

## For 9%Ni Steel and Nickel-Based Alloy

### For 9%Ni Steel

For welding of 9%Ni steel, Ni-base alloys such as Ni-Cr alloy (e.g., Inconel) and Ni-Mo alloy (e.g., Hastelloy) welding consumables are commonly used to obtain sufficient notch toughness at cryogenic temperatures. 9%Ni steel is used for storage tanks for liquefied natural gas (LNG), liquefied oxygen and liquefied nitrogen, and LNG carriers. In the construction of such cryogenic temperature service equipment, automatic gas tungsten arc welding and submerged arc welding are often used to ensure consistent weld quality, as shown in Fig. 1.

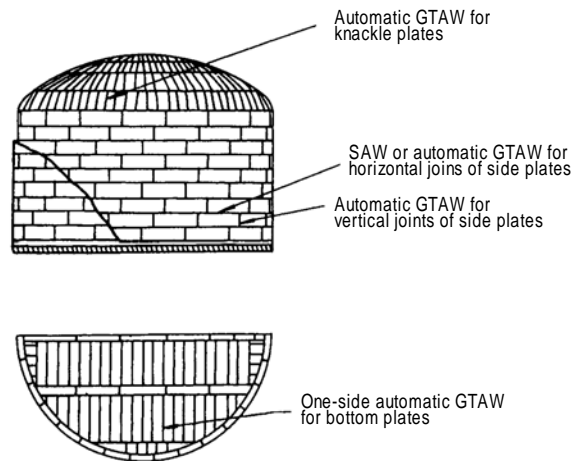


Fig. 1 Typical applications of automatic welding processes for a LNG storage tank

### ■ Tips for better welding results

#### Common to individual welding processes

- (1) Remove scale, rust, and other dirt from welding grooves beforehand by grinding or other appropriate means.
- (2) Use no preheat and control interpass temperatures at 150°C or lower.
- (3) Minimize welding currents and welding speeds to prevent hot cracking.
- (4) Use no magnetic power crane because 9%Ni steel is likely to be magnetized.

#### SMAW

- (1) Re-dry covered electrodes by 200-250°C for 30-60 minutes before use.
- (2) Keep the arc length as short as possible.

#### FCAW, GMAW

- (1) Use Ar-CO<sub>2</sub> mixtures with 20-25%CO<sub>2</sub> for shielding gas. The gas flow rates should be 20-25 l/min.
- (2) Refer to Pages 205 and 207 of the stainless steel article about power source, wire extension, protection against wind and welding fumes, and storage of welding wires.

#### GTAW

- (1) Use multi-pass welding because the use of single-pass welding may cause a decrease of weld metal strength affected by the dilution from the base metal.

#### SAW

- (1) Re-dry fluxes by 200-300°C for 1 hour before use.
- (2) Use multi-pass welding because the use of single-pass welding may cause a decrease of weld metal strength affected by the dilution from the base metal.

## For 9%Ni Steel and Nickel-Based Alloy

### For Ni-base alloy

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Typical Ni-base alloys for welding are Ni-Cr alloy (e.g., Inconel) and Ni-Fe-Cr alloys (e.g., Incoloy). Ni-base welding consumables are used for joining these Ni-base alloys and dissimilar-metal joints consisting of Ni-base alloy and low alloy steel, stainless steel and low alloy steel, and the like.

### ■ Tips for better welding results for individual welding processes

#### SMAW

- (1) Use proper welding currents because the use of an excessive welding current causes electrode-burn and thereby usability and weld metal properties can be deteriorated.
- (2) Use no preheating for welding matching Ni-base alloys. Control interpass temperatures at 150°C or lower.
- (3) Use the backstep technique when an arc is struck in the welding groove, or strike an arc on a piece of metal outside the groove to prevent the occurrence of blowholes at the arc starting area of a bead.
- (4) Keep the arc length as short as possible.
- (5) Use flat-position welding as much as possible because vertical or overhead welding requires higher welding skill.
- (6) Minimize welding currents and speeds to prevent hot cracking.

