

WELDING SOLUTIONS FOR THE LNG INDUSTRY



Hyundai's Welding Solutions for the LNG Industry

LNG (Liquefied Natural Gas) is a colorless, odorless liquid that is liquefied to -162°C for mass transportation and storage of natural gas. Because impurities such as carbon dioxide, hydrogen sulfide, ammonia, and moisture are removed before liquefaction, it contains clean energy with almost no impurities. It takes up 1/600th the volume of natural gas.

Hyundai Welding provides total welding solutions for the construction of various types of LNG storage tanks. 9% Nickel (Ni) steel is the main grade used for fabrication of LNG storage tanks, depending on the application and use. LNG storage tanks mostly consist of aboveground full containment LNG storage tanks on land, and LNG carriers and propulsion vessels at sea.



Hyundai's 9% Ni Welding Consumables for the LNG Industry

9% Nickel Steel

Process	Product	AWS	Туре	Application
SMAW	SR-134	A5.11 ENiCrFe-4	Inconel	Inconel SMAW applied to aboveground LNG storage tanks and offshore LNG fuel tanks.
JWAW	SR-08	A5.11 ENiMo-8	Hastelloy	SMAW applied to aboveground LNG storage tanks.
SAW	S-Ni2 x SA-08	A5.14 ERNiMo-8	Hastelloy	SAW combination applied to aboveground LNG storage tanks and offshore LNG fuel tanks (S-Ni2 : flux, SA-08 : sub wire).
FCAW	SW-82H	- (ENiCrMo3 Modified Type)	Inconel	Inconel FCAW applied to LNG Fuel Tanks (Type C), for vertical upward welding (3G).
GTAW	SMT-08	A5.14 ERNiMo-8	Hastelloy	GTAW (TIG) for root pass welding and repair.

Welding Materials by LNG Type

Applie	cation	Туре	Shape	Process	Note
La (Aboves	nd ground)	Storage tank		SMAW, SAW	Aboveground full containment storage tanks are fabricated with 9% Ni steel.
	LNG	Independent		GMAW, GTAW	A vessel whose tank is independent of the hull and maintains pressure to trap LNG.
Sea	Carrier	Dependent		GTAW, PAW	A membrane-type vessel that uses the ship's hull to share pressure and weight of LNG.
	LNG- fuelled Ship	Prupulsion Ship	No.	FCAW	Ships that are fuelled by LNG and therefore comply with strict marine environmental regulations.

Aboveground LNG Storage Tank

Welding Process for Full Containment LNG Storage Tank

The inner tank of a full containment LNG storage tank is made of 9% Nickel steel, and the outer tank is made of Pre-stressed concrete (PC). A vapor barrier made of thin carbon steel plate and many different types of insulations exists between the inner and outer tank.

The roof can be made of concrete or 9% Nickel material. An aluminium suspended deck hangs from the roof, providing a vapor seal for the liquid product.

1 VAPOR BARRIER

Full Containment LNG Storage Tank

This protective layer is made of carbon steel, and is of a very low thickness. Therefore, the best method to weld this barrier is to use a flux cored wire.

Applied Products

SMAW · S-7018.1H FCAW · Supercored 81-K2

② INTERNAL PIPING

Through stainless piping, liquefied gas is transferred to and from the tank. Due to the toughness and lateral expansion, this piping requires special consumables.

Applied Products

SMAW · S-308L.16N · S-316L.16N FCAW · SW-308L Cored · SW-316L Cored GTAW · SMT-08 9% Nickel Steel

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Inner tank bottoms are welded in the 2G position. In most cases, bottom plates are pre-joined using automatic welding, and then welded with each other via SMAW or FCAW.

Welding Consumables for Full Containment LNG Storage Tank

Process	Product	AWS	Note
	S-7018.1H	A5.1 E7018-1 H4R	Extra low hydrogen
	S-308L.16N	A5.4 E308L-16	Stainless steel (18%Cr-8%Ni)
SMAW	S-316L.16N	A5.4 E316L-16	Stainless steel (18%Cr-12%Ni-2%Mo)
	SR-134	A5.11 ENiCrFe-4	For 9% Ni steel - Inconel modified
	SR-08	A5.11 ENiMo-8	For 9% Ni steel – Hastelloy
SAW	S-Ni2 x SA-08	A5.14 ERNiMo-8	For 9% Ni steel – Hastelloy
	Supercored 81-K2	A5.36 E81T1-C1A8-K2 H4	For carbon steel, low hydrogen level (H4)
	SW-308L Cored	A5.22 E308LT1-1/-4	Stainless steel (18%Cr-8%Ni)
FCAW	SW-316L Cored	A5.22 E316LT1-1/-4	Stainless steel (18%Cr-12%Ni-2%Mo)
	SW-625	A5.34 ENiCrMo3T1-4	Nickel-chromium-molybdenum alloys cladding steel & weld metal
	SW-82H	(ENiCrMo3 Modified Type)	For 9% Ni steel - Inconel modified
GMAW	SMT-5183(H)	A5.10 ER5183	5% Magnesium, 0.6% Mn aluminum filler metal
СТАМ	SMT-5183(H)	A5.10 ER5183	5% Magnesium, 0.6% Mn aluminum filler metal
GIAW	SMT-08	A5.14 ERNiMo-8	For 9% Ni steel - Hastelloy





