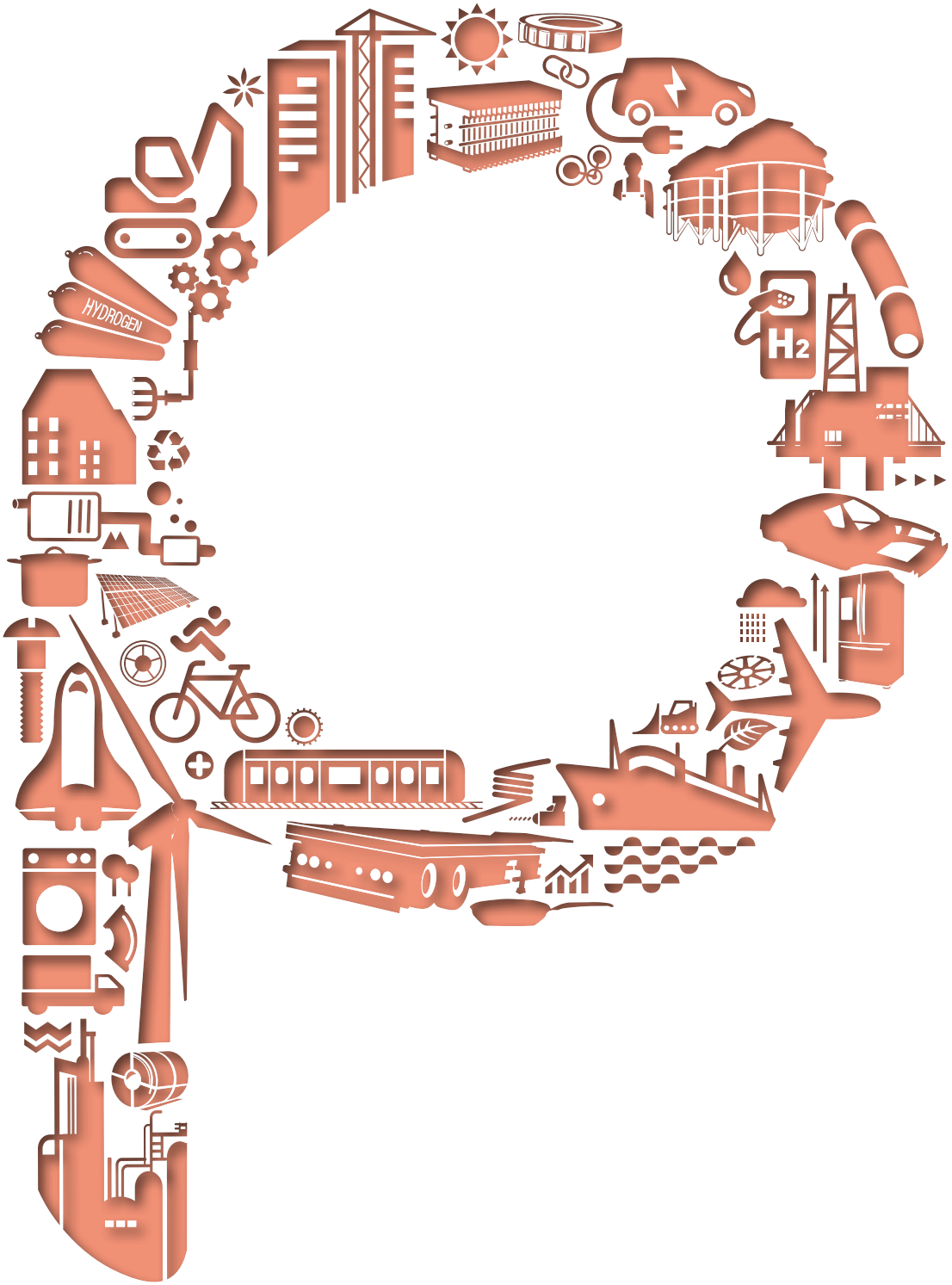


API Steel

posco

POSCO established the API Steel Application Center at Pohang, Korea. Major facility investments and ongoing R&D activities have enabled the company to produce steel for petroleum-related structures that exhibit outstanding performance under extreme conditions.

Contents

API Steel

posco

API Steel Overview

API stands for American Petroleum Institute, and the specifications applied by API steel for petroleum-related structures are globally in common use.

API-X70 means a minimum yield strength of 70 (**70ksi** = a minimum yield strength of 485MPa)

The strength of API steel is the required physical property value after the pipe has been welded and heat treated.

Oilwell pipe : Obtain the required strength through post-production heat treatment

What the Specifications Mean

The number after API is the minimum yield strength value required by the particular specification.

