

## NIPPON STEEL CORPORATION

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## NIPPON STEEL Stainless Steel Pipe Co., Ltd.

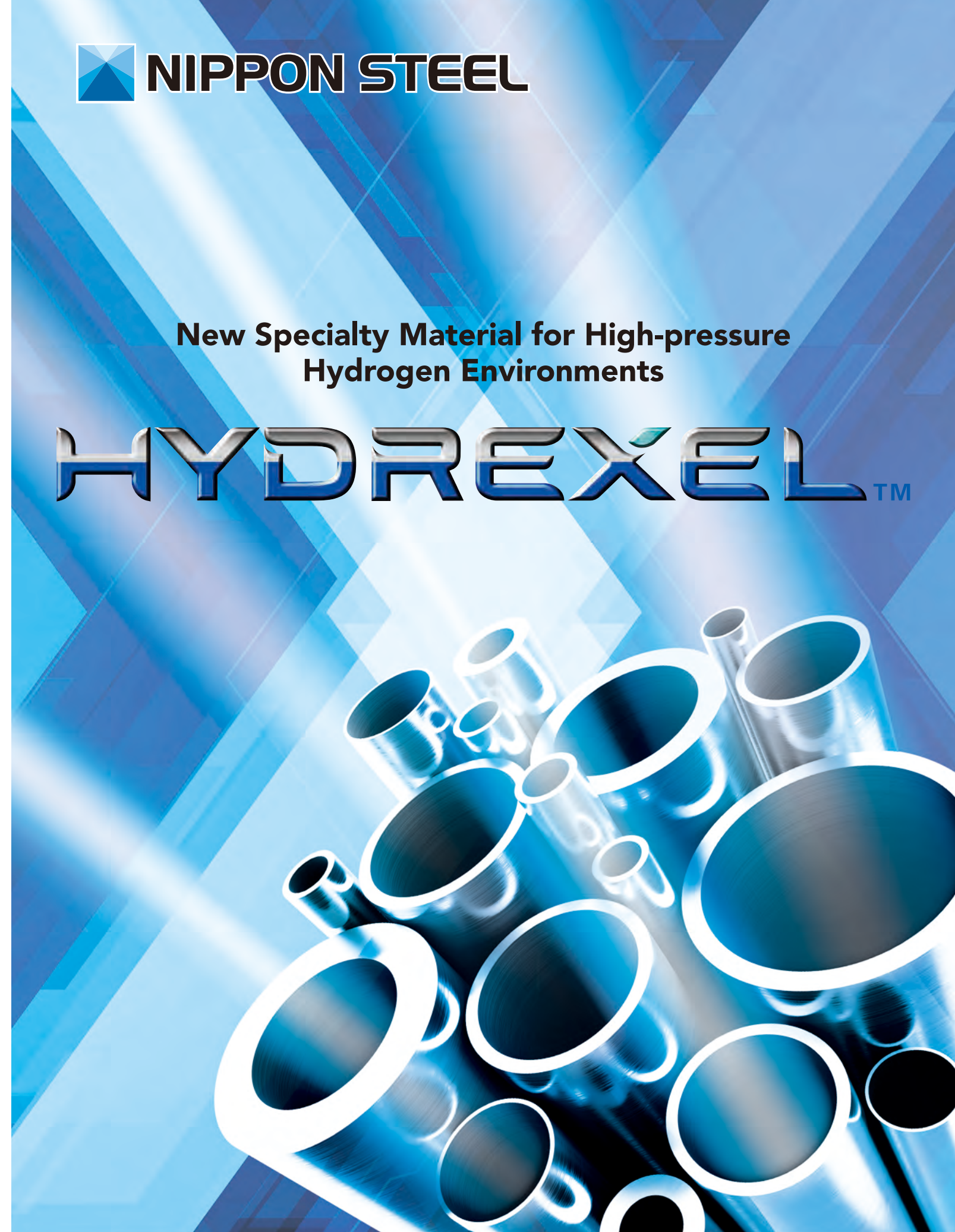
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HYDREXEL™



New Specialty Material for High-pressure  
Hydrogen Environments

# HYDREXEL™



NIPPON STEEL CORPORATION  
NIPPON STEEL Stainless Steel Pipe Co., Ltd.





