



# WELDING SOLUTIONS FOR THE LNG INDUSTRY



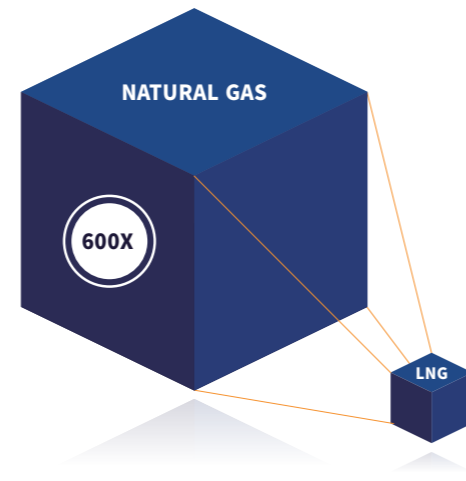
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**HYUNDAI**  
WELDING

## 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                      | Type      | Application  |
|---------|---------------|--------------------------|-----------|--|
| SMAW    | SR-134        | A5.11 ENiCrFe-4          | Inconel   | Inconel SMAW applied to aboveground LNG storage tanks and offshore LNG fuel tanks.                                     |
|         | 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

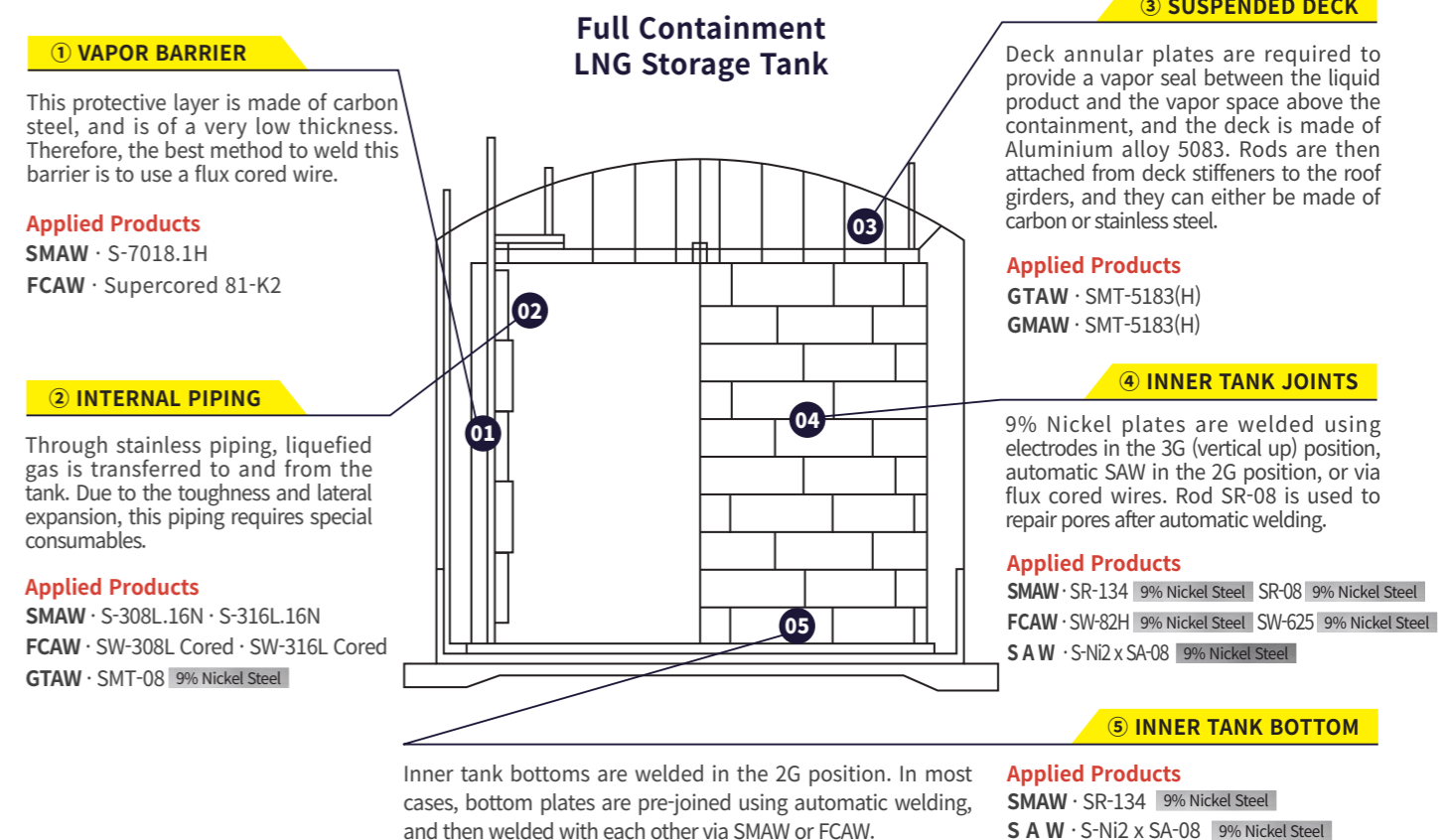
| Application        | Type             | Shape           | Process    | Note   |
|--------------------|------------------|-----------------|------------|--|
| Land (Aboveground) | Storage tank     |                 | SMAW, SAW  | Aboveground full containment storage tanks are fabricated with 9% Ni steel.                      |
| Sea                | LNG Carrier      | Independent     | GMAW, GTAW | A vessel whose tank is independent of the hull and maintains pressure to trap LNG.               |
|                    |                  | Dependent       | GTAW, PAW  | A membrane-type vessel that uses the ship's hull to share pressure and weight of LNG.            |
|                    | LNG-fuelled Ship | Propulsion Ship | 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.



