

Flux Cored Arc Welding Handbook

William H. Minnick



Contents *Flux Cored Arc Welding Process*

CHAPTER

1	<i>Flux Cored Arc Welding Process</i>	7
2	<i>FCAW Operation and Safety</i>	13
3	<i>Equipment Setup and Control</i>	23
4	<i>Shielding Gases and Regulation Equipment</i>	35
5	<i>Filler Material</i>	43
6	<i>Weld Joints and Weld Types</i>	47
7	<i>Welding Procedures and Techniques</i>	61
8	<i>Inspection, Defects, and Corrective Action</i>	69
9	<i>Welding Carbon and Low-alloy Steels</i>	81
10	<i>Welding Chromium-Nickel Stainless Steels</i>	89
11	<i>Welding Cast Irons</i>	95
12	<i>Surfacing</i>	101
13	<i>Procedure and Welder Qualification Test</i>	109
14	<i>General Welding Procedures</i>	125
	<i>Reference Section</i>	143
	<i>Glossary of Welding Terms</i>	161
	<i>Index</i>	171

Index

A

- American Iron and Steel Institute (AISI), 89–90**
- American Society of Mechanical Engineers (ASME)**
 - Boiler Code, 109–110**
- American Welding Society (AWS)**
 - address, 109
 - carbon steel electrode specifications, 81
 - D1.1 Structural Welding Code—Steel, 109, 110
 - D1.3 Structural Welding Code—Sheet Steel, 111
 - electrode classification, 44
 - FCAW definition, 7
 - filler material specifications, 43–44
 - low-alloy electrode specifications, 81
 - Structural Welding Code, 109
 - welder qualification test, 110–111
 - welding symbol, 51

analyzer, 41

antistick control, 27–28

arc, 13

arc blow, 93

arc gap, 14

arc voltage, 62

control, 24

argon (Ar), 35

austenitic stainless steel, 89

auxiliary shielding gas, 13

B

backflow check valve, 40

backhand welding, 64

backing, 93

backing bar, 49–50

base material, 61–62, 102

carbon steel, 81

cast iron, 95

chromium-nickel stainless steel, 89

dilution, 104

low-alloy steel, 81

bead

pattern, 66

sequence, 65–66

birdnesting, 29

Boiler Code (ASME), 109–110

build-up/overlay weld schedule, 127

buildup electrode, 102

buildup weld, 102

built-in backing bar, 49–50

burnback timer, 27–28

burn through, 75, 77

butt joint, 55–56

with prefabricated backing bar, 50

butt weld, 55–56

inspection, 70

buttering, 50, 101

C

carbide precipitation, 92

carbon dioxide (CO₂), 35

carbon steel, 81–88

AWS filler material specifications, 81

base materials, 81

electrode, 81–83, 102

filler material, 85–86

interpass temperature, 85

joint preparation, 85

material preparation, 84

postheating, 85

test welds, 86–87

welding procedures, 85–87

cast iron, 95–100

base material, 95

chemical values, 96

ductile, 95–96

electrode characteristics, 96

filler material, 96

gray, 95

cast iron, continued

- interpass temperature, 97
- joint preparation, 97–98
- malleable, 95
- material preparation, 96–97
- mechanical values (FCAW weld), 96
- postheating, 97
- preheating, 97
- problem areas, 98–99
- test welds, 98
- types, 95–96
- welding procedures, 97–99
- white, 95

certification, 122–123**chemical values**

- carbon steel, 83–84
- cast iron, 96

chill bars, 58**chromium-nickel stainless steel, 89–94**

- AISI identification (chart), 89–90
- base material, 89
- electrode, 90–92
- filler material, 89–93
- interpass, 92
- joint preparation, 92
- material preparation, 92
- postheating, 92
- preheating, 92
- problem areas, 94
- shielding gas, 93
- test welds, 93–94
- welding procedures, 92–94

cladding, 51, 102**constant current (CC) power supply, 9**

- electrode feed, 61–62

constant potential (CP) machine, 14**constant voltage (CV) power supply, 9**

- electrode speed, 61

contact tip, 18, 32**convex crown, 73****convexity, 76****corner joint weld, 48–49, 57****corner weld, 57****cracks**

- fillet weld, 77
- groove weld, 74
- plug weld, 78
- spot weld, 80

craters

- fillet weld, 77
- groove weld, 74
- plug weld, 77

current, 62**D****DCRP (reverse polarity), 62****DCSP (straight polarity), 62****defects**

- fillet weld, 75–78
- groove weld, 72–75
- plug weld, 78–79
- spot weld, 79–80
- weld, 72–80

destructive testing, 69

- welder qualification, 116–118

Dewar cylinder, 21, 36**direct current electrode negative (DCEN), 9****direct current electrode positive (DCEP), 9****discontinuities, 69****double weld, 49****double-groove weld, 49****downhill welding, 66****drag angle, 64–65****ductile iron, 95–96****ductility, 95****duty cycle, 23****E****edge joint, 49, 57****edge weld, 57****electrical current, 19****electrode**

