of large diameter wall thickness

         (a) Use backing ring

      (4) Reinforcement

         (a) Not in excess of 1/16"

   b. Tee joint using pipe

      (1) One member forms an angle to another

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c. Angle joint using pipe

(1) One member forms an angle to another

(a) Problem of fit-up much greater

(b) Template is needed to insure correct fit-up

1 Materials needed for template

a Straight edge

b Triangle

c Compass

d Rule

e Paper and pencil

Application:

1. Given material, students will lay out and fit-up various types of pipe joints in accordance with TO 00-25-224 and TO 34W4-1-5.

2. Students will observe all safety precautions during accomplishment of projects.

Evaluation:

1. Students projects will be checked for proper fit-up and alignment.

CONCLUSION TIME:

1. Summary

2. Remotivation

3. Assignment: have students read 3AZR53151-2-WS-106

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LESSON PLAN (Part I, General)

APPROVAL OFFICE AND DATE	INSTRUCTOR
TWSTI 6 AUG 75	
COURSE NUMBER	**COURSE TITLE**
3A2R53151-2	Welding High and Low Pressure Lines
BLOCK NUMBER	**BLOCK TITLE**
I	Welding High and Low Pressure Lines

LESSON TITLE

Metallic Arc Welding Machines

LESSON DURATION		
Classroom/Laboratory D&D .5 hr/Perf .5 hr	Complementary None	TOTAL 1 hr

PAGE NUMBER	POI REFERENCE PAGE DATE	PARAGRAPH
4 & 5	12 MAR 75	6

STS CTS REFERENCE NUMBER	DATE
CH52-3A2R53151-2	14 APRIL 75

SUPERVISOR APPROVAL SIGNATURE	DATE	SIGNATURE	DATE

PRECLASS PREPARATION

EQUIPMENT LOCATED IN LABORATORY	EQUIPMENT FROM SUPPLY	CLASSIFIED MATERIAL	GRAPHIC AIDS AND UNCLASSIFIED MATERIAL
1. Metallic Arc Welding Equipment consisting of 1 welding machine, welding table, cables and electrode holder (1)	None	None	1. 3A2R53151-2-SG-106 2. TO CC 25-22A 3. Chart: Color Code Classification of Electrodes

CRITERION OBJECTIVES AND TEACHING STEPS

a. Given a metallic arc welding machine, set up and make current adjustments for welding carbon steel pipe joints. Settings are to be made within the range of 80 to 120 amperes.

b. Given arc welding electrodes, select the proper electrodes for welding carbon steel pipe joints in the vertical, overhead, and horizontal positions. Each electrode selected must be equal to AWS E-6010.

Teaching steps are listed in Part II.

ATC FORM AUG 72 770

GPO 1972 779-396/23

INTRODUCTION Time:

ATTENTION:

REVIEW:

OVERVIEW:

MOTIVATION:

BODY Time:

PRESENTATION:

1. Principles of operation and use of various types of electric arc welding machines.

   a. Fundamentals of electricity

      (1) Electrical current has a positive and negative terminal or pole

      (2) Polarity is the direction of current flow

         (a) Straight polarity electrode negative, work positive

         (b) Reverse polarity electrode positive, work negative

      (3) Electric circuit - A complete conducting path over which an electric current flows

      (4) Electromotive Force (EMF) or volt - the push that moves the current

      (5) Ampere - the rate of current flow

(6) Ohm - the unit of resistance to the current flow

(7) Arc stream - a break or gap current flows across

b. Types of welders

(1) A.C. Welders

(a) Transformer

A.C. welders have no polarity choice

1 Most commonly used

2 Most economical

a Lower initial cost

b Lower maintenance cost

3 Rated in amperes

100 to 1200

4 Main parts

a transformer

b frame

c ventilating system

d shell

e adjustment mechanism

(2) AC-DC welding machines

(a) Produces both currents through the use of a rectifier

(3) D.C. Welders

(a) Driven by suitable motive power

1 Gasoline engine

2 Diesel engine

3 Electric motor

(b) Variable voltage type

1 Voltage automatic — 15-45 volts

2 Amperage manual

(c) Dual control type

1 voltage manual

2 amperage manual

2. Set up and adjust welding machine preparatory to welding

a. Current setting

(1) Size of electrode — 1/8 uses approx 110-135 amp.

(2) Thickness of metal

(3) Skill of operator

(a) In general, the proper current settings are obtained from experience and should be adjusted to fulfill the requirements of the particular welding operation.

b. Forces responsible for metal deposition are:

(1) Gravity

(2) Gas expansion

(3) Electric force

(4) Electromagnetic force

(5) Surface tension

c. Magnetic arc blow

(1) Erratic shifting of the arc

(2) Induced by D.C. current

(3) Overcome by

(a) Change position of ground

(b) Change angle of electrode

d. Major factors determining the quality of the weld

(1) Current setting

(2) Length of arc

C.L.A.S.S. Rule

(3) Angle of electrode

(4) Speed of travel

(5) Selection of electrode

3. Perform operator maintenance of arc welding machines

a. Cleaning

b. Check cables electrode holder

c. Fuses

4. Types of coatings on electrodes and types of electrodes

a. Designed with wire core and coated

(1) Prevention of oxides and nitrides

(a) Causes brittleness in weld

b. Types of electrode:

(1) Bare

(2) Light coated

(3) Heavy coated

c. Types of coatings:

(1) Cellulose

(a) Derived from wood pulp, sawdust, cotton or compositions of rayon.

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(b) D.C.R.P. current

(c) Protests weld with gas shield

(2) Mineral

(a) Clay asbestos

(b) D.C.S.P. current

(c) Protects with slag

5. Select and identify electrode types by

a. Military specifications

(1) Air Force Supply Catalogs identify arc welding electrodes by military specification number MIL-E6834

(a) Class A last two digits 12 or 13

(b) Class B last two digits 10 or 11

(c) Class C used to weld chrome molybdenum and chrome nickel molybdenum steel when heat treatment is required

(d) Class D same as class C on only gives deeper penetration

b. A.W.S. numerical and color code

(1) 4 digit code	Example: E6013
(a) Letter stands for electrodes	E
(b) First 2 digits = PSI in thousands	60
(c) Third digit = recommended position	1
(d) Fourth digit = type current	3

(2) Five digit number

(a) Same as 4 except first 3 digits = tensile strength in thousands of PSI

(3) Color code

(a) Primary - top tip of electrode

(b) Secondary - spot or band about 1/2" from top

(c) Group - just below upper edge of flux

6. Most common electrodes

a. E6010

(1) No color marking

(2) All position

(3) DCRP

(4) Cellulose coating

(5) Best for vertical and overhead work

(a) Good penetration

(b) Most used electrode

b. E6011

(1) Blue secondary

(2) All position

(3) AC or DCRP

(4) Designed as 6010 except for use on AC

c. E6012

(1) White on secondary

(2) All position

(3) AC or DCSP

(4) Mineral coating

(5) Very good for poor fit ups

(a) Less penetration

d. E6013

(1) Brown secondary

(2) All position

(3) AC or DCSP

Application:

1. Given equipment and materials students will:

   a. Set up and adjust welding machine for pipe welding without error

   b. Select the proper electrode for pipe welding in the vertical, overhead and horizontal positions without error

2. Students will observe all safety precautions during accomplishment of project

Evaluation:

1. Students' projects will be checked for

   a. Proper set up current adjustment and electrode selection

   b. Use of safety precautions during accomplishment of project

CONCLUSION TIME:

1. Summary:

2. Remotivation:

3. Assignment: Have students read 3AZR53250-X-WS-107

LESSON PLAN (Part I, General) 49

APPROVAL OFFICE AND DATE	INSTRUCTOR
CWSTI 6 ... 75	
COURSE NUMBER 3AZR53151-2	COURSE TITLE Welding High and Low Pressure Lines
BLOCK NUMBER I	BLOCK TITLE Welding High and Low Pressure Lines

LESSON TITLE
Prepare Various Types of Pipe Joints for Welding

LESSON DURATION

Classroom/Laboratory	Complementary	TOTAL
D&D .5 hr/Perf .5 hr	2 hrs	3 hrs

POI REFERENCE

PAGE NUMBER	PAGE DATE	PARAGRAPH
5	12 MAR 75	7

STS CTS REFERENCE

NUMBER	DATE
CH52-3AZR53157-2	14 APRIL 75

SUPERVISOR APPROVAL

SIGNATURE	DATE	SIGNATURE	DATE

PRECLASS PREPARATION

EQUIPMENT LOCATED IN LABORATORY	EQUIPMENT FROM SUPPLY	CLASSIFIED MATERIAL	GRAPHIC AIDS AND UNCLASSIFIED MATERIAL
1. Vapor Degreaser(8) 2. Sandblast Machine (8)	None	None	1. 3AZR53157-2 3c-107 2. TO 00-25-224

CRITERION OBJECTIVES AND TEACHING STEPS

a. Given the applicable equipment and various types of pipe specimens, while observing all shop safety requirements, set up and prepare joints for welding. Specimens must be free of burrs and all organic matter.

Teaching steps are listed in Part II

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INTRODUCTION

TIME:

1. Attention

2. Review

3. Overview

4. Motivation

BODY

TIME:

Presentation

1. Prepare pipe joints for welding
   a. Pipe specimens provided
      (1) Precut
      (2) Beveled
   b. Cleaning procedures
      (1) Remove all:
         (a) Rust
         (b) Scale
         (c) Paint
         (d) Oil and grease

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LESSON PLAN (Part I, General)

APPROVAL OFFICE AND DATE	INSTRUCTOR
ASTI 6 Jun 75	
COURSE NUMBER	COURSE TITLE
3ABR53151-2	Welding High and Low Pressure Lines
BLOCK NUMBER	BLOCK TITLE
I	Welding High and Low Pressure Lines

LESSON TITLE

Metallic Arc Welding of Carbon Steel Pipe Joints

LESSON DURATION

Classroom/Laboratory	Complementary	TOTAL
D&D 1 hr/Perf 17 hrs	4 hrs	22 hrs

POI REFERENCE

PAGE NUMBER	PAGE DATE	PARAGRAPH
6+7	12 MAR 75	8

STS/CTS REFERENCE

NUMBER	DATE
CH52-3ABR53151-2	14 APRIL 75

SUPERVISOR APPROVAL

SIGNATURE	DATE	SIGNATURE	DATE

PRECLASS PREPARATION

EQUIPMENT LOCATED IN LABORATORY	EQUIPMENT FROM SUPPLY	CLASSIFIED MATERIAL	GRAPHIC AIDS AND UNCLASSIFIED MATERIAL
1. Metallic Arc Welding Machine (1) 2. Pedestal Grinder and Buffer (1) 3. Sandblast Machine (8)	NONE	None	1. 3ABR53151-2-SG-108 2. TO [illegible]

CRITERION OBJECTIVES AND TEACHING STEPS

a. Given metallic arc welding equipment and carbon steel pipe specimens, while observing all shop safety measures, set up and weld butt joints in the fixed vertical position. Joints must have 100% penetration and be free of overlap, undercut, and slag inclusions for the entire length of the weld.

b. Given metallic arc welding equipment and carbon steel pipe specimens while observing all shop safety measures, set up and weld angle joints in the fixed vertical position. Joints must have 100% penetration and be free of overlap, undercut, and slag inclusions for the entire length of the weld.

c. Given metallic arc welding equipment and carbon steel pipe specimens, while observing all shop safety measures, set up and weld tee joints in the fixed vertical position. Joints must have 30 to 80% penetration and be free of overlap, undercut, and slag inclusions for the entire length of the weld.

d. Given metallic arc welding equipment and carbon steel pipe specimens, while observing all shop safety measures, set up and weld butt joints in the fixed horizontal position. Joints must have 100% penetration and be free of overlap, undercut, and slag inclusions for the entire length of the weld.

e. Given metallic arc welding equipment and carbon steel pipe specimens, while observing all shop safety measures, set up and weld angles in the fixed horizontal position. Joints must have 100% penetration and be free of overlap, undercut, and slag inclusions for the entire length of the weld.

f. Given metallic arc welding equipment and carbon steel pipe specimens while observing all shop safety measures, set up and weld tee joints in the fixed horizontal position. Joints must have 30 to 80% penetration and be free of overlap, undercut, and slag inclusions for the entire length of the weld.

g. Given metallic arc welding equipment and carbon steel pipe specimens while observing all shop safety measures, set up and weld butt joints in the fixed overhead position. Joints must have 100% penetration and be free of overlap, undercut, and slag inclusions for the entire length of the weld.

h. Given metallic arc welding equipment and carbon steel pipe specimens while observing all shop safety measures, set up and weld angle joints in the fixed overhead position. Joints must have 100% penetration and be free of overlap, undercut, and slag inclusions for the entire length of the weld.

i. Given metallic arc welding equipment and carbon steel pipe specimens while observing all shop safety measures, set up and weld tee joints in the fixed overhead position. Joints must have 30 to 80% penetration and be free of overlap, undercut, and slag inclusions for the entire length of the weld.

Teaching steps are listed in Part II.

INTRODUCTION TIME:

1. Attention

2. Review

3. Overview

4. Motivation

BODY TIME:

Presentation

1. Weld joint of carbon steel in the fixed vertical position

   a. Vertical position welding

      (1) More difficult than flat

      (2) Short arc

      (3) Reverse polarity

      (4) AWS - E - 6010 electrode

   b. Technique for welding vertical

      (1) Hold electrode perpendicular to plate

      (2) Upward tilt of electrode tip

      (3) Point electrode down to start

      (4) Shelf

      (5) Never break arc

(6) 3/16" electrode max diameter for vertical welding

c. Joint preparation and specifications

(1) 1/8" material

(2) No special preparation

(3) 1/4" or heavier

(4) Beveled

(a) J

(b) U

(c) V

2. Weld joints of carbon steel in the fixed overhead and horizontal positions to specifications.

a. Overhead welding

(1) Errection of structures

(2) Hardest position

b. Weld metal transfer

(1) Forces in electric arc

(2) Expansion of gases

(3) Electrode

(a) Type

(b) Size 3/16"

(4) Short arc

(5) Angle of electrode

(6) Also helped by

(a) Adhesion

(b) Surface tension

(c) These help overcome

1 Gravity

2 Surface tension of electrode

c. Preparation and specifications

(1) Clean metal

(2) 1/8" or under

(3) 1/4" or heavier

(4) Beveled

(a) J

(b) U

(c) V

d. Welding Techniques

(1) Hold short arc

(2) Don't weave

(3) Angle depends on type joint

e. Safety

(1) Wear protective clothing

(2) Check for electrical hazards

3. Application: Each student will weld carbon steel pipe butt, tee and angle joints in the fixed vertical, horizontal and overhead positions.

END OF DAY SUMMARY

1. Summary

2. Assignment: Have students review 3AZR53250-X-WS-108 and notes taken in class.

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INTRODUCTION TO NEW DAY'S INSTRUCTIONS

Continuation

1. Remotivation

2. Review

Presentation

Application:

1. Students will continue to weld carbon steel pipe butt, tee and angle joints in the fixed vertical, horizontal and overhead positions.

2. Students will observe all safety precautions.

END OF DAY SUMMARY

Summary:

Assignment: Have students review 3AZR53250-X-WS-108 and notes taken in class.

INTRODUCTION TO NEW DAY'S INSTRUCTIONS

Continuation

1. Remotivation

2. Review

Presentation

Application:

1. Students will continue to weld carbon steel pipe butt, tee and angle joints in the fixed, vertical, horizontal and overhead positions.

2. Students will observe all safety precautions.

Evaluation: Welds will be checked for porosity, slag inclusions, overlap, undercut and penetration.

CONCLUSION TIME:

1. Summary:

2. Remotivation:

3. Assignment: Have students read 3AZR53250-X-WS-109

LESSON PLAN (Part I, General)

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APPROVAL OFFICE AND DATE	INSTRUCTOR
STI 6 JUN 75	
COURSE NUMBER 3AZR53151-2	COURSE TITLE Welding High and Low Pressure Lines
BLOCK NUMBER I	BLOCK TITLE Welding High and Low Pressure Lines

LESSON TITLE
Inert Gas Shielded Arc Welding of Stainless Steel Pipe

LESSON DURATION		
Classroom/Laboratory D&D 2 hrs/Perf 12 hrs	Complementary None	TOTAL 14 hrs

POI REFERENCE		
PAGE NUMBER 8, 9, + 10	PAGE DATE 12 MAR 75	PARAGRAPH 9

STS CTS REFERENCE	
NUMBER CH52-3AZR53151-2	DATE 14 APRIL 75

SUPERVISOR APPROVAL

SIGNATURE	DATE	SIGNATURE	DATE

PRECLASS PREPARATION

EQUIPMENT LOCATED IN LABORATORY	EQUIPMENT FROM SUPPLY	CLASSIFIED MATERIAL	GRAPHIC AIDS AND UNCLASSIFIED MATERIAL
1. Inert Gas Shielded Arc Welding Equipment (1) 2. Pedestal Grinder and Buffer (1)	NONE	None	1. 3AZR53151-2-SG-109 2. T 33-25-224

CRITERION OBJECTIVES AND TEACHING STEPS

a. Given inert gas shielded arc welding equipment, set up and make current adjustments for welding stainless steel pipe joints. Settings must be made within the range of 60 to 80 amperes.

b. Given inert gas shielded arc welding equipment, set up and make correct gas flow adjustments for welding stainless steel pipe joints. Settings must be made within the range of from 10 to 15 cubic feet per hour.

c. Given stainless steel filler rods, select the correct filler rod for welding stainless steel pipe joints in the overhead, vertical, and horizontal positions. Each filler rod must be correctly selected.

d. Given inert gas shielded arc welding equipment and stainless steel pipe specimens, while observing all shop safety measures, set up and weld butt joints in the fixed vertical position. Joints must have 100% penetration and be free of overlap, undercut and surface oxidation for the entire length of the weld.

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☆ GPO 1973 770-380/33

LESSON PLAN (Part I, General) CONTINUATION SHEET

CRITERION OBJECTIVES AND TEACHING STEPS (Continued)

e. Given inert gas shielded arc welding equipment and stainless steel pipe specimens, while observing all shop safety measures, set up and weld angle joints in the fixed vertical position. Joints must have 100% penetration and be free of overlap, undercut, and surface oxidation for the entire length of the weld.

f. Given inert gas shielded arc welding equipment and stainless steel pipe specimens, while observing all shop safety measures, set up and weld tee joints in the fixed vertical position. Joints must have 30 to 80% penetration and be free of overlap, undercut, and surface oxidation for the entire length of the weld.

g. Given inert gas shielded arc welding equipment and stainless steel pipe specimens, while observing all shop safety measures, set up and weld butt joints in the fixed horizontal position. Joints must have 100% penetration and be free of overlap, undercut, and surface oxidation for the entire length of the weld.

h. Given inert gas shielded arc welding equipment and stainless steel pipe specimens, while observing all shop safety measures, set up and weld angle joints in the fixed horizontal position. Joints must have 100% penetration and be free of overlap, undercut, and surface oxidation for the entire length of the weld.

i. Given inert gas shielded arc welding equipment and stainless steel pipe specimens, while observing all shop safety measures, set up and weld tee joints in the fixed horizontal position. Joints must have 30 to 80% penetration and be free of overlap, undercut, and surface oxidation for the entire length of the weld.

j. Given inert gas shielded arc welding equipment and stainless steel pipe specimens, while observing all shop safety measures, set up and weld butt joints in the fixed overhead position. Joints must have 100% penetration and be free of overlap, undercut, and surface oxidation for the entire length of the weld.

k. Given inert gas shielded arc welding equipment and stainless steel pipe specimens, while observing all shop safety measures, set up and weld angle joints in the fixed overhead position. Joints must have 100% penetration and be free of overlap, undercut, and surface oxidation for the entire length of the weld.

l. Given inert gas shielded arc welding equipment and stainless steel pipe specimens, while observing all shop safety measures, set up and weld tee joints in the fixed overhead position. Joints must have 30 to 80% penetration and be free of overlap, undercut, and surface oxidation for the entire length of the weld.

Teaching steps are listed in Part II.

INTRODUCTION TIME:

1. Attention

2. Review

3. Overview: In this lesson you will learn inert gas shielded arc welding machine set up, filler rod selection, current setting and gas flow adjustment for stainless steel pipe welding.

4. Motivation

BODY TIME:

Presentation

1. Principles and uses of TIG

   a. Principles

      (1) Inert Gas

      (2) Protect Weld Area

      (3) Colorless, odorless

      (4) Nontoxic, non-flammable

   b. Source of Power

      (1) AC-DC Current

      (2) Accurate current control

      (3) Superimposes high frequency

      (4) Welding current

         (a) DC straight polarity

            1 Electrode negative

            2 Less chance of arc blow

            3 Used on stainless

e. Torch

(1) Types

(a) Air cooled

1 Thin material

2 AC-DC up to 100 amps

(b) Water cooled

1 Higher current ratings above 100-300 amps

2 1-2 pints of water through the torch per minute

3 45 amps fuse as safety device to prevent overheating in case of water stoppage

4 Water stoppage usually residue or dirt in passage

5 Disconnect waterline reverse water flow

(c) Basic parts of a torch

1 Collet used to hold electrode

2 Cup directs gas flow

3 Torch body

(d) Electrodes

1 Commercially pure

a Green tip

2 1% Thoriated

a Yellow tip

3 2% Thoriated

a Red

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4. Welding joints of corrosion and heat resistant ferrous alloy pipe in the vertical position to specification.

    a. Proper joint preparation as described above

    b. Tack weld

    c. Weld bead application

        (1) Penetration pass

        (2) Stringer beads

5. Welding joints of corrosion and heat resistant ferrous alloy pipe in the overhead and horizontal position.

    a. Proper joint preparation as described above

    b. Tack welds

    c. Weld bead application

        (1) Penetration pass

        (2) Stringer beads

Application:

1. Students will weld butt, angle and tee joints of stainless steel in the fixed vertical, horizontal and overhead positions.

2. Students will observe ~~all safety~~ precautions.

END OF DAY SUMMARY

Summary:

Assignment: Have students review 3AZR53250-X-WS-109 and notes taken in class.

LESSON PLAN (Part I, General)

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APPROVAL OFFICE AND DATE	INSTRUCTOR		
WSTI 6 AUG 75			
COURSE NUMBER	**COURSE TITLE**		
3A2R53151-2	Welding High and Low Pressure Lines		
BLOCK NUMBER	**BLOCK TITLE**		
I	Welding High and Low Pressure Lines		
LESSON TITLE			
Inert Gas Shielded Arc Welding of Aluminum Pipe Joints			
LESSON DURATION			
Classroom/Laboratory D&D 1 hr/Perf 12 hrs	Complementary None	TOTAL 13 Hrs	
POI REFERENCE			
PAGE NUMBER 10 11 + 12	PAGE DATE 12 MAR 75	PARAGRAPH 10	
STS/CTS REFERENCE			
NUMBER CH52-3A2R53157-2	DATE 14 APRIL 75		
SUPERVISOR APPROVAL			
SIGNATURE	DATE	SIGNATURE	DATE

PRECLASS PREPARATION

EQUIPMENT LOCATED IN LABORATORY	EQUIPMENT FROM SUPPLY	CLASSIFIED MATERIAL	GRAPHIC AIDS AND UNCLASSIFIED MATERIAL
1. Inert Gas Shielded Arc Welding Machine (1) 2. Pedestal Grinder and Buffer (1)	NONE	None	1. 3A2R53151-2-SG-110 2. TD 00 25-224

CRITERION OBJECTIVES AND TEACHING STEPS

a. Given an inert gas shielded arc welding machine, while observing all shop safety measures, set up and make correct current adjustments for welding aluminum pipe joints. Settings must be made within the range of 110 to 130 amperes.

b. Given an inert gas shielded arc welding machine, while observing all shop safety measures, set up and make correct gas flow adjustments for welding aluminum pipe joints. Settings must be made within the range of 10 to 15 cubic feet per hour.

c. Given aluminum and aluminum alloy filler rods, select the correct filler rod for welding aluminum or aluminum alloy pipe joints. Filler rod selected must be of the same chemical composition as the joint being welded.

d. Given inert gas shielded arc welding equipment and aluminum or aluminum alloy pipe specimens, while observing all shop safety measures, set up and weld butt joints in the fixed vertical position. Joints must have 100% penetration and be

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free of overlap, undercut, and surface oxidation for the entire length of the weld.

e. Given inert gas shielded arc welding equipment and aluminum or aluminum alloy pipe specimens, while observing all shop safety measures, set up and weld angle joints in the fixed vertical position. Joints must have 100% penetration and be free of overlap, undercut, and surface oxidation for the entire length of the weld.

f. Given inert gas shielded arc welding equipment and aluminum or aluminum alloy pipe specimens, while observing all shop safety measures, set up and weld tee joints in the fixed vertical position. Joints must have 30 to 80% penetration and be free of overlap, undercut, and surface oxidation for the entire length of the weld.

g. Given inert gas shielded arc welding equipment and aluminum or aluminum alloy pipe specimens, while observing all shop safety measures, set up and weld butt joints in the fixed horizontal position. Joints must have 100% penetration and be free of overlap, undercut, and surface oxidation for the entire length of the weld.

h. Given inert gas shielded arc welding equipment and aluminum or aluminum alloy pipe specimens, while observing all shop safety measures, set up and weld angle joints in the fixed horizontal position. Joints must have 100% penetration and be free of overlap, undercut, and surface oxidation for the entire length of the weld.

i. Given inert gas shielded arc welding equipment and aluminum or aluminum alloy pipe specimens, while observing all shop safety measures, set up and weld tee joints in the fixed horizontal position. Joints must have 30 to 80% penetration and be free of overlap, undercut, and surface oxidation for the entire length of the weld.