## Welding Consumables for Full Containment LNG Storage Tank

| Process | Product          | AWS                      | Note  |
|---------|------------------|--------------------------|---|
| SMAW    | S-7018.1H        | A5.1 E7018-1 H4R         | Extra low hydrogen  |
|         | S-308L.16N       | A5.4 E308L-16            | Stainless steel (18%Cr-8%Ni)                                  |
|         | 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                            |
| SAW     | SR-08            | A5.11 ENiMo-8            | For 9% Ni steel - Hastelloy                                   |
|         | S-Ni2 x SA-08    | A5.14 ERNiMo-8           | For 9% Ni steel - Hastelloy                                   |
| FCAW    | 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)                                  |
|         | 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 |
| GMAW    | SW-82H           | (ENiCrMo3 Modified Type) | For 9% Ni steel - Inconel modified                            |
|         | SMT-5183(H)      | A5.10 ER5183             | 5% Magnesium, 0.6% Mn aluminum filler metal                   |
| GTAW    | SMT-5183(H)      | A5.10 ER5183             | 5% Magnesium, 0.6% Mn aluminum filler metal                   |
|         | SMT-08           | A5.14 ERNiMo-8           | For 9% Ni steel - Hastelloy                                   |

# Offshore LNG Storage Tank

## Welding Process by LNG Carrier Type

| Item            | Independent  |  |   | Dependent   |
|-----------------|--|--|---|---|
|                 | Type A   | Type B   | Type C  | 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   | ≤ 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        | <ul style="list-style-type: none"> <li>High volume efficiency</li> <li>Complete secondary barrier</li> </ul> | <ul style="list-style-type: none"> <li>High volume efficiency</li> <li>Detail fatigue analysis required</li> </ul> | <ul style="list-style-type: none"> <li>Simple design and construction</li> <li>Low volume efficiency</li> </ul> | <ul style="list-style-type: none"> <li>High volume efficiency</li> <li>Complete heat protection and secondary barrier</li> <li>Unable to repair exterior of tank</li> </ul> |

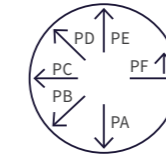
## Application References of Hyundai's Welding Consumables for 9% Ni Steel

| Item             | Independent Fuel Tank   |        |
|------------------|---|--------|
|                  | Type B  | Type C |
| Welding Material | 9% Ni steel (12~25T)  |        |
| Applied Products | FCAW : SW-82H (Main structure welding)<br>GTAW : SMT-08 (Repair and maintenance)<br>SAW : S-Ni2 x SA-08 (Tank bottom) |        |
| Pictures         |   |        |

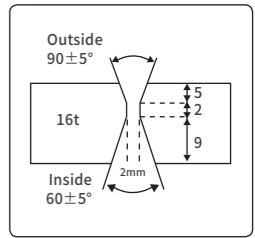
# Test Evaluation Results of Hyundai's Welding Consumables for 9% Ni Steel

