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HYUNDAI WELDING

WELDING SOLUTIONS FOR THE LNG INDUSTRY

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HYUNDAI WELDING MEETS DEMANDING REQUIREMENTS OF THE LNG INDUSTRY

Natural gas, which consists mainly of methane, emits 20-40% less CO_2 than other fossil fuels such as petroleum and coal. Many industrial states therefore consider it an intermediate step in the transition from fossil fuel to a fully renewable energy future. The supply of natural gas through land and sea pipelines to Western Europe was recently disturbed, however, causing a shortage which endangers further economic development and welfare of its citizens.

LNG (Liquefied Natural Gas) offers the possibility to diversify gas supply and enhance energy security. It is imported from gas fields all over the world and shipped in vessels with refrigerated tanks. Countries with LNG landing terminals and associated infrastructure are therefore in a better condition to fulfil their energy needs

HYUNDAI WELDING has traditionally been involved in the LNG industry with dedicated filler materials designed for typical welding applications in the construction of storage tanks, vessels, liquefaction plants and associated facilities. They cover all commonly applied material grades - such as 9% nickel steel, stainless piping and aluminium, while products are available for the entire scope of welding processes used in LNG fabrication.

HYUNDAI WELDING nickel-base and other high-alloyed consumables are specifically designed for LNG applications with high weld metal toughness requirements at cryogenic temperatures using adapted welding procedures. Over the last decade, significant volumes of nickel-base consumables for 9% Ni-steel – the main grade used for LNG storage tanks – have been supplied to fabricators all over the world. They have earned a strong reputation for quality, product testing and detailed certification throughout the industry.

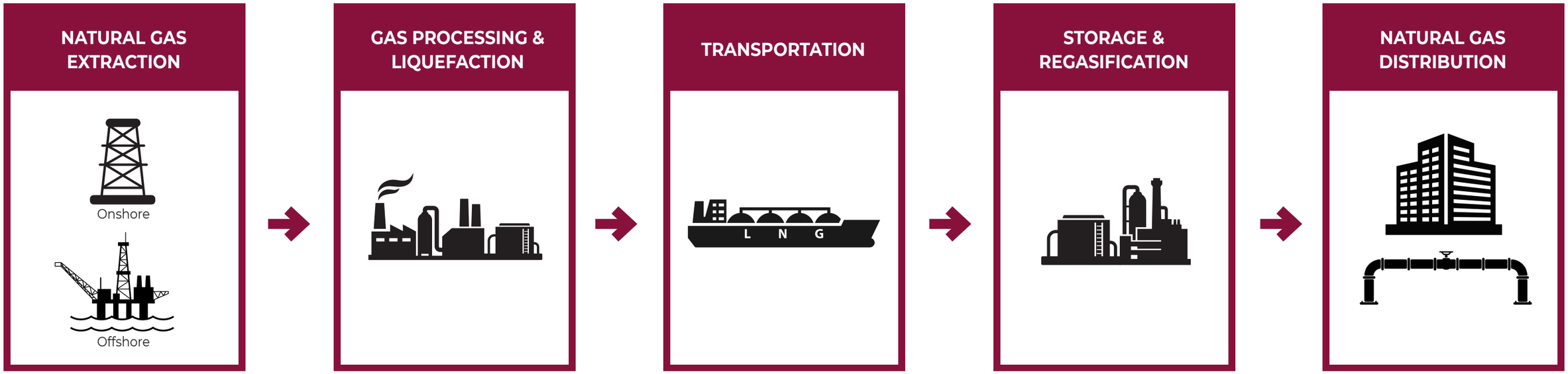
LIQUEFIED NATURAL GAS IS CRUCIAL IN GLOBAL ENERGY DIVERSIFICATION

LNG is a colourless and odourless liquid that forms when natural gas is cooled to -162°C at atmospheric pressure, taking up only 1/600th of the volume of the gas. This physical property facilitates transportation of natural gas over long distances without the need of pipelines; in specially designed LNG vessels over sea or in tank trucks over land. When it reaches its final destination, LNG is usually re-gasified and distributed through gas networks. Main LNG consuming countries are Japan, South Korea, China, the European Union and the USA. Important exporters of LNG are Iran, Qatar, Trinidad & Tobago, Malaysia, Nigeria, Egypt, Russia, Algeria and the USA.

Recently it became apparent that long term energy security was at stake. It triggered off a worldwide surge in LNG related investments and dynamic developments in LNG liquefaction, transportation, storage and gasification facilities. In addition, LNG is increasingly seen as an alternative lower emission fuel for ships and lorries. In Europe, the usage of LNG as fuel in maritime and terrestrial transportation is expected to increase drastically with the continuation of energy security issues and new regulations on sulphur emission.

The renewed interest in LNG is clearly demonstrated by a staggering use in the European Union. According to the European Commission, the EU imported almost three times as much LNG in 2022 (up to 100 bcm) as in 2021, underlining its crucial role in global energy diversification.

LNG PRODUCTION & DISTRIBUTION



LIQUEFACTION

After extraction from gas fields, natural gas is cleaned and cooled to its liquefaction temperature of -162°C, using cryogenic heat exchangers. The liquefied gas is contained in LNG storage tanks at export terminals, before shipping to its final destination by LNG carriers.

TRANSPORTATION

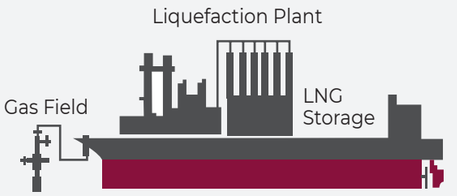
To transport LNG over long distances and maintain it liquefied, specially-designed LNG Carriers with refrigerated tanks or hulls are needed. These require materials with excellent strength and toughness properties at cryogenic temperatures. The same is valid for the welds in these materials, which are deposited using specialized filler materials. See page 13 for detailed information on LNG carriers.

REGASIFICATION

After transportation to a landing terminal at its destination, the LNG is taken in and stored in tanks. From here, it is re-gasified by means of heat exchangers and distributed to end users through the pipeline grid.