Teaching steps are listed in Part II.

INTRODUCTION TIME:

1. Attention

2. Review

3. Overview: In this lesson you will learn inert gas shielded arc welding machine set-up, filler rod selection, current setting and gas flow adjustments for aluminum pipe welding.

4. Motivation

BODY TIME:

Presentation

1. Principles and uses of TIG

   a. Principles

      (1) Inert Gas

      (2) Protect weld area

      (3) Colorless, odorless

      (4) Nontoxic, nonflammable

   b. Source of power

      (1) AC-DC Current

      (2) Accurate current control

      (3) Super imposes high frequency

      (4) Welding current

         (a) DC straight polarity

(3) Gas flow is measured in litres per hour or in cubic feet per hour

e. Torch

(1) Types

(a) Air cooled

1 Thin material

2 AC-DC up to 100 amps

(b) Water cooled

1 Higher current ratings above 100-300 amps

2 1-2 pints of water through the torch per minute

3 45 amps fuse as safety device to prevent over-heating in case of water stoppage

4 Water stoppage usually residue or dirt in passage

5 Disconnect waterline reverse water flow

(c) Basic parts of a torch

1 Colet used to hold electrode

2 Cup directs gas flow

3 Torch body

(d) Electrodes

1 Commercially pure

a Green tip

(2) 6061-T6

b. Type Filler Rod

(1) 4043 5% Silicon rod

4. Machine adjustment prior to welding

a. Current

(1) AC high frequency

(2) DCSP straight can be used

b. Tungsten

(1) AC-HF use 2% Thoriated

(2) DCSP - uses pure tungsten

5. Weld aluminum pipe vertical

a. Direction of travel

b. Speed of travel

c. Heat control

d. Filler rod deposit

e. Torch angle

f. Stop and starting of welds

6. Weld aluminum pipe horizontal position

a. Direction of travel

b. Speed of travel

c. Heat control

d. Filler rod deposit

e. Torch angle

f. Stop and starting of welds

7. Safety

a. Protective equipment

Evaluation:

1. Check students welds for porosity, contamination, undercut and overlap.

CONCLUSION TIME:

1. Summary

2. Remotivation

3. Assignment: Prepare for course exam.

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Technical Training

Welding High and Low Pressure Lines

BLOCK I
WELDING HIGH AND LOW PRESSURE LINES

5 December 1973

CHANUTE TECHNICAL TRAINING CENTER (ATC)

This supersedes 2ASR53250-30-SG-100, 16 March 1972.
OPR: TWS
DISTRIBUTION: X
TWS - 100; TTOC - 2

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TABLE OF CONTENTS

MODIFICATIONS

Pages 1 & 2 of this publication has (have) been deleted in adapting this material for inclusion in the "Trial Implementation of a Model System to Provide Military Curriculum Materials for Use in Vocational and Technical Education." Deleted material involves extensive use of military forms, procedures, systems, etc. and was not considered appropriate for use in vocational and technical education.

Metal and NDI Branch
Chanute AFB, Illinois

3AZR~~53250-4~~-SG-102 53151-2- 71

PRACTICE SHOP SAFETY REQUIREMENTS IN THE PERFORMANCE OF REQUIRED TASKS

OBJECTIVES

After completing this study guide and your classroom instruction, you will answer questions concerning protective equipment, and general shop safety practices. Safety practices will include the use of arc welding machines, grinders, and oxyacetylene cutting equipment.

INTRODUCTION

Personal safety and fire prevention are especially important in metals processing because of the types of equipment which are used. The use of gas welding and arc welding equipment involves working with open flames and exposed electric arcs. Weld repair of fuel lines, if proper precautions are not observed, can expose the worker to explosive or toxic gases. We will discuss specific safety and fire precautions relating to the various items of equipment and metals processing operations as we come to them in the course. In this study guide we mention briefly general precautions which must be observed with regard to shop safety, health, and safety equipment.

As a welder, you must be familiar with the correct procedure for the set-up and operation of both stationary and portable oxyacetylene welding equipment. Air Force shops make extensive use of portable welding equipment. In shops which have stationary equipment, the portable outfit is used for work which cannot be done in the shop. Basically, the equipment used for each is the same except that the gases are piped to the welding station in a stationary setup, while the portable outfit is operated directly from the cylinders of gases which are mounted on a cart or truck. Double stage (two gauge) regulators must also be used on portable outfits. The welding outfit is your most important tool as a welder. You must be familiar with the proper care of the outfit and be able to maintain each unit of the welding setup.

INFORMATION

SHOP SAFETY

These general shop safety rules must be strictly enforced:

1. Keep oily or greasy rags in covered metal containers.

2. Wipe up oil or grease spots from the floor and the work bench immediately.

3. Do not weld in the vicinity of flammable materials.

4. Make certain that a fire extinguisher is near before you begin welding.

5. Don't allow hoses or arc welding leads to clutter the area and become stumbling hazards.

6. Keep all handtools and special tools not in use in their proper places.

7. Store metals in a stock rack.

8. Keep the shop area clean, well lighted, and well ventilated.

HEALTH AND SAFETY EQUIPMENT

Observe these health and safety equipment rules:

1. Do not wear ragged clothing, or clothing with open pockets, missing buttons, or rolled cuffs.

2. Do not wear low cut shoes.

3. Wear approved helmets and lenses, gloves, and aprons for protection against infrared and ultra-violet rays when arc welding.

4. Warn all persons near electric welding operations against looking at the arc.

5. Wear the type of goggles appropriate for the types of welding being performed. Wear goggles while you are using a cutting torch.

6. Wear chipping goggles to protect against flying hot slag when you are cleaning welds.

7. Mark hot metal. Do not leave hot metal in places where it will create a hazard.

8. Do not hold hot welded material with rags or gloves which you use for buffing or grinding.

9. Cool all welds prior to buffing, grinding, or inspection.

10. When you are electric welding outside the stationary booth, inclose the area with a portable screen to protect personnel from possible eye damage.

FIRE PREVENTION

Equally as important as good housekeeping is an efficient fire prevention system. You should carry out all safety precautions that pertain to the prevention of fires. You must know what to do when a fire occurs. Many fires are caused by carelessness and by poor housekeeping. Oily rags are fire hazards. Poor storage practices, especially of flammable materials, may cause fires. Overloaded electrical outlets and defective circuit breakers are also fire hazards. Here are a few precautions that you should observe; you can add to the list from your own experiences.

1. Do not allow oily rags to accumulate.

2. Observe the signs in the NO SMOKING areas.

3. Do not allow your clothing to become saturated with fuel or oil. If they do, change your clothing as soon as possible.

4. Do not store gasoline, kerosene, jet fuel, or any other flammable fuel in open containers.

5. Make sure that the static lines are in place and that the aircraft is grounded properly before you work on it.

6. Do not open any oxygen valve near a flame or a lighted cigarette.

Since fires will occur, no matter how many precautions are taken, you must be ready to fight them quickly and effectively. You should know the telephone number of the base fire department, the location of the fire extinguishers, and which type of extinguisher to use for the type of fire you are fighting. The telephone of the base fire department is usually posted in large letters on posters in the shop, in the barracks, and on the flight line. As a rule, the base telephone directory has this number printed in large letters on the cover page or on one of the first pages of the book. If alarm boxes are installed on your base, learn where they are and how to use them. Locate the fire extinguisher in your immediate area, determine what type it is, and learn how to use it if the need ever arises.

WELDING AND CUTTING SAFETY

Because of the potential fire and explosion hazards present in any welding or flame cutting operation, safety rules must be followed very closely to avoid injury to personnel or damage to equipment.

1. No welding should be done on combustible materials or containers until the containers have been properly flushed and steamed.

2. Tanks removed from aircraft for flushing and steaming must be electrically grounded during the operation.

3. Welding on aircraft is to be done only in the case of emergency and by special permission of an officer or supervisor charged with the responsibility for welding and flame cutting operations.

4. If welding must be done within 100 feet of tanks containing flammable liquids or vapors, no one shall be allowed to work on the tank or remain closer to the tank than the welder.

5. A fire extinguisher must be in the immediate vicinity when welding must be done. One or more fire extinguishers should be carried as regular equipment on all portable welding apparatus.

Storage and Handling of Cylinders

1. Oxygen and acetylene cylinders should be stored separately in a cool, well ventilated, fireproof building.

2. Explosion-proof electrical equipment must be used in cylinder storage rooms.

3. No open flames, grinding tools, or spark-emitting devices should be used within the storage room.

4. Smoking or carrying matches must not be allowed in the storage room.

5. Cylinders should be stored in an upright position while in storage.

6. Cylinders must not be stored near combustible material.

7. Cylinders should be handled with more than ordinary caution. Rough handling may cause leaks that may result in an explosion.

8. Oil and oxygen under pressure may form a self-explosive mixture; therefore, no oil, gases, or lubricants of any kind should be used on oxygen cylinders or regulator connections.

Operation and Maintenance of Stationary and Portable Oxyacetylene Welding Outfits

1. Regulators are to be used only for the gases for which they are intended.

2. Welders must know the identifying characteristics of both oxygen and acetylene regulators.

3. Cylinder valves should be opened slowly; the oxygen valve should be opened fully, and the acetylene valve not more than one and one-half turns.

4. The acetylene cylinder valve wrench must be left in place on the acetylene cylinder valve so that the acetylene can be shut off quickly in case of an emergency.

5. Surplus hose should be coiled and out of the way of sparks and the flame.

6. When a flashback occurs, both torch valves must be shut off immediately, the acetylene valve first and then the oxygen valve. The torch should then be cooled and inspected before relighting.

7. When a backfire occurs, the tip size should be decreased or the pressure and volume of gases increased to overcome the burning back into the tip chamber.

8. When a job is completed, the cylinder valves must be closed; the regulator hose and torch should be bled to release the gas pressures; the regulator adjusting screws should be fully released; and the torch valve should be closed.

9. Copper tubing should not be used to splice acetylene hoses as an explosion could occur (copper, acetylite gas).

10. Only commercial bronze, brass, or steel fittings should be used to repair oxyacetylene equipment.

11. Faulty regulators must not be used and only qualified personnel may make repairs on regulators.

12. The acetylene operating pressure should never exceed 15 lbs per square inch on oxyacetylene equipment.

QUESTIONS

1. Where should oily rags be kept after use?

2. Prior to buffing or grinding a piece of metal after welding, what should you do?

3. How and where are oxygen and acetylene cylinders stored?

4. Who will repair oxyacetylene equipment regulators?

REFERENCES

AFM 127-101, Industrial Safety Accident Prevention Handbook.

PIPE WELDING REQUIREMENTS AND SPECIFICATIONS

OBJECTIVES

After completing this study guide and your classroom instruction, you will answer a series of questions on the specifications and requirements for pipe welding.

INTRODUCTION

Although, welding at first glance seems to be a very simple process, every bead welded, regardless of type of material or position of the weld is rigidly controlled. These controls are called weld specifications and give the correct dimensions and shape of every type of weld. They go hand in hand with weld requirements. In the simplest terms, weld requirements tell you what is needed and the specifications tell you how to achieve it.

INFORMATION

A welded pipe section is known to be the most efficient for application where handling of oil, gases, water, and other substances range from high vacuum to pressures of several thousand pounds per square inch. Mechanical joints are not satisfactory for many of these services. Electric arc welding provides effective joints in these services and also reduces weight, increases the strength, and lowers the cost on pipe maintenance and installation.

SPECIFICATIONS

Welding current, electrode size, mean voltage, and manner of depositing the weld metal shall be such that there will be no undercutting on the sidewalls of the welding groove or adjoining base metal. Each bead or layer of deposited weld metal shall be uniform, and shall blend smoothly and gradually with the base metal. Cracks or defects that appear in any bead or layer of weld deposit shall be removed before depositing the next successive bead or layer of weld metal in that location.

Root weld deposits shall have full penetration for the full length of the joint, and shall be started midway between tacks; subsequent passes shall be started 1/4 to 1/2 inch on the preceding pass. After every interruption of the arc, except at the completion of a pass, the arc shall be restarted ahead of the previous deposit and then moved back to fill the crater. This technique will ensure complete filling of the crater; complete fusion between the new and old deposits and the base metal at the point of junction; and complete resultant continuity of weld. Unfilled arc craters in weld deposits are not permitted, and will be rejected. Before welding

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over previously deposited metal, all traces of oxides, slag, and foreign material shall be removed from the weld deposit, and the weld deposit and adjoining base metal shall be wire brushed until thoroughly clean at all points. This shall apply not only to successive layers, but also to successive beads and to the overlapping area wherever a junction is made when starting a new bead or layer. All materials must be bright and clean throughout the welding operation.

Butt Welds

Butt welds shall have one pass for each 1/8 inch of pipe wall thickness. Butt welds and saddle welds shall be flush with the inside of the pipe. In cases where grinding is not possible, butt welds shall have a finished bead width approximately 1/16 inch on each side of the bevel. Under no conditions are wide beads to be used to cover poor fitup.

Reinforcement

Reinforcement of butt welds shall be not less than 1/16 inch, nor more than 3/32 inch above the surface of the base metal. Reinforcement shall be built up uniformly from the surface of the base material, to a maximum at the center of the weld; and shall blend smoothly and gradually with the base material at the weld edges. Finished weld contours shall be uniform and free from depressions lower than the surface of the base metal.

Inspection

Appearance of completed welds shall be reasonably smooth and uniform. They will be free from surfaced defects. All slags, weld spatter, and foreign material shall be removed from the surface of weld deposits and adjoining base metal. Completed fabrication shall have a bright, clean, surface.

Welds which require radiographic examination shall have the outside and inside weld ripples or surface irregularities removed where possible. This will be done by any suitable mechanical process. Removal of irregularities shall be such that the resulting radiographic contrast from any remaining irregularities cannot mask or be confused with that of any objectionable defects.

Requirements

The welded joint, in order to meet the requirements, must be of sound quality. In the case of a joint that is to be X-rayed, it is considered to be sound only if there is no evidence of inclusion, blow holes, burn through, cracks, porosity, or undercutting. X-ray of a welded joint is not the only method of testing a weld, you can also use a tensile test. The tensile test requires that a joint be considered satisfactory if the failure occurs in the base metal and not the joint. The weld can break next to the welded

SPECIAL PIPELINE WELDING REPAIR APPLICATIONS

OBJECTIVES

After completing this study guide and your classroom instruction, you will answer a series of questions concerning pipeline welding preparation procedures, operator qualifications, and welding techniques for special pipeline welding repair applications.

INTRODUCTION

Each of us appreciate a pat on the back for a job well done. The only way to do the job is the proper preparation of the joint; being qualified to complete the joint and to apply the proper techniques while doing the joint. This is the key to a job well done.

The objective of this lesson is to provide personnel who possess an AFSC 53250 or higher with the latest technical information on welding requirements. These requirements are specified by AFR 66-25, "Qualification of Weldors," and Military Specification MIL-T-5021D, "Aircraft and Missile Welding Operator's Qualification."

Subject material includes the welding of carbon steel, stainless steel, and aluminum alloy pipe in the fixed position; and inspection of welded repairs and safety requirements.

INFORMATION

PIPELINE REPAIR

Practically all metals can be welded successfully. Some of the metals require special welding applications in order to successfully join them. The welding of pipe joints is a popular means of making a pipe installation. The advantages of pipe welding is neatness, compactness, rigidity, and low cost. Arc welding can be satisfactorily done on pipe, but the welder must be adapt in flat, horizontal, vertical, and overhead welding techniques. Skill in the various position welding techniques is required because of the many positions involved in pipe installations. Inert gas welding of pipe gives excellent results. The high pressure pipe lines use this method of welding to ensure sound welds.

All metals cannot be welded without the use of special materials and supplementary operations, in that some metals, more than others, are susceptible to alteration caused by heat generated during the welding process. The application of heat produces a variety of structural, thermal, and mechanical effects on the metal being welded, and on any metal which may be added in making the weld. Technique of application and base metal as well as filler metal characteristics are prerequisites for producing a weld that is metallurgically equal to the service for which it is intended.

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WELDING CONTROL

To obtain satisfactory results during welding, it is necessary to examine the factors affecting the deposition of sound weld metal. The following factors will govern quality.

1. Cutting and edge preparation.
2. Cleaning.
3. Fitting up and tack welding.
4. General requirements.
5. Angle of electrode.
6. Welding current.
7. Travel speed.
8. Preheating.
9. Peening.
10. Conformance to welding procedure specifications.

PREPARATION PROCEDURES

Cleaning

The welding faces and the adjoining pipe surfaces should be cleaned back at least 1/4 inch from the welding groove. All rust, paint, scale, oil, or grease should be removed by either a chemical or mechanical method. It is difficult, if not impossible, to secure penetration and fusion to the base metal and a sound weld deposit unless you have a clean surface.

Alignment

Before welding, the pipe must be carefully lined up. If the two pieces to be joined have the same internal diameter, backing rings may be used to bring the bore of the two pieces into alignment, regardless of wall thickness. When backing rings are not used, the two pipes or fitting ends are often secured in a fixed position by means of an external clamp, or by positioning in a channel or section of angle iron large enough to permit the ends to fall into proper line, as shown in figure 1. Where the pipes meet at an angle, a suitable jib may be constructed if a number of such joints warrant its construction. Proper alignment for angular members can be closely maintained by predetermined allowances for contraction of the weld, along with proper welding procedures, thus eliminating the need for a jig.

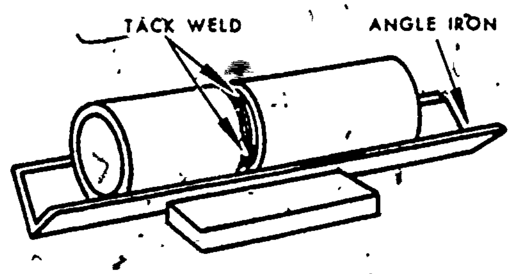

Figure 1. Angle Iron Serving as Jig For Small Diameter Pipe.

Tacking

After the joint is aligned, tack weld at regular intervals prior to actual welding. This maintains the joint alignment and permits you to remove any external fastenings which have been used for this purpose and which would interfere with the complete welding of the joint. Tack welding also permits you to handle the pipe after setting-up and before welding. As a rule, the length of the tack welds in arc welding should be two to three times the thickness of the parts joined. Tack welds should be thoroughly fused into the main weld.

WELDING TECHNIQUES

Pipe welding involves no new principles of welding. The main difference is that the position of the work or the welder must be constantly changed due to the circular form of the pipe.

There is no definite direction for welding pipe in a fixed position. The preferred direction is usually from the bottom upward. However, considerable welding, especially of thin or medium wall thickness pipe, is done in the opposite direction. Ordinarily, more metal per layer is deposited in welding upward, and the requirement of having the layers thin enough to undergo complete grain refinement must be watched. On the other hand, downward welding requires a higher degree of skill to secure adequate fusion with the side walls and to avoid trapping the slag.

The number of passes required in making a pipe weld varies with the wall thickness of the pipe and the position of the pipe when it is welded. When the work can be rolled or when the pipe is in a fixed horizontal position, a layer of metal is deposited across the full width of the welding groove during each pass. With the pipe in a fixed vertical position, the metal is deposited in a series of stringer beads. Regardless of the position of the pipe, there is usually one layer or pass for each 1/8 inch of wall thickness.

Each layer of weld metal should be thoroughly cleaned before depositing the next layer. Chip with a slag hammer and clean with a wire brush to remove all the slag deposits.

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Weld Repair

When a weld is to be repaired, the defect should be removed by chipping, machining, flame gouging, or flame cutting. After removing the defect, clean and shape the repair area so that a sound weld deposits can be obtained.

Procedure

1. Cut two pieces of pipe to the required length.

2. Clean and bevel the joint ends, as shown in figure 2.

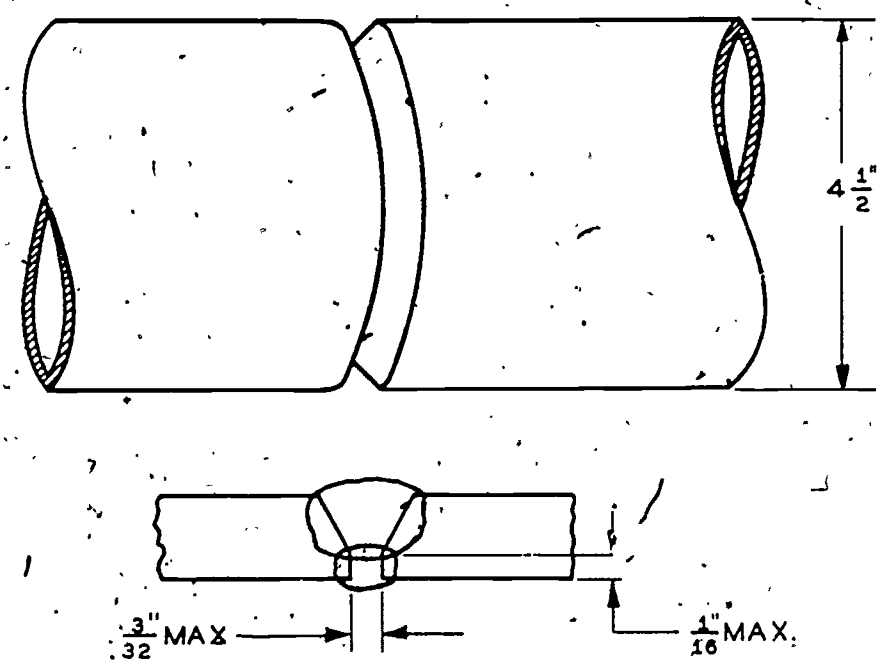


Figure 2. Butt Weld in Pipe.

3. Set up work in V blocks or at an angle and tack weld at four equally spaced points.

4. Using one hand to turn the work, weld the first pass using a 1/8 inch diameter electrode.

5. Chip off the slag and inspect the weld for penetration and fusion.

6. Weld the second pass in the same manner, using a 3/32 inch electrode.

7. Check the weld joints for welding faults.

QUESTIONS

1. List three preparation procedures.

2. What direction of travel is usually preferred when welding pipe?

3. What is done to prepare defective welds for rewelding?

REFERENCES

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

LAYOUT AND FIT-UP OF VARIOUS TYPES OF PIPE JOINTS

OBJECTIVES

After completing this study guide, assigned study, and your classroom instruction, you will lay out and properly fitup various types of pipe joints.

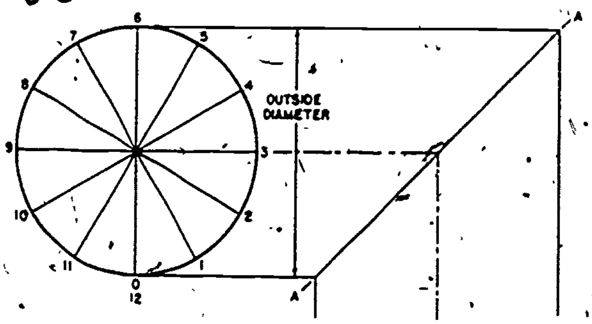
INTRODUCTION

Pipe welding is like working a jigsaw puzzle. Although you have a picture of the finished product in front of you, you still have to put the pieces together. Without learning the proper procedure for laying out and fitting up of various pipe joints, you may never get your "pipe puzzle" together.

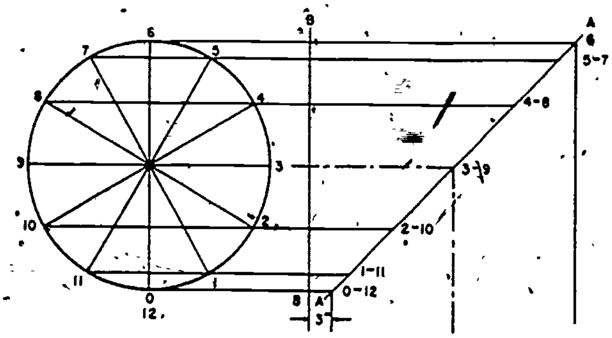
INFORMATION

The materials necessary for making patterns consist of a straight edge, triangle, compass, rule, piece of heavy paper, and a pencil. In preparing to lay out a pattern for a 90 degree bend, as shown in figure 3, first determine the size of the pipe, then proceed to lay out the pipe joint in actual size. Use the outside lines of the pipe to represent the outside diameter, as shown in figure 3, step 1. Next, inscribe a circle and divide it into 12 equal parts, numbering them beginning with zero (step one). Extend these points over the line AA and number the intersections so that they correspond with the points of the circle, as shown in figure 3, steps one and two. Draw the line BB at a right angle to the diameter, starting it exactly three inches from the right corner. This completes the preliminary details prior to making the actual pattern.