# HYDREXEL™

Stainless steel for high-pressure hydrogen  
“HYDREXEL™” will make innovation to the  
hydrogen-based society.

To supply energy to fuel cell vehicles (FCV), which use hydrogen as the next-generation clean energy, hydrogen stations are being established in the world.

NIPPON STEEL has developed “HYDREXEL™”, unique stainless steel with excellent hydrogen embrittlement resistance and higher strength for use in high pressure hydrogen environment. Its features of high strength and welding application availability can be applied most of parts and pipes. HYDREXEL™, the most suitable material for high-pressure hydrogen environments, makes hydrogen-based society and contributes to zero emission of CO<sup>2</sup>.

NIPPON STEEL has utilized its advanced technology to produce high-functionality stainless steel in order to supply high-pressure hydrogen to fuel cell vehicles (FCV).

The color logo uses the beautiful colors of stainless steel (silver gray), a sign of hydrogen and confidence (blue) and thought to the environment at the top right of the “X” (turquoise green).

The colored logo gives the feel of solidity, with shading to show light coming from the left top. The “HYD” of Hydrogen, “RE” of Revolution, followed by “X” indicate the potential of the coming hydrogen-based society, and the turquoise green suggests the environmental benefits.



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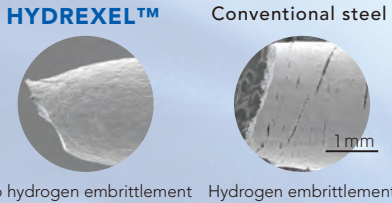
■ HYDREXEL™ uses different brand names for the domestic trademark (HRX19®) and overseas trademark.



### Hydrogen embrittlement resistance

HYDREXEL™ has excellent hydrogen embrittlement resistance even under high pressurized hydrogen gas at lower temperature by optimization of chemical compositions.

- Highest hydrogen embrittlement resistance in austenitic stainless steels
  - Ni equivalent(\*) ≥ 32.0%
  - Long term usage under high pressurized hydrogen gas environment
  - Free from hydrogen gas leakage and safety improvement of equipment
- \*Ni equivalent (%) =  $\text{Ni} + 0.65\text{Cr} + 0.98\text{Mo} + 1.05\text{Mn} + 0.35\text{Si} + 12.6\text{C}$



### High-strength

HYDREXEL™ can achieve about 1.5 times higher strength than Type 316 (L). Application of HYDREXEL™ to substitute for Type 316(L) will contribute to increase flow rate of hydrogen gas and decrease filling duration of hydrogen gas by decreasing wall thickness of pipe and expanding inner diameter of pipe. In addition, it is possible to decrease fabrication cost due to reduce total material weight.

- TS ≥ 800MPa
- About 1.5 times higher strength than Type 316(L)
- Decrease of fabrication cost by weight reduction and filling hydrogen gas with higher flow rate



### Weldability

HYDREXEL™ can prevent the leakage of hydrogen gas from fitting portion by applying welding fabrication even high pressurized hydrogen gas environment.

- Similar strength and hydrogen embrittlement resistance of weld to base material.
- Elimination of mechanical fitting by application of welding fabrication.
- Reduction of fabrication cost and maintenance cost
- safety for leakage of hydrogen gas