3 SUSPENDED DECK

Deck annular plates are required to provide a vapor seal between the liquid product and the vapor space above the containment, and the deck is made of Aluminium alloy 5083. Rods are then attached from deck stiffeners to the roof girders, and they can either be made of carbon or stainless steel.

Applied Products

GTAW · SMT-5183(H) **GMAW** · SMT-5183(H)

④ INNER TANK JOINTS

9% Nickel plates are welded using electrodes in the 3G (vertical up) position, automatic SAW in the 2G position, or via flux cored wires. Rod SR-08 is used to repair pores after automatic welding.

Applied Products

SMAW · SR-134 9% Nickel Steel SR-08 9% Nickel Steel FCAW · SW-82H 9% Nickel Steel SW-625 9% Nickel Steel SAW · S-Ni2 x SA-08 9% Nickel Steel

5 INNER TANK BOTTOM

Applied Products

SMAW · SR-134 9% Nickel Steel **SAW** · S-Ni2 x SA-08 9% Nickel Steel

Offshore LNG Storage Tank

Welding Process by LNG Carrier Type

ltom		Dependent		
item	Туре А Туре В		Туре С	Membrane
Shape				
Use	Medium to large LPG ships	Large LNG ships	Small LPG, LNG ships	Large LNG ships
Vapor Pressure	< 0.07 MPa	< 0.07 Mpa	High pressure	\leq 0.025 MPa
Base Metal	Carbon steel such as EH and FH	Al, 9% Ni	9% Ni	SUS 304L, Invar
Welding Process	FCAW, SAW	FCAW, SAW	FCAW, SAW	GTAW, PAW
Features	 High volume efficiency Complete secondary barrier 	 High volume efficiency Detail fatigue analysis required 	 Simple design and construction Low volume efficiency 	 High volume efficiency Complete heat protection and secondary barrier Unable to repair exterior of tank

Application References of Hyundai's Welding Consumables for 9% Ni Steel

ltom	Independent Fuel Tank					
item	Туре В	Туре С				
Welding Material	9% Ni stee	el (12~25T)				
Applied Products	FCAW:SW-82H (Main structure welding) GTAW:SMT-08 (Repair and maintenance) SAW:S-Ni2 x SA-08 (Tank bottom)					
Pictures	Tank dome Walkway Swash bhd Jaudaia					
	Invelation Inner hull Access spoce Support					

Test Evaluation Results of **Hyundai's Welding Consumables for 9% Ni Steel**

<u>SR-134</u>

AWS A5.11/ ASME SFA5.11 ENiCrFe-4 JIS Z3225 D9Ni-1 DNV GL VL9Ni H5



Test Evaluation Conditions (3G Position) of SR-134					
Base metal	A553-Type 1 16t				
Product		SR-134			
Weld specimen	16	16mm*300mm*1000mm			
Groove type	X-Groove				
Croovo anglo	Inside	60°±5°			
Groove angle	Outside	90°±5°			
Deet	Face	2mm			
RUOL	Gap	2mm			

Item		-	Weldi	ng con	ditions	Heat	
		Size (mm)	Current (A)	Voltage (V)	Welding speed (cpm)	input (kJ/cm)	Interpass temp(°C)
	1	4	115	28	7.5	25.8	50
Inside	2	4	130	28	6.9	31.4	45
	3	4	120	30	5.9	36.8	56
Grinding							
Outcido	4	4	129	31	8.9	26.8	46
Outside	5	4	130	29	6.1	36.8	46

S-Ni2 / SA-08

ABS Manufacturer's Spec. (-196°C) BV AN90M DNV VL1.5Ni up to VL9Ni LR 9NiM RS Manufacturer's Spec. (-196°C)

Test Evaluation Conditions

Base metal	A553-Type 1 16.3t		
Product	S-Ni2/SA-08		
Weld specimen	16.3mm*300mm*1000mm		
Groove type	X-Groove		
Crease angle	Inside	60°±5°	
Groove angle	Outside	60°±5°	
Post	Face	2mm	
ROOL	Gap	0mm	

Inside(330~400A/26~27V/36.5~63.2cpm)