USAGE OF NICKEL STEELS FOR LNG INDUSTRY

Nickel-alloyed steels offer a combination of strength, ductility and resistance to cracking at cryogenic temperatures. This makes them a popular choice for LNG applications. 9% nickel-alloyed types are the main grade used for LNG storage tanks and hulls (e.g. classified in ASTM A353 / A353M and ASTM A553 / A553M). See page 18 for detailed information. In addition, there are developments using steel with a lower nickel content (5-6%) to reduce material costs.



LNG FPSO (Floating Production Storage and Offloading)

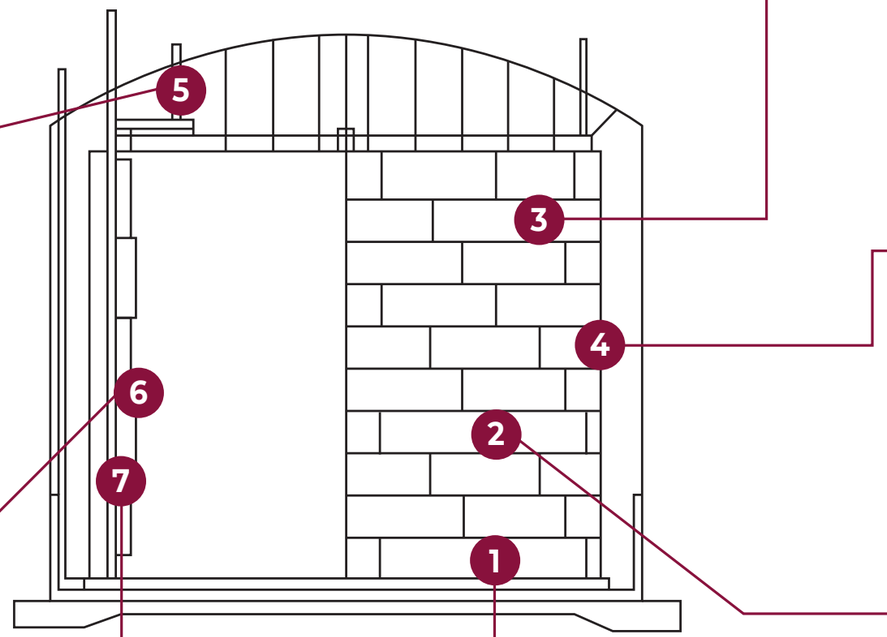
A floating vessel with gas processing and liquefaction capability to tap directly into remote offshore fields and load it directly onto an LNG carrier, instead of having the same process investment on land.

LNG FSRU (Floating Storage & Regasification)

A floating vessel with regasification capability to vaporize LNG taken from LNG carriers and load it into a distribution network, without the need of a regasification terminal on land.

LNG STORAGE TANK

The full containment LNG storage tank is the most commonly used type. It is designed with a safety barrier around an inner tank of 9% nickel-alloyed steel containing the LNG, ensuring maximum security in the event of a leak or other failure. The safety barrier consists of an outer shell of reinforced concrete with a carbon steel lining that serves as a vapour barrier. The space in between is filled with insulation material to reduce heat transfer from the outside, while maintaining the LNG at liquefaction temperature. The concrete shell also provides additional strength and stability to the tank.



Suspended Deck

A suspended deck, made of aluminium alloy 5083, provides a vapour seal and supports a layer of glass wool insulation between liquid gas and tank top. It is suspended from the roof structure by means of beams or rods. It is welded in 1F/1G position.

Required Consumable:
GTAW: SMT-5183 (S)
GMAW: SMT-5183 (S)

Inner Tank Vertical Joints

Vertical joints (3G) of tank shells in 9%Ni-steel are welded with SMAW or FCAW. The latter process is often mechanised with tractors walking over rails attached to the shell.

Required Consumable:
SMAW: SR-134
FCAW: SW-82H

Inner Tank Stiffener & Knuckle Joints

Stiffener elements on the inner tank and between inner tank and outside wall (ring beams) are predominantly in 4F/4G position requiring versatile filler materials. SMAW is commonly used.

Required Consumable:
SMAW: SR-134
FCAW: SW-82H

Stainless Steel Piping

Liquefied gas is pumped in and out of the storage tank through stainless steel piping. It has good corrosion resistance and excellent toughness properties at cryogenic temperatures. All main welding processes are used in prefab and on-site welding in 1G/2G/5G position.

Required Consumable:
SMAW: S-308LT.16, S-316LT.16
FCAW: SW-308LT, SW-316LT

Vapour Barrier

A vapour barrier prevents loss of LNG to the environment in case of leakage. It is a non-alloyed steel lining on the interior of the concrete outer shell made of non-alloyed steel. Sometimes the lower part is made of 9%Ni-steel. It has a limited plate thickness requiring control of distortion from welding. SMAW and FCAW are commonly used to weld in 2F and 3F positions.

Required Consumable:
SMAW: S-7018.1H
FCAW: Supercored 81-K2

Inner Tank Bottom Joints

Bottom plates in 9% Ni-steel of the inner tank are normally pre-joined with the SAW process in 1G position. These are laid out on the concrete floor of the tank and welded in the 1G and 2F positions. The corner joints, connecting the annular ring that runs around the circumference of the bottom to the first vertical shell – are welded in 2G position. Applicable welding processes for this stage are SMAW, FCAW and SAW.

Required Consumable:
SMAW: SR-134 / SR-08 (Repair Welding)
FCAW: SW-82H
SAW: S-Ni2 x SA-08

Inner Tank Horizontal Joints

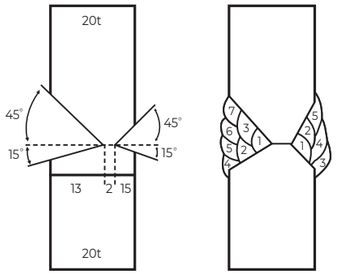
Horizontal joints (2G) of tank shells in 9%Ni-steel are almost exclusively welded with the SAW process. Simultaneous welding of both sides (double-sided) is universally applied for its high economy, when allowed by plate thickness. Special tractors support the welding flux in 2G position.