### Chemical Composition

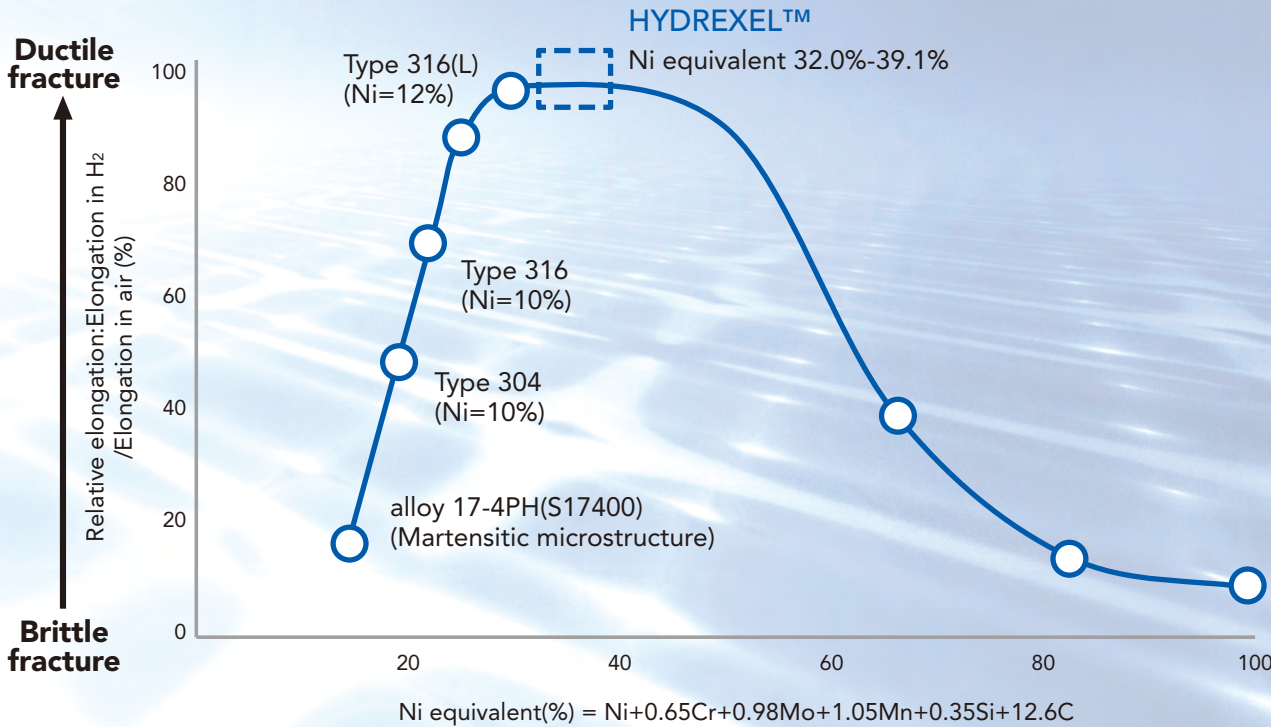
HYDREXEL™ has the optimized chemical composition within the range of XM-19 in ASME/ASTM standards (22%Cr-13%Ni-5%Mn-2%Mo-Nb, V) to improve strength and hydrogen embrittlement resistance.

#### Chemical Composition (mass %)

Component Range	C	Si	Mn	P	S	Ni	Cr	Mo	V	Nb	N
<b>HYDREXEL™</b> (Ni equivalent: 32.0~39.1%)	0.005 -0.060	0.20 -1.00	4.30 -6.00	≤ 0.030	≤ 0.001	12.0 -13.5	21.5 -23.5	1.50 -3.00	0.15 -0.30	0.15 -0.30	0.25 -0.40

### Hydrogen embrittlement resistance

Hydrogen embrittlement resistance is described by Ni equivalent. HYDREXEL™ has excellent hydrogen embrittlement resistance compared with conventional austenitic stainless steels such as Type 316(L) by higher Ni equivalent than 32.09%.







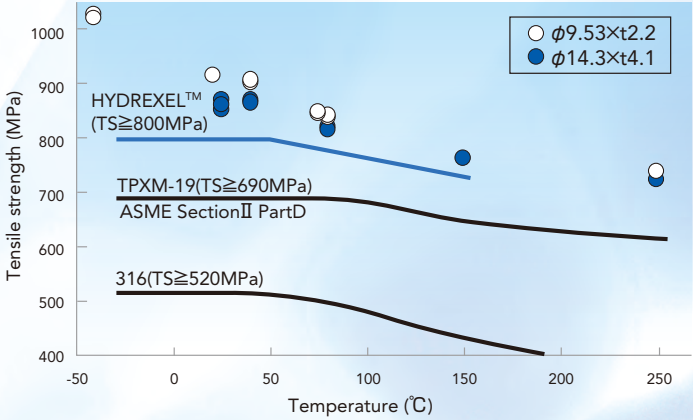
## High-strength

- Faster filling duration of hydrogen gas with higher flow rate
- Reduction of material weight and saving material cost by thinner wall thickness of pipe