		9% Nick	kel Steel
Diameter	Length mm(in)	PVC Packet	Carton
mm (in)	350 (14)	5kg (11lbs)	20kg (44lbs)
2.6 (3/32)			
3.2 (1/8)	V	٧	٧
4.0 (5/32)	V	٧	٧
5.0 (3/16)	V	V	V



Weldability Evaluation (3G Position) of SR-134



Inside(115A~130A/28~30V)

Diameter

mm(in)

2.0 (5/64)

2.4 (3/32)

3.2 (1/8)

9% Nickel Steel

Basket spool

25kg (55lbs)

V



Outside(130A/29~31V)



		Weld	ling condit	tions	Heat	
Item		Current (A)	Voltage (V)	Welding speed (cpm)	input (kJ/cm)	temp(°C)
	1	330	26	43.9	11.7	22
Incido	2	380	26	52.6	11.2	71
manue	3	390	27	36.5	17.3	93
	4	400	26	63.2	9.8	94
			Grindi	ing		
	5	410	27	36.5	18.2	29
Outsida	6	420	28	44.4	15.9	88
Outside	7	430	28	37.9	19	92
	8	420	28	55.4	12.7	95
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		in an	S. A. S.	in the big the first sectors.	CARGONIA STREET	

Outside(410~430A/27~28V/36.5~55.4cpm)

SW-82H

KR L91S ABS Manufacturer's Spec. (-196°C) LR 9NiS BV N90 DNV NV9Ni RS Manufacturer's Spec. (-196°C)

		9% Nickel Stee
Diameter	Sŗ	bool
mm (in)	10kg (22lbs)	12.5kg (27.6lbs)
1.2 (0.045)	V	V

Test Evaluation Conditions





Base metal		A553-Type 1	
Product	SW-82H		
Shielding gas		100% CO2	
Weld specimen	20mm*200mm*1000mm		
Groove type	X-Groove		
Croove angle	Inside	60°±5°	
Groove angle	Outside	90°±5°	
Poot	Face	2mm	
ROOL	Gap	2mm	

Pass No.	Current (A)	Voltage (V)	Welding speed (cpm)	Heat input (kJ/cm)	Interpass temp (°C)	Note
1	130	25	16.9	11.6	5	
2	135	26	10.5	20.1	40	
3	135	26	8.8	24	50	
4	130	26	9.3	21.7	15	1 Pass Grinding
5	130	26	7.9	25.8	-	

Weldability Evaluation of SW-82H (1.2mm/ 3G Position/ 9% Ni 30T 1m/ 100% CO2 gas)

○ Inside(130A~140A/24~26V)



Before and after slag peel of single pass

Outside(130A~140A/24V~26V)



Before and after slag peel of single pass







Before and after slag peel of 3rd pass



Before and after slag peel of 2nd pass

SMT-08

AWS A5.14/ ASME SFA5.14 ERNiMo-8 JIS Z3334 SNi1008 (NiMo19WCr) ABS Manufacturer's Spec. (-196°C) DNV VL 1.5Ni up to VL 9Ni LR 9NiS



RS Manufacturer's Spec. (-196°C)

Test Evaluation Conditions of SMT-08



	Welding conditions		Current	Voltage	Arcing time	Welding speed	Shielding gas	Interpass temp	Heat input
	Product	Diameter	(A)	(V)	(seconds)	(cpm)	(l/min)	(°C)	(kJ/cm)
1	SMT-08 (ERNiMo-8)	1.2	240-280	10	1477	4.75	25	35	30.3-35.3
2			265-300	10	1477	4.75	25	36	57.4-65.0
3			300	10	1787	2.52	25	57	71.48
4			300	10	1850	3.73	25	40	48.26
5			320	10	2465	2.8	25	44	68.59
6			290	10	2320	3.1	25	43	56.07
7			300	10	1475	4.35	25	38	41.46
8			240	10	1389	5.08	25	47	28.37

240A~280A/10V/4.75cpm



		9% Nickel Steel
Diameter	MIG	TIG
mm(in)	12.5kg (27.6lbs)	5kg (11lbs)
1.2 (0.045)	V	
2.0 (5/64)		V
2.4 (3/32)		V
3.2 (1/8)		V

Base metal	ASTM A553 TYPE1		
Thickness	32.9mm		
Product	SMT-08		
AWS	AWS A5.14 ERNiMo-8 EN ISO 18274 Ni1008(NiMo19WCr)		
Diameter	1.2mm		
Welding Position	V-up		
Application	LNG Storage Tank		

Client References for 9% Ni Steel LNG Tanks

South Korea

Hyundai Heavy Industries Hyundai Mipo Dockyard Hyundai Samho Heavy Industries Hyundai Engineering & Construction Kumho Engineering & Construction Korea Gas Corporation (KOGAS)



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