Required Consumable:
SMAW: SR-08 (Repair Welding)
FCAW: SW-82H
SAW: S-Ni2 x SA-08

INNER TANK – HORIZONTAL JOINTS

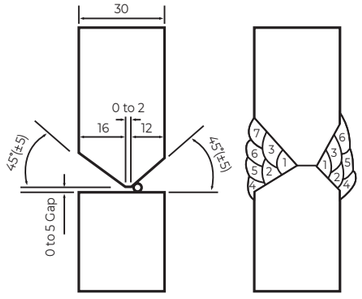
Horizontal joints (2G) of tank shells in 9%Ni-steel are almost exclusively welded with the SAW process, giving superior productivity. In comparison to downhand submerged arc welding (1G), the gravity does not pull the weld metal towards the root, making it the most critical step in LNG tank fabrication. Special care must be taken to ensure a fully fused root area. The joint design is adapted to allow, at the same time, access of the welding head and support of the weld pool. The welding flux is kept in place by a transport belt that travels with the welding head. Simultaneously welding from both sides is standard practice as from 13mm plate thickness, but it requires greater coordination and control of the welding process than single-sided welding. Torch positioning, wire feed speed and travel speed need to be carefully adjusted to assure proper weld penetration. HYUNDAI WELDING's wire/flux combination S-Ni2/SA-08 enjoys a strong reputation in this challenging welding application for its high productivity, dependable weld quality and excellent mechanical properties at cryogenic temperature. Next data summarises the approved welding procedure qualification for 20 mm and 35 mm thickness by one of the world's major fabricators of LNG installations.

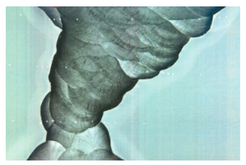
20mm plate thickness (9%Ni Steel)



Outside Pass	Speed CPM (IPM)	Current (A)	Voltage (V)	Heat input kJ/cm (kJ/in)
1	42 (16.5)	360	28	14.4 (5.7)
2	49 (19.3)	360	28	12.3 (4.8)
3	38 (15.0)	380	28	16.8 (6.6)
4	43 (16.9)	380	28	14.8 (5.8)
5	42 (16.5)	380	28	15.2 (6.0)
6	48 (18.9)	380	28	13.3 (5.2)
7	50 (19.7)	380	28	12.8 (5.0)
Back gouging Inside				
1	42 (16.5)	360	28	14.4 (5.7)
2	58 (22.8)	360	28	10.4 (4.1)
3	41 (16.1)	360	28	14.8 (5.8)
4	45 (17.7)	380	28	14.2 (5.6)
5	47 (18.5)	380	28	13.6 (5.4)

30mm plate thickness (9%Ni Steel)





Outside Pass	Speed CPM (IPM)	Current (A)	Voltage (V)	Heat input kJ/cm (kJ/in)
1	47 (18.5)	350	27	12.1 (4.8)
2	58 (22.8)	360	27	10.1 (4.0)
3	63 (24.8)	380	27	9.8 (3.9)
4	63 (24.8)	400	28	10.7 (4.2)
5	63 (24.8)	390	28	10.4 (4.1)
6	67 (26.4)	400	28	10.0 (3.9)
7	67 (26.4)	400	28	10.0 (3.9)
Back gouging Inside				
1	42 (16.5)	400	27	15.4 (6.1)
2	42 (16.5)	410	26	15.2 (6.0)
3	54 (21.3)	415	27	12.5 (4.9)
4	58 (22.8)	415	27	11.6 (4.6)
5	66 (26.0)	410	27	10.1 (4.0)
6	63 (24.8)	410	27	10.5 (4.1)

Welds tested and approved according to relevant standards:

Tension test	ASTM A 370	AWS B 4.0
Bending test	ASTM A 370	AWS B 4.0
Impact test	ASTM A 370	AWS B 4.0
Hardness test	ASTM A 370	AWS B 4.0
Chemical composition	ASTM E 354	

Mechanical properties of weld metal in 20mm plate thickness

Steel	YS (MPa)	TS (MPa)	EL (%)	CVN Impacts(J) @ -196℃			
				1	2	3	Avg.
9% Ni Steel (X-groove)	-	695 694	-	77	90	86	84

Mechanical properties of weld metal in 30mm plate thickness

Steel	YS (MPa)	TS (MPa)	EL (%)	CVN Impacts(J) @ -196℃			
				1	2	3	Avg.
9% Ni Steel (X-groove)	-	718 742	-	123	124	130	126

20mm plate thickness (9%Ni Steel)

Root Pass

3rd Pass

7th Pass

30mm plate thickness (9%Ni Steel)

Root Pass

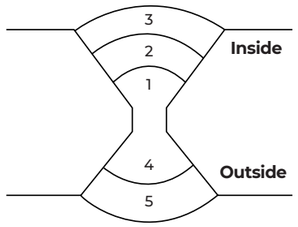
3rd Pass

7th Pass

INNER TANK - VERTICAL JOINTS

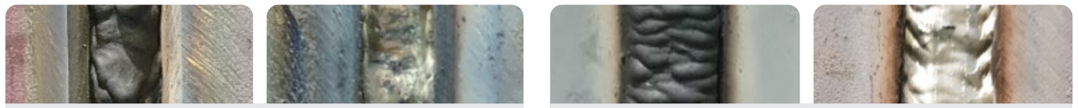
SMAW and FCAW are widely used for welding vertical welds of LNG inner tanks. Specially designed stick electrodes and flux-cored wires offer superior weldability along with reduced risk of fusion defects and provide welds with the desired mechanical properties at cryogenic temperature. FCAW has the additional advantage of a higher duty cycle, in general, as well as the possibility to mechanise the process using welding tractors climbing on rails.

