



WELDING

Skills, Processes and Practices
for Entry-Level Welders

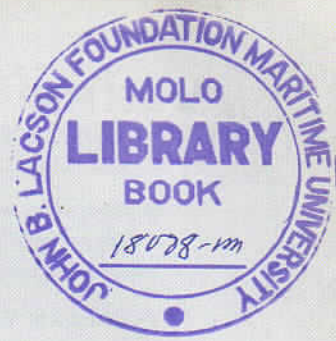


BOOK 3

- Shielded Metal Arc Welding
- Gas Tungsten Arc Welding

LARRY JEFFUS • LAWRENCE BOWER

671.52
J45
2010
C-3



Welding

Skills, Processes and Practices for Entry-Level Welders

Book 3

- **Shielded Metal Arc Welding**
- **Gas Tungsten Arc Welding**

Larry Jeffus
Lawrence Bower



Contents

Preface.....	ix
AWS Acknowledgment.....	xii
Acknowledgments.....	xiii
About the Authors.....	xiv

Chapter 1 Shielded Metal Arc Equipment, Setup, and Operation 1

<i>Introduction</i>	2
<i>Welding Current</i>	3
Measurement.....	4
Temperature.....	4
Currents.....	5
<i>Types of Welding Power</i>	6
<i>Open Circuit Voltage</i>	7
<i>Operating Voltage</i>	7
<i>Arc Blow</i>	7
<i>Types of Power Sources</i>	9
Transformers.....	9
Multiple-coil Machines.....	10
Movable-coil or Movable-core Machines.....	12
Inverter Machines.....	13
<i>Generators and Alternators</i>	13
<i>Rectifiers</i>	15
<i>Duty Cycle</i>	17
<i>Welding Cables and Leads</i>	18
<i>Electrode Holders</i>	20
<i>Work Clamps</i>	21
<i>Setup</i>	22
<i>Summary</i>	23
<i>Review</i>	23

Chapter 2 Shielded Metal Arc Welding of Plate 25

<i>Introduction</i>	26
<i>Effect of Too-High or Too-Low Current</i>	
<i>Settings</i>	29
<i>Electrode Size and Heat</i>	31
<i>Arc Length</i>	32
<i>Electrode Angle</i>	34

Leading Angle	34
Trailing Angle	35
<i>Electrode Manipulation</i>	37
<i>Positioning of the Welder and the Plate</i>	40
<i>Practice Welds</i>	40
Electrodes	40
<i>Stringer Beads</i>	41
<i>Square Butt Joint</i>	44
<i>Edge Weld</i>	49
<i>Outside Corner Joint</i>	54
<i>Lap Joint</i>	58
<i>Tee Joint</i>	63
<i>Summary</i>	66
<i>Review</i>	67

Chapter 3 Advanced Shielded

Metal Arc Welding 69

<i>Introduction</i>	70
<i>Root Pass</i>	71
<i>Hot Pass</i>	79
<i>Filler Pass</i>	81
<i>Cover Pass</i>	84
<i>Plate Preparation</i>	85
<i>Preparing Specimens for Testing</i>	88
Acceptance Criteria for Face Bends and Root Bends	88
<i>Restarting a Weld Bead</i>	89
<i>Preheating and Postheating</i>	92
<i>Poor Fitup</i>	101
<i>Summary</i>	103
<i>Review</i>	103

Chapter 4 Gas Tungsten Arc Welding Equipment, Setup, Operation, and Filler Metals 105

<i>Introduction</i>	106
<i>Tungsten</i>	107
<i>Types of Tungsten Electrodes</i>	110
Pure Tungsten Electrodes, EWP	111
Thoriated Tungsten Electrodes, EWTh-1 and EWTh-2	111
Zirconium Tungsten Electrodes, EWZr	112
Cerium Tungsten Electrodes, EWCe-2	112
Lanthanum Tungsten Electrodes, EWLa-1, EWLa-1.5, EWLa-2	112
Alloy Not Specified, EWG	113
<i>Shaping the Tungsten Electrode</i>	113

Grinding	113
Breaking and Remelting	114
Chemical Cleaning and Pointing	116
Pointing and Remelting	116
<i>GTA Welding Equipment</i>	117
Torches	117
Hoses	118
Nozzles	121
Flowmeter	122
<i>Types of Welding Current</i>	123
<i>AC Balance Control</i>	126
<i>Shielding Gases</i>	129
Argon	129
Helium	130
Hydrogen	130
Nitrogen	130
Hot Start	131
Preflow Time and Postflow Time	131
Gas Flow Rate	132
<i>Remote Controls</i>	133
<i>Summary</i>	138
<i>Review</i>	138