Now, proceed to lay off line CC, which represents the circumference of the circle, as shown in figure 3, step 3. Divide this line into as many equal parts as the circle was divided into, and number them, beginning at the left with zero. At each division, draw a line at a right angle to CC. Now, starting at 0, lay off the vertical line a length equal to B-0; on line 1, B-1; and so on until B-12 is laid off, which is equal to B-0. Now, join the extremities of these lines and the result should be the curve AA, which corresponds to the line A'A', as shown in step 3. The pattern is now cut out by cutting along the edges [illegible], A'A', A'C, and CC.



Laying Out a Pattern for a 90° Bend (First Step).



Laying Out a Pattern for a 90° Bend (Second Step).

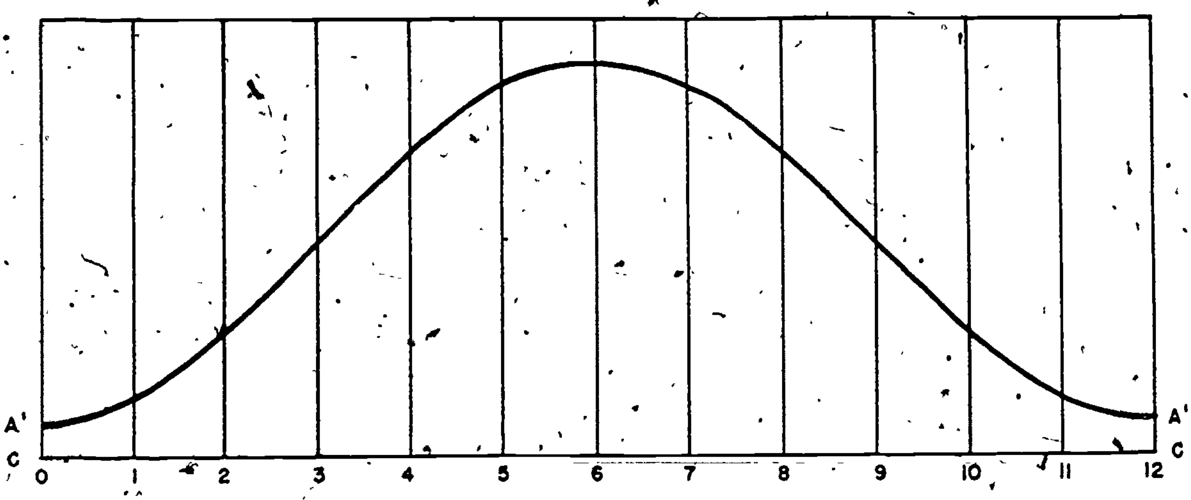


Figure 3. Pattern for 90° Bend.

The pattern is then wrapped around the pipe, holding it in position with one hand and marking an outline on the pipe with soapstone following the line A'A'. This is the cutting edge. Cutting the two pieces of pipe on the line A'A' and butting them together results in a 90 degree bend which should require no trimming other than beveling of the edges.

The procedure, as outlined above, can be applied to any sort of a pipe joint. If a pattern for a tee is to be made, the joint is laid out as in figure 4. The pattern is to be wrapped around the outlet of the tee so the circle is inscribed in the outlet and not in the run.

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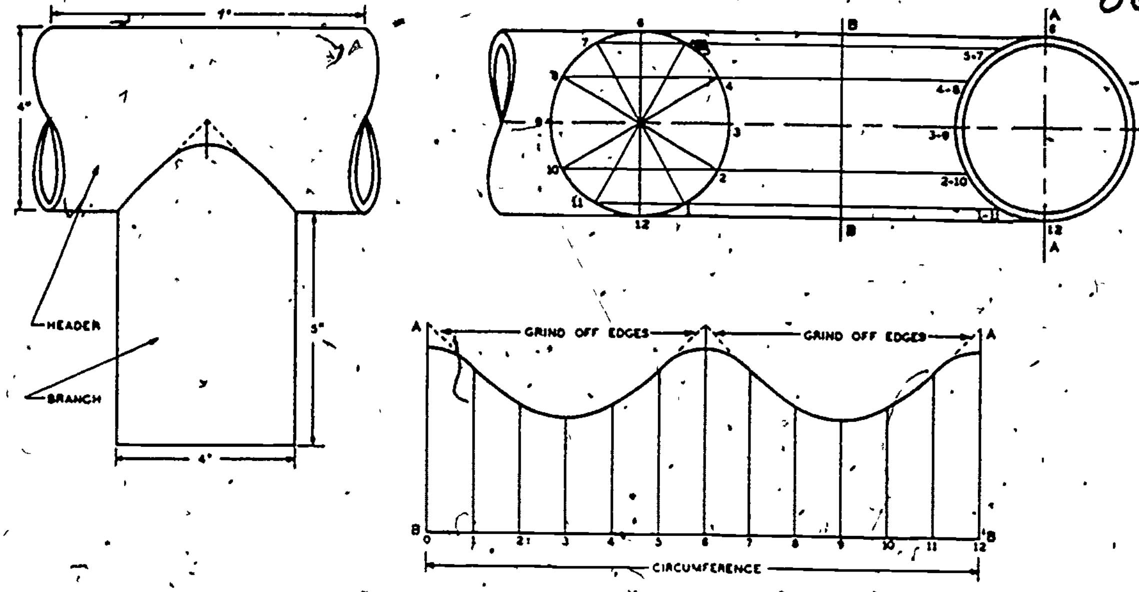

Figure 4. Laying Out the Pattern for a Tee.

The difference between this pattern and the previous pattern for the ell is that the cutting line AA is half a circle instead of a straight line. After the outlet is cut along the edge A'A' on the pattern, it is placed in position on the run and the outline marked and cut, the outlet serving as a pattern to cut the opening in the run. This procedure may also be used in laying out patterns for a pipe elbow, as shown in figure 5.

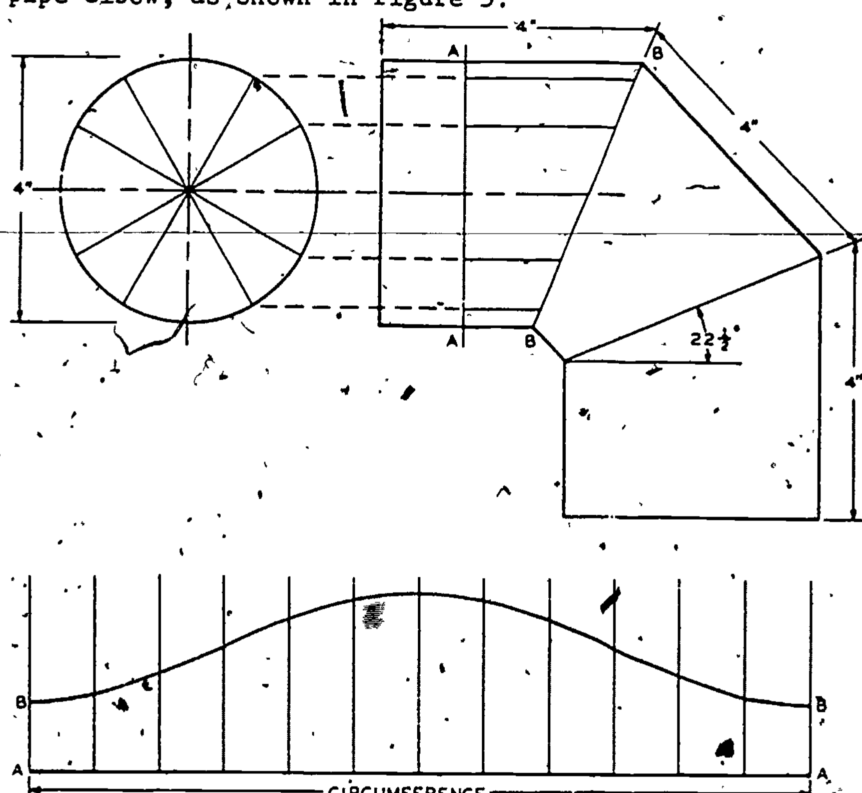

Figure 5. Layout of Welded Angle Joint of Heavy Pipe Construction.

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QUESTIONS

1. What materials are necessary to prepare a pattern for cutting pipe?

2. What is the difference between a pattern for an ell and a tee joint?

REFERENCES

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

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METALLIC ARC WELDING MACHINE

OBJECTIVES

After completing this study guide, assigned study, and your classroom instruction, you will set up the arc welding machines and select the proper electrodes for welding carbon steel pipe in the vertical, horizontal, and overhead position.

INTRODUCTION

The electric current used for metallic arc welding is supplied by a machine that converts line voltage of 110, 220, or 440 volts to a low voltage, high amperage current. The heat is generated in the space between the end of a consumable electrode and the base metal by the current jumping this space and creating an electric arc. The temperature of this arc varies from 5000 degrees to 10,000 degrees. Since you must know what controls this arc and why it needs to be controlled, you should become thoroughly familiar with the operation and maintenance of the various types of arc welding machines.

INFORMATION

The function of an electric arc welding machine is to provide the source of current necessary for welding. It also provides a means for sustaining and controlling the amount of welding current. These functions are achieved in many ways, representing numerous design features of the manufacturer. Although arc welding machines may be classified in various ways, you should be mainly interested in the type of current flow induced by the arc. They may be broadly classified as either direct current (DC) or alternating current (AC). In recent years, however, electronic and selenium plate rectifiers have been developed which operate on AC and produce a DC welding current.

DIRECT CURRENT ARC WELDING MACHINES

DC arc welding machines are suitable for use on all metals. They usually produce more satisfactory results for welding thin materials because low current settings are required. The type of machine best suited for metallic arc welding depends upon many factors. The main difference between AC and DC arc welding is in the lower initial and operating costs of AC equipment.

Electric Motor-Driven Generator

The most widely used welding machines are of the motor generator type, which operate by electric power to produce direct current of the proper characteristics for arc welding. They consist of a driving motor and a direct current generator with the armature

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of the generator mounted on the same shaft as the rotor of the driving motor. The shaft is supported at each end by ball bearings and the machine is made as compact as possible. Two controls for the welding current are provided: one for large increases or decreases, and the other for small changes. Some machines provide a switch for changing polarity; others require changing the position of the welding cable leads. A pushbutton switch, located on the control panel, allows convenient starting and stopping of the machine and overload protection for the driving motor. A voltmeter and ammeter permit you to set the machine to the correct current output. Most of these machines are mounted on a chassis so that you can move them around the shop. They can be mounted either vertically or horizontally. Motor-driven generator welders are rated by current output in amperes and range from 100 to 1200 amperes. A 300 amp welder is the average size used in most Air Force welding shops. These current ratings represent the amount of current which the machine can generate continuously for one hour without exceeding a specific temperature rise. They can deliver more than the rated current for a short period without damage to the machine.

Engine-Driven Generator

When an electric power source is not available, a gasoline or diesel engine is used to drive the welding generator. The engine is equipped with automatic throttle control and a governor to control the power demand on the generator. The complete unit, figure 6, is usually mounted on a trailer type chassis and can be towed to the job site.

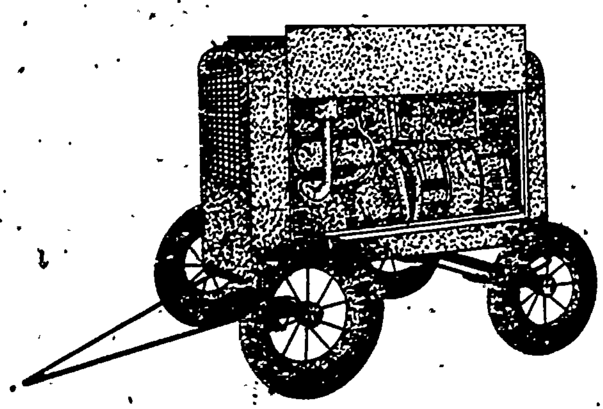

Figure 6. Portable Gasoline-Engine Driven Arc Welder.

The voltage of such a generator usually ranges from 15 to 45 volts across the arc, although any setting is subjected to constant variation due to changes in the arc length. Current output may vary from 20 to 800 amps, depending on the type of unit. In most DC welders, the generator is a variable voltage type and is arranged so that the voltage automatically adjusts itself to the proper demands of the arc. The amperage is adjusted manually and is set to the proper range by either a selector switch or a series of plug receptacles. When both voltage and amperage of the welder are adjustable by manual controls, the machine is classified as a dual control type, figure 7.

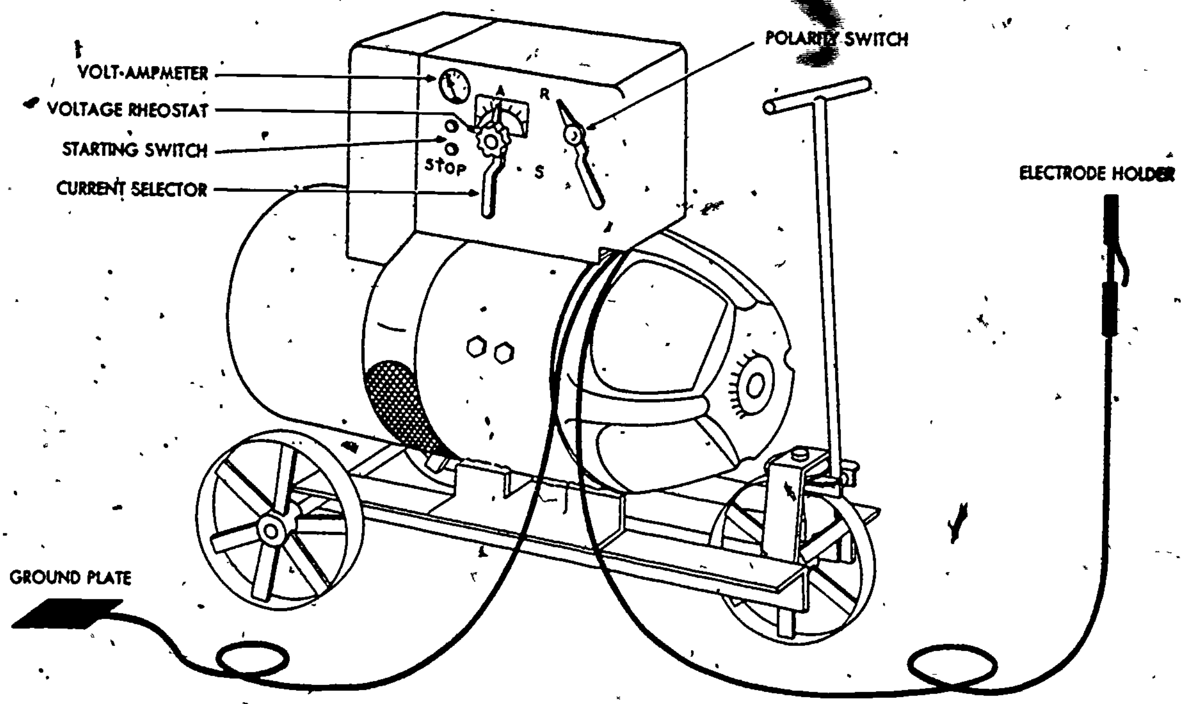

Figure 7. DC, Motor Generator Arc Welding Machine.

Rectifier Welder

The rectifier welder changes alternating current to direct current for welding. Electronic tubes or selenium plates are used to change or rectify three phase alternating current to direct current. There are controls to change the welding current, open circuit voltage, and change polarity. The current output of these machines allows a stable arc to be held at any setting from 5 to 75 amps. This allows you to weld metals as thick as 1/16 inch as easily as welding materials 1/4 inch thick.

ALTERNATING CURRENT ARC WELDING MACHINES

Two general types of AC arc welders are the transformer and rotating types. Most AC arc welding machines are essentially static transformers. The transformer offers three advantages: low initial cost, low operating cost, and low maintenance cost. Due to the absence of moving parts, the initial and maintenance costs are less than those for DC machines.

Transformer Type

The transformer type of AC welding machine operates from one phase of the power supply. The primary winding is connected

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to the power line and the secondary winding is connected to the welding cables. Some machines have the transformer windings tapped at intervals to allow you to make changes in the welding current. By using the different taps, you can increase or decrease the current to suit your needs. Other machines have a movable coil or core which is controlled by a hand wheel. Current settings are made by either turning the hand wheel clockwise or counterclockwise to raise or lower the current setting. These machines are rated by current output and are available in a wide range of current settings. Since these transformers draw current only during the time the weld is being run, they give remarkable economy in power consumption. They are easy to adjust to the required current settings and require very little maintenance.

Rotating Type

The rotating type of welding machine is a motor generator and may be combined with a frequency changer to allow the welding machine to be converted to heli-arc operations, or a phase changer to supply auxiliary power for tools or lights. A two position switch permits you to select either a high or low current. An auxiliary control is used for fine current adjustments.

Accessories

Arc welding machines require certain accessories to make a complete welding set.

WELDING CABLES. Welding cables are rubber-covered, multistrand, copper cables made specifically for arc welding. The size of cable you may use depends on the normal welding current and the distance from the machine to the work. For distances up to 50 feet, a 200 ampere machine should have a No. 2 cable, a 300 ampere machine should have a No. 0 cable, and a 400 ampere machine should have a No. 00 cable.

ELECTRODE HOLDER. The electrode holder is attached to one of the welding cables, and has a clamping device for holding the electrode. Various sizes are available according to the amperage capacity of the welding machine.

MAINTENANCE OF ARC WELDING MACHINES

Due to the amount of dust and grit present in all welding shops, proper maintenance of equipment is very important. Although you can perform routine maintenance, you should have a qualified electrician perform any extensive repair or adjustment. The following periodic maintenance schedule should help you to prevent a major breakdown and prolong the life of the equipment. You can find detailed instructions pertaining to the operation, maintenance, overhaul, and the parts catalog for specific types of arc welding machines in the 34W4 series TO entitled "Welding Machines and Related Equipment." An inspection record noting all maintenance performed and dates should be kept for each machine.

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Monthly Cleaning and Inspection

Air is drawn into the machine by the cooling fan and circulated through passages and around the windings. An accumulation of dust in these areas will cause increased operating temperatures. Clean out the machine with dry, compressed air, as shown in figure 8. If the machine is greasy, it should be taken apart and thoroughly cleaned.

Figure 8. Cleaning by Compressed Air.

Electrical Parts

During the monthly inspection, check the condition of the switch points, brushes, commutator, and the bearings, as shown in figure 9. Brushes that have worn enough to reduce their spring tension appreciably should be replaced. Brush springs that have been weakened from overheating should be replaced to assure positive brush contact.

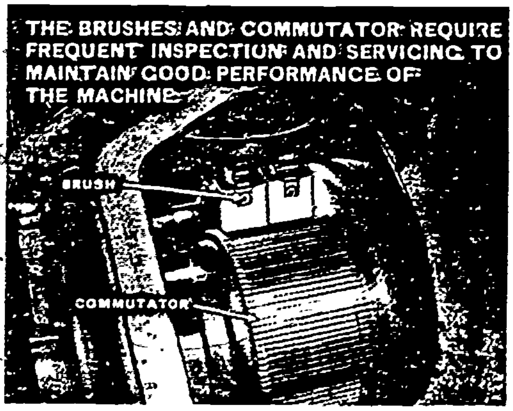

Figure 9. Brushes and Commutator.

93 Each time the brushes are replaced, the commutator should be checked for cleanliness and wear. A commutator in good condition has a deep bronze color. Ridges or pockets on the surface of the commutator should be removed by turning it down on a lathe.

Electrical switch contacts should be sanded smooth if they are pitted, as shown in figure 10. Badly burned contacts should be replaced. The windings of the generator and motor should be inspected once a year and given a coat of shellac if they are dry or cracked.

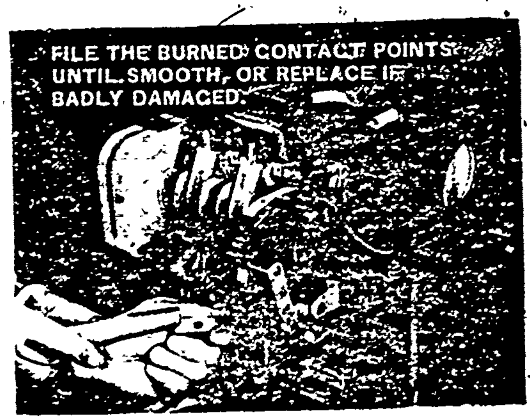

Figure 10. Contact Points.

Lubrication

Welding machines that have moving parts should be lubricated at 4-6 month intervals, depending upon the number of operating hours. The more you use the welder, the shorter the time between lubrications should be. Be sure you don't use too much grease. The excess grease could be thrown on the commutator or windings, causing deterioration of the insulation and a possible short circuit. Use the grease specified by the manufacturer on the data place or in the Military Specifications.

FUNDAMENTALS OF ELECTRICITY IN ARC WELDING

There are some basic electrical facts which you should know to help you understand the purpose and use of electricity in arc welding.

Circuit

An electric current cannot flow without a complete conducting path. This path is called a circuit. In arc welding, this circuit is made up of the welding leads, electrode, and the arc stream, as shown in figure 11.

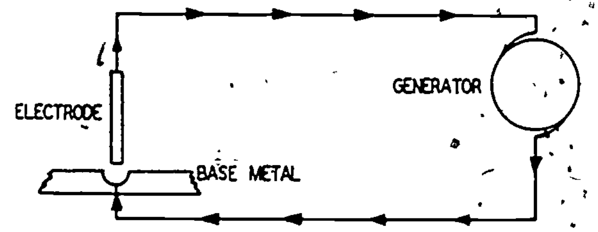

Figure 11. Simplified Diagram of Electric Arc Welding Circuit.

Voltage

Electricity needs a push to move through the circuit. This push is supplied by the electromotive force which is commonly known as voltage. The voltage is created by an imbalance of electricity. This imbalance is created when the welding generator builds up an electrical charge greater than the resistance in the leads. The voltage then forces the electric current through the welding lead and electrode. As the current reaches the end of the electrode, the voltage builds up until, like lightning, it has the necessary push to force the current across the arc gap. The current passing across the arc gap releases energy in the form of heat, causing the molten pool to form almost immediately.

Ampere

In order to control the amount of electricity in any given circuit, it needs to be measured. The unit of measurement is called an ampere. The ampere tells the amount of electricity flowing per second past a given point.

Ohm

The amount of current flowing in the circuit is determined by the amount of resistance in the circuit. The resistance is known as an ohm. The ohm measures the resistance to current flow. Each metal has its own resistance. In welding, you need leads made from a metal which has a low resistance. Since copper is one of the best conductors, it is used in all electrical appliances, generators, lines, and welding leads. Steel has a much higher resistance and would become too hot for welding purposes other than its use as an electrode.

Arc Length

In metallic arc welding, the proper length of arc is necessary to make good welds. With the proper arc length, the heat is concentrated on the work. With a long arc, much of the heat is lost by radiation to the atmosphere. A short arc is more stable than a long arc, giving you more control of the molten pool. With a short arc, vapors from the burning electrode coating surround the electrode metal and the molten pool, preventing air from reaching these hot points.

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ARC WELDING PRINCIPLES

When a circuit carrying a current is broken, the current continues to flow across the gap until the space becomes too wide. In bridging this gap, the current is carried by superheated gases from the heated atmosphere and particles of metal from the terminals. This causes an intensely bright light which is called an electric arc. Since the resistance is very high in the arc, a great deal of electrical energy is converted into heat, both in the arc and at the points at which it enters and leaves the terminals. The proper arc length causes metal exposed to it to melt almost instantly. Figure 12 shows the characteristics of the electric arc.

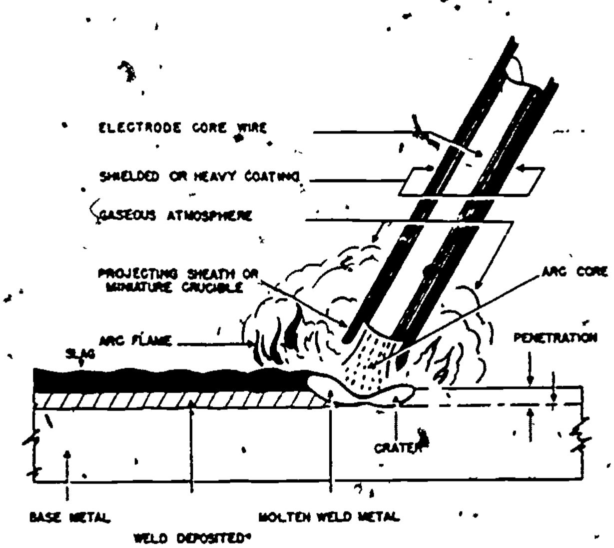
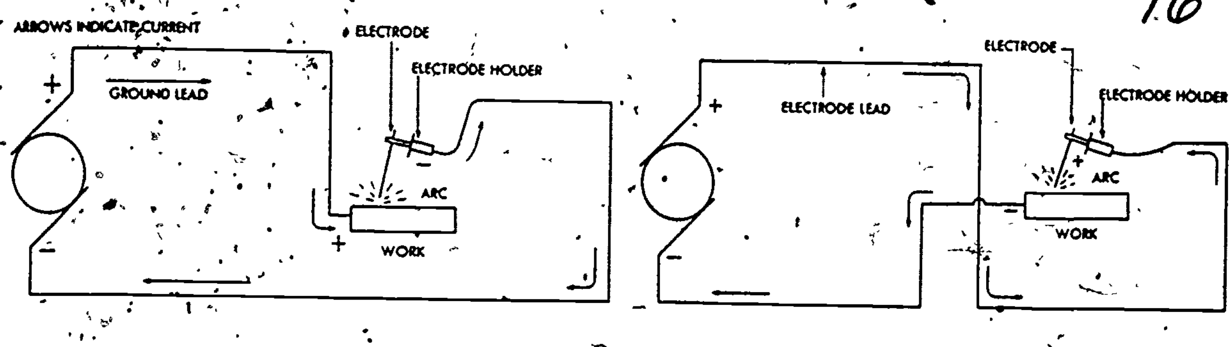


Figure 12. Arc Characteristics of Heavy-Coated Electrode.