## SR-134

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



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



### Test Evaluation Conditions (3G Position) of SR-134

|               |                   |        |
|---------------|-------------------|--------|
| Base metal    | A553-Type 1 16t   |        |
| Product       | SR-134            |        |
| Weld specimen | 16mm*300mm*1000mm |        |
| Groove type   | X-Groove          |        |
| Groove angle  | Inside            | 60°±5° |
|               | Outside           | 90°±5° |
| Root          | Face              | 2mm    |
|               | Gap               | 2mm    |

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

### Weldability Evaluation (3G Position) of SR-134



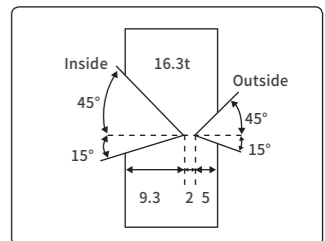
Inside(115A~130A/28~30V)

Outside(130A/29~31V)

## 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)

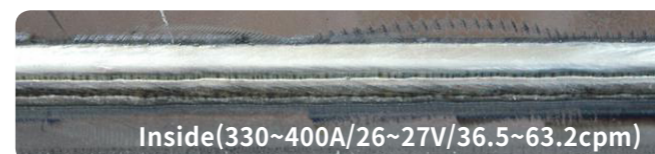
| 9% Nickel Steel |              |
|-----------------|--------------|
| Diameter        | Basket spool |
| mm(in)          | 25kg (55lbs) |
| 2.0 (5/64)      | V            |
| 2.4 (3/32)      | V            |
| 3.2 (1/8)       | V            |



### 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            |        |
| Groove angle  | Inside              | 60°±5° |
|               | Outside             | 60°±5° |
| Root          | Face                | 2mm    |
|               | Gap                 | 0mm    |

| Item     | Welding conditions |             |                     | Heat input (kJ/cm) | Interpass temp(°C) |
|----------|--------------------|-------------|---------------------|--------------------|--------------------|
|          | Current (A)        | Voltage (V) | Welding speed (cpm) |                    |                    |
| Inside   | 1 330              | 26          | 43.9                | 11.7               | 22                 |
|          | 2 380              | 26          | 52.6                | 11.2               | 71                 |
|          | 3 390              | 27          | 36.5                | 17.3               | 93                 |
|          | 4 400              | 26          | 63.2                | 9.8                | 94                 |
| Grinding |                    |             |                     |                    |                    |
| Outside  | 5 410              | 27          | 36.5                | 18.2               | 29                 |
|          | 6 420              | 28          | 44.4                | 15.9               | 88                 |
|          | 7 430              | 28          | 37.9                | 19                 | 92                 |
|          | 8 420              | 28          | 55.4                | 12.7               | 95                 |



SMW

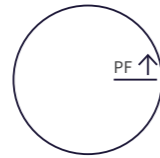
SAW

FCAW

GTAW

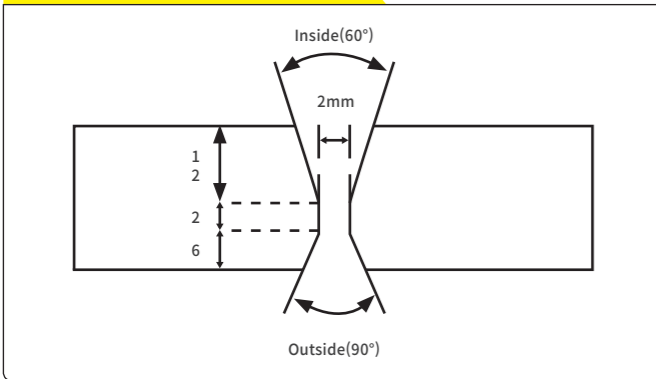
# SW-82H

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

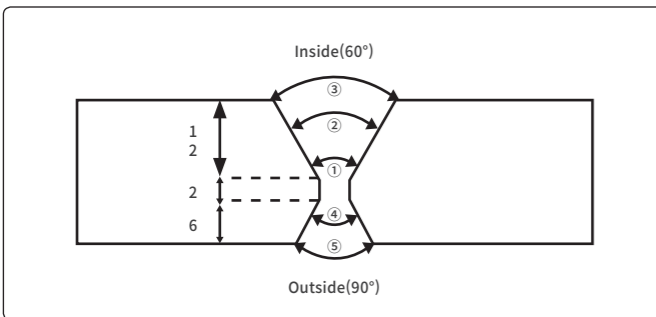


| 9% Nickel Steel |              |                  |
|-----------------|--------------|------------------|
| Diameter        | Spool        |                  |
| mm (in)         | 10kg (22lbs) | 12.5kg (27.6lbs) |
| 1.2 (0.045)     | V            | V                |