Chapter 5 Gas Tungsten Arc Welding of Plate 141

<i>Introduction</i>	143
<i>Torch Angle</i>	143
<i>Filler Rod Manipulation</i>	144
<i>Tungsten Contamination</i>	146
<i>Current Setting</i>	146
<i>Experiments</i>	147
<i>Gas Flow</i>	149
<i>Practice Welds</i>	151
Low-Carbon and Mild Steels	151
Stainless Steel	152
Aluminum	153
Metal Preparation	154
<i>Summary</i>	191
<i>Review</i>	191

Appendix	193
Glossary	195
Index	201

Grinding	113
Breaking and Remelting	114
Chemical Cleaning and Pointing	116
Pointing and Remelting	116
<i>GTA Welding Equipment</i>	117
Torches	117
Hoses	118
Nozzles	121
Flowmeter	122
<i>Types of Welding Current</i>	123
<i>AC Balance Control</i>	126
<i>Shielding Gases</i>	129
Argon	129
Helium	130
Hydrogen	130
Nitrogen	130
Hot Start	131
Preflow Time and Postflow Time	131
Gas Flow Rate	132
<i>Remote Controls</i>	133
<i>Summary</i>	138
<i>Review</i>	138

Chapter 5 Gas Tungsten Arc Welding of Plate 141

<i>Introduction</i>	143
<i>Torch Angle</i>	143
<i>Filler Rod Manipulation</i>	144
<i>Tungsten Contamination</i>	146
<i>Current Setting</i>	146
<i>Experiments</i>	147
<i>Gas Flow</i>	149
<i>Practice Welds</i>	151
Low-Carbon and Mild Steels	151
Stainless Steel	152
Aluminum	153
Metal Preparation	154
<i>Summary</i>	191
<i>Review</i>	191

Appendix	193
Glossary	195
Index	201

Index

Italic page numbers indicate material in tables or figures.

- AC (alternating current), 5, 6, 8-9, 111-113, 123-129
- advanced square wave, 126-127
- air-cooled torches, 117-119
- alloy not specified tungsten electrodes (EWG), 113
- alternating current (AC), 5, 6, 8-9, 111-113, 123-129
- alternators, 13-15
- aluminum base metal, 107, 112, 146, 151-154, 158t
- aluminum deposits, 114
- American Bureau of Ships, 87
- American Society of Mechanical Engineers (ASME), 87, 88
- American Welding Society (AWS), 71, 87, 88
- amperage, 4, 32, 146-147
 - estimating and calculating, 11-12
 - range charts, 29, 135, 147
- angle, torch, 143-144
- angle, trailing, 35-36
- anode, 6
- arc, 3, 7
 - cleaning, 165
 - reestablishing the, 125
 - striking the, 15, 27-29, 136-138
 - temperature of, 4-5
- arc blow, 7-8, 9, 21
- arc length, 32-34, 78
- arc strike defects, 28-29
- argon, 107, 129
- ASME Boiler and Pressure Vessel (BPV) Section IX, 87, 88
- ASTM standards, 87, 88
- AWS Certified Welder program, 71
- AWS standards, 88
- back caps, 118-119
- back edge, 52, 81, 85
- back gouging, 72, 73, 86, 87f
- backing gas, 130, 171, 177
- backing strips, 72, 74f
- backing tapes, 72
- bead color, 153
- belt sander, 113
- breaking and remelting tungsten electrodes, 114-115
- bridge rectifiers, 16, 17f
- burn back, 83f
- burn-through, 31, 45, 72, 75-77, 148-149
- cathode, 6
- CC (constant current), 6, 7f
- cellulose-based fluxes, 41
- cerium, 110, 112
- cerium tungsten electrodes (EWCe-2), 111, 112, 152, 153
- checklist, portable welder, 16t
- chemical cleaning and pointing, 116
- chill plate, 156
- clamps, 21
- cleaning action, 124, 129
- cold lap, 34-35
- collet, 108-109, 136f
- condensation, 121
- constant current (CC), 6, 7f
- constant voltage (CV), 6, 7f
- contamination, 107
 - and max cleaning setting, 127
 - atmospheric, 143-144, 171, 177
 - carbon, 115
 - from dirt, 154, 181, 182, 189
 - from grinding, 113-114
 - from high gas flow rate, 132, 149
 - from oxygen, 106
 - from vaporized droplets, 112
 - from weld pool, 112, 146
 - of inert gas, 129
 - of shielding gas, 120
 - of stainless steel, 152-153
 - on tungsten electrode, 115-116, 138, 146
 - radioactive, 112
- copper, 18-19, 116, 130
- cover passes, 84-85
- cracking the valve, 134
- crater cracking, 145
- cups (nozzles), 121-122, 132, 133, 136f
- current settings, 29-31, 146-149
- CV (constant voltage), 6, 7f
- DAV (dropping-arc voltage), 6
- DC (direct current), 14-16, 17, 112-113
- DCEN (direct current electrode negative), 5, 107, 108-110, 123-126
- DCEP (direct current electrode positive), 5, 6, 106-107, 109-110, 116, 123-126
- DCRP (direct current reverse polarity). *See* DCEP (direct current electrode positive)
- DCSP (direct current straight polarity). *See* DCEN (direct current electrode negative)
- defects
 - arc strikes, 28-29
 - overlaps, 73
 - root surface, 72-73
 - undercuts, 39, 63, 73, 79, 84-85, 88
- deoxidizers, 152
- deposition rate, 31
- direct current (DC), 14-16, 17, 112-113
- direct current electrode negative (DCEN), 5, 107, 108-110, 123-126
- direct current electrode positive (DCEP), 5, 6, 106-107, 109-110, 116, 123-126
- direct current reverse polarity (DCRP). *See* direct current electrode positive (DCEP)
- direct current straight polarity (DCSP). *See* direct current electrode negative (DCEN)
- drag electrodes (drag rods), 33
- dropping-arc voltage (DAV), 6
- duty cycles, 17-18
- E6010 electrodes, 41
- E6011 electrodes, 41
- E6012 electrodes, 41
- E6013 electrodes, 41
- E7016 electrodes, 41
- E7018 electrodes, 35, 41, 44, 71