#### FCAW

- (1) Use Ar-CO<sub>2</sub> mixtures with 20-25%CO<sub>2</sub> for shielding gas. The gas flow rates should be 20-25 l/min.
- (2) Refer to Pages 205 of the stainless steel article about power source, wire extension, protection against wind and welding fumes, and storage of welding wires.

#### GMAW

- (1) Pulsed arc welding with the spray droplet transfer mode using low currents is most appropriate, although conventional gas metal arc welding power sources can be used. DC-EP polarity is suitable.
- (2) Argon gas shielding with gas flow rates in the 25-30 l/min range is suitable. Ar-He mixture gases are also suitable.
- (3) Use no preheating and control interpass temperatures at 150°C or lower.
- (4) Minimize welding currents and speeds to prevent hot cracking.

#### GTAW

- (1) Use DC-EN polarity.
- (2) Argon gas shielding with gas flow rates in the 10-15 l/min range is suitable where welding currents are within 100-200A. In one-side welding, back shielding is needed to avoid oxidation of the back side bead.
- (3) Control the arc length at approximately 2-3 mm because the use of an excessive arc length may cause lack of shielding, thereby causing blowholes.
- (4) Use no preheating and control interpass temperatures at 150°C or lower.
- (5) Minimize welding currents and speeds to prevent hot cracking.

## Covered Electrodes for 9%Ni steel

Brand name	ASME AWS Class.	Type of covering	Pol.	Features	WP	Chemical composition of all-weld metal (%)											Mechanical properties of all-weld metal			
						C	Si	Mn	Ni	Cr	Nb	Fe	Mo	Others	0.2%OS (MPa)	TS (MPa)	EI (%)	IV (J)		
NIC-70S	A5.11 ENiCrFe-9	Low hydrogen	AC	▪Suitable for 9% Ni steel ▪RC: 200~250°Cx 0.5~1h	F HF H VU OH	Ex	0.09	0.26	2.26	67.60	13.90	1.70	9.80	3.70	W: 0.6	Ex	430	680	41	-196°C: 67
						Gt	≤0.15	≤0.75	1.00~ 4.50	≥55.00	12.00~ 17.00	0.50~ 3.00	≤12.00	2.50~ 5.50	W ≤1.5	Gt	-	≥650	≥25	-
NIC-1S	A5.11 ENiMo-8	Low hydrogen	AC	▪Suitable for 9% Ni steel ▪RC: 200~250°Cx 0.5~1h	F HF H VU OH	Ex	0.03	0.49	0.28	68.60	1.90	-	6.80	18.60	W: 2.9	Ex	440	730	48	-196°C: 83
						Gt	≤0.10	≤0.75	≤1.50	≥60.00	0.50~ 3.50	-	≤10.00	17.00~ 20.00	W: 2.0~ 4.0	Gt	-	≥650	≥25	-
NIC-70E	A5.11 ENiCrFe-9	Low hydrogen	AC	▪Suitable for 9% Ni steel ▪RC: 200~250°Cx 0.5~1h	F HF H VU OH	Ex	0.09	0.22	2.58	72.30	12.70	2.40	6.50	3.20	-	Ex	430	690	40	-196°C: 56
						Gt	≤0.15	≤0.75	1.00~ 4.50	≥55.00	12.00~ 17.00	0.50~ 3.00	≤12.00	2.50~ 5.50	-	Gt	-	≥650	≥25	-

Note: Welding tests are as per AWS. Ex: Example, Gt: Guaranty (polarity: AC)

Diameter and Length (mm)				
Dia.	2.6	3.2	4.0	5.0
NIC-70S	-	300	350	350
NIC-1S	-	300	350	350
NIC-70E	-	350	400	-