### Test Evaluation Conditions



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



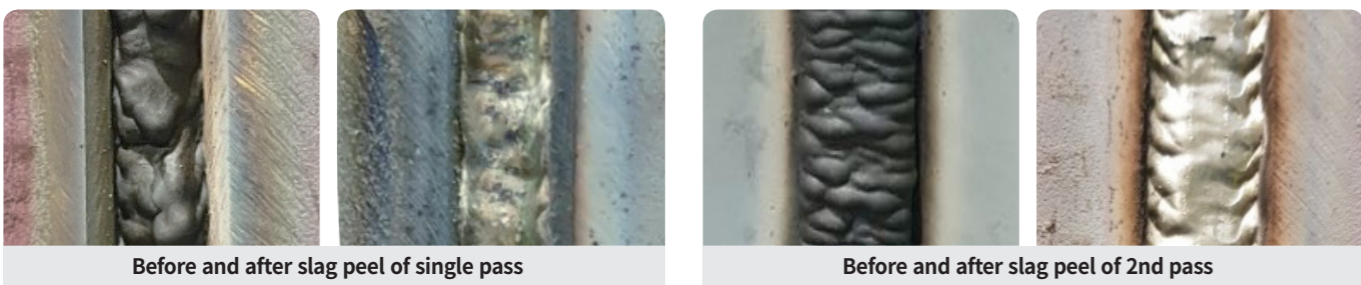
| Pass No. | Current (A) | Voltage (V) | Welding speed (cpm) | Heat input (kJ/cm) | Interpass temp (°C) | Note            |
|----------|-------------|-------------|---------------------|--------------------|---------------------|-----------------|
| 1        | 130         | 25          | 16.9                | 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)

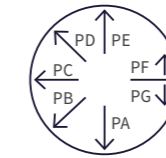


#### ○ Outside(130A~140A/24V~26V)



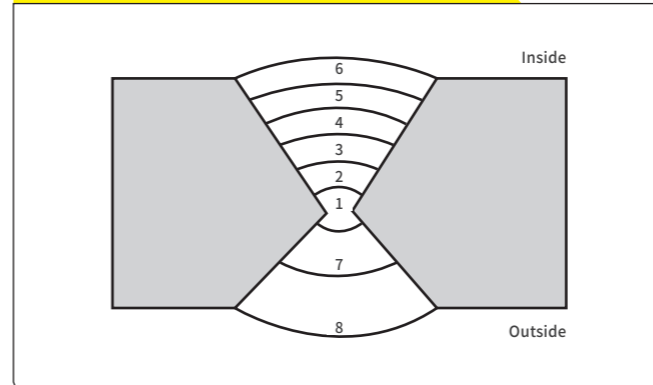
# SMT-08

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)



| Diameter    | 9% Nickel Steel  |             |
|-------------|------------------|-------------|
|             | 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           |

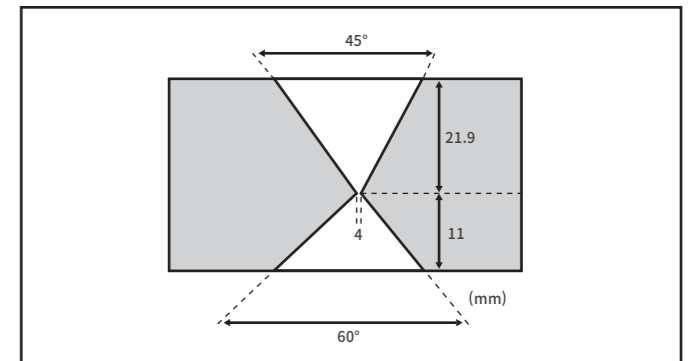
### Test Evaluation Conditions of SMT-08



|                  |   |
|------------------|---|
| 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                                  |

| Product           | Diameter | Welding conditions |             |                       |                     |                       |                     |                    |           |
|-------------------|----------|--------------------|-------------|-----------------------|---------------------|-----------------------|---------------------|--------------------|-----------|
|                   |          | Current (A)        | Voltage (V) | Arcing time (seconds) | Welding speed (cpm) | Shielding gas (l/min) | Interpass temp (°C) | Heat input (kJ/cm) |           |
| SMT-08 (ERNiMo-8) | 1.2      | 1                  | 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



SAW  
 FCW  
 GTAW

# Client References for 9% Ni Steel LNG Tanks



E-book

## 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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