Polarity

Every electrical circuit has a positive and negative terminal or pole. In a DC circuit, the current flows in one direction only. The line that carries current from the supply is called the positive side, and the line that returns the current to the supply is called the negative side.

In straight polarity, the work is connected to the positive side and the electrode is connected to the negative side. In reverse polarity, the work is connected to the negative side and the electrode is connected to the positive side. Figure 13 illustrates current flow in straight and reverse polarity DC welding.



A. Straight Polarity. B. Reverse Polarity.

Figure 13. Polarity of Welding Circuits.

When you are using AC welding machines, you have no polarity choice. Alternating current changes its direction of flow twice each cycle. Because of this, you cannot use AC machines for all types of welding. AC welding does have one advantage over DC welding; the changing polarity in AC reduces or eliminates "arc blow."

Weld Metal Disposition

In all metallic arc welding processes, five separate and distinct forces are responsible for the transfer of molten filler metal and slag to the base metal.

GRAVITY. This is the principle which accounts for the transfer of molten metal in the flat position. In the other welding positions, gravity may cause a loss of weld metal and slag because surface tension cannot retain large amounts of molten metal and slag in the weld crater. In these cases, a smaller electrode with lower current settings should be used.

GAS EXPANSION. A gas is produced by the burning of the electrode coating. This gas expands from the heat at the electrode tip and helps to project the molten globules of metal and slag away from the electrode tip and into the molten pool. The electrode coating, which extends beyond the tip of the electrode, controls the direction of gas expansion and directs the molten metal into the molten pool.

ELECTROMAGNETIC FORCES. The electrode tip acts as an electrical conductor and, since the molten metal globule is also an electrical conductor, it is affected by the magnetic forces acting at 90 degrees to the direction of current flow. These forces produce a pinching effect on the metal globule and speeds the separation from the end of the electrode. This is particularly helpful in transferring the metal in the horizontal, vertical, and overhead positions.

ELECTRIC FORCES. The force produced by the voltage across the arc pulls the pinched off globule of metal into the molten pool, regardless of the welding position.

97. *SURFACE TENSION*. Surface tension is the force which keeps the filler metal and slag in contact with the molten base metal in the arc crater. It helps to retain the molten metal in the horizontal, vertical, and overhead positions. It is also a determining factor in the shape of the weld contour.

Magnetic Arc Blow

A phenomenon of DC arc welding is the tendency of the arc to waver as if a blast of air were being blown against it. This trouble is often encountered in the welding of corners and at the start and end of butt joints. The arc is forcibly moved by a magnetic field set up in the work by the flow of the welding current. The direction and amount of bending of the arc depends upon the direction and strength of the magnetic field. In order to eliminate or minimize this interference, change the position of the ground in relation to the arc, or change the angle of the electrode. Although these two methods are not the only way to eliminate arc blow, they do work more often than any other method. As you become more proficient in welding, you may find another method which works better for you.

SAFETY

Eyes

The helmet is the most important item of personal equipment. When it is fitted with the proper lens, it protects you from three types of radiation: heat, light, and infrared and ultraviolet rays. Since these light rays can be harmful to other people in the area, you should always use screens or shields around your work area. If you have to weld in an open area, keep all unnecessary personnel away and be sure that your helper has a helmet and uses it. Lens shades are determined by the amperage used in welding. Normally, a No. 10 shade is satisfactory up to 200 amps. From 200 to 400 amps, a No. 12 shade is used. For over 400 amps, use a No. 14 shade.

Clothing

Wear gauntlet type leather gloves to protect your hands from heat and sparks. Use a leather apron to protect your clothing from sparks and globules of molten metal. Wear high top shoes and trousers with no cuffs. Cuffs can collect hot sparks and molten metal which may ignite your clothing, resulting in serious burns. Never wear torn or ragged clothing. It can catch fire easier and exposed parts of the body may be painfully burned.

Electric Shock

When you work in wet places, be very careful when you change electrodes, stand on a dry board or some other type of insulating material. Be sure that the machine is grounded.

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SELECTION OF CURRENT AND ELECTRODE

The selection of the proper welding current and voltage depends upon the size of the electrode, the thickness of the metal being welded, the position of the weld, and the experience and skill of the welder. Since several factors may affect the current settings, information published by welding machine manufacturers should only be used as a guide.

One of the difficulties you may have in learning to strike an arc is having the electrode freeze to the work. You can overcome this by moving the electrode across the work as if you were striking a match, as shown in figure 14.

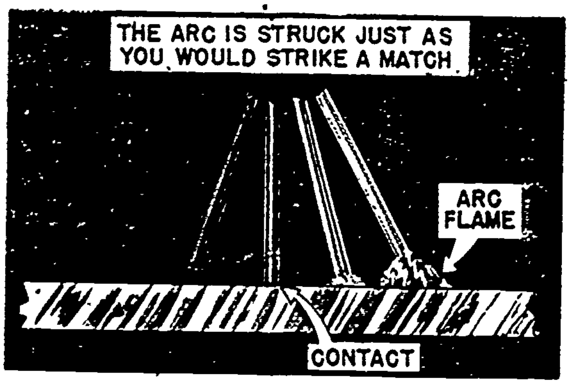

Figure 14. Procedure for Striking the Arc.

After you have established the arc, hold a long arc momentarily to preheat the base metal, then shorten it to the proper length and continue the weld. The proper arc length is approximately the same as the electrode diameter and has a characteristic hissing and crackling sound. If the arc is too short, it sputters, goes out intermittently, and the electrode sticks to the work. An arc that is too long causes spattering, loss of puddle control, and poor penetration.

EXAMPLE OF PROCEDURE FOR PRACTICE

1. Clean the surface of the metal to be welded.

2. Uncoil the welding cables, placing the ground plate on the welding table and electrode holder in its receptacle.

3. Plug in the power cable and start the machine.

4. Grip the electrode in the holder near the end.

5. Pick out a definite spot on the plate, lower the helmet, and strike the arc.

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6. Hold a long arc momentarily, then shorten it to the proper length.

7. Break the arc after depositing a few globules of metal.

8. Continue this procedure until the arc can be struck at the first attempt and at the right spot.

PRECAUTIONS: 1. AVOID "FLASHING" YOURSELF OR OTHERS.

2. MAKE SURE THE GROUND CONNECTION ON THE MACHINE IS PROPERLY MADE.

3. USE PLIERS TO HANDLE HOT METAL.

IDENTIFICATION AND SELECTION OF ELECTRODES

In order to protect the weld metal from the harmful effects of oxygen and nitrogen in the air surrounding the arc, some form of protection should be provided in the arc stream. Since absorption of the oxygen and nitrogen by the hot weld causes brittleness in the weld, the electrodes are designed with a suitable coating to prevent absorption. This coating produces a gas shield and a layer of slag which acts as a blanket, keeping the air from quickening the cooling rate of the molten pool, and aids in purifying the weld by letting the impurities float to the surface.

Types

Shielded arc or heavy coated electrodes are made from wire of a definite composition with a heavy coating around the wire. These coatings have been designed to improve the physical properties of the weld deposit, to control arc stability, and to increase the speed and ease of welding in the vertical and overhead positions. These electrodes are manufactured by extrusion, wrapping, heavy clipping, or combinations of these processes. The coating of these electrodes may be either cellulose, mineral, or a combination of both.

Reverse polarity electrodes have a cellulose coating which is made from wood pulp, sawdust, cotton, or different compositions of rayon. This type of coating protects the weld by forming a gaseous shield as it burns away. This gas shield allows the weld to cool and set up faster which is a distinct advantage when you are welding in the vertical and overhead positions.

Straight polarity electrodes have a mineral coating made from metallic oxides in the form of natural silicates, such as asbestos or clay, or in specially manufactured forms of silicates. This coating protects the weld by forming a blanket of slag which reduces the cooling rate. Figure 15 illustrates the shielding effect of the heavy mineral coating.

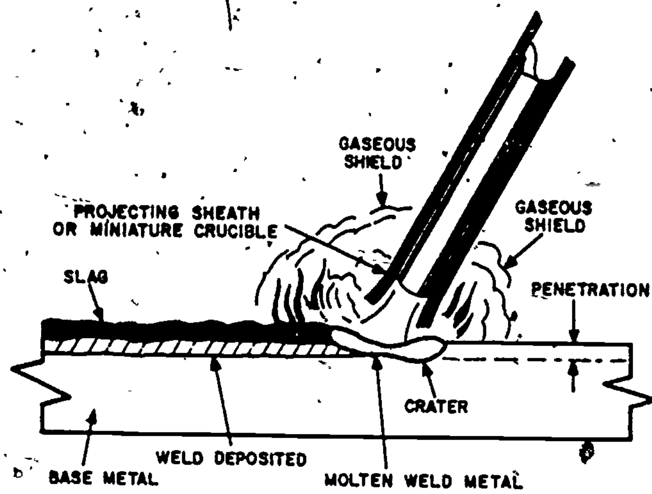

Figure 15. Action of Heavy Electrode Coating.

Identification of Electrodes

The American Welding Society has established a number and color code system for identification and selection of electrodes. It is absolutely necessary that you understand the system in order to select the proper electrode for the job.

NUMBER CODE. This code is used on mild steel and low alloy electrodes. It may be either a four or five digit number with each digit having a specific meaning.

Since the E-6010 electrode is the most commonly used, we can use it as an example of how to read this number.

The letter E designates this as an electric welding filler rod. The first two numbers (60) indicate the minimum tensile strength in thousandths of pounds per square inch. In this case then, the tensile strength of this electrode is a minimum of 60,000 psi.

The third number (1) indicates the weld position in which the electrode can be best used. This number can be any one of three. The one (1) indicates this as an all position electrode. A two (2) would indicate flat and horizontal welding positions, and a three (3) would indicate welding in the flat position only.

The fourth number (0) refers to the type of current to be used, and indirectly, to the type of electrode coating. This number may be any number from zero (0) to eight (8). Table 1 shows the current and coatings for each of these numbers.

0 - DC reverse when third digit is 1.

0 - DC reverse polarity; AC when third digit is 2 or 3.

1 - AC* or DC reverse polarity.

2 - DC straight polarity or AC.

3 - AC* or DC straight polarity.

5 - DC reverse polarity (lime or titania sodium low hydrogen).

6 - AC* or DC reverse polarity (titania or lime potassium low hydrogen).

8 - AC or DC reverse polarity (iron powder plus low hydrogen sodium covering).

*Preferred

Table 1. Electrode Covering Compositions and Current Selection.

The five digit number gives you the same information as the four digit number. In this case, the first three digits are read as the tensile strength with the last two still being the position and the current selection.

AWS COLOR CODE. This code consists of three markings: The end, spot, and group, as shown in table 2. The end and spot color indicates the composition of the electrode while the group color indicates the type of current. The end color is on the top of the base or grip end of the electrode. The spot color is located on the grip end midway between the end of the electrode and the flux coating. The group color is located on the flux coating just below the grip end of the electrode. The color coding for common characteristics is shown in table 2.

Characteristics of Common Electrodes

The E-6010 electrode is the most universally used of all metallic arc welding electrodes, principally because it can be used in all positions, and the weld deposit has physical properties at least as good as any other specified electrode. It is sometimes referred to as the cellulosic type because the coating contains a considerable amount of cellulose, such as wood flour or paper flour, combined with other ingredients, which are added to obtain certain specific

Table 8. Electrode Identification and Operating Data.

COATING COLOR	IDENTIFICATION MARKING (E) END	(S) SPOT	(G) GROUP	(L) SPECIAL	AWS CLASS	POLARITY DC (+) = "REVERSE" DC (−) = "STRAIGHT"	SIZES AND CURRENT RANGES (Amps.) (electrodes are manufactured in those sizes for which current ranges are given) 5/64" SIZE	3/32" SIZE	1/8" SIZE	5/32" SIZE	3/16" SIZE	7/32" SIZE	1/4" SIZE	5/16" SIZE
MILD STEEL														
White					E6010	DC (+)			75 130	90 175	140 225	200 275	250 325	280-400
Brick Red					E6010	DC (+)			75-130	90 175	140 225			
Tan		White			E6012	DC (−) AC		55 80 60 90	80 130 90 140	120 180 130 200	180 250 200 275	210 280 230 310	250 315 280 350	320 410 350 450
Gray		White			E6012	DC (−) AC			90 135 100 150	120 190 130 210	150 265 165 290	225 300 250 325	250-340 275 375	315 405 350 450
White		Blue			E6011	AC DC (+)		40 75 35 70	75 120 70 110	90 160 80 145	120 200 110 180	150 260 135 235	180 300 170-270	
Dark Tan		Brown		Green	E6013	AC DC (−)	40 75 35 65	65 100 60 90	90 140 80 125	140 200 125 180	200 260 180 235			
Gray Brown	Black	Brown			E7014 E6014	AC DC (−)			110 160 100 145	150 225 135 200	200 280 180 250	260 340 235 305	315 425 285 380	370 500 330 450
Tan					—	DC (−) AC				175 250 160 225	230 350 210 315	300 450 275 410		
Tan		White		Green	E6012	DC (−) AC			80 135 90/150	110 180 120 200	155 250 170 275	225 295 250 325	245 325 275 360	
Brown		Blue			E6011	AC DC (+)		40 90 40 80	60 120 55 110	115 150 105 135	160 210 145 190			
Dark Gray	Black	Yellow			E7024 E6024	AC DC (+)			130 190 120 180	190 250 180 230	240 300 220-280	300 380 280 360	360 440 330 400	
Red Brown		Silver			E6027	AC DC (+)				190 240 175 215	250 300 230 270	300 380 270 340	350 450 315 405	475 600
Gray	Black	Yellow		Green	E7024 E6024	AC DC (+)		65 120 60 110	115-175 100 160	180 240 160 215	240 300 215 270	300 380 270 340	350 450 315 405	450 600
Gray	Black	Orange	Green		E7018 E6018	DC (+) AC		70 100 80 120	95 155 115 165	120 200 145 230	160 280 200 310	190 310 240 350	230 360 290 410	375 475 400 500
Gray Brown	Black	Black			E7028 E6028	AC DC (+)				180 270 170 240	240 330 210 300	275 410 260 380	360 520	
LOW ALLOY, HIGH TENSILE STEEL														
Pink	Blue	White			E7010 A1	DC (+)		50 90	75 130	90 175	140 225		190 325	
Pink	Blue			Green	E7010 G	DC (+)					140 225			
Pink					—	DC (+)			75 130	90 175	140 175			
Dark Red	Blue	Yellow	Silver		E7020 A1	AC DC (+)				190 240 175 215	250 300 230 270	275 375 250 320	350 450 330 370	
Gray				9018	E9018 G	DC (+) AC			90 150 110 160	110 200 140 230	160 280 200 310			
Gray				11018	E11018 G	DC (+) AC			95 155 115 165	120 200 145 230	160 280 200 310	190 310 240 350	230 360 290 410	
STAINLESS STEEL														
Pale Green	Yellow		Black	308 15	E308 15	DC (+)	20 55	30 70	50 100	75 130	95 165		150 225	
Gray	Yellow		Yellow	308 16	E308 16	DC (+), AC	20 45	30 60	55 95	80 135	115 185		200 275	
Gray	Brown		Yellow	308L 16	E308L 16	DC (+), AC		30 65	55 100	80 140	115 190		200 285	
Pale Green	Red		Black	310 15	E310 15	DC (+)		30 70	45 95	80 135	100 165		140 225	
Gray	Red		Yellow	310 16	E310 16	DC (+), AC		30 65	55 100	80 140	120 185		200 275	
Gray	Brown	White	Yellow	316L 16	E316L 16	DC (+), AC		30 65	55 100	80 140	115 190		200 285	
Pale Green	Yellow	Green	Black	318 15	E318 15	DC (+)		30 75	45 95	80 135	100 165			
Pale Green	Yellow	Blue	Black	347 15	E347 15	DC (+)	20 55	30 70	50 100	75 130	95 [illegible]		150 225	
Gray	Yellow	Blue	Yellow	347 16	E347 16	DC (+) AC		30 60	55 95	80 135	115 185			
BRONZE & ALUMINUM														
Peach	Yellow	Blue	Blue		E CuSn C	DC (+)			50 125	70 170	90 220			
Peach					Al 43	DC (+)		20 55	45 125	60 170	85 235		125 360	
CAST IRON														
Light Tan	Orange				ESi	DC (+), AC			80 100					
Black	Orange	Blue	White		ENi	DC (+) AC			60 110 65 120	100 135 110 150				
HARDSURFACING														
Black						DC (+) AC			40 150 50 165	75 200 80 220	110 250 120 275		150 375 165 410	
Slate	Yellow					DC (+), AC					60 150			145 350
Slate	Pink					DC (+), AC					60 150			145 350
Gray						DC (+), AC				115 225	200 290		255 375	
Bare Wire						DC (+)					130 170		170 225	
Dark Gray	Orange	Red				DC (+) AC				125 210 135 230	150 260 165-285		200-350 220-385	
Slate						DC (−), AC		40 85	65 130					
Gray						DC (+)			65 100					
Dark Gray						DC (+) AC					110 275 125 275		150 400 200-400	

qualities, such as volume and fluidity of the slag. The heat of the arc causes the coating to burn and generate large volumes of gases which effectively shield the molten metal from the air, preventing the formation of harmful oxides and nitrides. Good penetration is characteristic of this type electrode because of the quick freezing of the weld metal slag, which makes it applicable for vertical and overhead work.

E-6011 ELECTRODE. The E-6011 electrode is designed to perform the same work using alternating current that the E-6010 performs on reverse polarity direct current. It is an all-position rod with somewhat more slag than the E-6010. The range of welding current in which various sizes of electrodes can be used satisfactorily, is narrower than in the case with E-6010, which means that the welding current controls must be set more exactly.

E-6012 ELECTRODE. The E-6012 electrode is for use with direct current straight polarity, but works very well on alternating current, as is the case with most straight polarity electrodes. Penetration is not deep, consequently, the E-6012 has many advantages on jobs where the "fit-up" is poor and on light gage material because there is less tendency to burn through than with the E-6010 or E-6011. The E-6012 is an all-position electrode which has fast welding speeds and gives less spatter than most other types. The bead profile is not as flat as that of the E-6010, but is often preferred for horizontal fillets because of the appearance of the weld.

E-6013 ELECTRODE. The E-6013 electrode, operating on alternating current, is designed to fulfill the same purpose as the E-6012, operating on straight polarity direct current. The coating contains a high percentage of material for stabilizing and maintaining the arc. Penetration is less than that usually obtained with the E-6012 and spatter is low. This electrode proved to be the most successful for welding light tubular assemblies and, consequently, was much used in aircraft construction. It is often used with straight polarity direct current, but the original intention was to pair it with the E-6011 in the same way that the E-6012 is paired with the E-6010.

Classification

Air Force Supply catalogs identify arc welding electrodes by military specification numbers, rather than AWS classification numbers. The following information is of importance to Air Force welders and can be found in the 34W4 series technical orders.

CLASS A ELECTRODE. These correspond to the AWS electrodes whose last two digits are 12 or 13, such as E-6012 or E-6013.

CLASS B ELECTRODE. These correspond to the AWS electrodes whose last two digits are 10 or 11. This type of electrode is used with DC reverse polarity except when specified as an AC electrode. Penetration is deep, which is normally preferred for good fit-ups and vertical or overhead welding. This electrode should not be used when heat treatment is required.

CLASS C ELECTRODE. These are alloy steel electrodes to be used in welding of chrome molybdenum and chrome-nickel-molybdenum steels when heat treatment is required. The corresponding AWS electrode specification would be E-7020 or E-10020. This type of electrode is generally used with straight polarity, but may also be used on AC current. Only the smaller diameter electrodes, 5/64" and 3/32", are adaptable to all positions. The larger diameter electrodes are generally used for horizontal fillets and flat work where deep penetration is not required.

CLASS D ELECTRODE. This is a companion rod to the class C electrode under the same specification and is used where deeper penetration is required.[4] Its purpose is for the welding of chrome-molybdenum (4135 and 4140) and chrome-nickel-molybdenum (8735 and 8740) steels (with preheat of the parts to 400 degrees to 500 degrees F). The corresponding AWS electrode specification would be E-7030 or E-10030. This type of electrode is generally used with reverse polarity, but may also be used with AC current. It is an all-position electrode.

Welding Current

The selection of the proper welding current and voltage depends upon the size of the electrode, the thickness of the plate being welded, and the welder's skill. If flat position welding, higher current values and voltage may be used than for vertical and overhead welds with an electrode of the same size. In general, the proper current and voltage settings are obtained from experience and should be adjusted to fulfill the requirements of the particular welding operation. Since several factors affect the current and voltage requirements, data published by the manufacturers should be used only as a guide.

Electrode Diameter	Amperes Minimum	Amperes Maximum	Standard Electrode Lengths
1/16 in	40	60	8 in
3/32 in	70	90	11 1/2 in
1/8 in	110	135	14 or 18 in
5/32 in	150	180	14 or 18 in
3/16 in	180	220	14 or 18 in
1/4* in	250	300	14 or 18 in
5/16* in	300	425	14 or 18 in
3/8* in	450	550	14 or 18 in

* Diameters, 1/4 in 5/16 in and 3/8 in are for flat position only

Table 3. Currents Used With Gaseous and Slag Type Electrodes.

The mineral-coated type of shielded arc electrode, which produces a slag as a shield, requires higher welding currents than the cellulose-coated type, which produces a large volume of gases to shield the arc stream. Table 3 shows the current requirements for the mineral-coated or slag-forming electrode and the cellulose-coated or gaseous-type of electrode. The welding voltage varies from about 20 volts for the 3/32 inch electrodes to 50 volts for the 1/4 inch heavy-coated electrodes of either the gaseous or slag-forming electrodes.

The shielded arc electrode has replaced the bare and light-coated electrodes for most welding applications. The factors largely responsible for this have been higher welding speeds, better weld metal quality, and the ability to introduce certain alloying elements into the weld metal through the heavy-coating on the electrode.

QUESTIONS

1. What is the difference between a DC welder and an AC welder?

2. In what technical order is maintenance on arc welding machines found?

3. What are the five distinct forces responsible for weld metal transfer?

4. What determines the welding current and voltage?

5. What is the difference in the coating on the electrode, between reverse and straight polarity?

6. In electrode coding, what does E-6010 mean?

7. In what position can E-6010 be used?

REFERENCES

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

Metal and NDI Branch
Chanute AFB, Illinois

PREPARE VARIOUS TYPES OF PIPE JOINTS FOR WELDING

OBJECTIVES

After completing this study guide, assigned study, and your classroom instruction, you will apply the principles and techniques involved in the preparations of various types of pipe joints for welding.

INTRODUCTION

Preparations of a pipe joint for welding is probably the most important operation involved in pipe welding. A part that has not been properly aligned, or cleaned prior to welding may fail under severe operating conditions.

INFORMATION

Edges or surfaces of parts to be joined by welding may be prepared by machining, shearing, flame cutting, or other suitable means. Regardless of which method is used, the resulting joint must meet the required geometry, and must provide a sound, bright, metal surface. It is desirable to control the geometry of the joint to minimize any notch condition that might lead to concentration of stress. Sharp corners, or sudden changes in size or contour are to be avoided.

All metal that is to be fused during welding must be absolutely clean. This is a basic requirement to obtain sound weld metal within the weld deposit. Cleaning is imperative to edges that have been prepared for welding, to electrodes, and to surrounding equipment, such as welding benches, jigs, and holddown devices. Cleanliness also is a requisite to flux coating remaining on weld metal or base metal upon which subsequent weld metal is to be deposited.

Pipe to be welded is usually supplied with a V bevel having an angle of 37-1/2 $\pm$ 2-1/2 degrees with a 1/16 $\pm$ 1/32 inch root face land at the bottom of the edge to be welded, as shown in figure 16. Pipe saddle joints should be beveled in the same manner as butt welds.

In the event that operating personnel have a doubt as to the nature of the joint or its preparation, the project engineer must be consulted before proceeding with any further preparation or welding of the joint in question.