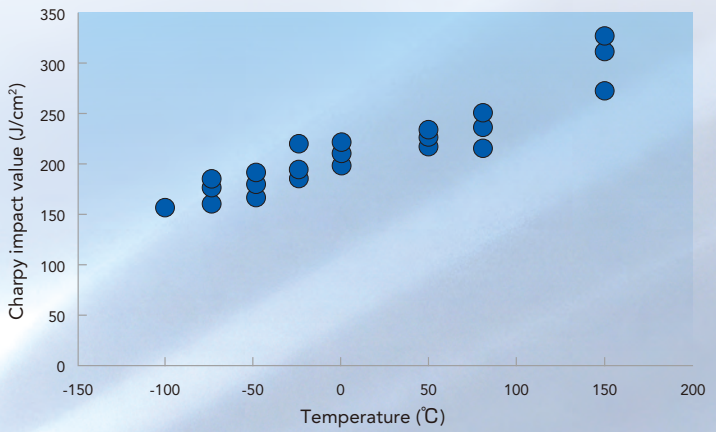
### (1) Comparison of mechanical properties

	Yield strength (MPa)	Tensile strength (MPa)	Elongation (%)	Reduction of area (%)
Pipe	≥430	≥800	≥35	—
Rod(≤φ100)	≥430	≥800	≥35	≥55
Rod(>φ100)	≥380	≥690	≥35	≥55

### (2) Tensile strength (TS)



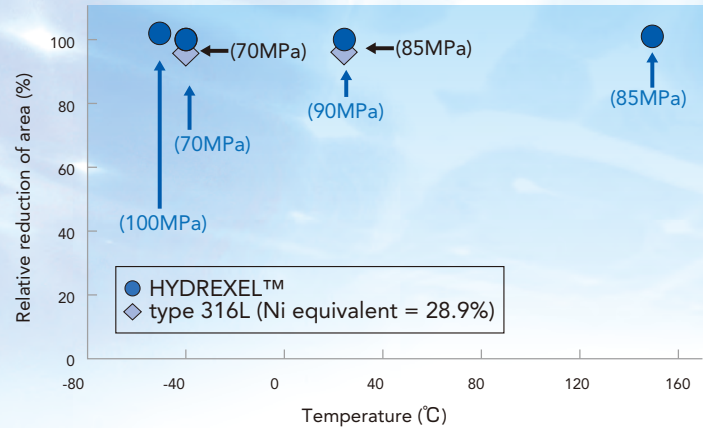
### (3) Toughness



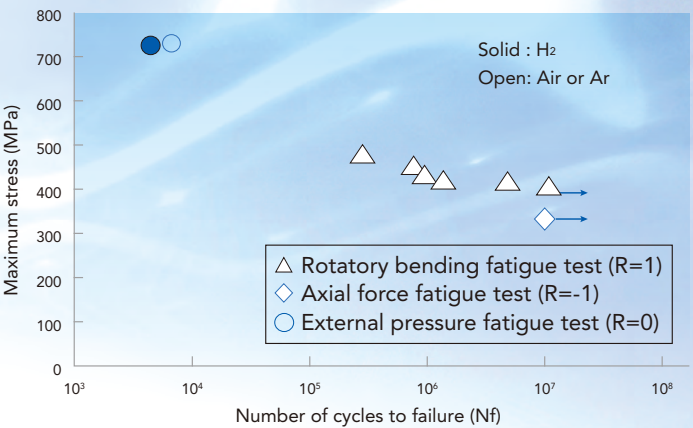
## Hydrogen embrittlement resistance

- Excellent hydrogen embrittlement resistance even under high pressurized hydrogen gas at lower temperature
- Reliability for long term operation

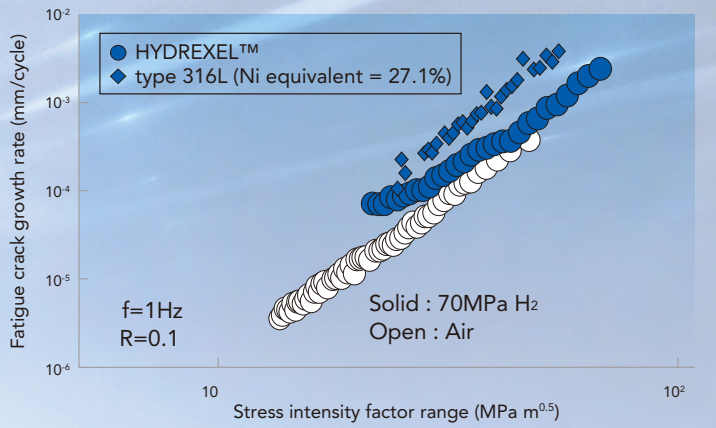
### (1) Susceptibility to hydrogen embrittlement (Slow Strain Rate Test)