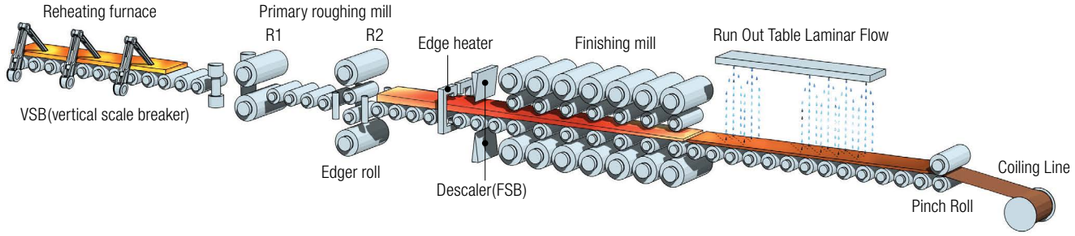
Unit conversion : 1ksi = 6.8947MPa = 0.70307 kgf/mm^2

Major Specifications

Application		Main Specifications	Purpose	Remarks
Pipelines API-5L	General service Sour service Arctic service	B, X42, X46, X52, X56, X60, X65, X70, X80	Transport (crude oil, natural gas) from oilfield through refinery to end-user	
Oilwell pipe casing & tubing API-5CT	General service Sour service High strength	J55, K55, N80, L80, R95, P110, Q125	Transport crude oil or natural gas from deep in the earth to the surface	
Offshore structures API-2W, API-2H		• TMCP: 2W-42, 50, 50T, 60 • Normalized: 2H-42, 50	Steel for resource recovery facilities in or above the sea	

Production Processes

Hot-rolling



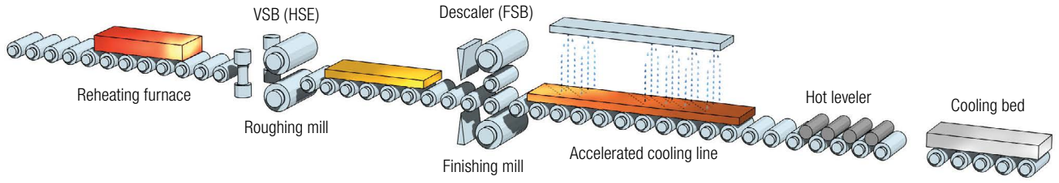
Reheating Furnace
Slabs transferred from the continuous casting mills are uniformly reheated to the ideal temperature for hot rolling.

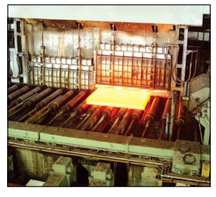
Roughing Mill
The vertical scale breaker and high-pressure descaler are used to remove scales from the slab surface. The slabs are also shaped to the proper thickness, width and shape for rolling in the finishing mill.

Finishing Mill
The strip is rolled to the dimensions required by the specific customer applications. The pair-cross mill and online roll grinder control the shape and crown of the strip, improving quality and productivity.

Cooling and Coiling
The strip is cooled to the aimed temperature. The cooling speed and cooling water spray pattern are adjusted to control mechanical properties.

Plate Production





Reheating Furnace
Slabs transferred from the continuous casting mill are reheated uniformly in all directions (width, breadth and depth) to the optimum rolling temperature (1000~1300°C).

Roughing Mill
The vertical scale breaker and high-pressure descaler remove the scales from the slab surface. The slabs are also shaped to the proper thickness, width and shape for rolling in the finishing mill.

Finishing Mill
The steel sheet is rolled to the dimensions required by individual customers.

Accelerated cooling Line
The steel sheet is cooled to the aimed temperature. The cooling speed is controlled to satisfy mechanical requirements by adjusting the flow rate of the cooling water.

Hot Leveler
The flatness of the steel sheet is controlled in the hot leveling process.

Special Features

Quality Features of Hot-rolled API Steel

Division	Main Quality Requirements	Detailed Quality Features
Regular toughness	• Low YR • Higher yield strength than usual specs • Toughness (CVN, DWTT) • Shape quality (telescope, camber)	• Excellent crack propagation resistance • Excellent cold crack resistance • Good formability, shape, external appearance, internal quality
Low-temperature toughness	• Low YR • Higher yield strength than usual specs • Toughness (CVN, DWTT) • Diagonal-oriented yield strength • Shape quality (telescope, camber)	• Excellent crack propagation resistance • Can endure repeated vertical load from ground surface freezing and thawing in cold climate • Good formability, shape, external appearance, internal quality • Comparatively higher yield strength for each grade guaranteed
Sour-resistant	• HIC resistance (CLR≤15% in very high acidity) • SSCC resistance (85% in FPBT and CLT SMYS) • Low YR • Toughness (CVN and DWTT) • Shape quality (telescope, camber)	• Excellent resistance to hydrogen craking and crack propagation • Comparatively higher yield strength for each grade guaranteed • Excellent resistance to cold crack • Good formability, shape, external appearance, internal quality