- E7024 electrodes, 33, 40–41
 E7028 electrodes, 40–41
 edge weld, 49
 electrode amperage range table, 29, 135, 147
 electrode angle, 34–37
 electrode holders, 5, 20–21, 28
 electrode lead, 5f
 electrode manipulation, 37–39
 electrodes, 2, 3f. *See also* tungsten electrodes
 and arc length, 32–33
 F-number classes, 40–41
 size and heat of, 31, 32f
 electrons, 3
 ER1100 filler metal, 154t
 ER308, ER308L filler metal, 153t
 ER309 filler metal, 153t
 ER310 filler metal, 153t
 ER316L filler metal, 153t
 ER4043 filler metal, 154t
 ER410 filler metal, 153t
 ER70S-3 filler metal, 152t
 erosion, electrode, 108–110
 EWCe-2 (cerium tungsten electrodes), 111, 112, 152, 153
 EWG (alloy not specified tungsten electrodes), 113
 EWLa-X (lanthanum tungsten electrodes), 111, 112–113, 152, 153
 EWP (pure tungsten electrodes), 111, 153
 EWTh-X (thoriated tungsten electrodes), 111–112, 152
 EWZr (zirconium oxide tungsten electrodes), 112, 153
- F-number electrode classes, 40–41
 face bends, 88–89
 filler metals, 106, 114, 129, 152–153
 filler passes, 81–84
 filler rod manipulation, 144–145
 fitup, 101–102
 flame-cut specimens, 88–89
 flowmeters, 122–123
 flux, 2, 28–29, 33, 40–41
 frequency, 125
- gas coverage, 143
 gas flow rate, 132, 133, 149–151
 gas metal arc welding (GMAW), 107
 gas tungsten arc welding (GTAW). *See also* tungsten electrodes
 metal preparation, 154–155
 overview, 106–107, 143
 setup, 120, 133–136
 types of current, 123–126
 generators, 13–15
 gouging, back, 72, 73, 86, 87f
 grain growth, 107, 112
 grinding, 113–114
 grinding stone wheel, 114
 guided bend specimen, 89f
- hard spatter, 30, 33, 41, 132
 heat. *See* amperage
 heliarc welding, 106
 helium, 106, 130
 high frequency arc starting, 125–126, 137
 hoses, 118, 119–121
 hot pass, 71, 79–81
 hot start, 131
 hydrogen additives, 130
- icicles, 53, 54f
 inclusions, 82, 94, 108
 inert gases, 129–130
 interpass temperatures, 100–101
 inverters, 13, 14, 125–126
 iron core, in transformer, 9, 13
 iron-powder-based fluxes, 40–41
- keyhole, 73–74
 knobs, adjustment, 11–12
- lanthanum, 110
 lanthanum tungsten electrodes (EWLa-X), 111, 112–113, 152, 153
 lap joints, 58–63
 leading angle, 34–35
 lugs, 19, 20f
- magnesium base metal, 107, 112
 magnetic flux lines, 7–8
 max cleaning setting, 127–128
 max penetration setting, 127–128
 metals, reactive, 107
 mild steel, 151–152
 mineral-based fluxes, 41
 molten weld pool, 2–4
 movable-coil machines, 12, 13f
 multiple pass weld, 71
 multiple-coil machines, 10–11
- nameplate, 18
 nickel alloy base metal, 111
 nitrogen additives, 130–131
 nozzles, 121–122, 132, 133, 136f
- open circuit voltage, 7
 open root, 72–73
 operating voltage, 7
 output, 7
 outside corner joints, 54–58
 overlaps, 73
 oxide layers, 146, 153–154, 165f
- patterns, weave, 37–39
 penetration, minimizing, 35
 plasma arc welding (PAW), 13
 point gap setting, 125
 pointing tungsten electrodes, 116
 poor fitup, 101–102
 porosity, 41, 78, 94, 130, 152
 portable welders, 15, 16t
 postflow time, 131–132, 149
 postheating temperatures, 92, 100
 power cable safety fuse, 118
 power supplies, 6–7, 9–13
 practice welds, 40–41, 151–155
 preflow time, 131, 149
 preheating temperatures, 92
 protective zone, 143–144
 pure tungsten electrodes (EWP), 111, 153
- reactive metals, 107
 rectification, 125
 rectifier, 15–16, 17, 126–128
 remelting
 filler, 145
 tungsten electrodes, 116
 remote controls, 120, 133, 147
 return water hose, 120
 RG45 gas welding rods, 152
 RG60 filler metal, 152t
 root bends, 88–89
 root fusion, 59, 166f
 root opening (root gap), 44, 45f
 root pass, 71–78, 143
 root penetration problems, 33–34
 root surface defects, 72–73
 run-off tabs, 83f
 rutile-based fluxes, 41
- safety
 setup considerations for, 22
 SMAW, 27
 when grinding tungsten electrodes, 114
 when using chemical cleaners, 154
 safety fuse, 118