### (2) Fatigue strength



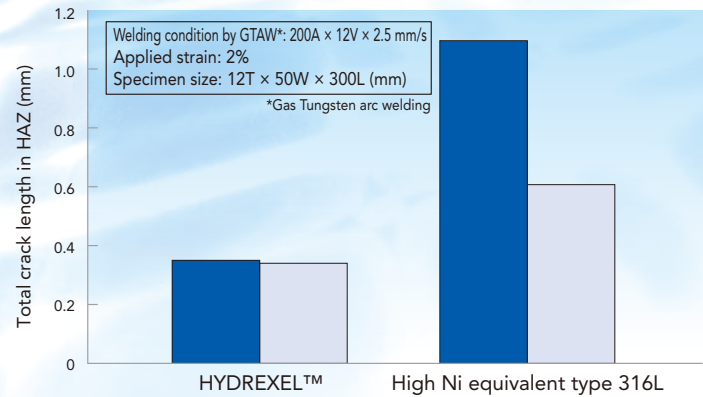
### (3) Fatigue crack growth rate



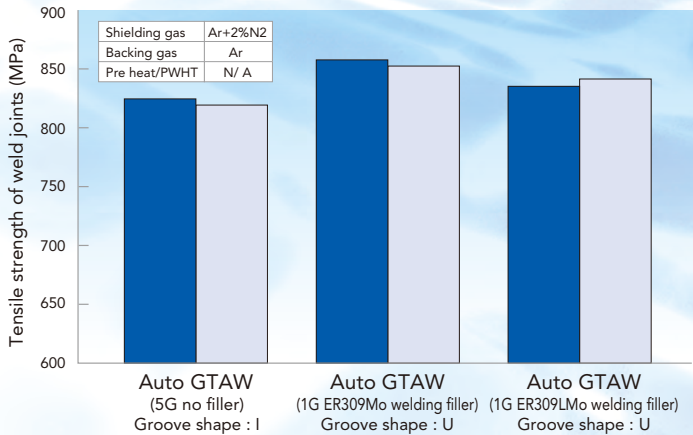
## Weldability

- Dramatic decrease of number of mechanical fittings
- Not required additional wall thickness for machining screw
- Improvement of productivity ⇒ Fabrication cost saving
- Reliability for no leakage of hydrogen gas ⇒ Maintenance cost saving

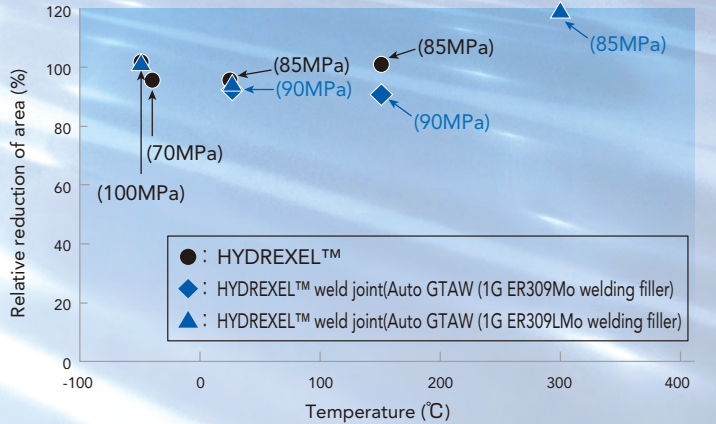
### (1) Resistance to weld cracking (longitudinal vareststraint test)