Note) DWTT (Drop Weight Tear Test), HIC (Hydrogen Induced Crack), SSCC (Sulfide Stress Corrosion Crack), FPBT (Four Point Bending Test)
CLT (Constant Loading Test), CVN (Charpy V-Notch Test)

Quality Features of API Plate

Division	Main Quality Requirements	Detailed Quality Features
Regular toughness	• Low YR • Higher yield strength than usual specs • Toughness (CVN, DWTT) • Flatness	• Excellent crack propagation resistance • Excellent cold crack resistance • Good formability, shape, external appearance, internal quality • Comparatively higher yield strength for each grade guaranteed
Low-temperature toughness	• Low YR • Higher yield strength than usual specs • Toughness (CVN, DWTT) • Longitudinal-oriented yield strength • Uniform elongation • Flatness	• Excellent crack propagation resistance • Can endure repeated vertical load from ground surface freezing and thawing in cold climate; Longitudinal-oriented yield strength and uniform elongation both excellent • Good formability, shape, external appearance, internal quality • Comparatively higher yield strength for each grade guaranteed
Sour-resistant	• HIC resistance (CLR≤15% in very high acidity) • SSCC resistance (85% in FPBT and CLT SMYS) • Low YR • Toughness (CVN and DWTT) • Flatness	• Excellent resistance to hydrogen craking and crack propagation • Comparatively higher yield strength for each grade guaranteed • Excellent resistance to cold cracking • Good formability, shape, external appearance, internal quality

Note) DWTT (Drop Weight Tear Test), HIC (Hydrogen Induced Crack), SSCC (Sulfide Stress Corrosion Crack), FPBT (Four Point Bending Test)
CLT (Constant Loading Test), CVN (Charpy V-Notch Test)

Testing and Evaluation Methods • DWTT

Drop Weight Tear Test (DWTT)

■ Test Features

Test the resistance to brittle fracture propagation with the same specimen thickness as a pipe

■ Test Equipment Specifications

Capacity	· Impact Energy: 10,000J ~ 100,000J · Load Cell: 1,500kN
Temperature Control	· Cooling Media: Gaseous / Liquid Nitrogen · Temperature Range: -196°C ~ 100°C
Specimen Loading	· Weight Capacity Robot: 90Kgf · Specimen Thickness: 6mm ~ 50mm

■ Test Results

API 5L (46th Edition) ;
for PSL2 welded Pipe
- For each test (of a set of two test pieces), the average shear fracture area shall be ≥85%, based upon a test temperature of 0°C (32°F) or, if agreed, a lower test temperature.

Model: DWTT-100 (IMATEK, UK)

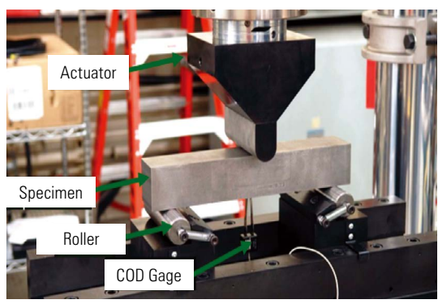
Crack Tip Opening Displacement (CTOD)

■ Test Features

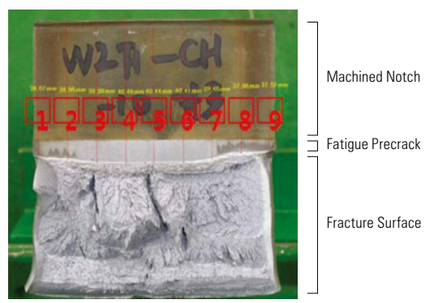
Test measures the resistance of a material to the propagation of a crack. It is used on materials that can show some plastic deformation before failure occurs causing the tip to stretch opening.

■ Quality Assessment Method

ASTM E1290, BS7448



Instrumented CTOD Tester



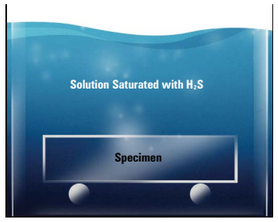
Sour Resistance

■ Sour Resistance (Resistance to HIC and SSCC)

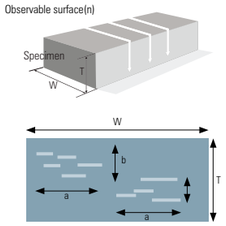
A way to evaluate quality and resistance to hydrogen induced cracking (HIC)

Cracks occur in line pipe steel used in sour gas environment without any applied loading.

Quality Assessment Method: NACE TM 0284



Immersed for 96 hours at 25°C



■ Solution A (strong acid)

5% NaCl + 0.5% CH_3COOH

The pH is 2.7 at first and 4.0 or lower by the end.

■ Solution B (weak acid)

synthetic seawater

The pH is 8.2 at first and 4.8~5.4 by the end.