## Covered Electrodes for Nickel-Based Alloy

Brand name	ASME AWS Class.	Type of covering	Pol.	Features	WP	Chemical composition of all-weld metal (%)										Mechanical properties of all-weld metal				
						C	Si	Mn	Ni	Cr	Nb	Fe	Mo	Others	0.2%OS (MPa)	TS (MPa)	EI (%)	IV (J)		
NIC-70A	A5.11 ENiCrFe-1	Low hydrogen	AC	<ul style="list-style-type: none"> <li>•Suitable for Inconel and dissimilar- metal joints such as Inconel to low alloy steel, and stainless steel to low alloy steel</li> <li>•AC is only applicable</li> <li>•RC: 200~250°Cx 0.5~1h</li> </ul>	F HF H VU OH	Ex	0.04	0.25	2.84	70.66	14.75	1.94	9.24	-	Co: 0.03	Ex	380	610	44	-196°C: 93
						Gt	≤0.08	≤0.75	≤3.50	≥62.00	13.00~17.00	1.50~4.00	≤11.00	-	Co ≤0.12	Gt	-	≥550	≥30	-
NIC-703D	A5.11 ENiCrFe-3	Low hydrogen	DC-EP	<ul style="list-style-type: none"> <li>•Suitable for Inconel and dissimilar metal joints such as Inconel to low alloy steel, and stainless steel to low alloy steel</li> <li>•DC-EP is only applicable</li> <li>•RC: 200~250°Cx 0.5~1h</li> </ul>	F HF H VU OH	Ex	0.06	0.34	6.55	69.40	13.21	2.00	7.90	Ti: 0.01	Co: 0.03	Ex	360	620	45	-196°C: 110
						Gt	≤0.10	≤1.0	5.00~9.50	≥59.00	13.00~17.00	1.00~2.50	≤10.00	Ti ≤1.00	Co ≤0.12	Gt	-	≥550	≥30	-
NIC-625	-	Low hydrogen	AC DC-EP	<ul style="list-style-type: none"> <li>•Suitable for Inconel 625, Incoloy 825, dissimilar-metal joints and overlaying</li> <li>•RC: 200~250°Cx 0.5~1h</li> </ul>	F HF H VU OH	Ex	0.04	0.32	0.67	61.10	21.65	3.41	3.66	8.70	-	Ex	420	760	47	-
						Gt	≤0.10	≤0.75	≤1.00	≥55.0	20.00~23.00	3.15~4.15	≤7.00	8.00~10.00	-	Gt	-	≥690	≥30	-

Note: Welding tests are as per AWS. Ex: Example, Gt: Guaranty (Polarity: as specified above)

Diameter and Length (mm)				
Dia.	2.6	3.2	4.0	5.0
<b>NIC-70A</b>	-	300	350	350
<b>NIC-703D</b>	250	300	350	350
<b>NIC-625</b>	-	300	350	350

Flux Cored Wires for 9%Ni steel and Nickel-Based Alloy

Brand name	ASME AWS Class.	Type of cored flux	SG	Pol.	Features	WP	Chemical composition of all-weld metal (%)						Mechanical properties of all-weld metal					
							C	Si	Mn	P	S	Ni	0.2%OS (MPa)	TS (MPa)	EI (%)	IV (J)		
DWN-70S	-	Rutile	Ar-CO <sub>2</sub>	DC-EP	•Suitable for 9% Ni steel	F HF	Ex	0.046	0.20	5.91	0.003	0.002	62.61	Ex	425	716	46	-196°C: 106
							Gt	≤0.15	≤0.75	≤8.00	≤0.020	≤0.015	≥55.00					
							Ex	16.84	10.22	0.01	1.88	2.02		Gt	-	≥650	≥25	-
							Gt	13.00~22.00	≤12.00	-	≤15.00	≤4.00						
DWN-82	-	Rutile	Ar-CO <sub>2</sub>	DC-EP	•Suitable for Inconel and dissimilar-metal joints such as Inconel to low alloy steel and stainless steel to low alloy steel	F HF	Ex	0.038	0.23	3.40	0.002	0.005	70.65	Ex	380	650	46	0°C: 128
							Gt	≤0.10	≤0.50	2.50~3.50	≤0.030	≤0.015	≥67.00					
							Ex	21.21	0.01	1.51	2.30	0.31		Gt	-	≥560	≥30	-
							Gt	18.00~22.00	≤0.50	≤3.00	2.00~3.00	≤0.75						