- alloy content, 84
- AWS classification, 44
- buildup, 102
- carbon steel, 81–83, 85–86, 102
- cast iron, 96
- chemical composition (chart), 83
- chemical values, 91–92
- chromium-nickel stainless steel, 90–91
- diameter, 61
- feed, 61–62
- filler material, 43–46
 - specifications, 43–44
 - using, 45–46
- identification and packaging, 45
- inching control, 28
- jog control, 28
- low-alloy steel, 81–83
- manganese steel, 102
- manufacturing, 43
- mechanical properties (charts), 84
- mechanical values, 91–92
- speed, 61
- stickout (ESO), 14, 63
- surfacing, 102–103
- wiper, 29

equipment, 9–10

setup and control, 23–34

ESO (electrode stickout), 14**excessive penetration**

groove weld, 75

plug weld, 78

spot weld, 80

excessive spatter, 75**F****FCAW-g, 7****FCAW-ss, 7****feeder, 26–30**

controls, 27–28

drive roll system, 28–29

maintenance, 29–30

portable semiautomatic, 29–30

stationary, 26–29

ferrous metal, 81**filler material, 61–62, 102**

AWS specifications, 43–44

carbon steel, 81–86

cast iron, 96

chromium-nickel stainless steel, 89–93

form, 44

low-alloy steel, 81–84

selecting, 46

specifications, 43–44

using, 45–46

fillet weld, 49

defects, 75–78

inspection, 70

lengths, 57

linear porosity, 78

porosity, 77

welder qualification test, 118–122

welding schedule, 140

uphill, 136

horizontal, 126, 131, 133, 134, 137, 139, 141

flat weld position, 54**flowmeter, 17, 38****forehand welding, 64****G****gas**

analyzer, 41

distribution, 37–38

mixing, 39–40

purity, 36

regulation, 38–39

safety, 19–21

shielding. *See* shielding gas

storage, 36

supply, 36

supply and regulation, 16–18

testing for leaks, 38

gas-shielded arc process (FCAW-g), 7**globular arc mode, 81****gray iron, 95****groove weld**

defects, 72–75

destructive testing, 116–118

double, 49

inspection, 116

V-groove (schedule), 130, 135, 138

welder qualification test, 114–118

welding schedule, 132

ground clamp, 33**gun, 9–10**

air-cooled, 30

angles, 64–65

cables, 30

contact tip, 18, 32

gas-cooled, 30

maintenance, 32–33

mechanized, 31–32

nozzles, 32

types, 18–19, 30–32

water-cooled, 30–31

H**hardfacing, 101****heat removal, 58****helium, 26****horizontal weld position, 54****I****inspection criteria, 118****inspection methods**

liquid penetrant, 70–71

magnetic particle, 71–72

radiographic, 72

ultrasonic, 72

visual, 69–70

interpass temperature, 58, 105

carbon steel, 85

cast iron, 97

chromium-nickel stainless steel, 92

J**joint**

butt, 55–56

with prefabricated backing bar, 50

corner, 57

edge, 57

joggle-type, 49

lap, 56

nonqualified, 110

joint, continued

- pipe, 51
- preparation, 47
 - carbon steel, 85
 - cast iron, 97-98
 - chromium-nickel stainless steel, 92
- prequalified, 110
- T-joint, 56-57
- tubular butt joint with built-in backing bar, 49-50
- types, 47

L**lack of fusion**

- fillet weld, 76
- groove weld, 73

lack of penetration

- fillet weld, 75
- plug weld, 78
- spot weld, 79

lap joint, 56**lap weld, 56****linear porosity**

- fillet weld, 78
- groove weld, 74

liquid penetrant inspection, 70-71**long stickout, 14****low-alloy steel, 81-88**

- electrode characteristics, 81-83
- filler material, 81-84
- material preparation, 84
- welding procedures, 85-87

M**macroetch test, 121****magnetic particle inspection, 71-72****malleable iron, 95****manganese steel, 102****manifold, 37****mechanical values**

- carbon steel, 83-84
- cast iron, 96

metal deposition, 13-14**mismatch, 55****mode control, 27****N****National Electrical Manufacturers Association**

(NEMA), 23

nitrogen, 26**nodular iron, 95****nondestructive testing, 69****nonprequalified joint, 110****O****open arc process (FCAW-ss), 7****open circuit voltage (OCV) range switch, 24****operation, 13-19**

- automatic, 8
- problems, 67
- semiautomatic, 8

oscillated bead, 66**oscillated weld, 104****overhead weld position, 54****overlap**

- fillet weld, 76
- groove weld, 73
- plug weld, 76

overlay weld

- welding schedule, 128

oxidation, 10**P****parameters, 14****pipe joint, 51****plug weld defects, 78-79****polarity, 62****porosity**