■ Crack length ratio (CLR) = $\frac{\Sigma a}{W}$ x 100%

■ Crack thickness ratio (CTR) = $\frac{\Sigma b}{T}$ x 100%

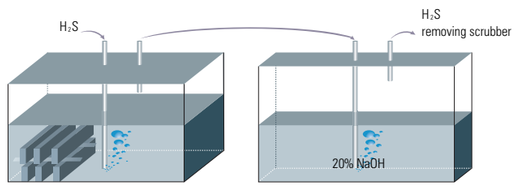
■ Crack sensitivity ratio (CSR) = $\frac{\Sigma(a \times b)}{W \times T}$ x 100%

HIC

Hydrogen Induced Cracking Test System

Test Equipment Specifications

Test Method (Standard)	NACE TM0284 or EFC16
Capability	Vessel : 15liter x 20ea 20 specimens/vessel
Test Solution	H_2S saturated acidic solution
Others	Temperature control : ±1°C



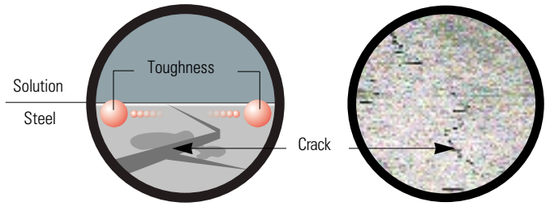
Test Vessel(96hours) H_2S Removal Tank

Sulfide Stress Corrosion Cracking(SSCC)

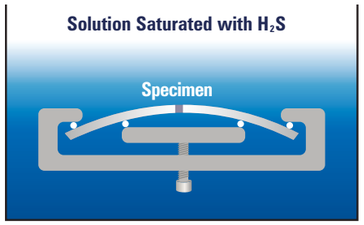
Static load method : proof ring type

■ Quality Assessment Method : NACE TM 0177

Test for 720 hours at 25°C : static load and bending deformation are typical methods.



Sudden fracture when subjected to tensile stress in a corrosive environment that contains H_2S



Immersion for 720hours at 25°C

■ ASTM G39(Four Point Load Test)

Many customers require this method for determining SSCC resistance

■ SSCC Test System

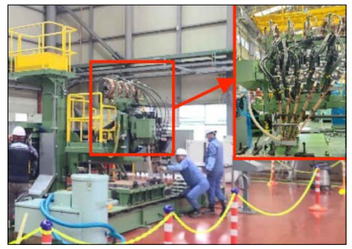
Test Equipment Specifications

Method(Standard)	NACE TM0177 or EFC16
Characteristics	Loading type: dead weight Maximum applied load: 3tons 44 testers
Test Solution	H_2S saturated acidic solution
Others	Temperature control: ±1°C

Welding & Testing Facilities

Welding Facilities

Pipe Seam Welding System	→ Seam Welding for Pipe Manufacturing
Pipe Girth Welding System	→ Girth Welding for Pipeline Construction
Welding Wire Pilot Plant	→ Facility for Manufacturing of Welding Materials
Programable Gas Cutting Machine	→ Precise Plate & Pipe Cutting for Test Specimen



Pipe Seam Welding System

Pipe Girth Welding System

Welding Wire Pilot Plant

Testing Facilities

Charpy Impact Tester	→ Evaluation of Brittle Crack Initiation Resistance
Drop Weight Tear Tester	→ Evaluation of Brittle Crack Propagation Resistance
Large Tensile Test Machine	→ Large Scale Tension or Compression Test
CTOD (Crack Tip Opening Displacement) Tseter	→ Evaluation on fracture resistance of a material containing a crack
Dynamic Tear Tester	→ Evaluation on Fracture Resistance of High Strength Steel
Automatic Macro Etching System	→ Evaluation of Internal Defects of Cast Products
Ultrasonic Test System	→ Non-destructive Detection of Defects and Flaws in Metal
Hydrogen Induced Cracking Test System	→ Evaluation of the Hydrogen Induced Cracking Resistance of Plate/Hot Coil/Pipe
Sulfide Stress Corrosion Cracking Test System	→ Evaluation of the Sulfide Stress Corrosion Cracking Resistance of Plate/Hot Coil/Pipe

Charpy Impact Tester

Large Tensile Test Machine

CTOD Tester

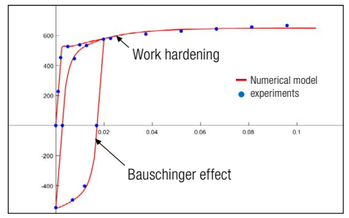
Steel Solutions

Prediction of mechanical properties of linepipe after the pipe forming

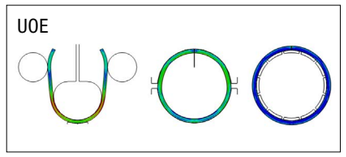
- Needs of predicting the changes in mechanical properties as accurately as possible to meet the specified requirements of linepipes and supply appropriate coils
- Prediction of mechanical properties based on the pipe forming simulation