Note: Welding tests are as per Kobe Steel's Standard. Ex: Example, Gt: Guaranty

Diameter (mm)	
DWN-70S	1.2
DWN-82	1.2

## Flux Cored Wires for Nickel-Based Alloy

Brand name	ASME AWS Class.	Type of cored flux	SG	Pol.	Features	WP	Chemical composition of all-weld metal (%)						Mechanical properties of all-weld metal					
							C	Si	Mn	P	S	Ni	0.2%OS (MPa)	TS (MPa)	EI (%)	IV (J)		
DWN-625	-	Rutile	Ar-CO <sub>2</sub>	DC-EP	▪Suitable for Inconel 625, dissimilar-metal joints and overlaying	F HF	Ex	0.028	0.31	0.88	0.004	0.004	59.07	Ex	470	750	44	0°C: 57
							Gt	≤0.10	≤0.75	≤1.00	≤0.030	≤0.020	≥55.00					
							Ex	21.43	9.21	0.01	4.84	3.42	Gt	-	≥690	≥25	-	
							Gt	20.00~23.00	8.00~10.00	≤0.50	≤7.00	3.15~4.15						
DWN-625M	-	Rutile	Ar-CO <sub>2</sub>	DC-EP	▪Suitable for super stainless steels, dissimilar-metal joints and overlaying	F HF	Ex	0.021	0.60	2.61	0.004	0.004	60.81	Ex	460	730	42	0°C: 68
							Gt	≤0.10	≤0.75	2.00~3.50	≤0.030	≤0.020	≥55.00					
							Ex	21.20	9.94	0.01	3.02	1.98	Gt	-	≥690	≥25	-	
							Gt	20.00~23.00	8.00~11.00	≤0.50	≤7.00	1.50~3.00						

Note: Welding tests are as per Kobe Steel's Standard. Ex: Example, Gt: Guaranty

Diameter (mm)	
DWN-625	1.2
DWN-625M	1.2

Solid Wire for Nickel-Based Alloy

Brand name	ASME AWS Class.	SG	Pol.	Features	WP	Chemical composition of wire (%)						Mechanical properties of all-weld metal					
						C	Si	Mn	P	S	Ni	0.2%OS (MPa)	TS (MPa)	EI (%)	IV (J)		
MGS-70NCb	A5.14 ERNiCr-3	Ar	DC-EP	<ul style="list-style-type: none"> <li>Inconel 82 type filler wire</li> <li>Suitable for Inconel, Incoloy, dissimilar-metal joints and overlaying on carbon steel</li> </ul>	F HF H VU OH	Ex	0.03	0.22	3.05	0.003	0.002	72.01	Ex	370	660	41	-196°C: 140
						Gt	≤0.10	≤0.50	2.50~3.50	≤0.030	≤0.015	≥67.0					
						Ex	20.01	0.28	1.73	2.63	0.01		Gt	-	≥550	≥30	-
						Gt	18.00~22.00	≤0.75	≤3.00	2.00~3.00	≤0.50						