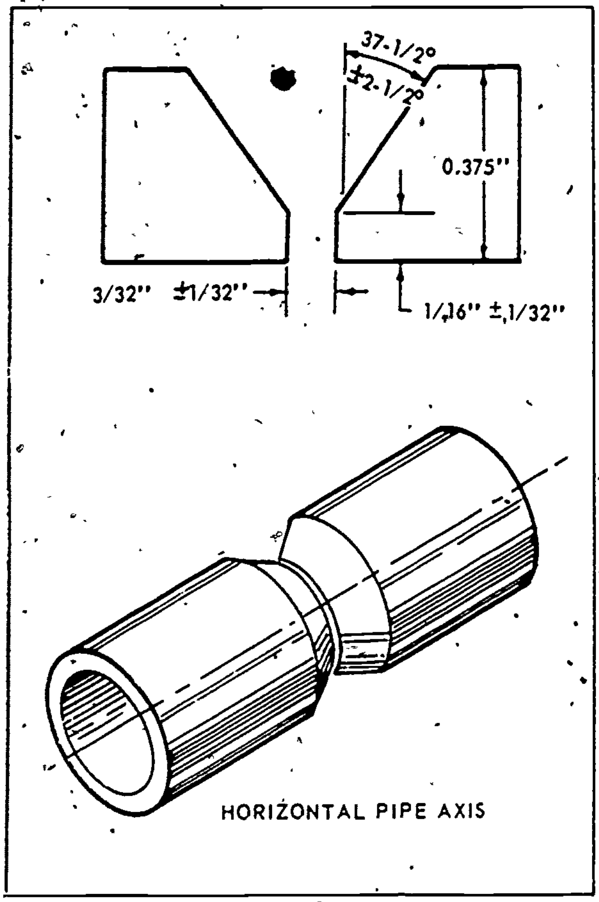

Figure 16. Weldment With Root Opening, Horizontal Attitude.

CUTTING OF PIPE

Cutting pipe is necessary when the pipe must be of a specific length requirement. To ensure a leakproof welded joint, the pipe must be cut in a true circle with a plane perpendicular to the centerline of the pipe. A straight edge or roundabout made of a strip of heavy paper, cardboard, leather belting, or gasket material may be used to aid in layout. The strip is made longer than the circumference of the pipe to be welded. The sheet material or roundabout is wrapped around the pipe, as shown in figure 17, and the line of the cut marked with a soapstone pencil. The cut is beveled with a hand cutting torch along the line, as shown in figure 18, and the cut checked with a carpenter's square.

Figure 17. Use of Roundabout or Paper to Make True Circle.

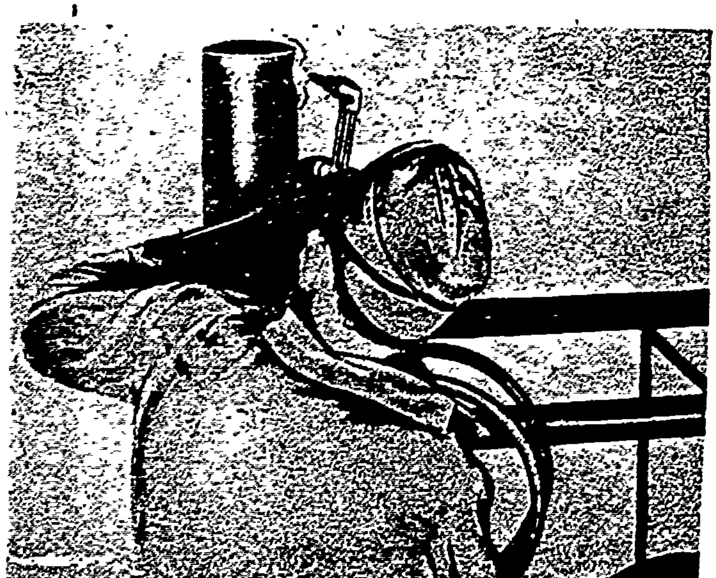

Figure 18. Beveling Pipe With Hand Cutting Torch on Line Made by Means of Paper Strip or Roundabout.

FITTING UP AND TACK WELDING

Joints which require a root opening must have a separation between lands or welding edges of 3/32 $\pm$ 1/32 inch for the full length of the joint, as shown in figure 16. The ends of the pipe are aligned accurately. In no case will the welding edges at the joint be offset from each other in excess of 1/16 inch, or 1/5 of the wall thickness of the lighter material whichever is less.

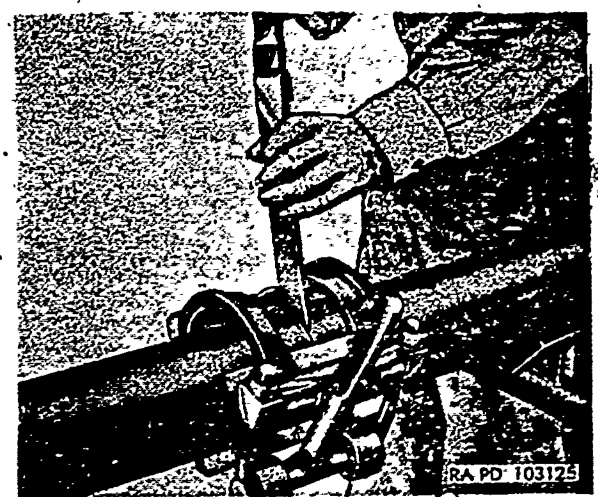

Figure 19. Pipe Lineup Clamp and Spacing Tool.

All parts to be joined by welding are securely held in correct position by jigs, clamps, clips, or other suitable devices, as shown in figure 19, or by tack welds, as shown in figures 20 and 21. Holding devices must be adequate to maintain alignment of all parts throughout the entire welding operation. Tack welds must be of the same quality and made by the same procedure as the completed weld.

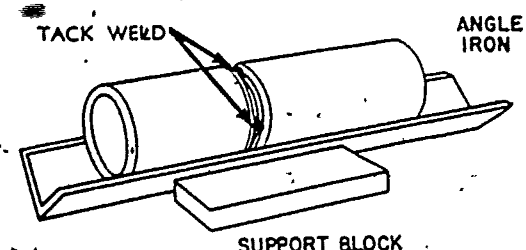

Figure 20. Angle Iron Serving as Jig for Small Diameter Pipe.

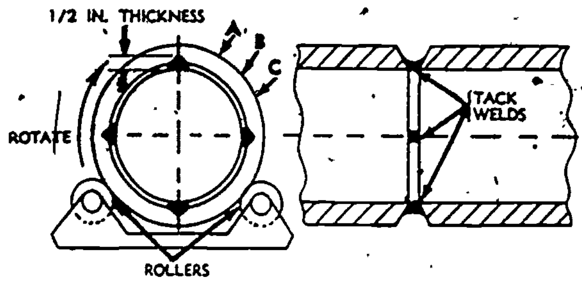

Figure 21. Diagram of Tack Welded Pipe on Rollers.

The orientation of weld joints with respect to horizontal and vertical planes of reference must be in accordance with that illustrated in figure 22.

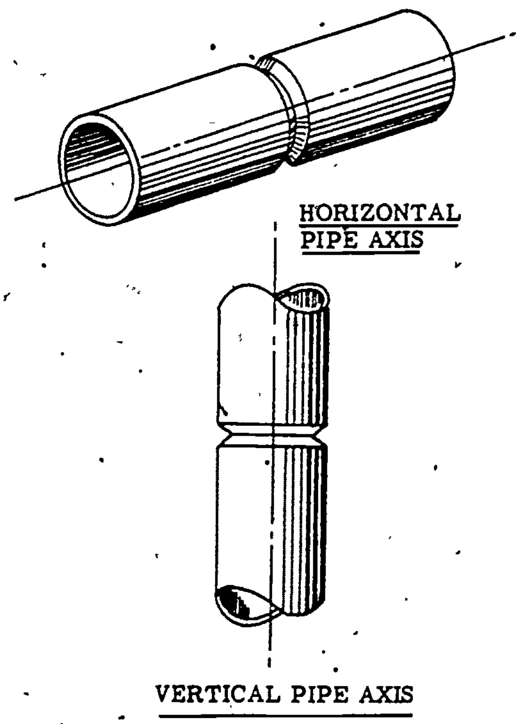

Figure 22. Position of Pipe for Fixed Position Welding.

FIXED POSITION WELDING

Welding must be accomplished without pipe rotation, so that weld metal is deposited in the overhead, vertical, flat, and horizontal fixed position.

Welding must be started at the bottom of the joint and must progress upward to the top of the joint. Under no conditions will welding be performed in the reverse order.

QUESTIONS

1. What is the angle used when making a V bevel on pipe?

2. What is the purpose of tack welding a pipe joint prior to welding?

REFERENCES

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

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METALLIC ARC WELDING OF CARBON STEEL PIPE JOINTS

OBJECTIVES

After completing this study guide, assigned study, and your classroom instruction, you will apply the fundamental principles and techniques for welding carbon steel butt, angle, and tee pipe joints in the fixed vertical, horizontal, and overhead positions.

INTRODUCTION

Although the overhead position in welding is considered by some to be the most difficult, it does not have to be any more difficult than any other position. In the case of overhead pipe welding, only about one-third of the weld bead is actually made in the overhead position. The other two-thirds is equally divided between the vertical and flat welding position.

INFORMATION

In the erection of structures or equipment and especially in repair work, it is often necessary to weld in the overhead position. Fortunately, there are forces present in the electric arc sufficiently powerful to overcome the force of gravity and make it possible to deposit metal overhead. One of the most effective of these forces is the propelling power of the gases formed by the combustion of the coating. Due to the heat of the arc, these gases are expanding at a tremendous rate.

OVERHEAD POSITION WELDING

The overhead position of welding is defined as one in which filler metal is deposited from the underside of the joint and the face of the weld is approximately horizontal.

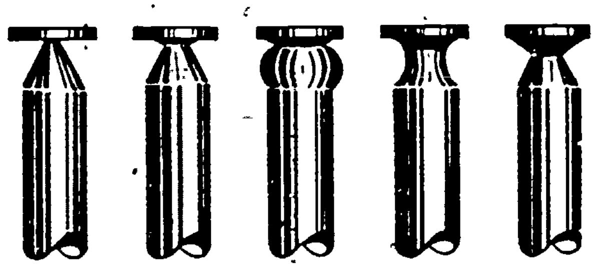

Figure 23. Theory of Overhead Arc Deposits.

The transfer of metal in overhead arc welding is accomplished in different ways depending on arc lengths. An overhead deposit made while holding a long arc will be relatively small and due only to condensation of vaporized metal. In the case of the short arc, there is a globular growth until contact is made with the liquified plate, figure 23, or surface of the deposit, thus the forces of adhesion and surface tension at the plate overcome the combined forces of gravitation, cohesion and surface tension acting to hold the globule to the electrode surface.

It is evident that the force of adhesion and surface tension of the plate, combined with the force of the gases produced by the coated electrode, must overcome the forces of gravitation, cohesion, and surface tension at the end of the electrode. These forces acting against the depositing of molten metal may be overcome by using a small diameter electrode and holding a somewhat shorter arc length. Also helpful, is heating of the overhead joint locally to start an effective metal deposit. This can be accomplished by holding a long arc length at the start of the weld. It is often desirable, especially on heavy plate, to burn 2 to 3 inches of electrode in heating the joint.

Electrodes, Polarity, and Current Settings

In metallic arc welding, only those electrodes designed for overhead welding should be used. Welding with large diameter electrodes is difficult. The 3/16 inch diameter electrode is considered the maximum practical size used for welding overhead. The amount of welding current should be carefully adjusted in order that a short arc length can be held. Usually only a slight movement of the electrode is necessary if other factors, such as a current adjustment and electrode angle, are correct.

When using a DC arc welding machine, reverse polarity (electrode positive) is used. Since the greater amount of heat is at the positive terminal of the welding circuit, penetration is more easily obtained. This serves as an aid in a position in which penetration is otherwise difficult to obtain.

The selection of the proper welding current depends upon the size of the electrode, the thickness of the plate being welded, the position of welding, and the welder's skill. In overhead position welding, lower current values must be used than for flat welding with an electrode of the same size. In general, the proper current settings are obtained from experience and should be adjusted to fulfill the requirements of the particular welding operation. Since several factors affect the current requirements, data published by manufacturers should be used only as a guide.

Overhead Position

For bead welding, the electrode should be held at an angle of 90 degrees to the base metal, as illustrated in A, figure 24, or may be tilted approximately 15 degrees in the direction of welding shown in B, figure 24. This will provide a better view of the arc and crater of the weld.

Overhead Position

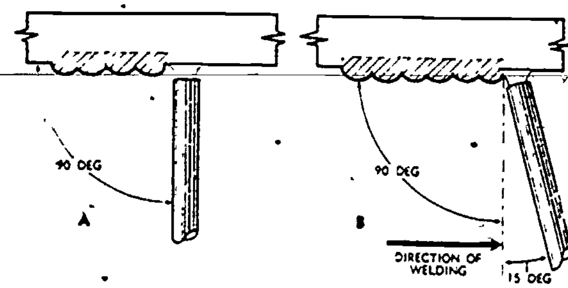

Figure 24. Bead Welding in Overhead Position.

Weave beads can be made in the overhead position by using the motion illustrated in figure 25. A rather rapid motion is necessary at the end of each semicircular weave in order to control the molten metal deposit. Excessive weaving should be avoided because this will cause overheating of the weld deposit and the formation of a large pool, which will be hard to control.

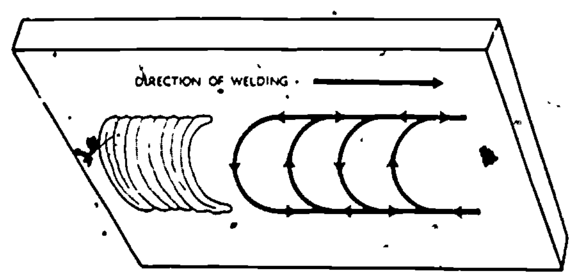

Figure 25. Position of Electrode and Weave Motion in Overhead Position.

Butt Joint

The plates should be prepared for butt welding in the overhead position in the same manner as that required in the flat position and the most satisfactory results are obtained if backup strips are used. If the plates are beveled with a featherlike ridge and no backup strip is used, the weld will tend to burn through repeatedly unless extreme care is taken by the operator.

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For overhead butt welding, beads rather than weave welds are preferred. Each bead should be cleaned and the rough areas chipped out before the following pass is deposited.

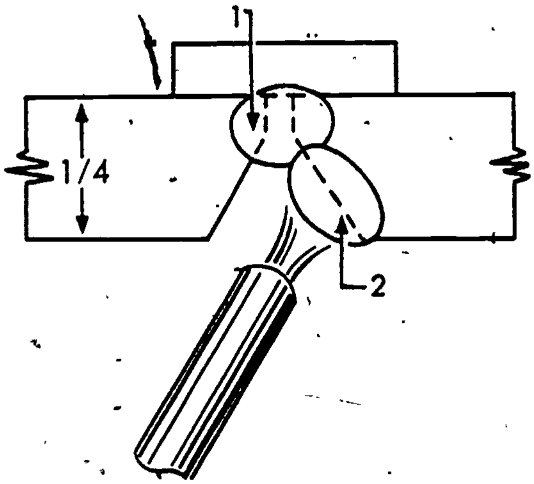

Figure 26. Welding Butt Joint in Overhead Position.

The positions of the electrode and the order to be followed in depositing beads on 1/4 and 1/2 inch plates are shown in figures 26 and 27.

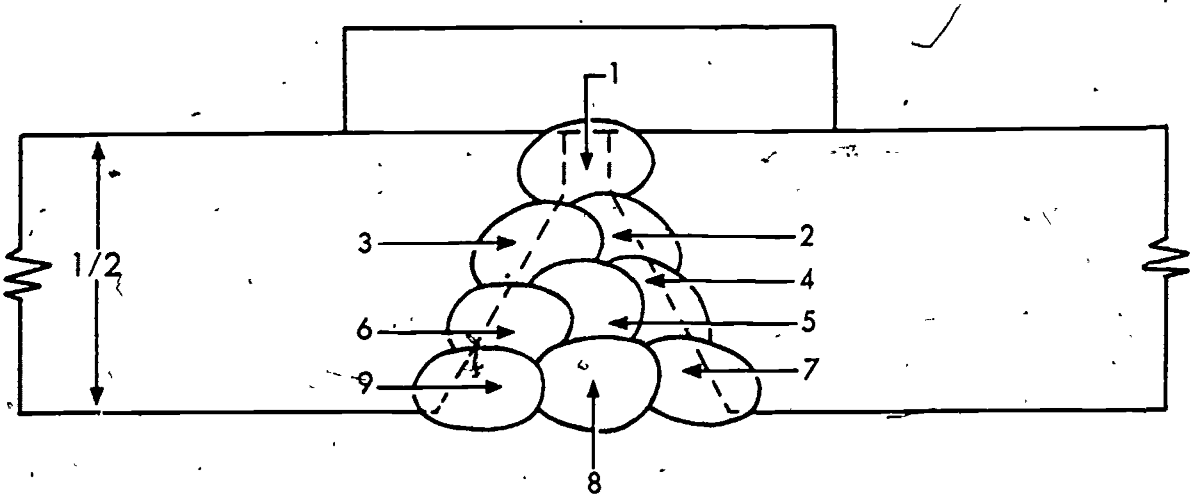

Figure 27. Multipass Butt Joint in the Overhead Position.

The first pass should be made with the electrode held at 90 degrees to the plate, as shown in figure 28.

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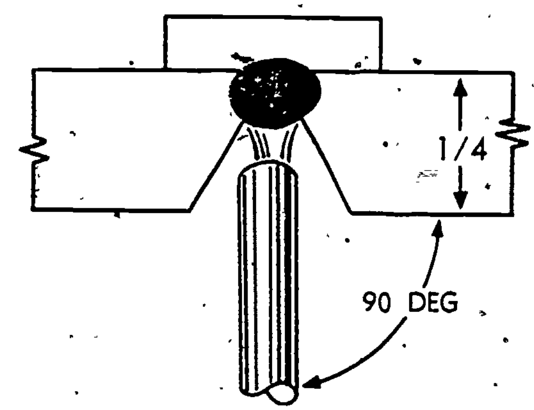

Figure 28. Position of First Pass for Overhead Welding.

VERTICAL POSITION PIPE WELDING

Welding in the vertical position is much more difficult than welding in the flat position. The force of gravity acting on the globules passing across the arc to the molten pool tends to deflect them from the crater so that the operator is forced to hold a short arc and to manipulate the electrode in order to control the size of the molten pool. A force which is probably the strongest in propelling the globules across the arc is that exerted by gas produced from the electrode coating. This gas expands at a rapid rate forcing the metal across the gap.

The electrodes used for vertical welding have lighter coatings than the type used only for the flat position. They are so designed that the weld metal and slag solidify quickly. Electrodes of this type require the use of reverse polarity. Since the greater amount of heat is at the positive side of the welding circuit (the tip of the electrode) penetration is more easily secured with reverse polarity. This serves as an aid in a position in which penetration is otherwise more difficult to obtain. They are classified under American Welding Society specifications as AWS E-6010 and in AF supply catalogs as class B electrodes.

When using coated electrodes in the vertical position, it is necessary to use smaller electrodes at lower current settings (as compared to flat position welding). This serves as an aid in maintaining a small pool of molten metal, thus permitting surface tension to overcome the force of gravity. The current settings recommended by the electrode manufacturer may serve as a guide in making initial settings for a given electrode size.

Joint Preparation and Weld Specifications

The preparation of the joint for welding in the vertical position is the same as required for welding in the flat position. Also, weld specifications are the same for vertical and flat welds. It may, however, be necessary in vertical welding to make a number of passes for a joint which would require only one pass in the flat position.

117 Techniques of Vertical Welding Beads on Steel Plate

The correct position and manipulation of the electrode for welding upward in the vertical position is shown in figure 29. The electrode is held perpendicular to the plates laterally, but inclined down about 5 degrees from the horizontal plane, so the tip of the electrode points slightly upward and away from the crater.

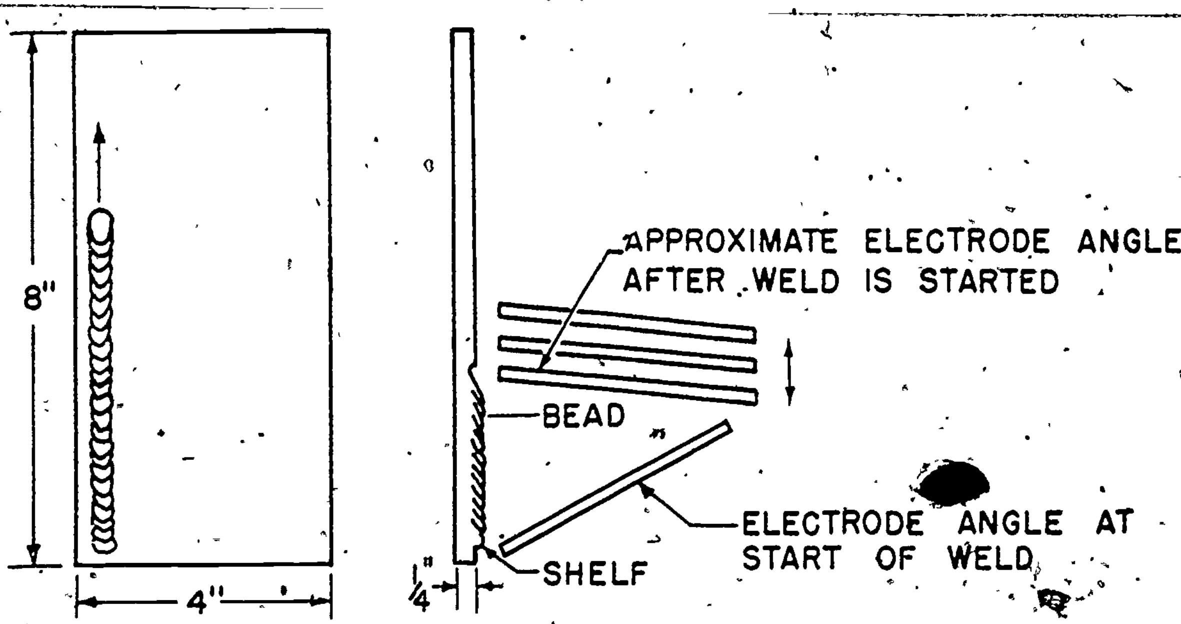

Figure 29. Technique for Welding Upward in the Vertical Position.

The weld is started by directing the end of the electrode down as shown in figure 29. This permits the deposited metal to form a shield; after building of the shield, the angle of the electrode is then changed with the end directed upward as previously stated. As the weld progresses the tip of the electrode is momentarily moved upward ahead of the pool of molten metal long enough to permit the deposit to solidify. This is repeated along the line of the weld to the top of the plate.

A somewhat shorter arc length is required in order to control the size of the molten pool. The arc is never broken throughout the movement of the electrode, the end is merely moved from the crater just long enough to permit the deposited metal to solidify and form a shelf upon which additional metal is deposited. Since some operators will work faster and use higher current values than others, the timing of this movement will vary, depending upon the individual. Actually, effective disposition of metal should take place only during the time in which the electrode is in position at the downward end of the movement.

To obtain welds which are wider than welds produced by the above technique, a slight weaving motion of the electrode is used. A slightly larger diameter electrode with higher welding current aids in producing larger welds; however, 3/16 inch diameter electrode is considered the maximum practical size for vertical welding.

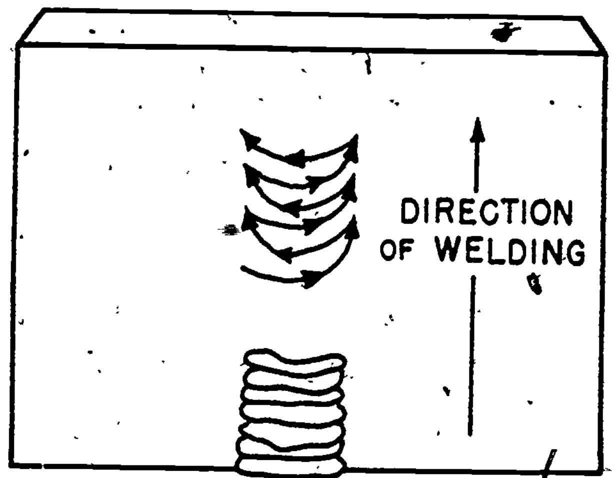

Figure 30. Vertical Weave Bead, Welding Up.

An example of a typical weave when welding in the vertical position is shown in figure 30. The electrode is moved in a slight side-to-side movement in the crater during the disposition of weld metals, followed by a movement of the electrode upward momentarily to allow the deposited metals to solidify. This procedure will eliminate a highly crowned head which may result when the weaving motion is not used. When large maximum strength welds are required, a series of stringer beads are deposited.

PIPE WELDING TECHNIQUES

The actual welding process is similar to welding flat plates. In the vertical position, the pipe is positioned as shown in figure 31, and the weld progresses completely around the pipe. Welding should be accomplished without pipe rotation.

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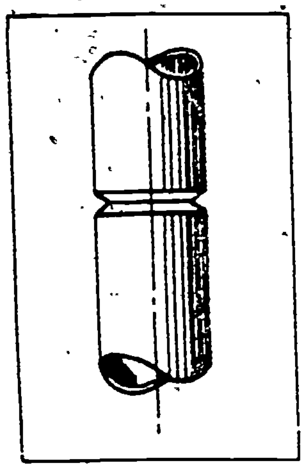

Figure 31. Vertical Positioning.

Welding in the overhead position is defined as the position in which filler metal is deposited from the underside of the joint. In pipe welding, this is the most difficult of all welding positions. It should be accomplished without pipe rotation and in the position shown in figure 32. The weld metal is deposited from the overhead, vertical, flat, and horizontal positions. The weld should be started at the bottom of the joint and progress upward to the top of the joint. Under no conditions will welding be performed in the reverse order.

