

For Heat-Resistant Low-Alloy Steel

A guide for selecting welding consumables

Steel type	ASTM / ASME steel grade		SMAW	FCAW	GMAW	GTAW	SAW
	Plate	Pipe / Tube					
Mn-Mo Mn-Mo-Ni	A302Gr.B,C,D A533Type A,B,C,D	-	BL-96 BL-106	-	MGS-56 MGS-63S	TGS-56	MF-27/US-56B PF-200/US-56B PF-200/US-63S
0.5Mo	A204Gr.A,B,C	A209Gr.T1 A335Gr.P1	CMA-76	-	MGS-M MG-M	TGS-M	MF-38/US-40 MF-38/US-49 MF-38/US-A4
0.5Cr-0.5Mo	A387Gr.2 Cl.1,2	A213Gr.T2 A335Gr.P2	CMB-83 CMB-86	-	MG-CM	TGS-CM	-
1Cr-0.5Mo 1.25Cr-0.5Mo	A387Gr.12 Cl.1,2 A387Gr.11 Cl.1,2	A213Gr.T11,12 A335Gr.P11,12	CMA-96 CMA-96MB CMA-96MBD CMB-95 CMB-98	DW-81B2 DWA-81B2	MGS-1CM MG-1CM	TGS-1CM TGS-1CML TGS-80B2	MF-29A/US-511 PF-200/US-511N PF-200D/US-511ND
2.25Cr-1Mo	A387Gr.22 Cl.1,2	A213Gr.T22 A335Gr.P22	CMA-106 CMA-106N CMA-106ND CMB-105 CMB-108	DW-91B3 DWA-91B3	MGS-2CM MGS-2CMS MG-2CM	TGS-2CM TGS-2CML TGS-90B3	MF-29A/US-521 PF-200/US-521S PF-200D/US-521S
2.25Cr-1Mo-V	A542Type D Cl.4a A832Gr.22V	-	CMA-106H CMA-106HD	-	-	TGS-2CMH	PF-500/US-521H PF-500D/US-521HD
Low C 2.25Cr-W-V-Nb	-	SA213Gr.T23 SA335Gr.P23	CM-2CW	-	MGS-2CW	TGS-2CW	PFH-80AK/US-2CW
5Cr-0.5Mo	A387Gr.5 Cl.1,2	A213Gr.T5 A335Gr.P5	CM-5	-	MGS-5CM	TGS-5CM	PF-200S/US-502
9Cr-1Mo	A387Gr.9 Cl.1,2	A213Gr.T9 A335Gr.P9	CM-9	-	MGS-9CM	TGS-9CM	-
9Cr-1Mo-V-Nb	A387Gr.91 Cl.2	A213Gr.T91 A335Gr.P91	CM-9Cb CM-96B9	-	MGS-9Cb	TGS-9Cb TGS-90B9	PF-200S/US-9Cb
9Cr-W-V-Nb 12Cr-W-V-Nb	-	A213Gr.T92 A335Gr.P92 SA213Gr.T122 SA335Gr.P122	CR-12S	-	MGS-12CRS	TGS-12CRS	PF-200S/US-12CRS

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Tips for better welding results for individual welding processes

SMAW

- (1) Remove scale, rust, oil, grease, water, and other dirt from welding grooves beforehand to prevent defects such as porosity and cracking in the weld metal.
- (2) Use welding currents in the recommended range because the use of excessively high currents can cause imperfections such as poor X-ray soundness, much undercuts, much spatter, and hot cracking.
- (3) With low-hydrogen type electrodes, keep the arc length as short as possible to prevent porosity caused by nitrogen in the atmosphere. Limit the weaving width within two and a half times the diameter of the electrode. When striking an arc in the welding groove directly, use the backstep technique or strike an arc on a scrap plate before welding the groove to prevent blowholes in the arc starting bead.
- (4) Use preheating and interpass temperatures in the recommended range as shown in Table 1 in order to prevent the occurrence of cold cracks.
- (5) Use proper postweld heat treatment (PWHT) temperatures to ensure good mechanical properties of the weld. The use of an excessively high temperature can damage the weld causing inadequate tensile strength and impact value of the weld. In contrast, the use of an excessively low temperature can cause poor ductility and impact toughness of the weld in addition to inadequate stress relieving. The recommended ranges of PWHT temperatures are shown in Table 1. Hold weldments at PWHT temperatures for appropriate time according to the thickness of the base metal to ensure the quality of the weld.
- (6) Control heat input in predetermined ranges because heat input can markedly affect the crack resistibility and mechanical properties of the weld.

Table 1 Recommended temperatures for preheating and interpass control and PWHT

Type of steel	Preheating and interpass temperature (°C)	PWHT temperature (°C)
Mn-Mo-Ni steel	150-250	590-650
0.5Mo and 0.5Cr-0.5Mo steel	100-250	620-680
1Cr-0.5Mo and 1.25Cr-0.5Mo steel	150-300	650-700
2.25Cr-1Mo steel	200-350	680-730
5Cr-0.5Mo and 9Cr-1Mo steel	250-350	710-780

FCAW, GMAW

- (1) Use DC-EP polarity.
- (2) Use and appropriate shielded gas flow rate as shown in Table 2 for recommendation.
- (3) In spray arc welding with a shielding gas of Ar/O₂ or Ar/5-20%CO₂ admixture, short circuiting noise may occur when the arc voltage is excessively low. In such a case, keep the arc length about 4-5 mm in order to prevent blowholes in the weld metal.
- (4) Refer to (1), (4), (5), (6) of the tips for SMAW.

Table 2 Recommended shielding gas flow rate

Flow rate (liter/min)	Nozzle standoff (mm)	Max wind velocity (m/sec)
20-25	20	2

GTAW

- (1) Use DC-EN polarity.
- (2) Use an appropriate shield gas flow rates as shown in Table 3.
- (3) Use back-shielding to ensure good reverse bead appearance and prevent the occurrence of porosity in the weld metal for low-alloy steels containing Cr over 1.25%.
- (4) Refer to (1), (4), (5), (6) of the tips for SMAW.

Table 3 Recommended shielding gas flow rate

Flow rate (liter/min)	Max. wind velocity (m/sec)
10-15	1

SAW

- (1) Control flux supply at an appropriate flux-burden height. The flux-burden height can affect the appearance of beads and X-ray soundness. The most appropriate height varies depending on flux mesh size, shape of welding groove and other welding conditions; however, single electrode welding commonly use 25-35 mm while tandem welding generally use 30-45 mm.
- (2) Use lower currents and slower speeds for root pass welding of thick plates to prevent cracking.
- (3) Refer to (1), (4), (5), (6) of the tips for SMAW.