### (2) Welded joint strength



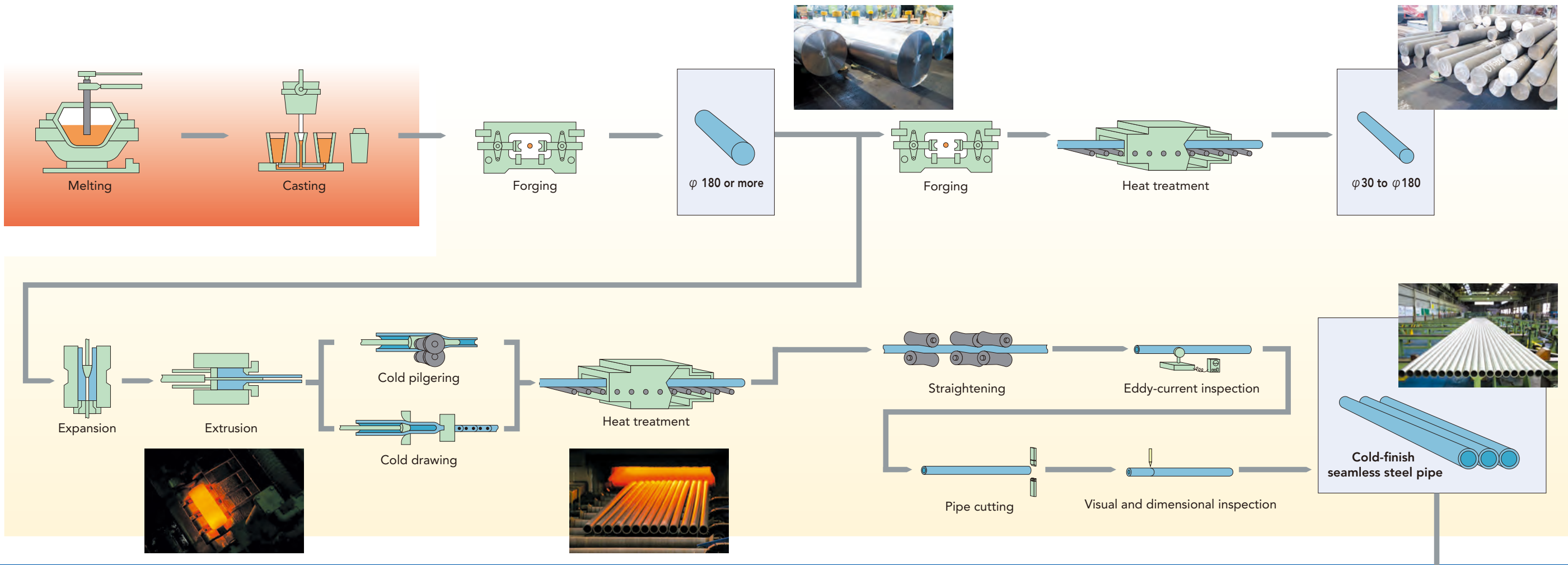
### (3) Susceptibility to hydrogen embrittlement for HYDREXEL™ weldment (Slow Strain Rate Test)