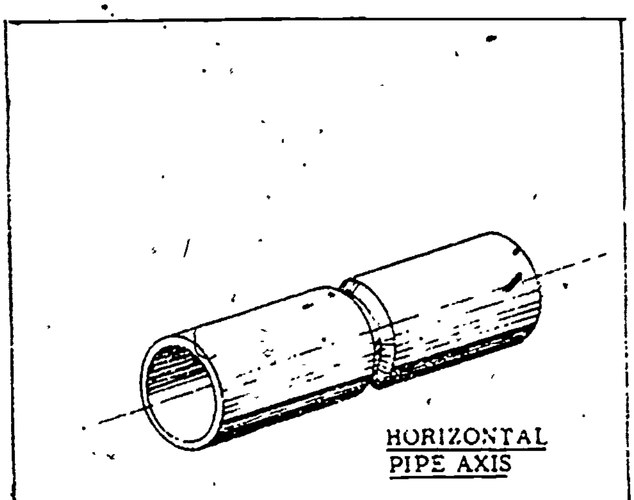

Figure 32.

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When welding carbon steel pipe joints, the same principles and practices used for flat plate welding are employed. The pipe joint may be preheated by using a long arc, but actual transfer of metal should be accomplished with a short arc. The E-6010 electrode should be used, DC reverse polarity employed, and current adjusted to suit individual welding characteristics.

QUESTIONS

1. Define the overhead welding position.
2. Why are back-up strips used in overhead welding?
3. Why do you use smaller electrodes when welding vertically?
4. In what direction is pipe welding performed?

REFERENCES

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

INERT GAS SHIELDED ARC WELDING OF STAINLESS STEEL PIPE JOINTS

OBJECTIVES

After completing this study guide and your classroom instructions, you will apply the fundamentals, principles, and techniques of welding stainless steel pipe in the fixed vertical, horizontal, and overhead positions for the butt, angle, and tee joints.

INTRODUCTION

Inert-gas shielded welding is a welding process which uses an inert gas to protect the weld zone from atmospheric oxidation which would contaminate the weld. It produces welds that are stronger, more ductile, and more corrosion resistant than welds made with ordinary metallic arc welding. The protective shield that envelops the weld enables the joints to be fabricated without the use of flux, thus eliminating the corrosion due to flux entrapment, and also expensive postwelding operations. The entire welding operation takes place without spatter, sparks, or fumes.

INFORMATION

There are many inert gas shielded welding processes. The process that you are going to become familiar with is tungsten inert-gas (TIG), figure 33. Tungsten inert-gas uses a nonconsumable electrode, as compared to metallic inert-gas (MIG), figure 34.

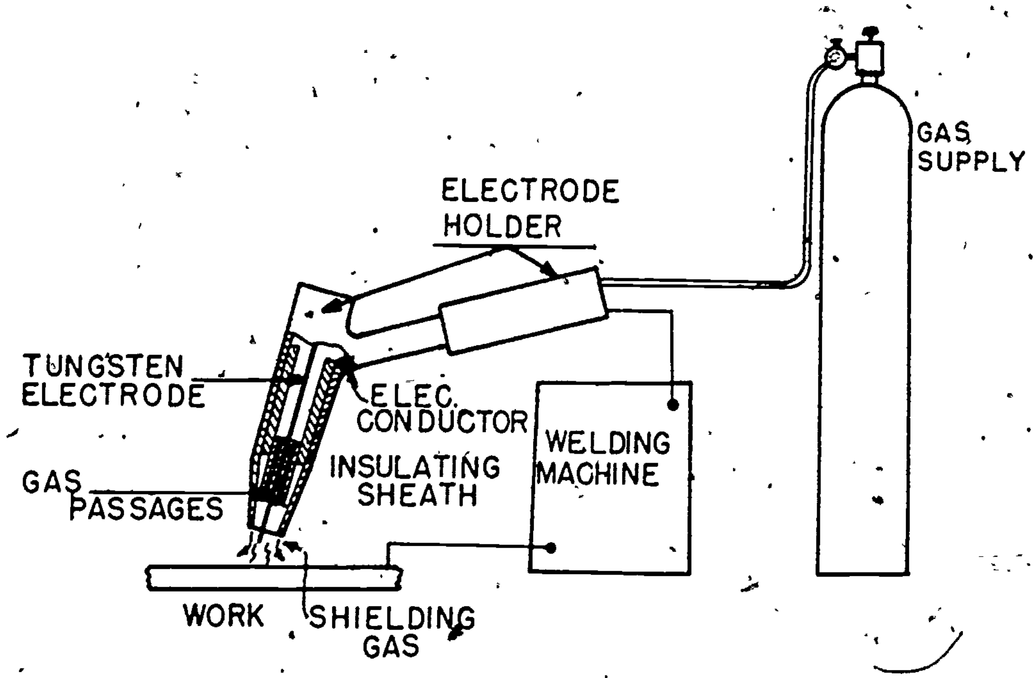

Figure 33. Inert-Gas Shielded Process (Nonconsumable Electrode) TIG.

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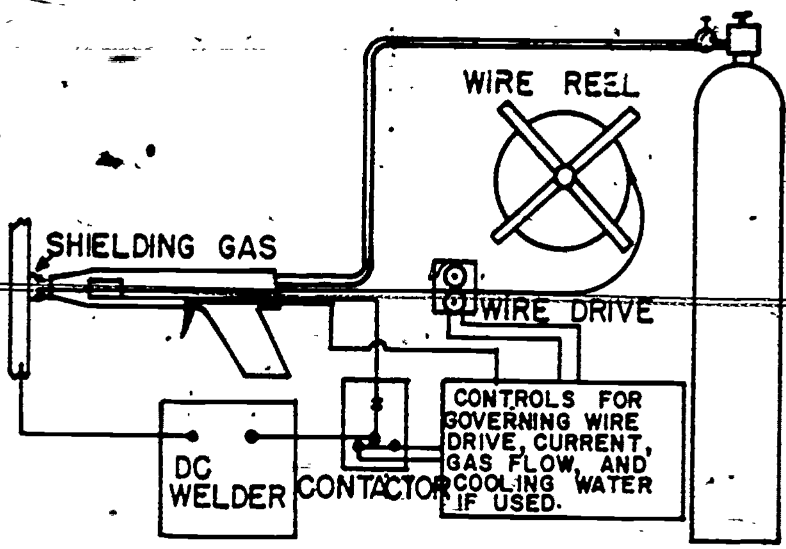


Figure 34. Inert-Gas Shielded Process (Consumable Electrode) MIG.

The tungsten inert-gas shielded welding process is especially adapted for welding light gage work requiring the highest quality and/or finish because of the exceptional concentration of heat, precise heat control, and the ability to weld with or without filler metal. It is one of the few processes which permits the rapid welding of tin or light-walled objects.

An arc from the electrode in the atmosphere of inert gas provides an intense source of heat which is very clean and operates very quietly. The inert gases provide an almost ideal shielding cover in which to melt most metals for welding, refining, or casting. Because of this, the inert gas process is generally adapted for welding a wide range of materials.

Most metals or alloys which do not vaporize under the heat of the arc, and which solidify without cracking, can be welded. Some of the metals that can be satisfactorily welded by this method are most grades of carbon alloy and stainless steels, aluminum, and most of its alloys, magnesium and most of its alloys, copper, copper-nickel, phosphor bronze, tin bronzes of various types, brasses, nickel, monel, iconel, high temperature alloys, titanium, zirconium gold, and silver.

TIG WELDING

The basic requirements for inert-gas shielding arc welding consists of a power unit, gas shielded welding torch, shielding gases, auxiliary equipment, and protective welding equipment.

Power Source

The welding current may be supplied through either a welding generator, DC rectifier, or an AC transformer. Figure 35 illustrates a standard TIG welder. It is important that the unit have good current control at the lower end of the current range. Standard DC welding machines are employed and selected on the basis of the current output and the range necessary to meet the requirements of the work. Superimposed high frequency is used in some machines to permit starting the arc without the electrode contacting the work.

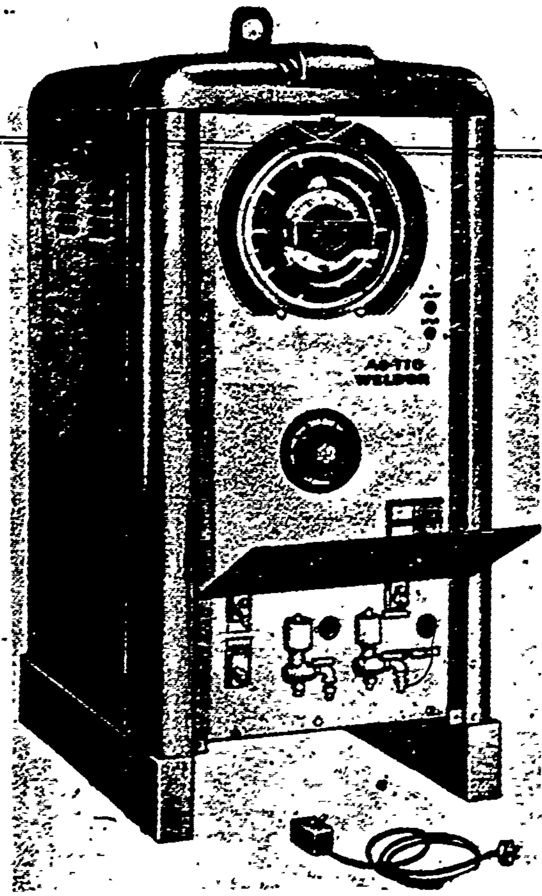


Figure 35. TIG Welder.

Torch

There are several types and models of gas-shielded welding torches being used today. The operation and design are basically the same with the exception of the manner in which they are cooled.

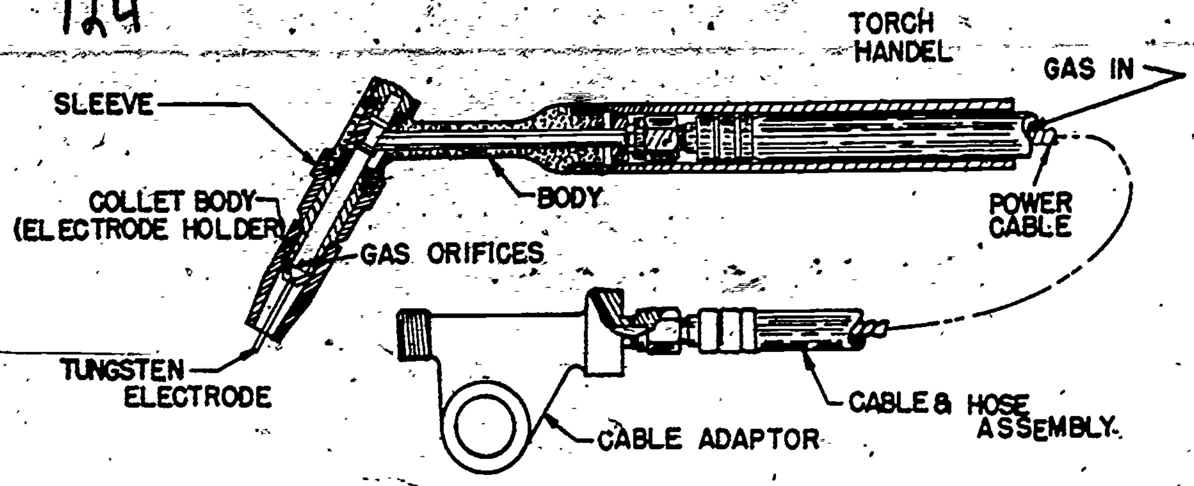


Figure 36. Air Cooled, Gas Shielded Arc Welding Torch.

The air-cooled torch, figure 36, is designed for manual welding of thin gage materials and is excellent for weld repairing thin sections of jet engine parts. This torch can be used for welding with high frequency stabilized alternating current or straight polarity direct current, depending on the job requirements. It can perform continuously on AC or DC current up to 100 amps.

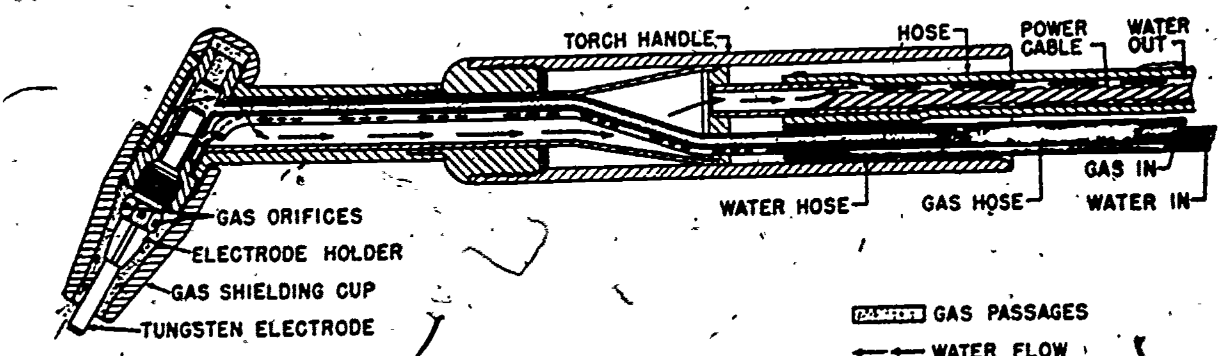


Figure 37. Water Cooled, Inert-Gas Shielded Arc Welding Torch.

The water-cooled torch, figure 37, is designed to operate at higher current ratings above 100 amperes and up to 300 amperes current capacity. Water cooling of the torch and power cable for inert-gas shielded welding makes possible the use of lightweight parts capable of carrying the rated current without danger of overheating. The power cable is located in the water discharge line hose. Water requirements are from one to two pints per minute. A special fuse of about 45 amps is installed in the power lead line to the torch to protect the equipment from overheating in case of water stoppage. The torch head basically consists of three parts: the collet or electrode holder, the gas shielding cup, and the tungsten electrode. The shielding gas enters through a plastic hose fitted to the rear of the torch handle, passes through the body, and emerges from the gas orifices in the torch head. It is then guided down toward the weld or molten pool by the gas shielding cup that surrounds the electrode.

The tungsten electrode is held firmly in place by a replaceable eletrode holder (collet) that screws into the torch head. The threaded end that screws into the torch head is split into four parts. When the electrode holder is tightened, a clamping action takes place on the electrode and holds it firmly in place. The holders are made in various sizes and hold electrodes from .020 to 1/4 inch in diameter and from 3 to 12 inches long.

Gas shielding cups are made from plastic, metal, and ceramic tile. They are made in various sizes and the size selected depends on the size of the electrode to be used. The cup number indicates the diameter of the cup in 1/16 of an inch. Continued use of the torch at high amperage tends to deteriorate the shielding gas cup. For this reason, metal water-cooled cups are used with currents above 100 amps.

Hose

Rubber or plastic hose is used to circulate water for cooling the torch and power cable lead. The bare, flexible lead cable is enclosed in the water outlet hose. A separated hose is used for the water inlet and another for feeding the shielded gas to the torch. In case of water stoppage, welding must be stopped to prevent damage to the welding equipment.

Water stoppage may result from an accumulation of dirt in the small passages of the torch. This condition can usually be corrected by disconnecting the water lines and momentarily reversing the flow of water. Three possible causes of leakage in water lines are an excessive high water pressure, mistreatment of equipment, and improperly sealed hose connection. If leaking occurs in the torch handle, soldered repairs may be necessary. When the hose is damaged near a connection, it is only necessary to cut away the broken section and reinstall it to the fitting. Rubber cement or a hose clamp may be used for securing a leakproof joint. When repairing the water outlet hose, it is necessary to remove an equal length of electrical cable.

The argon or helium hose must be gastight. If the molten pool becomes cloudy or the tungsten electrode turns a blue while cooling, it is an indication of a leak in the hose or hose connections. If, for any reason, the plastic hose is subjected to temperatures above 125 degrees, it becomes soft and loses its strength. It should be protected carefully and not allowed to come in contact with hot metal. Hose that has been burned or broken should be replaced because it cannot be effectively repaired. Leaks cause the shielding gas to become diluted with air and causes contamination of the molten pool and the adjacent metal.

Tungsten Electrodes

Four types of tungsten electrodes are used for gas shielded welding. They are commercially pure tungsten, 1% thoriated tungsten, 2% thoriated tungsten, and tungsten containing .3 to .5 percent zirconium. The thoriated tungsten electrodes are superior to pure tungsten electrodes because of their higher electron flow, better arc starting and stability, high current carrying capacity, and higher resistance to contamination. The tungsten electrodes containing zirconium have been refined and improved to make them better than the thoriated tungsten electrodes but are considered to be too expensive for normal Air Force use.

The tungsten electrodes are color coded for easier selection. Pure tungsten has a green end, 1% thoriated has a yellow end, 2% thoriated has a red end, and the zirconium tungsten has a brown end.

Tungsten electrodes are practically nonconsumable, but when the electrode unintentionally touches the molten pool, a small ball forms on the end, which may cause an erratic arc. This metal pickup should be removed by grinding or breaking it off with a pair of pliers. Electrode loss due to oxidation can be prevented by leaving the gas on a short time after the arc is broken, allowing it to cool in the protective atmosphere of the shielding gas. Tungsten electrodes are available in diameters of .020 to 1/4 inch and in lengths of 3 to 12 inches. The diameter of the electrode to be used depends upon the current setting used in welding.

Foot Control

The foot control is a foot-operated rheostat which is installed in the field circuit of the welding machine to change the arc for varying thicknesses of metal. This provides a convenient method of making slight changes in current settings during welding. This control enables you to start and stop the machine, and provides a convenient method of making current settings during welding. Another advantage is that the control shuts off the welding and at the same time allows the gas to flow, which protects the weld during cooling, and helps to control crater cracking.

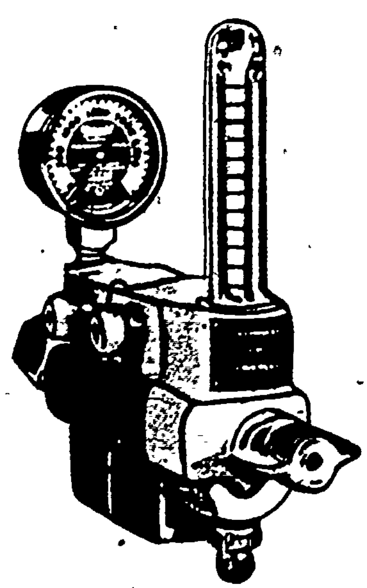


Figure 38. Argon Regulator Flowmeter.

Gas Regulator

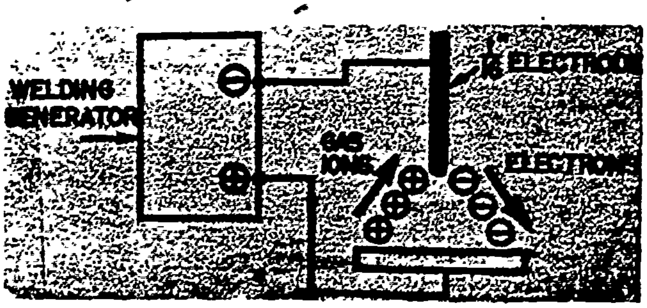
A combination regulator-flowmeter, figure 38, has been developed to control the flow of shielding gases. It steps down the high pressure in the cylinder or manifold to lower working pressures. The gas flow to the apparatus is indicated on a flowmeter tube. In operations in which the gas consumption is high, a central cylinder manifold system can be installed and the gas piped to the various welding stations. The flowmeter is equipped with a manual throttle valve for gas flow adjustment so the welder can set the gas flow required. The flowmeter tube is calibrated at a positive pressure which normally exceeds any back pressure produced by the equipment. This makes a true reading of the gas pressure possible.

For economic reasons and for ease in handling, both manual and mechanical shutoff valves are made available in the power unit. Electric solenoid valves are installed in the unit, allowing the flow of shielding gas and water to be turned on automatically when the foot control is used. These valves are designed in such a manner that they can be timed to allow the gas and water to flow before the arc is struck. When the foot control is used to stop the arc, the gas and water continue to flow for a specified time. The flowing of gas and water after the arc is stopped permits cooling of the electrode and molten pool, protecting them from atmospheric contamination.

Welding Current

DIRECT CURRENT. The welding circuit may be connected as either straight or reverse polarity. The choice of polarity depends upon the type of metal to be welded.

In direct current straight polarity (DCSP) welding, the electrode is negative and the work is positive, as shown in figure 39A. In straight polarity welding, the electrons strike the plate at high velocity, producing a concentration of heat effect upon the plate. The heat not only influences the welding action, but the shape of the weld also. DCSP produces a deep, narrow weld, as shown in figure 39B.



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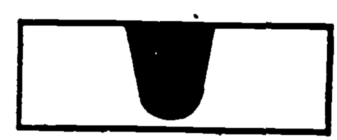
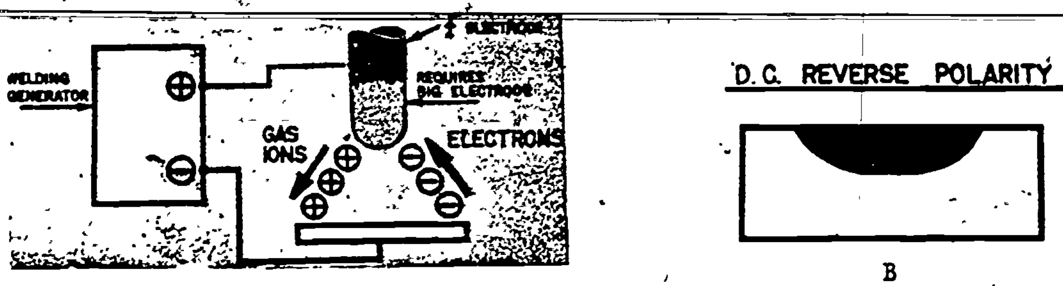


B

Figure 39. Welding Current.

128 Direct current reverse polarity (DCRP) welding, the electrode is positive and the work is negative, as shown in figure 40A. In reverse polarity welding, the electrons are flowing from the plate to the electrode. This requires the use of large diameter electrodes to absorb the extra heat generated and helps to prevent the electrode from burning off. DCRP produces a wide, shallow weld, as shown in figure 40B. For any given welding current, DCRP requires a larger diameter electrode than DCSP.



A

B

Figure 40. Direct Current - Reverse Polarity.

ALTERNATING CURRENT. Alternating current (AC) welding is a combination of DCSP and DCRP welding current. One-half of each complete cycle is DCSP and the other half is DCRP, as shown in figure 41. Foreign matter, such as moisture, oxides, or scale, on the surface of the plate, tends to prevent the flow of current in the reverse polarity direction. If no current flows in the reverse direction, rectification is taking place and the current wave would look like figure 42. To prevent this from occurring, it is common practice to superimpose high voltage, high frequency additional current on the standard welding current. When high frequency is superimposed upon AC welding current, a continual flow of electrons is jumping the gap between the electrode and the work piece, piercing the oxide film and forming a path for the welding current to follow. Some advantages that are obtained from using high frequency current are starting the arc without touching the electrode to the work piece, better arc starting and stability, a longer arc is possible, welding electrodes have a longer life, and wider current ranges can be used. A typical weld contour produced with high frequency stabilized AC is shown in figure 43, with DCSP and DCRP welds for comparison.

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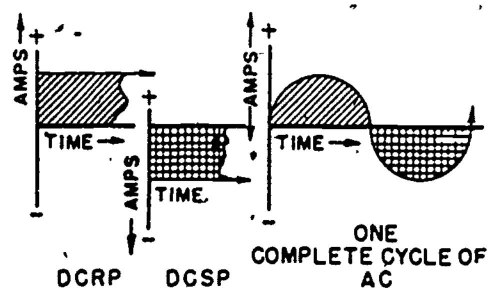

Figure 41. AC Wave.

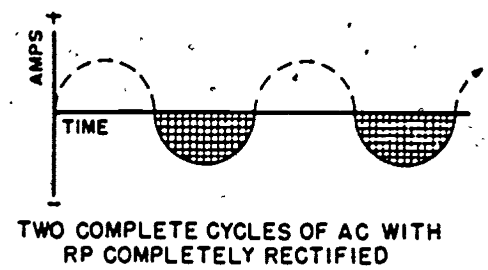

Figure 42. Rectified AC Wave.

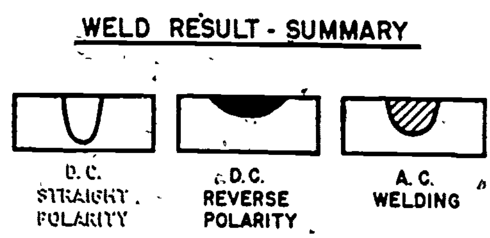

Figure 43. Comparison of Weld Contours.

Shielding Gas

Although there are several inert gases which may be used for gas shielded welding, argon and helium are the two most commonly used. The main reasons for this is the complete chemical inertness and insolubility in molten metals; electrical characteristics that are favorable to smooth, quiet arc action, and efficient metal transfer at high current density. Whether argon or helium is used for the shielding gas depends on the distinctive characteristics required to produce the desired results. Argon is used in most cases, but helium is used when more heat per ampere of welding current is needed. This characteristic of helium becomes a disadvantage when welding very light gages of metal, 1/32 inch or less.