HYUNDAI WELDING's SW-82H is a modified Inconel 625 gas-shielded flux-cored wire with all-positional weldability. It can be used under 100% CO_2 gas shielding, which brings a cost advantage over more expensive mixed gases. It shows a nice weldability with a smooth, stable spray arc. The fast freezing slag supports the weld metal allowing high productivity in positional welding.



Pass No.	Current (A)	Voltage (V)	Speed CPM (IPM)	Heat input kJ/cm (kJ/in)	Interpass temp °C (°F)	Note
1	130	25	16.9 (6.7)	11.6 (29.5)	5 (41)	
2	135	26	10.5 (4.1)	20.1 (51.1)	40 (104)	
3	135	26	8.8 (3.5)	24.0 (61.0)	50 (122)	
4	130	26	9.3 (3.7)	21.7 (55.1)	15 (59)	1 pass Grinding
5	130	26	7.9 (3.1)	25.8 (65.5)	-	

Before and after slag peel of 2nd pass

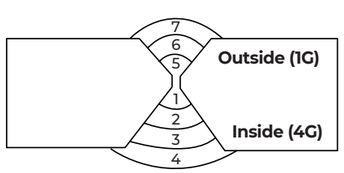


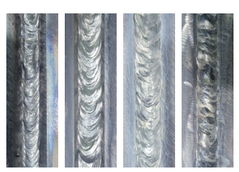
Outside | Inside

INNER TANK - STIFFENER & KNUCKLE JOINTS

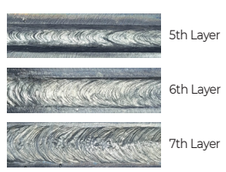
Stiffener elements on the inner tank and between inner tank and outside wall (ring beams) are predominantly in 4F/4G position requiring versatile filler materials with good characteristics for overhead welding. Joints are in 9% Ni-steel or dissimilar between 9% Ni-steel and non-alloyed construction steel. SMAW is commonly used for these characteristic welds in tank fabrication. We recommend our stick electrode SR-134.

Pass No.		Size mm(in)	Weding position	Polarity	Current (A)	Voltage (V)	Speed CPM (IPM)	Interpass temp °C (°F)	Heat input kJ/cm (kJ/in)
In side	1	4.0 (5/32)	4G	AC	105~110	24~25	13.3 (5.2)	18 (64)	1.14-1.24 (2.90-3.15)
	2	4.0 (5/32)	4G	AC	115~125	26~28	15.2 (6.0)	45 (113)	1.18-1.38 (3.00-3.51)
	3	4.0 (5/32)	4G	AC	115~125	26~28	16.4 (6.5)	58 (136)	1.09-1.28 (2.77-3.25)
	4	4.0 (5/32)	4G	AC	115~125	26~28	12.1 (4.8)	60 (140)	1.49-1.74 (3.78-4.42)
Grinding									
Out side	5	5.0 (3/16)	1G	AC	210~220	33~35	9.6 (3.8)	17 (63)	4.34-4.82 (11.02-12.24)
	6	5.0 (3/16)	1G	AC	210~220	33~35	9.5 (3.7)	68 (154)	4.40-4.89 (11.18-12.42)
	7	5.0 (3/16)	1G	AC	210~220	33~35	9.3 (3.7)	102 (216)	4.49-4.99 (11.40-12.67)





1st Layer 2nd Layer 3rd Layer 4th Layer



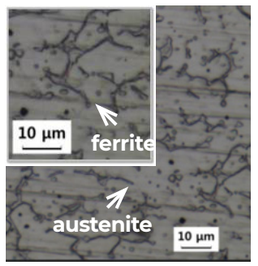
5th Layer
6th Layer
7th Layer

STAINLESS STEEL PIPING - CRYOGENIC

Pipework for LNG storage tanks is typically made of AISI 304L and 316L austenitic stainless steel, which are both suited for service temperatures down to -196°C. To establish safe LNG constructions, it is necessary to set high toughness requirements at operating temperature (-162°C). The test temperature for mechanical properties has been set at -196°C due to safety reasons, but also for easy reproducibility of testing in liquid nitrogen.

Impact energy and lateral expansion are useful material properties to express low temperature toughness behaviour and therefore threshold values are stipulated in design codes for both construction material as well as for weld metal. For austenitic weld metal, ASME prescribes ≥ 0.38mm lateral expansion at -196°C, while the comparable European code requires a CVN impact value of ≥ 0.32J. To meet cryogenic toughness requirements with austenitic weld metal, stainless steel consumables with a controlled ferrite number are essential. Too high delta ferrite reduces low-temperature toughness, while too low delta ferrite increases the risk of hot cracking.

Product Name	Typical Chemical Composition of All-Weld Metal(wt.%)						Ferrite number	Charpy V-notch test (at-196°C)	
	C	Si	Mn	Cr	Ni	Mo	WRC1992	Impact values (J)	Lateral Expansion (mm)
SW-308LT	0.02	0.67	1.53	18.3	9.9	0.05	5.8	36	0.75
SW-316LT	0.02	0.77	1.52	17.3	12.4	2.4	3.2	33	0.53

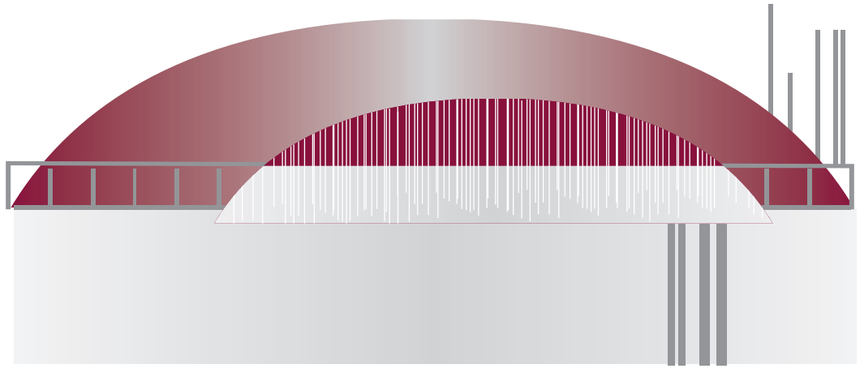


HYUNDAI balances the chemical composition of its SMAW Electrodes (S-308LT.16 and S-316LT.16) and Flux Cored Wires (SW-308LT and SW-316LT) for LNG applications such that it reaches the ASME requirement of FN 2-5 for the undiluted weld metal, while meeting all strength and toughness requirements for cryogenic applications.