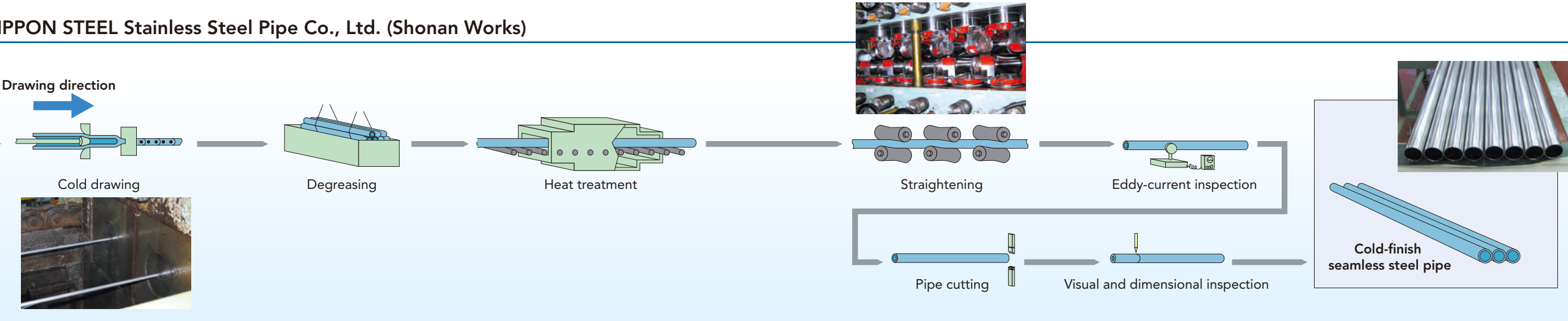


# Manufacturing Process of HYDREXEL™

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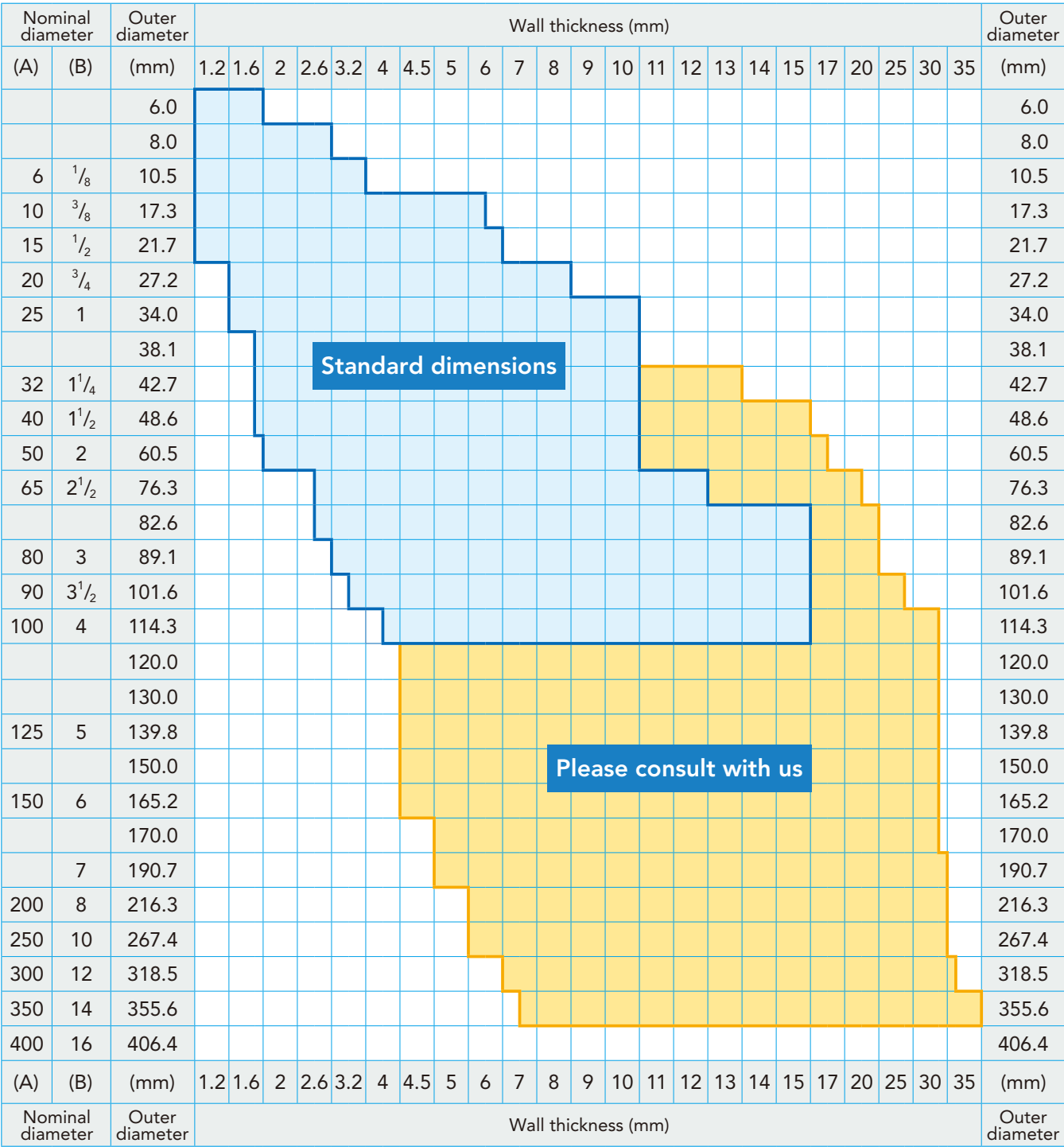
## NIPPON STEEL Stainless Steel Pipe Co., Ltd. (Shonan Works)



# Feasible Manufacturing Range of HYDREXEL™

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### Cold-finished seamless steel pipe



