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.

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

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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 CO₂.
**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 (NI) ≥ 33.2%
- Long term usage under high pressurized hydrogen gas environment
- Free from hydrogen gas leakage and safety improvement of equipment

\[ \text{Ni equivalent} = \text{Ni} + 0.65\text{Cr} + 0.98\text{Mo} + 1.05\text{Mn} + 0.35\text{Si} + 12.6\text{C} \]

**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 %)**

<table>
<thead>
<tr>
<th>Component</th>
<th>C</th>
<th>Si</th>
<th>Mn</th>
<th>P</th>
<th>S</th>
<th>Ni</th>
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<th>Mo</th>
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<th>Nb</th>
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</thead>
<tbody>
<tr>
<td>HYDREXEL™</td>
<td>0.005</td>
<td>0.20</td>
<td>4.30</td>
<td>a</td>
<td>a</td>
<td>12.0</td>
<td>21.5</td>
<td>1.50</td>
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<td>(Ni equivalent: 32.0%~39.1%)</td>
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**New Specialty Material for High-pressure Hydrogen Environments**

**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

**Welding**

- Similar strength and hydrogen embrittlement resistance of weld to base material
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**Hydrogen embrittlement resistance comparison**

- Type 316(L) by higher Ni equivalent than 32.09%.

**New Specialty Material for High-pressure Hydrogen Environments**

**High-strength**

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

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**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

**Hydrogen embrittlement resistance**

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

**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. Comparison of mechanical properties**

<table>
<thead>
<tr>
<th>Material</th>
<th>Yield strength (MPa)</th>
<th>Tensile strength (MPa)</th>
<th>Elongation (%)</th>
<th>Reduction of area (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pipe</td>
<td>≥430</td>
<td>≥800</td>
<td>≥35</td>
<td>0</td>
</tr>
<tr>
<td>Rod (Ø100)</td>
<td>≥430</td>
<td>≥800</td>
<td>≥35</td>
<td>≥55</td>
</tr>
<tr>
<td>Rod (&gt;Ø100)</td>
<td>≥380</td>
<td>≥690</td>
<td>≥35</td>
<td>≥55</td>
</tr>
</tbody>
</table>

**2. Tensile strength (TS)**

- HYDREXEL™ (TS ≥ 800MPa)
- HYDREXEL™ type 316L (Ni equivalent = 27.1%)

**3. Fatigue crack growth rate**

- HYDREXEL™: Fatigue crack growth rate (ΔK = 1.5 MPa m^{0.5})
- Solid: 70MPa H, Open: Air or Ar
- Stiffness: 0-10
- Stress intensity factor range (MPa m^{0.5})

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

- HYDREXEL™ type 316L (Ni equivalent = 28.9%)

---

**1. Susceptibility to hydrogen embrittlement (Slow Strain Rate Test)**

- HYDREXEL™ type 316L (Ni equivalent = 28.9%)

**2. Fatigue strength**

- HYDREXEL™: Fatigue strength (ΔK = 1.5 MPa m^{0.5})
- Solid: 70MPa H, Open: Air or Ar

---

**1. Resistance to weld cracking (longitudinal varestraint test)**

- HYDREXEL™: 0.6 mm
- High Ni equivalent type 316L: 1.2 mm

**2. Welded joint strength**

- HYDREXEL™: Tensile strength (TS) ≥ 800MPa
- HYDREXEL™ type 316L: Tensile strength (TS) ≥ 800MPa

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

- HYDREXEL™: Fatigue crack growth rate (ΔK = 1.5 MPa m^{0.5})
- Solid: 70MPa H, Open: Air or Ar
New Specialty Material for High-pressure Hydrogen Environments

Manufacturing Process of HYDREXEL™

NIPPON STEEL CORPORATION

Melting → Casting → Forging → φ 180 or more → Forging → Heat treatment → φ 30 to φ 180

Expansion → Extrusion → Cold pilgering → Heat treatment → Cold drawing

Eddy-current inspection → Straightening → Visual and dimensional inspection → Pipe cutting

Cold-finish seamless steel pipe

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

Drawing direction

Cold drawing → Degreasing → Heat treatment → Straightening → Eddy-current inspection

Pipe cutting → Visual and dimensional inspection → Cold-finish seamless steel pipe
**Nominal diameter**

<table>
<thead>
<tr>
<th>Outer diameter</th>
<th>Wall thickness (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Outer diameter</td>
<td>Wall thickness (mm)</td>
</tr>
<tr>
<td>6</td>
<td>1.0</td>
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<tr>
<td>10</td>
<td>1.0</td>
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<td>15</td>
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<tr>
<td>400</td>
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</tr>
</tbody>
</table>

**Remarks:**

- Please consult us for details about dimensions not shown on these charts.
- 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).

**Stainless steel rod**

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