Austenitic micro structure with reduced delta ferrite of weld metal deposited with SW-316LT flux cored wire. Chemical composition optimised to fulfil LNG strength and toughness requirements with good corrosion resistance.

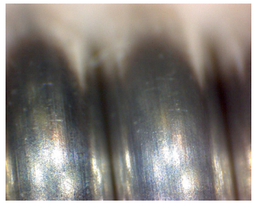
SUSPENDED DECK

A suspended deck, typically made of aluminium alloy 5083, provides a vapour seal and supports a layer of glass wool insulation between liquid gas and tank top. It is suspended from the roof structure by means of beams or rods. The deck is designed to withstand the thermal and atmospheric conditions in the tank environment and must be strong enough to support the weight of personnel.



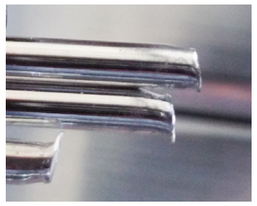
Superior Quality with S-Line Aluminum MIG Wires

The GMAW process is universally applied for welding suspended decks, along with GTAW. Process stability is one of the most important criteria for successful welding, in which the quality of the welding wire plays a key role. The new HYUNDAI WELDING S-Line range of aluminium wires provides a new level of wire surface cleanness and finish. This is essential in the avoidance of wire feeding problems and related arc instability, as too often encountered in aluminium welding. Stable wire feeding results in a nice weld quality and appearance as well as optimal productivity.



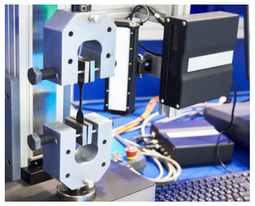
Surface Finish & Feedability

Smooth wire surface without surface failures such as flaking and shaving provides better feedability and a stable arc.



Cleanness of Wire Surface

Due to an excellent clean welding wire surface, there is no porosity in the welding bead.



Chemical Composition & Mechanical Properties

Due to tightly controlled chemical composition, consistent mechanical properties (elongation, tensile & yield strength) are achieved.

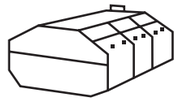
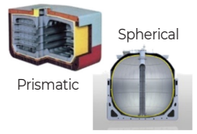
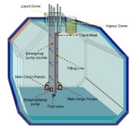
Convenient Packaging

A unique spooling system prevents tangling and twisting issues for spool packaging.

LNG CARRIERS

Welding Process by LNG Carrier Type

Liquefied Natural Gas (LNG) carriers are specialized ships designed to transport LNG from the production site to the import terminal. There are several types of LNG carriers, each with its own unique design features and capabilities. The choice of type will depend on factors such as the size of the shipment, the transport route, and the cargo handling requirements at the import terminal. The most common types of LNG carriers are:

Item	Independent			Dependent
	Type A	Type B	Type C	Membrane
Shape		 Prismatic / Spherical	 Cylindrical / Bilobe	
Vapour Pressure	< 0.07 MPa	< 0.07 Mpa	High pressure	≤ 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 Consumables for 9% Ni Steel

The use of 9% nickel steel in LNG carriers is critical to the safe and efficient transportation of LNG. The high-strength and corrosion-resistant properties of the steel ensure that the LNG carrier can withstand the demanding conditions of the transport environment, while maintaining the structural integrity and safety of the ship. Below, you can see the consumable list which are used for Type B and Type C LNG Carrier Tanks.

LNG Fuel Tank (Type B)				LNG Fuel Tank (Type C)			
Application	Welding Process	Welding Position	Filler Metal	Application	Welding Process	Welding Position	Filler Metal
*Butt for Plate	FCAW+SAW	1G	SW-82H+SA-08+Ni2	Internal Ring Plate	FCAW+SAW	1G	SW-82H+SA-08+Ni2
*Block Assembly	FCAW	2G	SW-82H	Shell	FCAW	2G	SW-82H
	FCAW	3G	SW-82H		FCAW	3G	SW-82H
*Stiffener	FCAW	2F	SW-82H	Stiffener	FCAW	1F 2F 3F	SW-82H
*Internal of block	FCAW	1F 2F 3F	SW-82H	Head	FCAW	2G 3G 4G	SW-82H
Other	TIG	4G 4F	SMT-08				