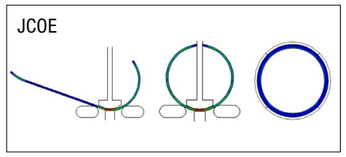
TCT test and numerical material model

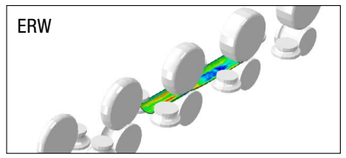
TCT(Tension-compression-tension) tests on the coil or plate



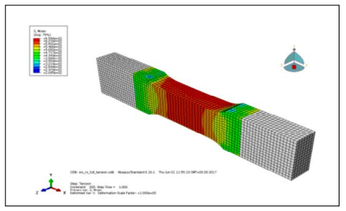
The pipe forming simulation (UOE, JCOE, Spiral, ERW forming)

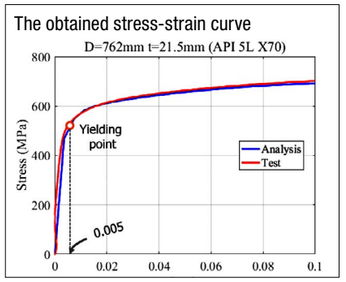






Tensile testing simulation on the specimen

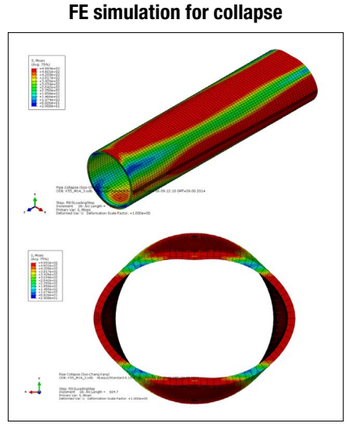




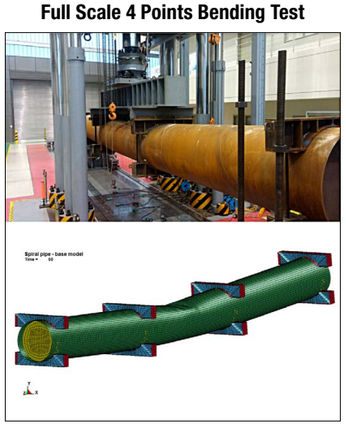
Improvement of structural performance for linepipe and OCTG

- Needs for developing the high performance linepipe & OCTG with the high collapse and bending capacity

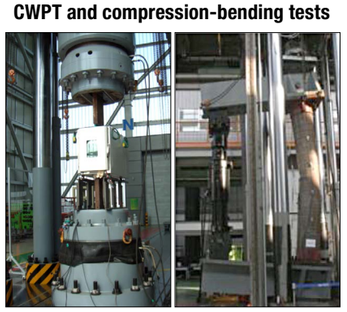
FE simulation for collapse



Full Scale 4 Points Bending Test



CWPT and compression-bending tests



Line Pipe

■ Chemical Composition by Grade

Unit: %

Division	Grade	C Max	Si Max	Mn Max	P Max	S Max	V, Nb, Ti Max	Other
PSL 1	A	0.22	-	0.9	0.03	0.03	-	Cu≤0.5, Ni≤0.5, Cr≤0.5, Mo≤0.15, B≤0.001
	B	0.26		1.2			Nb+V≤0.06,Nb+V+Ti≤0.15	
	X42			1.3			Nb+V+Ti≤0.15	
	X46,X52,X56			1.4				
	X60			1.4				
	X65			1.45				
	X70			1.65				
PSL 2	B	0.22	0.45	1.2	0.025	0.015	Nb≤0.05, V≤0.05, Ti≤0.04	Cu≤0.5,Ni≤0.3,Cr≤0.3, Mo≤0.15,B≤0.001
	X42, X46			1.3				
	X52, X56			1.4			Nb+V+Ti≤0.15	
	X60, X65	0.12	0.45	1.6	0.025	0.015	Nb+V+Ti≤0.15	Cu≤0.5,Ni≤0.5,Cr≤0.5, Mo≤0.5,B≤0.001
	X70			1.7				
	X80	0.12	0.45	1.85	0.025	0.015	Nb+V+Ti≤0.15	Cu≤0.5,Ni≤1,Cr≤0.5,Mo≤0.5,B≤0.001
	X100	0.10	0.55	2.10	0.020	0.010	Nb+V+Ti≤0.15	Cu≤0.5,Ni≤1,Cr≤0.5,Mo≤0.5,B≤0.004