Note: Welding tests are as per AWS. Ex: Example, Gt: Guaranty

Diameter (mm)	
MGS-70NCb	0.8, 1.2, 1.6

## Filler Rods and Wires for 9%Ni Steel and Nickel-Based Alloy

Brand Name	ASME AWS Class.	SG	Pol.	Features	Chemical composition of rod and wire (%)							Mechanical properties of all-weld metal									
					C	Si	Mn	P	S	Ni	0.2%OS (MPa)	TS (MPa)	EL (%)	IV (J)							
TGS-709S	A5.14 ERNiMo-8	Ar	DC-EN	•Suitable for 9% Ni steel	Ex	0.017	0.02	0.02	0.001	0.001	69.81	Ex	460	730	47	-196°C: 160					
					Gt	≤0.10	≤0.50	≤1.0	≤0.015	≤0.015	≥60.0										
					Ex	1.97	19.07	2.99	5.56	0.01	Gt	-	≥650	≥30	-						
					Gt	0.5~3.5	18.0~21.0	2.0~4.0	≤10.0	≤0.50											
					TGS-70NCb	A5.14 ERNiCr-3	Ar	DC-EN	•Suitable for Inconel and Incoloy, dissimilar-metal joints and overlaying	Ex	0.022	0.20	2.99	0.002	0.001	72.39	Ex	370	680	40	-196°C: 150
										Gt	≤0.10	≤0.50	2.5~3.5	≤0.030	≤0.015	≥67.0					
Ex	19.87	2.50	0.30	1.65						0.01	Gt	18.00~22.00	2.00~3.00	≤0.75	≤3.00	≤0.50					
Gt	18.00~22.00	2.00~3.00	≤0.75	≤3.00						≤0.50											
TGS-N625	A5.14 ERNiCrMo-3	Ar	DC-EN	•Suitable for Inconel 625, dissimilar-metal joints and overlaying						Ex	0.010	0.08	0.05	0.002	0.001	63.58	Ex	480	770	41	-
										Gt	≤0.10	≤0.50	≤0.50	≤0.020	≤0.015	≥58.0					
					Ex	21.85	8.95	3.55	0.21	0.21	1.44	0.02	Gt	20.00~23.00	8.00~10.00	3.15~4.15	≤0.40	≤0.40	≤5.00	≤0.50	
					Gt	20.00~23.00	8.00~10.00	3.15~4.15	≤0.40	≤0.40	≤5.00	≤0.50									

Note: Welding tests are as per AWS. Ex: Example, Gt: Guaranty

#### Approvals

TGS-709S NK

#### Diameter (mm)

TGS-709S 1.2, 1.6, 2.0, 2.4  
TGS-70NCb 0.8, 0.9, 1.0, 1.2, 1.6, 2.0, 2.4, 3.2, 4.0  
TGS-N625 1.6, 2.4

## Flux and Wire Combinations for 9%Ni Steel

Brand name	ASME AWS Class.	Type of flux	Pol.	Features	Chemical composition (%)									Mechanical properties of weld metal				
					C	Si	Mn	Ni	Cr	Mo	W	Fe	0.2%OS (MPa)	TS (MPa)	EI (%)	IV (J)		
PFN-3/ US-709S	A5.14 ERNiMo -8	Bonded	AC  DC-EP	•Hastelloy type consumables •Suitable for flat welding of 9%Ni steel •RC: 200~300°Cx1h	Wire-Ex	0.02	0.01	0.01	Bal.	2.0	19.1	2.9	5.5	Ex	400	690	44	-196°C: 80
					Wire-Gt	≤0.10	≤0.50	≤1.0	≥60.0	0.5~3.5	18.0~21.0	2.0~4.0	≤10.0					
					Weld-Ex	0.03	0.12	1.70	64.1	1.6	16.6	2.5	14.7					
PFN-4/ US-709S	A5.14 ERNiMo -8	Bonded	DC-EP	•Hastelloy type consumables •Suitable for horizontal and horizontal fillet welding of 9%Ni steel •RC: 200~300°Cx1h	Wire-Ex	0.02	0.01	0.01	Bal.	2.0	19.1	2.9	5.5	Ex	410	680	43	-196°C: 70
					Wire-Gt	≤0.10	≤0.50	≤1.0	≥60.0	0.5~3.5	18.0~21.0	2.0~4.0	≤10.0					
					Weld-Ex	0.03	0.74	0.58	64.0	1.7	17.2	2.7	14.9					

Note: Welding tests are as per Kobe Steel's Standard. Wire-Ex: Example of wire, Wire-Gt: Guaranty of wire, Weld-Ex: Example of weld metal  
Ex: Example of weld metal (polarity: AC)

## ■ Approvals

PFN-4 / US-709S	NK
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## ■ Diameter of wire (mm)

US-709S	1.6, 2.4
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## ■ Mesh size of flux

PFN-3	12x48
PFN-4	12x65