TYPICAL MECHANICAL PROPERTIES AND CHEMICAL COMPOSITION (%) OF ALL-WELD METAL

Process	Product Name	AWS	EN ISO	Typical Chemical						Composition of All-Weld Metal(%)							Typical Mechanical Properties of All-Weld Metal					
				C	Si	Mn	P	S			Cr	Ni	Mo	Nb	W	Fe		YS MPa(lbs/in²)	TS MPa(lbs/in²)	EL (%)	Impact ISO-V	
																					°C (°F)	J (ft·lbs)
SMAW	SR -134	A5.11 ENiCrFe-4	-	0.12	0.40	3.20	0.001	0.001			15.9	66.4	2.4	2.1	-	9.2	As Welded	-	705 (102,300)	40	-196 (-321)	58 (43)
	SR-08	A5.11 ENiMo-8	-	0.03	0.40	0.20	0.001	0.001			1.7	70.9	17.2	-	2.9	5.7	As Welded	-	730 (105,900)	41	-196 (-321)	70 (52)
	S-308LT.16	A5.4 E308L-16	ISO 3581-A E 19 9 L R	0.03	0.77	1.74	0.020	0.012			19.2	9.9	0.1	-	-	-	As Welded	-	576 (83,600)	49	-196 (-321)	36 (27)
	S-316LT.16	A5.4 E316L-16	-	0.03	0.75	1.80	0.020	0.016			17.8	13.5	2.3	-	-	-	As Welded	-	570 (82,700)	40	-196 (-321)	36 (27)
	S-7018.1H	A5.1 E7018-1 H4R	ISO 2560-A E 42 4 B 3 2 H5	0.08	0.22	1.09	0.011	0.004			-	-	-	-	-	-	As Welded	492 (71,400)	542 (78,600)	27	-45 (-50)	97 (71)
FCAW	SW-82H * / **	A5.34 ENiGT1-1/-4 (61Ni, 18Cr, 11Mo, 2Nb)	-	0.02	0.45	3.25	0.001	0.003			18.3	61.5	10.9	1.9	-	3.2	As Welded	-	725 (105,200)	45	-196 (-321)	74 (55)
	SW-308LT * / **	A5.22 E308LT1-1/-4	ISO 17633-A T 19 9 L P M21/C1 2	0.02	0.67	1.53	0.015	0.010			18.3	9.9	0.05	-	-	-	As Welded	-	573 (83,100)	48	-196 (-321)	36 (25)
	SW-316LT * / **	A5.22 E316LT1-1/-4	-	0.02	0.77	1.52	0.015	0.009			17.3	12.4	2.4	-	-	-	As Welded	-	542 (78,600)	46	-196 (-321)	33 (24)
	Supercored 81-K2 **	A5.29 E81T1-K2C H4	ISO 17632-A T 46 6 1.5Ni P C1 1 H5	0.04	0.35	1.35	0.012	0.011			-	1.5	-	-	-	-	As Welded	540 (78,300)	620 (90,000)	28	-60 (-75)	60 (44)
SAW	S-Ni2 / SA-08	A5.14 ERNiMO-8	ISO 18274 S Ni2 1008	0.03	0.34	0.32	0.010	0.010			2.1	68.8	17.1	-	2.3	8.3	As Welded	505 (73,300)	729 (105,800)	38	-196 (-321)	70 (52)

Process	Product Name	AWS	EN ISO	Typical Chemical					Composition of All-Weld Metal(%)					Typical Mechanical Properties of All-Weld Metal		
				Al	Si	Fe	Cu		Mn	Mg	Cr	Zn	Ti	YS MPa(lbs/in²)	TS MPa(lbs/in²)	EL (%)
GMAW	SMT-5183S	AWS A5.10 ER 5183	ISO 18273 S Al 5183 / AlMg4,5Mn0,7(A)	Remainder	0.4	0.4	0.1		0.5 - 1.0	4.3 - 5.2	0.05-0. 25	0.25	0.15	130 (18,800)	275 (39,900)	18
GTAW	SMT-5183S															

APPROVALS

Process	Product Name	AWS	EN ISO	CWB	TÜV	DB	CE	KR			ABS	LR	BV	DNV	NK	RS	RINA	CCS	CRS
SMAW	SR -134	A5.11 ENiCrFe-4	-	-	-	-	-	-			-	-	-	VL9Ni H5	-	-	-	-	-
	SR-08	A5.11 ENiMo-8	-	-	-	-	-	-			-	-	-	-	-	-	-	-	-
	S-308LT.16	A5.4 E308L-16	ISO 3581-A E 19 9 L R	-	-	-	-	-			E308L-16 (-196°C)	-	-	-	-	-	-	-	-
	S-316LT.16	A5.4 E316L-16	-	-	-	-	-	-			E316L-16 (-196°C)	-	-	-	-	-	-	-	-
	S-7018.1H	A5.1 E7018-1 H4R	ISO 2560-A E 42 4 B 3 2 H5	✓	-	-	✓	-			4Y H5	4Y H5	4Y HHH	4Y H5	-	-	-	-	-
FCAW	SW-82H	A5.34 ENiGT1-1/-4 (61Ni, 18Cr, 11Mo, 2Nb)	-	-	-	-	-	L91S(C)			Manufacturer's Spec. (-196°C)	9NiS	N90	NV9Ni	KSWL92G(C)	Manufacturer's Spec. (-196°C)	-	-	-
	SW-308LT	A5.22 E308LT1-1/-4	ISO 17633-A T 19 9 L P M21/C1 2	-	-	-	-	-			E308LT1-1/4 (-196°C ≥27 J)	-	-	-	-	-	-	-	-
	SW-316LT	A5.22 E316LT1-1/-4	-	-	-	-	-	-			E316LT1-1/4 (-196°C ≥27 J)	-	-	-	-	-	-	-	-
	Supercored 81-K2	A5.29 E81T1-K2C H4	ISO 17632-A T 46 6 1.5Ni P C1 1 H5	✓	-	-	✓	5Y40SG© H5 L3SG(C)			5Y400SA H5	5Y40S H5	SA5Y40M HHH	VY40MS H5 NV2-4L, 4-4L	KSW54Y40G(C) H5 KSWL3G(C)H5	5Y40SM H5	5YS H10	5Y40S H5	-
SAW	S-Ni2 / SA-08	A5.14 ERNiMO-8	-	-	-	-	-	-			Manufacturer's Spec. (-196°C)	9NiM	AN90M	VL1.5Ni up to VL9Ni	-	Manufacturer's Spec. (-196°C)	-	-	-
ALU	SMT-5183S (GMAW)	AWS A5.10 ER 5183	ISO 18273 S Al 5183 / AlMg4,5Mn0,7(A)	-	✓	✓	✓	-			-	-	-	5183	-	-	-	-	-
	SMT-5183S (GTAW)			-	✓	✓	✓	-			-	-	-	5183	-	-	-	-	-

*** With M21 Shielding Gas** **** With C1 Shielding Gas** *** / ** Can be used with M21 and C1 Shielding Gas**

PROPERTIES AND USAGE OF 9%-NICKEL STEEL

There are two types of land-based LNG tanks: aboveground and underground. Aboveground or full containment LNG tanks use 9%Ni-steel for storage of LNG at liquefaction temperature as shown in below figure for gases vs used material for their storage tanks, whereas underground tanks are made of AISI304 and/or 316L austenitic stainless steel. HYUNDAI WELDING supplies dedicated welding consumables for both types, but in this brochure we discuss the aboveground LNG tank, which is the mainly applied type.