Note) Based on API-5L, 46th edition

■ Strength by Grade

Grade		YS Min		YS Max		TS Min		TS Max	
		psi	MPa	psi	MPa	psi	MPa	psi	MPa
PSL 1	B	35,500	245	-	-	60,200	415	-	-
	X42	42,100	290	-	-	60,200	415	-	-
	X46	46,400	320	-	-	63,100	435	-	-
	X52	52,200	360	-	-	66,700	460	-	-
	X56	56,600	390	-	-	71,100	490	-	-
	X60	60,200	415	-	-	75,400	520	-	-
	X65	65,300	450	-	-	77,600	535	-	-
	X70	70,300	485	-	-	82,700	570	-	-
PSL 2	B	35,500	245	65,300	450	60,200	415	95,000	655
	X42	42,100	290	71,800	495	60,200	415	95,000	655
	X46	46,400	320	76,100	525	63,100	435	95,000	655
	X52	52,200	360	76,900	530	66,700	460	110,200	760
	X56	56,600	390	79,000	545	71,100	490	110,200	760
	X60	60,200	415	81,900	565	75,400	520	110,200	760
	X65	65,300	450	87,000	600	77,600	535	110,200	760
	X70	70,300	485	92,100	635	82,700	570	110,200	760
	X80	80,500	555	102,300	705	90,600	625	119,700	825
	X100	100,100	690	121,800	840	110,200	760	143,600	990

OCTG

■ Chemical Composition & Mechanical Properties

Division	Grade	YS min(MPa)	YS max(MPa)	TS min(MPa)	TS max(MPa)	C max(w%)	Si max(w%)	Mn max(w%)	P max(w%)	S max(w%)
Casing & Tubing Welded pipe	J55	379	552	517	-	-	-	-	-	0.03
	K55	379	552	655	-	-	-	-	-	
	N80	552	758	689	-	-	-	-	0.03	
	L80	552	655	655	-	0.43	0.45	1.9		
	R95	655	758	724	-	0.45	0.45	1.9		
	P110	758	965	862	-	-	-	-	0.02	0.01
	Q125	862	1034	931	-	0.35	-	1.35		

Note) Based on API-5CT(10th edition)

Division	Grade	YS min(MPa)	YS max(MPa)	TS min(MPa)	Hardness max(HRC)	C max(w%)	Si max(w%)	Mn max(w%)	P max(w%)	S max(w%)
Coiled Tubing	CT70	483	552	552	22	0.16	0.5	1.2	0.025	0.005
	CT80	551	620	607	22	0.16	0.5	1.2	0.02	0.005
	CT90	620	689	669	22	0.16	0.5	1.2	0.02	0.005
	CT100	689	-	758	28	0.16	0.5	1.65	0.025	0.005
	CT110	758	-	793	30	0.16	0.5	1.65	0.025	0.005

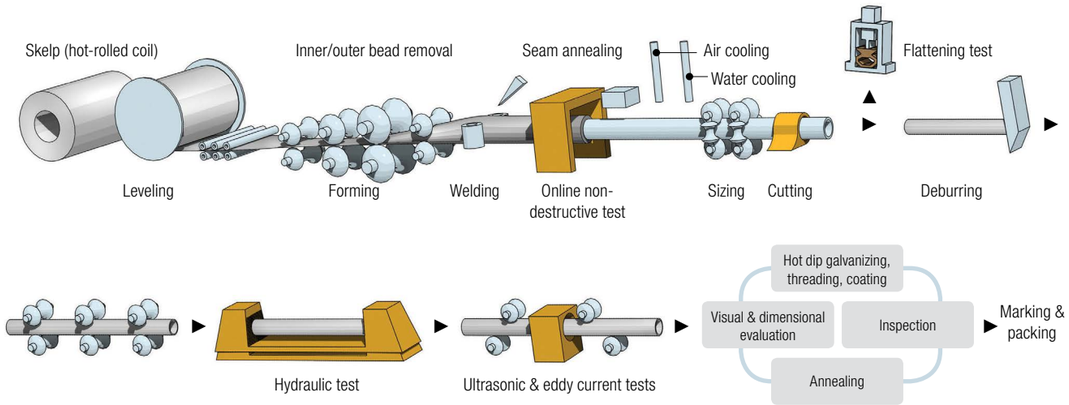
Note) Based on API-5ST(1st edition)

■ Material properties of welded pipes made of POSCO steel

Spec.	Welding type	Yield Strength (MPa)	Tensile Strength (MPa)	CVN on weld at -45°C (J)	RNTS (relative notch tensile strength)	K1H (Fracture toughness) ≥55MPa.√m (ASME B32.12)	K1H Test Pressure / Lab.
***X52 for H_2**	HFW	410	521	186	BM 1.00 WM 1.00	BM 116.5 WM 110.7	100bar / KRISS
X65 for H_2	L.SAW	504~521	606~626			BM 56.8~79.4 HAZ 55.2~79.6 WM 55.1~79.9	200bar / RINA
X70 for CO_2	HFW	489~564	587~631	90~160	-	BM 74.1~81.2 HAZ 79.6~80 WM 74.7~79	100bar / RINA