The term "inert-gas" suggests a chemically inactive gas, one which will not combine with any other element. The two gases produce different effects upon the materials to be welded due to arc voltage, argon producing a narrow bead with deep center penetration, while helium produces a wide bead with comparatively shallow penetration. These differences often make one or the other of the two gases, or a mixture of the two, preferable for specific applications.

Many other types of gases and gas mixtures have been tested, but all have some deficiency which prevented them from being used, such as causing rapid deterioration of the electrode, porosity in welds, and arc instability. Some have been found quite useful for specific purposes, such as nitrogen, which is used as a shielding gas for welding copper. Also, mixtures of argon, helium, and hydrogen have been used in welding stainless steel and some nickel-bearing alloys, such as monel. Both gases are plentiful, but due to the difference in weight, three times as much helium is required for shielding as argon.

ARGON. Argon is a colorless, odorless, nontoxic, and nonflammable inert-gas, which is somewhat heavier than air. It is supplied in cylinders similar in size and shape to oxygen cylinders, carrying pressure between 2000 and 2500 pounds per square inch. The cylinder may be identified by the distinctive color markings of gray with a white band painted horizontally around the cylinder. The cylinder is considered empty when the pressure is reduced to 40 pounds per square inch and should be replaced with a full cylinder.

Gas purity may have considerable bearing on welding, depending upon the extent to which materials are affected by impurities, stainless steel, as a rule, is not significantly affected by small percentages of impurity in the shielding gas. Nonferrous metals, such as aluminum and magnesium, are relatively sensitive to impurities and are best welded with high-purity gas. The argon and helium gases which are commercially available from most sources are of high purity and average well over 99.95% pure.

Argon is generally used for all alternating current welding applications, such as welding aluminum, magnesium, or copper. The arc is relatively hard to start in helium gas shielding when very low welding current is used. This difficulty is not encountered with argon and the low arc voltage characteristic is particularly helpful in the welding of thin materials since the tendency toward burn-through is reduced.

HELIUM. Helium is a colorless, odorless, nontoxic, and tasteless inert-gas. It is also much lighter than air being the second lightest of all gases. Helium is nonflammable and is placed under pressure in cylinders, like argon, with 2000 to 25000 pounds per square inch. The cylinders may be identified by the distinctive color markings of gray with a buff top (light brown). The cylinder is considered empty when the pressure is reduced to 25 pounds per square inch and should be replaced with a full cylinder.

Helium is used mainly with direct current welding machines, using DCSP. This shielding gas is used to weld magnesium using DCRP. High arc voltage and current settings are desirable for welding thick metallic materials which have high heat conductivity.

WELDABILITY OF STAINLESS STEELS

Stainless steels are probably the most easily welded of all metals by the gas shielded process. They are generally welded with direct current straight polarity, using argon as the shielding gas. These factors give maximum heat input, resulting in deep penetration and fast welding speeds. This technique minimizes carbide precipitation in nonstabilized stainless steel and helps reduce distortion on thin sections.

Carbide precipitation is an important factor to consider in welding stainless steel. When the metal is kept at an elevated temperature for any length of time, the carbon combines with chromium and forms chromium carbide. In the region of this carbide formation, a loss of corrosion resistance results and the tensile strength and ductility are reduced. This usually occurs near the fusion line in the welding of stainless steel. The effect can be reduced to a minimum by confining the arc or heat to as small an area as possible. This means that best results are obtained by the use of smaller electrodes, higher amperages, and faster welding speeds. Inert-gas shielded welding is very adaptable in this respect as the tungsten electrode has a very high melting point, allowing the use of high amperages with smaller diameter electrodes. This permits higher welding speeds, a narrow heat affected zone, and more rapid cooling of the metal.

The coefficient of expansion for stainless steel is approximately 60% greater than for carbon steels, and special precautions are a necessity. To resist the tendency to warp during welding, joint edges must be correctly aligned and properly spaced. Tack welds must be closely spaced in accordance with metal thickness. Thin gage metals offer less resistance in warpage when heat is applied and must, therefore, be tack welded at closer intervals than heavy gage metals.

WELDING STAINLESS STEEL PIPE

The corrosion resistant pipe welding represents a very large portion of the welding being performed. There are countless applications where the techniques of modern pipe welding may be successful and profitably employed. Heli-arc pipe welding is a recent advance in the joining of corrosion resistant metal. High quality welds with uniform penetration may be readily made at a lower cost than welds made with either oxyacetylene or covered electrode welding.

132 Corrosion resistant steels, such as stainless steels have come into their present wide use mainly because of one characteristic they have in common; they are all resistant to corrosion and oxidation. This corrosion resistant property is due to a chromium content in amounts of over 10 percent. Other elements added to impart certain desirable properties are nickel, manganese, columbium, titanium, molybdenum, silicon, and carbon.

BUTT JOINTS

The most common type of joint used in the fabrication of welded pipe systems is the butt joint. It is the most satisfactory from the standpoint of stress distribution.

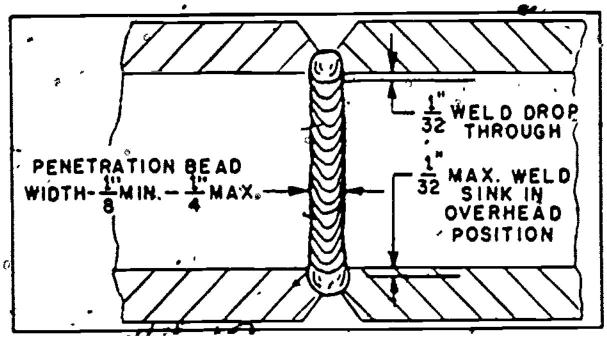

Figure 44. Typical Weld Dimensions of a Standard Vee Joint With Joint Spacing.

Butt joints should be reinforced with weld metal in excess of the net throat dimension by at least 1/16 inch. The reinforcement should be so built up that there is a gradual increase in thickness from edge to center. Excessive reinforcement should be avoided, as it may introduce undesirable stress concentration. Figure 44 shows typical weld dimensions of a butt joint.

Reinforcement of butt welds shall be not less than 1/16 inch, nor more than 3/32 inch above the surface of the base material. Reinforcement shall be built up uniformly from the surface of the base material to a maximum at the center of the weld, and shall blend smoothly and gradually with the base material. Finished weld contours shall be uniform and free from depressions below the surface of the base material.

Butt welds shall have a finished bead width approximately 1/16 inch on each side of the bead. Under no conditions are wide welds to be used to cover poor fit-up.

Joint Designs

Five joint designs have been developed for pipe welding using heli-arc process and are illustrated in figures 45 through 49.

These joints are satisfactory for rolled pipe, as well as pipe in the fixed vertical positions. All pipe with a wall thickness greater than approximately 1/8 inch should be beveled for heli-arc welding. It must be beveled if filler rod is used.

STANDARD VEE JOINT. The vee groove joint illustrated in figure 45 has been widely accepted as a standard joint design for pipe welding. The standard vee joint may be butted together and welded without filler rod on the root pass. However, for higher quality welds, filler rod is required.

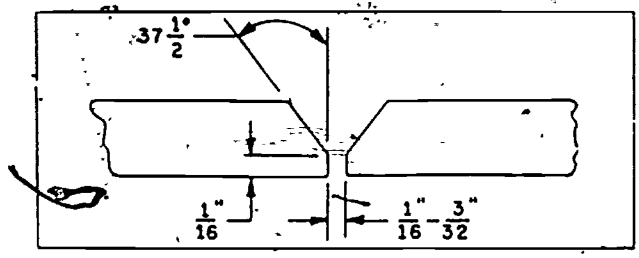

Figure 45. Standard Vee Joint.

SHARP VEE JOINT. The vee joint illustrated in figure 46 will be called the sharp vee joint to distinguish it from the standard vee. The sharp vee joint is adaptable to field erection of pipe.

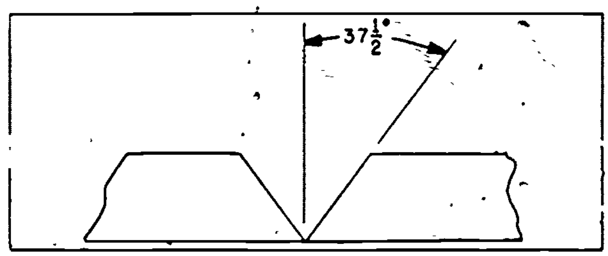

Figure 46. Sharp Vee Joint.

U GROOVE JOINT. The joint illustrated in figure 47 is recommended where more uniform welds and higher quality welds are required than could be obtained with the vee groove joints. Penetration is uniform with this design and weld "sink in" in vertical position is minimized.

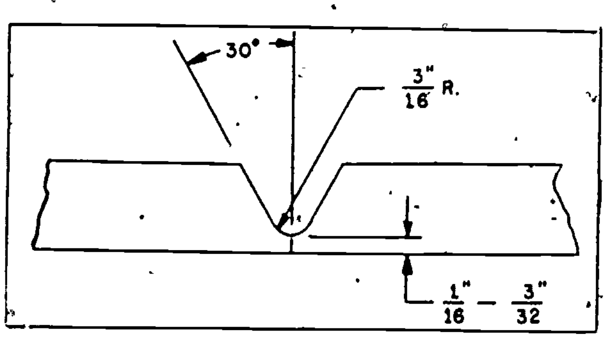

Figure 47. U Groove Joint.

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CONSUMABLE INSERT JOINTS. Consumable inserts are available and will produce the highest weld quality and the strongest inside weld reinforcement. Figure 48 illustrates the consumable insert joint design as well as the insert. The joint preparation requires close joint tolerances, and fitting the insert into the joint is time consuming; but since the composition of the insert may be selected to vary the composition of the weld, the weld results may be superior.

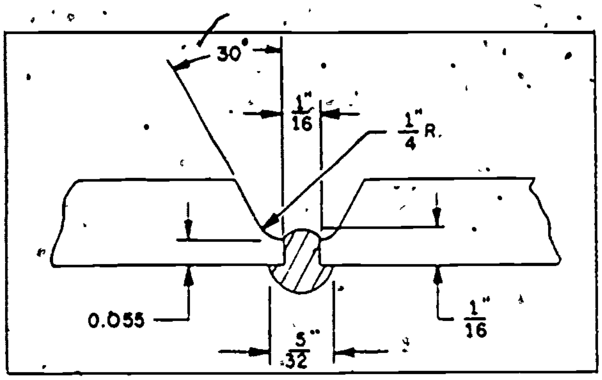

Figure 48. Consumable Insert Joint, Wall Thicknesses Less Than 1/8 Inch.

ROLLED EDGE JOINT. Another method of obtaining inside weld reinforcement is the rolled edge joint. The lefthand section of figure 49 shows the first stage in preparing this joint; the righthand section of the same figure shows the finished joint. The rolled edge joint is recommended for killed steels or stainless steels. It is ~~less costly~~ than the consumable insert joint, and the fit-up conditions are less critical.

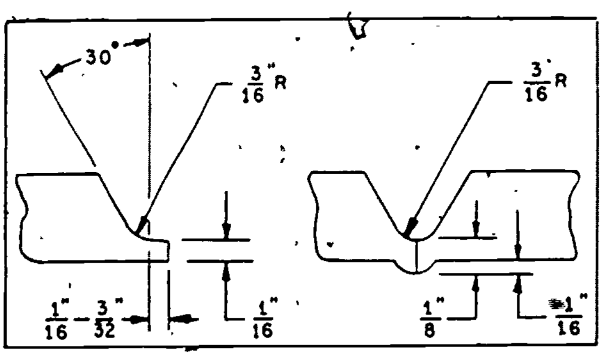

Figure 49. Rolled Edge Joint Preparation.

BUTT JOINT SPECIFICATIONS. Butt welds should have one pass for each 1/8 inch of pipe wall thickness, with a minimum of two passes. Butt welds will be flush with the inside of the pipe. In cases where grinding is not possible, the following even underhang dimensions are allowed.

Pipe Size	Maximum Protrusion
up to 2 inches	1/32 inch
2-1/2 inch and over	1/16 inch

WELDING TECHNIQUES

Starting the Arc

Whenever possible, the arc should be started by a high frequency arc starter attachment. The high frequency current shall be sufficient to start the arc without touching the electrode to the workpiece.

Use the foot control rheostat to adjust arc to the approximate desired heat.

Move the arc to the joint edges and travel steadily along (forehand), holding the electrode as near vertical to the joint as possible.

Filler rod should be added at the forward edge of the pool.

If your welding speed is too slow, you will have excessive penetration inside the pipe. The weld puddle will then have a rounded opening at the front of the puddle which will be wider than the joint opening (keyhole shape). Remember that a keyhole shaped puddle for a spaced joint shows excessive penetration, since too much of the edges are being melted back.

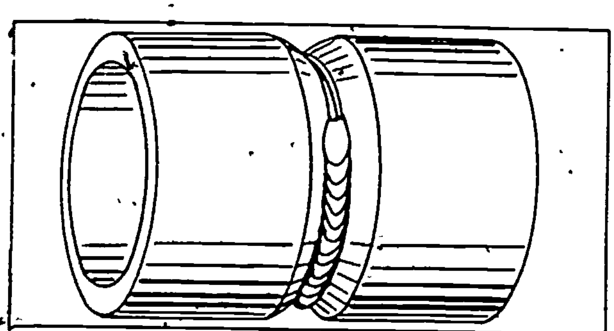

Figure 50. Correct Puddle Shape for Standard Vee With Joint Spacing.

To overcome excessive penetration, add more filler rod to the puddle, slant the torch sharply toward the filler rod so more rod is melted, and increase your welding speed. The effect will be to put more heat into the filler rod and less into the pipe itself. This will close the enlarged opening at the front of the puddle, figure 50.

Breaking the Arc

The preferred method for breaking the arc shall be to extinguish the arc by use of a foot-operated current control to decrease the welding current gradually until the arc will travel without fusing the base metal. If the foot-operated current control is not available, the rate of travel shall be increased to a speed at which the arc will travel without fusing the base metal, and the arc can then be broken.

Purging

Pipe shall be purged before welding is started, and purging shall be maintained throughout the entire welding operation. When conditions permit, the purging gas should be introduced at the lowest point in the pipe or system and vented out at the high points. Oxidation of weld deposits and/or base metal is not permitted.

When you add the filler rod, the rod should be almost tangent to the pipe surface and the heli-arc torch should be slanted about 15 to 20 degrees toward the rod with an arc length of about 1/16 inch, figure 51.

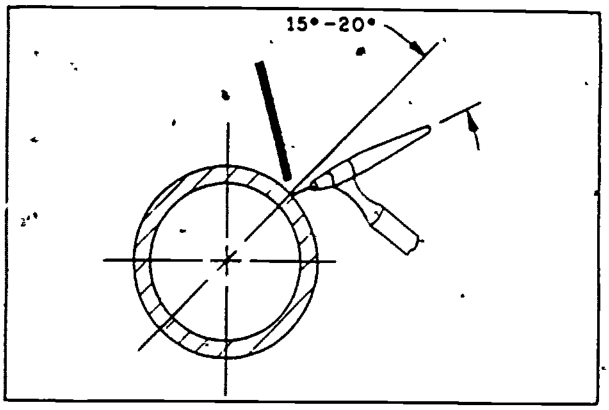

Figure 51. Relative Position of Torch and Filler Rod to Pipe.

When the puddle increases to about 1/8 inch thick, remove the rod and hold the torch stationary. The weld puddle will now begin to flatten out in front, forming a thin front edge and will take a wedge shape, with rounded corners extending to the bottom of the joint. This wedge shape means that penetration is complete. Figure 52 illustrates the correct puddle shape for complete penetration on this joint.

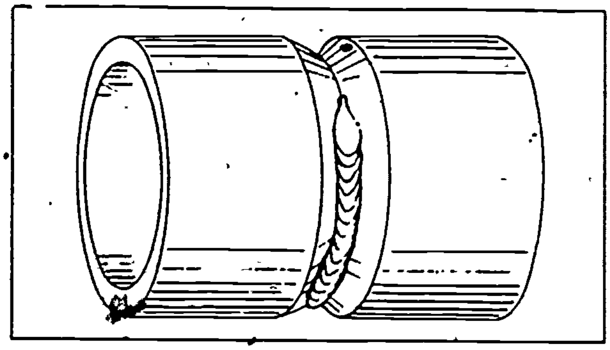

Figure 52. Correct Puddle Shape for Sharp Vee Joint.

As soon as penetration is complete, as shown by the puddle shape, add filler rod and advance the heli-arc torch simultaneously. Keep advancing the correct puddle shape to complete the pass. When you have mastered the technique, you will be able to keep the height of the puddle even and about 1/8 inch thick (depending on the pipe size).

Note: Manipulation of the torch is not necessary to obtain the proper width of weld in light gage metals.

When terminating the weld, the foot control should be swung to the low position, the arc broken, and the shielding gas permitted to flow over the weld area until it has cooled to a black heat.

In order to avoid overlap when restarting a weld, the arc is struck ahead of the terminated weld (approximately 1/4 inch) and then moved back to the end of the weld so as to bring it to the molten state before adding rod.

Vertical Position Welding

Pipe welding in the vertical position is where welding is performed in the horizontal position and the pipe may not be rotated.

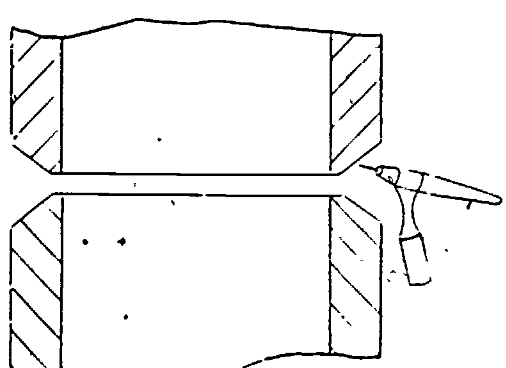

Figure 53. Torch Position for Welding Pipe in the Vertical Position.

Special techniques are required to compensate for the sagging of the puddle due to gravity. Position your torch as shown in figure 53. The weld puddle is formed on the upper side of the joint and is kept slightly above the centerline of the joint. Move the torch in small circles, from the top of the puddle around the puddle to the bottom and then up the other side to the top. Do not let the arc dwell too long on the bottom, but let it favor the top of the weld. This circular motion will ensure fusion of the bottom of the joint with the filler rod, and yet will not undercut the upper side of the weld bead.

Overhead Position Welding

In the overhead weld position, the entire weld is accomplished with the material at or above the welder's eye level. After tack welding, the pipe is set up so that the centerline is horizontal or approximately so. The pipe must not be moved in any direction.

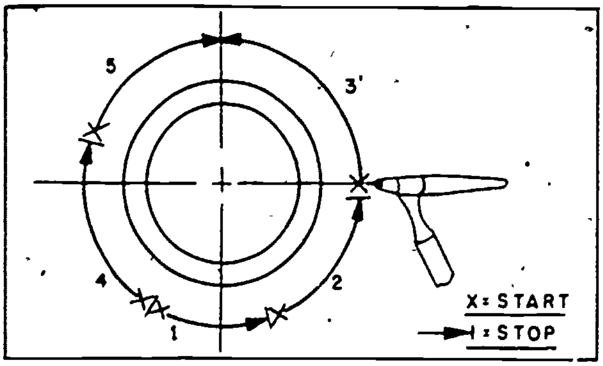

Figure 54. Welding Sequence for Pipe.

After the joint has been properly tacked and placed in position for welding, figure 54, strike an arc on the side of the joint and carry it to the bottom of the joint. Let the arc dwell on the bottom of the joint until a small weld puddle forms on each side of the vee. Then add filler rod to the front of the weld puddle until the puddle bridges the joint opening. (Do not put the filler rod directly into the arc.)

QUESTIONS

1. What type of inert gas is most commonly used?

2. What is the minimum number of weld passes on a stainless steel pipe weld?

3. What are the reinforcement requirements on a stainless steel pipe weld?

4. What are the five joint designs that have been developed?

REFERENCES

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

INERT GAS SHIELDED ARC WELDING OF ALUMINUM PIPE JOINTS

OBJECTIVES

After completing this study guide, you will apply the fundamental principles and techniques involved in machine set-up, current settings, gas adjustment, filler rod selection, and welding aluminum pipe in the fixed vertical, horizontal, and overhead positions for the butt, angle, and tee joints.

INTRODUCTION

Although the basic procedures involved in welding aluminum and alunimum alloy pipe and tubing are the same as for welding other types of pipe, the machine set-up and filler rod differ considerably. A weld placed on aluminum alloy pipe using the settings and procedures for stainless steel would cause the joint to fail immediately. For this reason, extreme care must be taken to ensure you are using the correct settings, procedures, and filler rod for each pipe joint regardless of the material involved.

INFORMATION

Pure aluminum weighs approximately 1/3 that of steel. It is a very good conductor of electricity, has a high resistance to corrosion, and is a good conductor of heat. It is easily formed by rolling, drawing, hammering, pressing, etc., into any of the many shapes required. It has very good casting qualities by the die cast, permanent mold, or sand casting method. In spite of these desirable properties, aluminum in its pure or nearly pure form has very low strength characteristics. This factor makes unalloyed aluminum useless for structural aircraft parts.

Aluminum alloy can be made as strong as low carbon steel. In fact, some fully heat-treated, cold worked, and artificially aged aluminum has the highest weight-strength ratio of any structural alloy known. Although the aluminum alloys, as such, possess higher strength characteristics than the pure metal, most of the aluminum alloys have lower corrosion resistance qualities than the pure aluminum. For this reason, most alloys possess a clad or alclad coating of pure aluminum or some more corrosion resistant alloy than the base metal. On metal parts where this clad coating is not present to protect the base metal, other corrosion preventive treatment, such as painting, anodizing, etc., are used to induce high surface corrosion resistance. Heat treatment may increase or decrease the corrosion resistance of aluminum alloys.

TEMPER DESIGNATIONS

Temper designation for aluminum and its alloys is an alphabetical-numerical code system used to properly designate the physical or mechanical properties of the alloy. These designations differ for each type of alloy according to the heat treatment, forming, or other operations to which the alloy has been subjected. The temper designations are divided into two main classes; those pertaining to alloys that are hardenable by heat treatment and those that are not hardenable by heat treatment. The temper designations are the letter and numerical code numbers immediately following the numerical alloy designation.

Old Temper Designations	New Temper Designations: Strain Hardened Only	Strain Hardened Then Partially Annealed	Strain Hardened Then Stabilized
	Alloy 1100 & 3003 (Formerly 2S & 3S)		
1/4 H	-H 12	-H 22	
1/2 H	-H 14	-H 24	
3/4 H	-H 16	-H 26	
H	-H 18	-H 28	
Extra Hard (Not Standard)	-H 19		
	Alloy 3004, 5052 & 5056*-(Formerly 4S, 52S and 56S)		
1/4 H			-H 32
1/2 H			-H 34
3/4 H			-H 36
H			-H 38
Extra Hard (Not Standard)			-H 39

*These alloys may also be obtained in -H1 and -H2 tempers but -H3 is not applicable to alloys 1100 and 3003.

Table 4. Temper Conversion for Nonheat Treatable Aluminum Alloys.

Nonheat Treatable Alloys

The letter "F" designating "as fabricated" in the case of wrought alloys, indicates that no control has been exercised over the temper, and the part is to be used in this condition. The "O" temper designation indicates the annealed condition of an aluminum alloy. These two designations are applicable to either heat treatable or to nonheat treatable alloys. Prior to the introduction of the newer temper designations for nonheat treatable wrought alloys, the only temper designations for these alloys other than "O" or "F" were 1/4 H, 1/2 H, 3/4 H and "H", denoting a strain hardened condition from 1/4 hard through full hardness for any nonheat treatable alloy. Table 4 gives a breakdown of the new system as compared with the old one.

Heat Treatable Alloys

The temper designations for heat treatable aluminum alloys consist of the letter "T" followed by a one or two digit number. The "T" designation after the alloy designation denotes that a basic heat treatment has been performed for the purpose of inducing increased hardness, tensile strength, etc. The one or two-digit number following the "T" denotes supplementary operations and/or the degree of increased hardness, tensile strength, etc., gained by the combination of strength producing operations. These operations may include solution heat treatment, natural or artificial aging, cold working, stabilization treatment, or any other operation that may induce the desired or required properties in the various alloys.

Interpretation of Individual Temper Designations

In addition to understanding the meaning of the basic problems involved by the "T" designation on aluminum alloy, the man in a shop should also know what the individual numerical designations following the "T" mean, as shown in table 5.

1. -W designation on alloy indicates that the part has been given the required soak at the solution temperature and quenched, but has not been aged either naturally or artificially. 2024 alloy ages naturally at room temperature and must be kept under refrigeration, or within 24 hours, 90% of the age hardening will take place and the "W" temper will then be present. With alloy 7075, artificial precipitation is necessary to age harden the alloy, which will remain in the "W" condition for several weeks because it takes up to two months for 7075 alloy to naturally age harden.

2. -F and -O temper designates the "as fabricated" and annealed conditions respectively.