Gas	Liquefaction Temperature(°C)	Used Material for Storage Tank
Ammonia:	-33.4	Al-killed steel
ProPane(LPG):	-42.1	
		2.5% Ni steel
Carbon dioxide:	-78.5	3.5% Ni steel
Acetylcne:	-84.0	
Ethane:	-88.0	
Methane(LNG):	-161.5	**9% Ni steel**
Oxygen:	-182.9	
Argon:	-185.9	
Nitrogen:	-196.0	
		Aluminum alloy Austenitic stainless steel 36% Ni steel
Hydrogen:	-252.8	
Helium:	-268.9	

9% Ni-steel is commonly applied for the inner tank, because it offers a combination of strength, ductility and resistance to cracking at cryogenic temperatures and combines this with good formability and weldability. It is normally supplied in the double normalised and tempered condition (NNT) or the quenched and tempered condition (QT). During tempering, a small amount of austenite is formed in a low-carbon martensitic matrix. This austenite is stable at sub-zero temperatures and contributes to the good toughness properties. In addition, there are developments using steel with a lower nickel content (5-6%) to reduce material costs.

Standard		Max. plate thick. (mm)	Heat treatment	C (%)	Si (%)	Mn (%)	P (%)	S (%)	Ni (%)	0.2%PS (Mpa)	TS MPa	El(%), l. Thick. (mm)	IV(J) at 190 ℃	LE*3 (mm) at -190℃
ASTM	A353	50	NNT	≤0.13	0.15 0.40	≤0.90	≤0.035	≤0.035	8.50-9.50	≥515	690-825	≥20.0	≥34	≥0.38
	A553 Type I	50	QT							≥585				

9%Ni-steels applied in LNG fabrication are mainly according A353 and A553 Type 1. The QT type has a higher proof stress and is therefore most used, especially when tank volumes require a high wall thickness.

WELDABILITY OF 9%-NICKEL STEEL

The weldability of 9%Ni-steel is excellent. It requires no preheating and generally no post weld heat treatment, while the increase of hardness in the heat affected zone of the weld stays within safe limits. Welding consumables are nickel-base, such as the Inconel type (Ni-Cr) or Hastelloy type (Ni-Mo). Their austenitic weld metal is not sensitive to brittle fracture at cryogenic temperature and it has a great capacity to absorb welding stresses. Hastelloy types have better hot cracking resistance; a feature related to fully austenitic weld metals and to be avoided in welding 9% Ni-steel. Ni-base welding consumables for SMAW, FCAW, GMAW, GTAW and SAW are classified in standards such as AWS A5.11, A5.14 and A5.34.

SMAW is generally used for welding “out of position”, because of its simplicity and flexible use. The SAW process is used for welding the bottom of tanks in 1G position and the vertical shell in 2G position, benefitting from the high economy of automated welding. FCAW offers a productive solution for the joints in 3G position on the vertical shell, using specially designed flux-cored wires and mechanised processes.

Welding recommendations

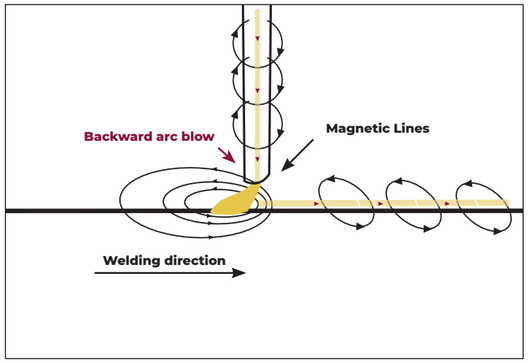
- Although not required for 9% Ni-steel, limited preheating up to 50°C is recommended to remove moisture from the welding zone.
- The interpass temperature must be kept below 150°C and the heat input should be maintained below 2 kJ/mm.
- To prevent hot cracking of fully austenitic weld metal, excessive weaving and dwelling is to be avoided and crater ends should be ground out. Fat, grease, paint and other contaminants must be removed from the joint, prior to welding.

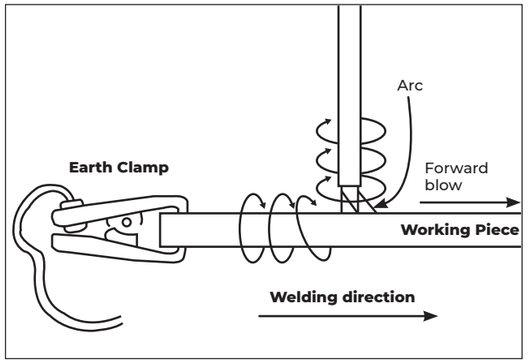
9% Ni-steel is easily magnetised, causing arc blow while welding. A number of precautions can be taken to avoid arc blow and resulting poor welding results:

- Make sure the material is purchased in de-magnetised condition.
- Avoid exposure of the material in the neighbourhood of high voltage cables
- Do not use magnetic clamps for lifting
- In case of doubt, measure and de-magnetise the welding zone with special equipment available for this purpose.
- Use AC welding processes and AC welding consumables

Practical measures to counteract arc blow are:

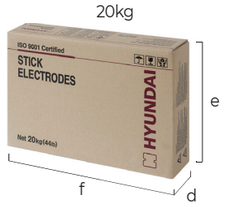
- Place more than one earth clamp
- Reduce the welding current and use a shorter arc length.
- Make a heavy tack on both ends of the seam and several tack welds throughout the seam.
- Weld towards a tack or a weld that is already made
- Weld away from the earth clamp to reduce backwards directed arc blow
- Weld towards the earth clamp to reduce forward directed arc blow