Note) * X52 : Supplied for 30km H_2 pipelines at Ansan, Ulsan, Pohang city in Korea('21~'23)

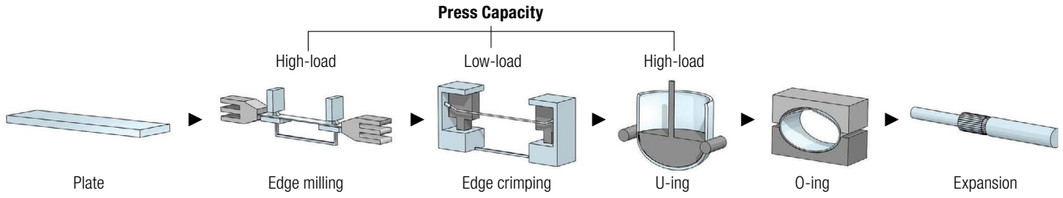
Electric Resistance Welded(ERW) Pipe



Production Features

- Heat is generated at the interface of the parts to be joined by passing an electrical current through electrical resistance.
- Consumables, such as brazing materials, solder, or welding rods are not needed.
- Weldability and dimensional precision are excellent : the method is suitable for sheet and pipe with a diameter of 24” or smaller.
- This process is commonly used in Korea for making API pipe because of low production cost and high productivity.

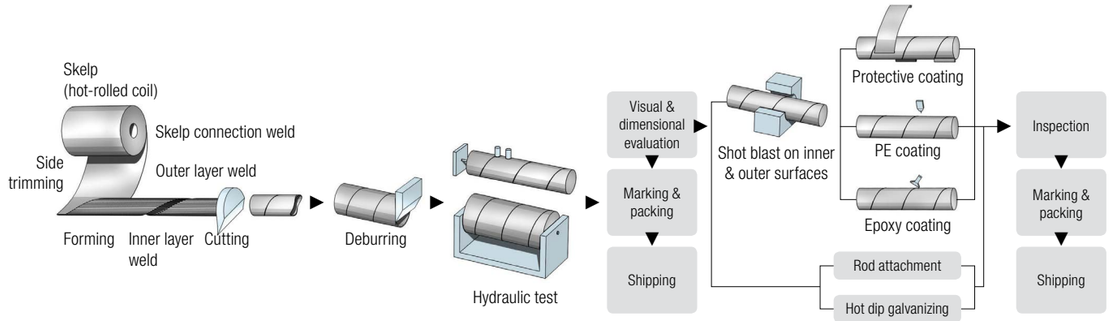
UOE Steel Pipe



Production Features

- After milling the press is used to shape the plate into U’s and O’s. Then the expansion process is performed.
- The initial investment expense is high, but productivity is high as well.
- The expansion process results in deviation from roundness, so the flatness of the initial plate is not an issue.
- This method is usually used for large diameter (e.g. 56” with 23mm thickness) pipe.

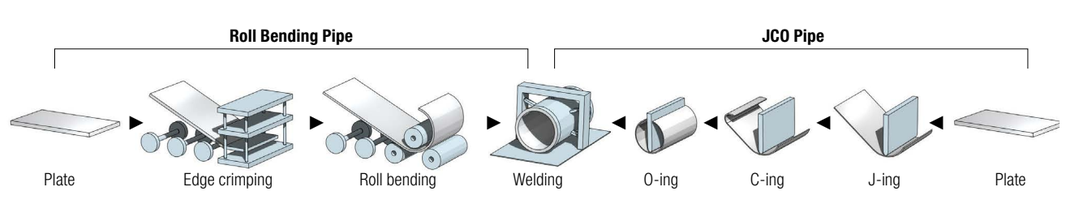
Spiral(Submerged-Arc Welded) Steel Pipe



Production Features

- The seam is a spiral, and an arc generated between the base metal and the seam is used to perform the welding.
- The feed angle depends on strip width and final outside diameter.
- This is the method employed at many overseas (Chinese, Turkish, Pakistani and other) customers for hot-rolled API steel.
- Hot-rolled plate is used to make large-diameter (e.g. 56” with 20mm thickness) pipe.

Roll Bending & JCO Pipe



Production Features

- Roll bending is a time-consuming process for making pipe. Productivity is low, but the facility investment is also relatively low. Diverse sizes can be produced.
- JCO lags behind UOE in terms of productivity, but changing the pipe size is easier when using the JCO method.