- semiautomatic operation, 117f
- settings, suggested
 - aluminum, 158t
 - mild steel, 157t
 - stainless steel, 157t
- setup
 - gas tungsten arc welding (GTAW), 120, 133-136
 - shielded metal arc welding (SMAW), 22
- shelf, support, 38, 39, 44, 47
- shielded metal arc welding (SMAW)
 - overview, 2-3
 - power supply requirements, 7
 - safety, 27
 - setup, 22
 - to join plate, 27
- shielding gas, 3, 90, 129-131
 - argon, 107, 129
 - coverage, 143
 - effect of low amperage, 30f
 - flow rate, 132, 133t
 - helium, 106, 130
 - hydrogen additives, 130
 - nitrogen additives, 130-131
 - protective zone, 143-144
- shielding gas hose, 120
- slag, 2, 3, 47, 79-81
- slag inclusions, 30, 35
- spark gap oscillator, 125
- splatter, hard, 30, 33, 41, 132
- splices (welding cables), 19, 20f
- square butt joints, 44-49
- square wave, 126-127
- stabilizers, arc, 4
- steel base metal
 - low-carbon and mild, 92, 151-152
 - stainless, 107, 111, 130, 151-153, 157t
- step-down transformers, 9-10
- stick welding. *See* shielded metal arc welding (SMAW)
- sticking, 66-67
- stone grinding wheel, 114
- striking the arc, 27-29, 136-138
- stringer beads, 41-43
- surface tension, 146
- tack welding, 44-45, 161f-162f
- tap-type machines, 10-11
- tee joints, 63-66
- testing, 82, 88-89
- thermal conductivity, 108, 113, 131, 154
- thoriated tungsten electrodes (EWTh-X), 111-112, 152
- thorium, 110-111
- tip color chart for tungsten electrodes, 111t
- titanium base metal, 107
- torches, 108, 117-119, 143-144
- trailing angle, 35-36
- trailing edge, 31, 52, 59, 61, 85
- transformers, 9-10
- tungsten (W), properties of, 107
- tungsten electrodes
 - amperage chart for, 135t
 - erosion of, 108
 - properties of, 106-110
 - shapes and shaping of, 110, 113-117
 - types of, 110-113
- tungsten inert gas welding (TIG). *See* gas tungsten arc welding (GTAW)
- under-fill, 83, 88f
- undercuts, 39, 63, 73, 79, 84-85, 88
- valve, cracking the, 134
 - voltage, 4
 - closed circuit, 7
 - constant, 4, 6, 7f
 - open circuit, 7
 - operating, 7
 - rising-arc, 6, 7f
- wagon tracks, 80
- water-cooled torches, 117-119
- water-in hose, 120
- wattage, 4
- waveforms, AC, 126-129
- weave pattern, 37-39
- weld beads, 89-92
- weld failure from
 - backing strip, 72
 - inclusions, 82, 108, 146
 - inert gas contamination, 129
 - poor surface preparation, 89
 - rapid cooling, 92
- weld groove, 85, 86f
- weld pool, 2-4
- weld specimen, 88-89
- weld toes, 76f
- welders, vision of, 42
- welding cables (leads), 13, 18-19, 22
- welding current, types of, 5-6
- welding position, 40
- welds, practice, 40-41, 151-155
- work (base metal), 106
- work clamps, 21
- work lead cable, 8-9f
- zip-on hose protection, 121
- zirconium, 110-112
- zirconium oxide tungsten electrodes (EWZr), 112, 153