3. -T2 temper applies only to cast products annealed to increase ductility.

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Temper Designation		Meaning of Temper Designation
"S" means a wrought alloy when this letter follows the old alloy designation as opposed to the cast condition. No particular temper is indicated unless followed by one of the designations below.		
	-W ----------------	-Solution heat-treated, but not aged.
	-T2----------------	-Annealed (applicable to casting only).
	-T3----------------	-Solution heat-treated, cold worked.
	-T4-----------------	Solution heat-treated, naturally aged.
	-T5-----------------	Artificially aged only.
	-T6-----------------	Solution heat-treated and artificially aged.
	-T7-----------------	Solution heat-treated and stabilized.
	-T8-----------------	Solution heat-treated, cold worked, artificially aged.
	-T9-----------------	Solution heat-treated, artifically aged, cold worked.
	-T10----------------	Artifically aged and cold worked.

Table 5. Explanation of Temper Designations.

4. -T3 temper applies to parts which have been solution heat treated and then cold worked. T3 alone applies to sheet stock in which the slight effect of cold working after the hardening quench, such as flattening during manufacture, is recognized. Additional cold working is designated by a second digit after the 3, such as T31, T34, T36, etc. The larger the second digit, the greater will be the amount of cold working and final hardness. This final hardness is induced by stretching.

5. -T4 temper denotes parts which have been solution heat treated and naturally aged. It applies when a part is not cold worked after heat treatment and is the true temper induced by a shop heat treatment on a newly fabricated aircraft part.

6. -T5 temper designation applies to products that are artificially aged without prior solution heat treatment. It is not normally used with regular sheet stock, but is visually applicable to casting alloys and large extrusions.

7. -T6 temper indicates products which are solution heat treated and artificially aged with no cold working after the solution treatment. This temper is well known in alloys 7075, 6061, and 2014.

8. -T7 temper indicates solution heat treated and stabilized mainly for the purpose of reducing stress after solution heat treatment. It is usually applicable to cast alloys and not to the wrought alloys in common use.

9. -T8 temper designates a part that is solution heat treated, cold worked, and artificially aged. It is quite widely used to designate the strongest tempers available on plain 2024 and 2024 clad aluminum alloys and other wrought alloys. This temper number is found as the first digit indicating the above processes; the second digit used in conjunction with the 8, indicates the amount cold working due to stretching (elongation) that the part or sheet has been subjected to ranging from T81 through T86.

10. -T9 temper applies mainly to cast products that have been solution heat treated, artificially aged, and then cold worked. This temper is not usually found on wrought alloy products.

11. T-10 temper is also one of the less known temper designations because it pertains to cast materials that have been artificially aged and cold worked.

TIG WELDING PROCESS

Tungsten inert-gas process is preferred for welding aluminum sections which are less than 1/8 inch in thickness. Welding jigs are sometimes necessary and should be used in welding thin gage material to prevent warpage. TIG may also be used to weld heavier sections but the metal inert-gas process is usually chosen for its higher welding speed and needed voltage. In the TIG process, the arc is established between a nonconsumable tungsten electrode and the parts to be welded with a shield of inert-gas enveloping the arc and weld pool. The arc melts the base metal and a bare filler rod of suitable alloy is manually added to the molten pool. Welding can be done rapidly from all positions. Flux is not required in TIG welding because the action of the arc breaks up the oxide film and allows a good weld metal flow. A shield of inert-gas surrounds the electrode and the weld pool to prevent oxidation during welding. TIG welding is faster than gas welding due to the heat of the tungsten arc concentrated in a small area. Distortion in TIG welds are less than for gas welds.

Power Source

For any welding process, heat must be supplied to the base metal and the filler metal (if used) to fuse the component parts. The source of heat in the TIG process is the electric arc maintained between the electrode and the work piece.

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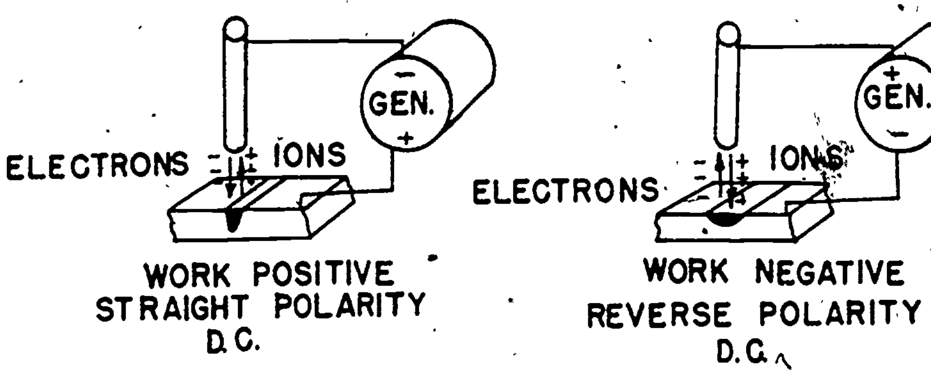

Figure 55. Machine Connections for DC Straight and Reverse Polarity Welding.

Alternating current is recommended for TIG welding of aluminum. For some welding applications, direct current, DCSP is used successfully. To better understand why alternating current is recommended for TIG welding applications, DCSP and DCRP are to be considered first. Machine connections for direct current straight and reverse polarity welding are shown in figure 55. In DCSP welding, the electrode is negative and the work positive, so that the electrons go from the electrode to the plate. In DCRP, the electrons flow from the plate to the electrode. In DCSP welding, there is considerable heating of the base plate, which is receiving electrons, while the electrode stays relatively cool. During DCRP welding, the opposite is true. As the electrode receives the heat from the electron transfer, it is overheated at quite low currents. This limits DCRP for TIG welding, since there is likely to be tungsten burn-off and contamination of the weld.

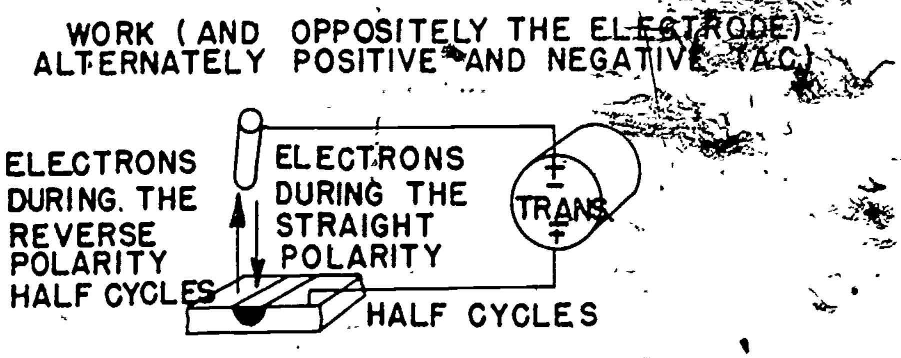

Figure 56. Electron Flow in AC Welding.

Alternating current is widely used for it offers both the advantages of DCSP and DCRP welding. Theoretically, AC welding can be called a combination of DCSP and DCRP welding, as illustrated in figure 56.

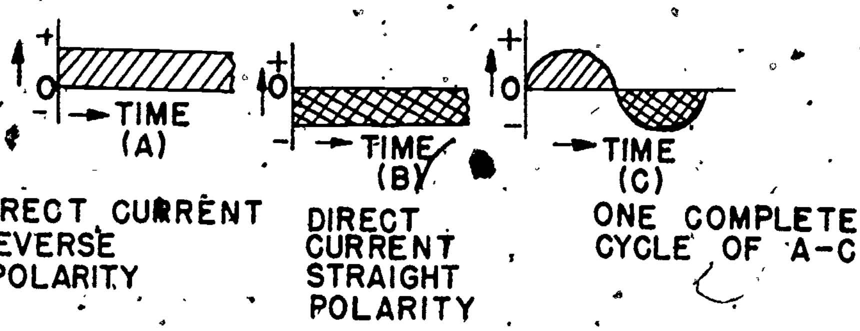

Figure 57. Current Flow in AC Welding.

In AC welding, when the current passes through zero, figure 57, the arc is broken. To restart the arc, high voltage, high frequency (120,000 cycles) low power additional current is superimposed on the welding current. Low frequency AC is difficult to start and maintain the arc. In using high frequency, a path is established for the current to follow when the arc is struck at zero current. After the arc is started and stabilized, the high frequency is automatically cut off.

Welding Equipment

In addition to the AC power source, the required equipment is as follows:

1. TIG welding torch.
2. Inert-gas supply, regulator-flowmeter, hose, and fittings.
3. Filler metal.
4. Water supply and fittings.
5. Helmet or eye shielding, and protective clothing.
6. Welding jigs or backup plates.

For currents above 100 ampers, cooling the torch and power cable with water is necessary because of heat generated by the arc and the current passing through the cable. For welding currents below 100 ampers, air-cooled torches are satisfactory.

Water used to cool the welding gun should be clean to prevent clogging or flow restriction. Overheating can melt the silver brazed metal joints in the gun and the plastic water tube which sheaths the electric cable. A control mechanism is available which does not allow the welding current to start unless the water is flowing. Some TIG welding equipment is provided with solenoid valves and valve timing controls to control the flow of water and gas during welding. When the welding is stopped, the timer allows the water and gas to flow for a sufficient length of time to allow the tungsten electrode to cool, thus preventing contamination when it is exposed to air. The tungsten must cool bright and shiny. Any bluing or blackening of the tungsten indicates a lack of gas coverage.

The TIG welding torch carries the welding current and directs the inert gas to the weld area. The torch must be properly insulated for the maximum current ranges to ensure operational safety. Current is transmitted from the AC transformer through the power cable to a collet holding the tungsten electrode. Gas ports surrounding the electrode permit the inert gas to enter the nozzle or cup which is directed upon the surface to be welded.

The electrode should extend beyond the end of the gas shielding cup a distance equal to its diameter for butt welding and slightly further (1/8 to 3/16 inch) for fillet welding. Selecting the right size electrode for each job is important in preventing electrode damage (pure tungsten melts at 6125°F) and causing poor welds by too high or too low a current. Excessive current will cause tungsten particles to transfer to the weld while insufficient current allows the arc to wander erratically over the end of the electrode. Recommended electrode sizes for various ranges of welding current are shown in table 6.

Electrode	Gas Cup	Welding Current (Amperes)		
Dia In.	No.	AC	DCSP	DCRP
.040	6	10-40	10-40	
1/16	6	20-60	20-75	10-20
3/32	6-7-8	30-100	30-100	15-20
1/8	6-7-8	150	100-150	25-40
3/16	7-8	200	125-200	40-80

Table 6. Selection of Electrode Diameter, Gas Cup and Current Setting.

Filler Material

Additional filler metal is not necessary in TIG welding when enough parent metal is provided by the joint design to form the weld bead. For other welds it is often necessary to add filler metal. Filler metal in the form of straight length, bare rod, is used for manual welding; while filler metal in wire form, spool wound, is used in both manual or automatic welding. The filler rod or wire should always be placed within the inert-gas shield and at the leading edge of the weld pool. Too large a rod or wire disturbs and often freezes the pool; while a rod too small in size forces the welder to feed too fast for steady hand operation. Care must be taken to see that a compatible filler metal is used in welding different alloys or longitudinal cracking may result. Dirty rods will contaminate the weld and every effort should be made to use only clean rods.

Metal Preparation

Cleaning the surfaces to be welded is of major importance in all aluminum joining regardless of the welding process. Oxide grease or oil film remaining on the edges to be joined causes unsound welds. Mild alkaline solutions and commercial degreasers that do not give off toxic fumes during welding are used successfully to remove surface contaminants before welding. All welding surfaces should be thoroughly dry after cleaning to prevent porosity in the weld metal. Oxide film should be removed from the surface of the aluminum by using aluminum wool or brushing with a clean stainless steel wire brush.

WELDING SET-UP AND APPLICATION

1. Place the pieces of metal in a jig and butt edges to check for fit-up and alignment. Clamp the pieces for alignment and spacing. Good joint fit-up makes welding easier.

2. Adjust the current setting and argon flow for the thickness of the metal being welded.

3. Tack weld at about 1 to 1-1/2 inch intervals; the tacks should be neat and small.

4. Adjust the arc to the desired length, between 1/8 to 3/16 inch.

5. Hold the arc at the starting point until the metal liquifies and a molten pool is established.

6. Add the filler rod manually to the front edge of the molten pool, melting a small amount and withdrawing the rod.

7. Point the torch in the direction of travel with a 10 - 20 degree angle from the vertical position.

8. Keep the filler rod fairly flat to the work surface between 15 - 30 degrees from horizontal position.

9. Advance steadily along the line of weld, keeping a uniform bead with evenly spaced ripples.

10. To terminate the weld, depress the foot control switch, keeping the torch directed on the molten pool. Gas and water will continue to flow for a few seconds, cooling the weld, preventing contamination of the metal and tungsten electrode.

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VERTICAL FIXED POSITION

Because of the lack of color change in aluminum at the melting temperature, welding of aluminum pipe has been a rather difficult operation until the TIG welding process came into use. With the more precise heat control and smaller heat affected area, welding of aluminum pipe in the fixed vertical position is a relatively simple operation.

For many years, aluminum pipe was generally jointed with threaded fittings. A trend toward welded joints gradually became evident. Today, welded piping systems are specified in a wide variety of industries. Initially, gas welded methods using oxhydrogen and oxyacetylene were used for welding aluminum pipe. These processes required the use of fluxes, which, unless removed subsequent to welding, were a corrosion hazard to the pipe in the presence of moisture. Welding other than in the flat position was very difficult. Both of these factors imposed a severe limitation on the use of welded piping systems.

Aluminum alloy pipe characteristics make them useful materials of construction. Many of these properties are of value in piping systems, including resistance to corrosion, strength, lightweight, protection of purity and color of the product, and ease of joining.

There is a variety of aluminum alloys, but only three are generally produced in pipe form. The first is alloy 3003-H112 which is a nonheat treatable alloy containing manganese. It provides adequate strength for many applications together with high resistance to corrosion. Alloy 6063-T6, a heat treated aluminum magnesium silicide type alloy, provides higher strength and equivalent resistant to corrosion. Alloy 6061-T6 is similar to 6063-T6 but has higher strength. In most environments its resistance to corrosion is equivalent to that of the other two alloys. Other pipe alloys such as 5052, 5154, 5083, 5454, and 5456 have excellent strength and ductility.

WELDING PROCESSES

AC High Frequency - Argon Gas

A gas tungsten arc method commonly used for aluminum pipe uses AC with superimposed high frequency, pure or 2% tungsten electrodes, and argon gas.

DC Straight Polarity

A second method uses DC straight polarity current, pure tungsten electrode, and helium gas.

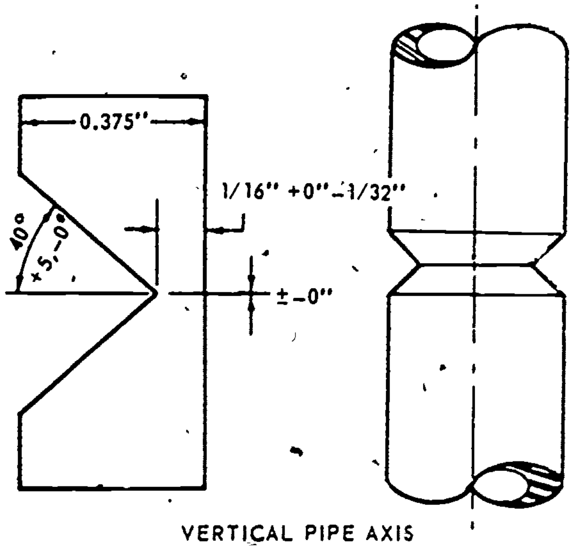

Figure 58. Weldment With No Root Opening - Vertical Attitude.

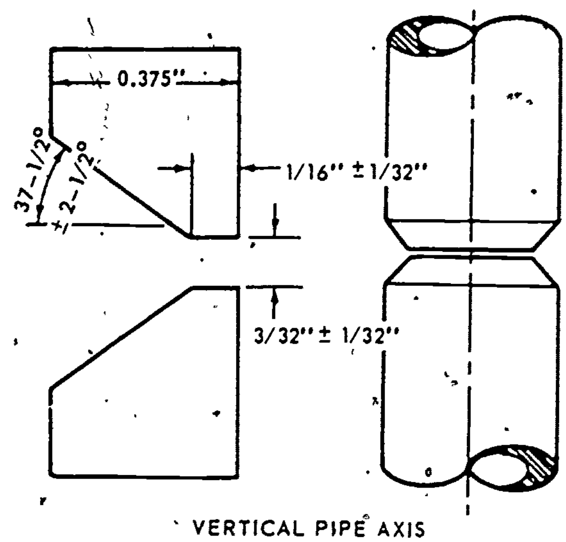

Figure 59. Weldment With Root Opening - Vertical Attitude.

WELDING PIPE BUTT JOINTS IN VERTICAL FIXED POSITION

Edge preparation of all butt joints must be melted through their full thickness to obtain a complete penetration weld. This can be facilitated by a combination of proper edge preparation as shown in figures 58 and 59. Figure 60 shows the finished joint.

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Figure 60. Finished Vertical Butt Joint.

AA Alloy Designation	AWS-ASTM Filler Metal Classification
1060	ER 1060
1100	ER 1100
5050	ER 5050
5086	———
5456	———
5052	ER 5052
5154	ER 5154
5254	ER 5254
6063	———
6061	———
6061	———
7072	———
6062	———
3003	———
3003	———
7072	———
3004	ER 3004
5356	ER 5356
5556	ER 5556
4043	ER 4043
5083	———
5183	ER 5183
5454	———
5554	ER 5554
5652	ER 5652

Table 7. Filler Metal Classification.

Filler Rod Selections

Filler metal selection can be made from figure 61.

Welding Technique

The successful welding of any joint requires proper edge preparation, cleanliness, and good fit, in addition to the actual deposition of the weld metal. Tungsten contaminated with molten aluminum must not be used. First, clean the prepared edges to remove all traces of combustible material and then assemble the joint. When the joint has been properly aligned, tack weld at three or more locations. The tack weld should be fully penetrated and rather flat; that is, not built up and should not exceed one inch in length. Three such welds placed equidistantly around the joint will usually maintain alignment. When applying a weld with the pipe in the vertical position, all passes should be applied as stringer passes.

When welding pipe, it is most satisfactory to point the electrode toward the center or axis of the pipe. This is more satisfactory than trying to modify the angle of the electrode along the length of the weld. The arc should be maintained at a controllable length, usually about 1/4 inch or just long enough to prevent contamination of the electrode when the welding rod is added. Short arcs do not contribute to ease of application or improvement of weld soundness or appearance. The inert gas should be adjusted to flow at a rate which will provide good cleaning; when operating on the bottom section of a joint in the horizontal fixed position, the gas flow must be increased in order to obtain freedom from porosity.

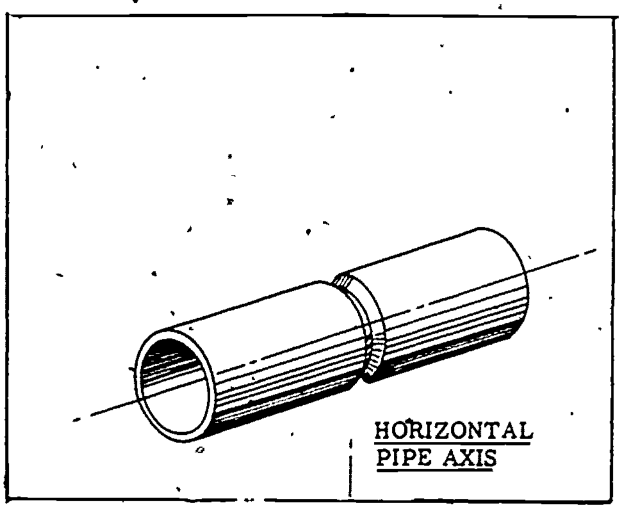


Figure 61. Orientation of Weld Joint.

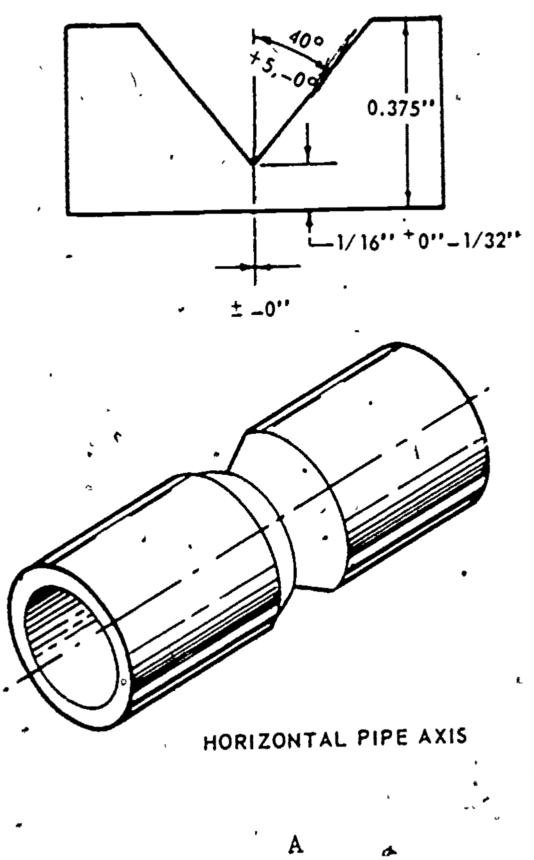
OVERHEAD FIXED POSITION

Using a little common sense and a whole lot of practice, the welding of aluminum alloy pipe joints in the fixed horizontal and overhead positions become no more difficult than welding in any other position. The key to all welding processes and positions can be summed up in one word - PRACTICE.

The orientation of weld joints with respect to horizontal and vertical planes of reference shall be in accordance with figure 61. Welding shall be accomplished without pipe rotation, so that weld metal is deposited from the overhead, vertical, flat, and horizontal fixed positions.

Welding shall be started at the bottom of the joint and progress upward to the top of the joint; under no conditions shall welding be performed in the reverse order. The horizontal reference plane is taken to lie always below the weld under consideration. Inclination of axis is measured from the horizontal reference plane toward the vertical.

Joint Preparation



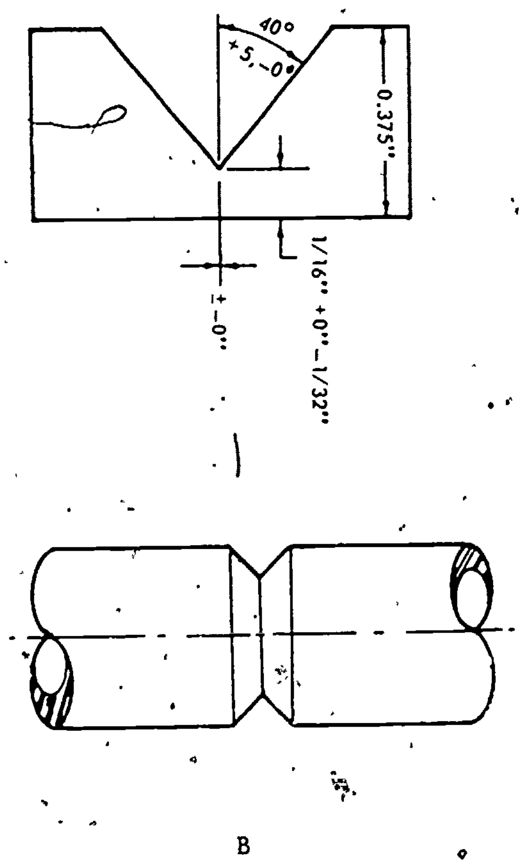


Figure 62. Joint Preparation Requirements.

HORIZONTAL POSITION WELDING

Joint Preparation

Welding edges of aluminum and nonferrous metals, with a wall thickness of 3/4 inch or less shall be beveled at a 40 (+5, -0) degree angle, leaving a 1/16 (+0 - 1/32) inch root face land at the bottom of the welding edge, figure 62.

Joints which require a root opening shall have a separation between lands or welding edges of 3/32 (±1/32) inch for the full length of the joint.

Joints which require no root opening shall have the lands or welding edges butted together so that the lands are touching and the beveled edges form a groove. There shall be no clearance between lands.

Weld Specification

WIDTH. Butt welds shall have a finished bead width approximately 1/16 inch on each side of the bevel. Under no conditions are wide welds to be used to cover poor fit-up.

REINFORCEMENT. Reinforcement of butt welds shall be not less than 1/16 inch, nor more than 3/32 inch above the surface of the base material. Reinforcement shall be built up uniformly from the surface of the base material to a maximum at the center of the weld, and shall blend smoothly and gradually with the base material. Finished weld contours shall be uniform and free from depressions below the surface of the base material.

PENETRATION. Butt welds shall be flush with the inside of the pipe. In cases where grinding is not possible, the following even underhang dimensions are allowed:

Pipe Size	Maximum Protrusion*
Up to 2 inches	1/32 inch
2-1/2 inch and over	1/16 inch

QUESTIONS

1. Into what two classes are the temper designations divided?

2. What current is used to weld aluminum?

3. What are the three aluminum alloys generally used in the manufacture of pipe?

4. What direction of travel will you use when welding pipe in the overhead position?

154 5. How far will the weld bead overlap the bevel on an aluminum pipe weld?

REFERENCES

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