Available Size

Currently in production | Planned for production | Under development

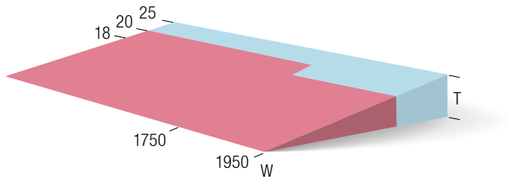
Unit: mm / **T**: Thickness / **W**: Width

Hot Rolled

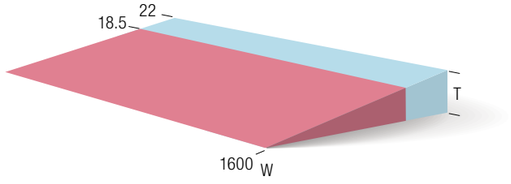
Sweet Service

- Sweet Service : grade guarantee and impact / DWTT -10°C and higher (as coil)
- Toughness conditions : required or not required
- Please inquire separately for API-X80, products scheduled for future production and R&D scope.

■ **API-X70**



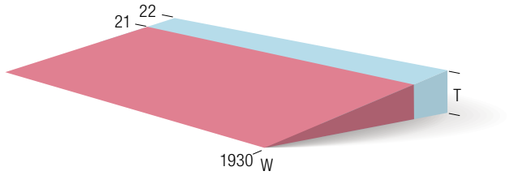
■ **API-X80**



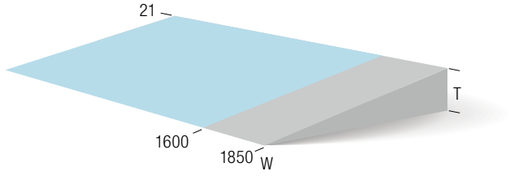
Sour Service

- Solution A: initial ph of 2.6~2.8
- Solution B: initial pH of 8.1-8.3 (HIC) / initial pH of 3.4-3.6 (SSCC)

■ **API-X65**



■ **API-X70**

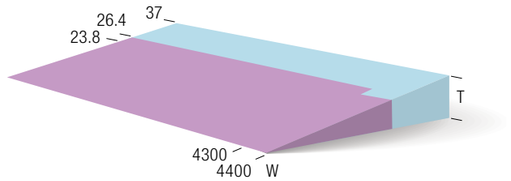


Plate

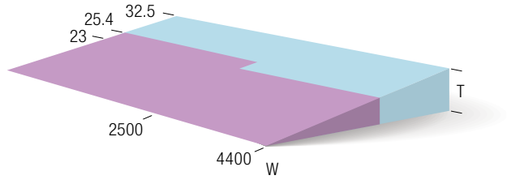
Sweet Service

- Sweet Service : grade guarantee and impact / DWTT -20°C and higher (as plate)
- Toughness conditions: required or not required
- Please inquire separately for API-X80, products scheduled for future production and R&D scope.

■ **API-X70**



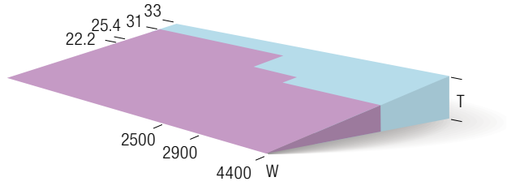
■ **API-X80**



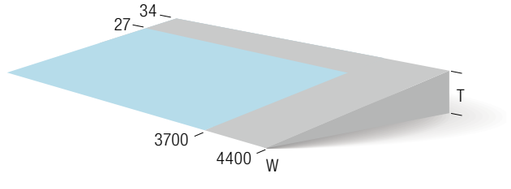
Sour Service

- Sour-resistant API-X70: initial products under development

■ **API-X65**



■ **API-X70**



Packing & Marking

Packing Types

Product	Domestic		Export	
	Code	Types	Code	Types
Coil	DA	Exposed Package	EA	Exposed Package (Regular)
			EA 1	Exposed Package (Extra Bands)

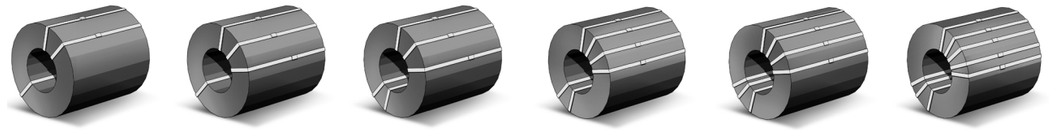
Binding Types

"L" Bindings

This category is commonly used to bind the coil in the longitudinal direction.

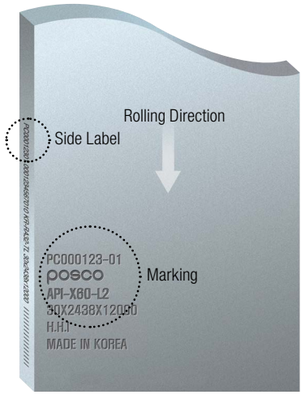
"C" Bindings

This category binds the coil crosswise and is divided into six types (from 3 to 8 strands). Customers are requested to specify the type they want when placing the order.



Type 3 | Type 4 | Type 5 | Type 6 | Type 7 | Type 8

Marking (Plate)



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