PACKAGING SPECIFICATIONS

SMAW Electrodes

Type	Packet	Carton
STANDARD	5kg 	20kg 
	5kg 	
ALUMINUM VACUUM PACK	1.5kg 	15kg 

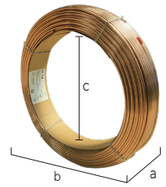
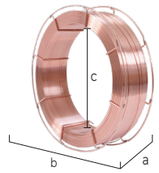
Carton Size mm (in)	
d	82 (3.2)
e	180-275 (7.1-10.8)
f	312-562 (12.3-22.1)

Carton Size mm (in)	
d	96 (3.8)
e	260 (10.2)
f	470-570 (18.5-22.4)

Type	Packet	Carton
PVC BOX (HEXAGONAL)	2.5kg (5.5lbs) 	10-20kg (22-44lbs) 
TIN CAN	4.5kg (9.9lbs) 	
PVC BOX (SQUARE)	5kg (11lbs) 	

Carton Size mm (in)			
Packet	PVC 2.5kg (5.5lbs)	Can 4.5kg (9.9lbs)	PVC 5kg (11lbs)
Carton	10kg (22lbs)	18kg (39.7lbs)	20kg (44.1lbs)
d	80 (3.1)	85 (3.3)	80-85 (3.1-3.3)
e	310-330 (12.2-13)	317 (12.5)	310-345 (12.2-13.6)
f	360-405 (14.2-16)	383-433 (15.1-17)	325-375 (12.8-14.8)

Subarc Wire

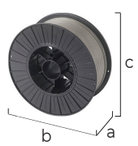
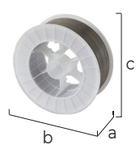
Type	Wire	Size mm (in)			
		Wire	a	b	c
Coil Type		25kg (55lbs)	75/100 (3.0/3.9)	410/420 (16.1/16.5)	305/315 (12.0/12.4)
		30kg (66lbs)	95 (3.7)	400 (15.7)	305 (12.0)
		100kg (220lbs)	90/100 (3.5/3.9)	760 (29.9)	630 (24.8)
		150kg (330lbs)	90 (3.5)	790 (31.1)	630 (24.8)
Basket Spool		25kg (55lbs)	103 (4.1)	413-419 (16.3-16.5)	297-303 (11.7-11.9)

* Other coil sizes available upon request

Subarc Flux

Packaging		
TIN CAN	PE BAG	PAPER BAG
		
15kg, 20kg (33lbs, 44lbs)	20kg, 25kg (44lbs, 55lbs)	20kg, 25kg (44lbs, 55lbs)

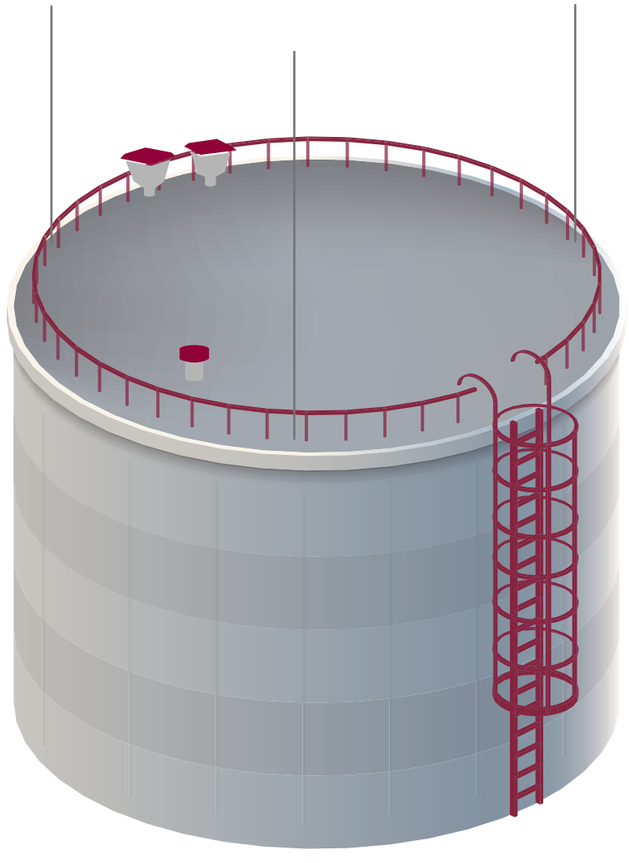
Flux Cored Wires

Type	Spool	
Spool Type	Plastic Spool	12.5kg (27.6lbs) / 15kg (33lbs)
		

Spool Size mm(in)	
a	110 (4.3)
b	270-280 (10.6-11.0)
c	270-280 (10.6-11.0)

REFERENCES

HD	HYUNDAI HEAVY INDUSTRIES HYUNDAI SAMHO HEAVY INDUSTRIES HYUNDAI MIPO DOCKYARD
HYUNDAI ENGINEERING & CONSTRUCTION	HYUNDAI ENGINEERING & CONSTRUCTION
SAMSUNG C&T	SAMSUNG C&T



HYUNDAI WELDING is a global manufacturer of welding consumables and equipment. As the top leading manufacturer of welding consumables in Korea, and with a global network of sales, distribution and manufacturing plants, HYUNDAI WELDING has developed into a key player in the international welding industry.

Our company is fully committed to the ever-changing needs of our customers and has evolved in just under 50 years to provide welding expertise and breakthroughs in welding technology. HYUNDAI WELDING understands customer needs and offers customers world-class products and world-class solutions.

HYUNDAI WELDING's LNG welding solutions meet customer requirements for LNG carrier and storage tank fabrication backed with a superior customer service and support. By using high quality consumables and equipment portfolio of HYUNDAI WELDING, our customers experience improved productivity and competitiveness in the market.

HYUNDAI WELDING is a world-class manufacturer that specializes in providing optimum welding solutions to its customers, by supplying top-notch welding consumables and equipment. HYUNDAI WELDING has contributed to the development and success of the global welding industry for almost 50 years since its foundation in 1975.

For more information on HYUNDAI WELDING, please visit www.hyundaiwelding.com

E-book

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