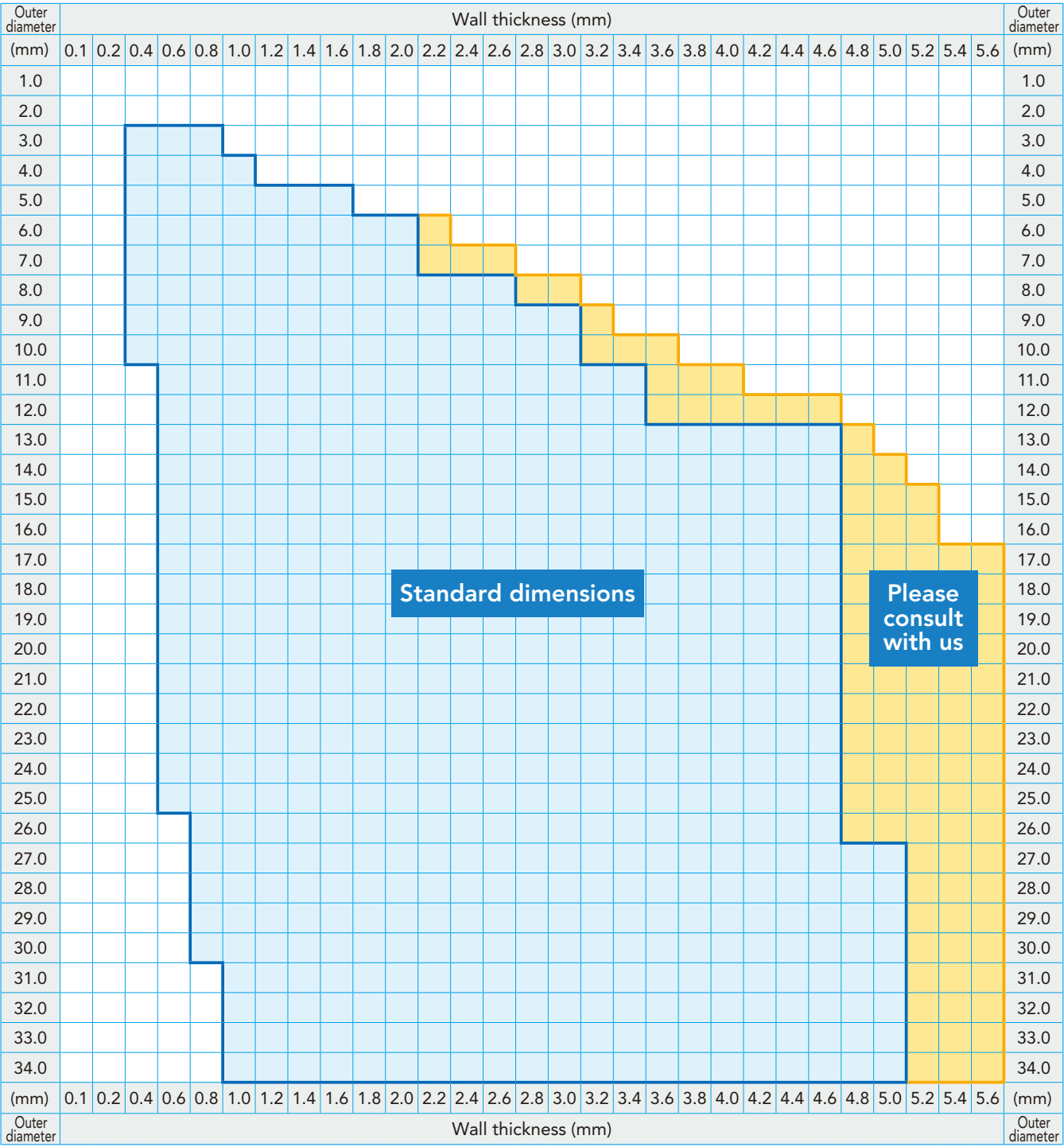
Remarks: Please contact us for details about dimensions not shown on these charts.

### Stainless steel rod

Outer diameter and length: upon request  
\*Results obtained for provision of rods with outer diameter 25 mm to 200 mm.

## NIPPON STEEL Stainless Steel Pipe Co., Ltd.

### Cold-finished seamless steel pipe



Remarks: The strength of steel pipes with an outer diameter of 34 mm or more and round bars with an outer diameter that exceed 100 mm requires separate consultation in accordance with ASME Sec. II-Part D SA-312 TPXM-19 and SA-479 XM-19 (1998).