- fillet weld, 77
- groove weld, 74
- plug weld, 77
- spot weld, 80

postflow timer control, 28**postheating, 58, 105**

- carbon steel, 85
- cast iron, 97
- chromium-nickel stainless steel, 92

power supply, 14-15, 23-26

- arc voltage control, 24
- constant current (CC), 9
- constant voltage (CV), 9
- controls, 24-25
- direct current (dc) control, 24
- direct current electrode negative (DCEN), 9
- direct current electrode positive (DCEP), 9
- feeder, 26-30
- inductance, 25
- installation, 25
- maintenance, 25-26
- open circuit voltage (OCV) range switch, 24
- slope, 24
- specifications, 23

prefabricated backing bar, 50**preheating, 58, 105**

- carbon steel, 85
- cast iron, 97
- chromium-nickel stainless steel, 92

prepurge timer control, 28
 prequalified joint, 110
 primary power fusing, 23
 Procedure Qualification Record (PQR), 110
 pull welding, 64
 pull-type feeder, 26
 purge control, 28
 purge gas, 26, 36
 push welding, 64
 push-pull type feeder, 26–27
 push-type feeder, 26

Q
 qualified welding procedure, 69

R
 radiographic inspection, 72
 rated welding amperes, 23
 reference line, 51–53
 regulator, 17, 38
 regulator/flowmeter, 17, 38–39
 reverse polarity (DCRP), 62
 run-off tabs, 92
 run-on tabs, 92

S
 semiautomatic operation, 8
 shielding gas, 9, 63

- argon (Ar), 35
- auxiliary, 13
- carbon dioxide (CO₂), 35
- carbon steel, 86
- chromium-nickel stainless steel, 93
- handling, 20–21
- mixes, 35
- safety, 19–21
- storage, 20
- types, 35

 side bend test, 118
 solenoid, 18
 spatter, 75
 spheroidal iron, 95
 spot weld

- timer, 28
- defects, 79–80

 spray arc mode, 81
 stainless steel, 89

- See also* chromium-nickel stainless steel

 stepover distance, 104
 stickout, 14, 63
 straight polarity (DCSP), 62
 stringer bead, 57

- pattern, 66

 Structural Welding Code, 109

surface overlay weld

- welding schedule, 129

 surfacing, 51, 101–108
 surfacing area safety, 108
 surfacing electrodes, 102
 symbols, 51–53

T
 T-joint, 56–57
 tacker, 123
 temperature

- carbon steel, 85
- cast iron, 97
- chromium-nickel stainless steel, 92
- interpass, 58, 105

 test welds, 66–67, 108

- carbon steel, 86–87
- cast iron, 98
- chromium-nickel stainless steel, 93–94

 tooling, 58

- stainless steel, 93

 transverse shrinkage, 55
 triangular weave bead pattern, 66
 trigger lock-in control, 27
 tubular butt joint with built-in backing bar, 49–50
 turbulence, 17

U
 ultrasonic inspection, 72
 undercut, 66

- fillet weld, 76
- groove weld, 73

 uphill welding, 66

V
 V-groove weld

- welding schedule, 130, 135, 138

 vertical weld position, 54
 visible stickout, 14, 63
 visual inspection, 69–70
 voltage-sensing wire feeder, 16

W
 weave bead pattern, 66
 weld

- butt, 55–56
- corner, 48–49, 57
- defects and corrective action, 72–80
- design considerations, 55–59
- double, 49
- double-groove, 49
- edge, 57
- fillet, 49, 57
- joint, 57

weld, continued

- lap, 56
- mismatch, 55
- oscillated, 104
- positions, 53-55
- schedule, 67, 126-141
- setup, 14-19
- shrinkage, 55-56
- special designs and procedures, 58
- T-joint, 56-57
- test plate preparation, 111-114
- types, 48-49

weld-joint configurations, 49-51

weld symbol, 51

welder qualification test, 114-123

- AWS, 110-111
- certification, 122-123
- destructive testing, 116-118
- fillet weld, 118-122
- groove weld, 114-118
- inspection criteria, 118
- performance, 110-114
- rejected, 122
- rejection criteria, 118
- tacker, 123

weld test plate preparation, 111-114

weld types and positions, 111

welding operators, 123

welding

- carbon steel, 85-87
- cast iron, 97-99
- chromium-nickel stainless steel, 92-94
- low-alloy, 85-87
- material preparation, 102-103
- procedure requirements, 61
- procedures, 103-108
- schedules, 126-141
- symbols, 51-53
- techniques, 64, 105-108

welding gun. See gun

welding operator, 123

Welding Procedure Specifications (WPS) form, 109-110

white iron, 95

wire feeder, 9, 16

cable connection, 62

work leads, 33

Y

Y-valve system, 40

