NSS 445M2
Ferritic Marine Grade
Stainless Steel

Available exclusively from Wakefield Metals

Quality System
Quality
Endorsed
Company
ISO 9001 Lic QEC 3491
SAI Global

This report compares the technical performance of Nisshin Steel Co Ltd Ferritic Marine Grade Stainless Steel NSS 445M2 to the common grades of austenitic stainless steel, 304 and 316, and to the ferritic grade 444.

		Page
1. FEATURES	NSS 445M2 is a ferritic stainless steel with corrosion resistance superior to grade 316. It has been developed for roofing and façades of buildings, and for hot water applications, and is used wherever high resistance to corrosion and staining is needed.	**3**
2. CHEMICAL COMPOSITION	NSS 445M2 contains 22% chromium and 1.2% molybdenum. Both elements contribute to the outstanding corrosion resistance. NSS 445M2 does not contain a nickel addition, which is present in austenitic grades to stabilise the austenite.	**3**
3. MICROSTRUCTURE	NSS 445M2 is supplied in the annealed condition, with a clean, equiaxed microstructure.	**3**
4. PHYSICAL PROPERTIES	As with all ferritic grades, NSS 445M2 is less dense than the austenitic grades, which gives 3.5% more area per unit of weight. It also has lower thermal expansion and higher thermal conductivity, so is less prone to distortion in welding and expansion in the heat of the sun.	**4**
5. MECHANICAL PROPERTIES	The yield strength and hardness of 445M2 are higher than 304 & 316. The tensile strength and elongation are lower.	**5**
6. FORMABILITY	As a ferritic stainless steel, the work hardening coefficient of 445M2 is much lower than the austenitic grades. It can be formed in a similar way to carbon steel, and is often used where the lower springback and easier shearing give better performance in tools and equipment designed for carbon steel.	**5**
7. CORROSION RESISTANCE		
7.1 Pitting Corrosion	Electrochemical tests in chloride solutions show 445M2 clearly resists pitting corrosion better than grade 316.	**6**
7.2 Crevice Corrosion	Electrochemical tests in chloride solution show 445M2 clearly resists crevice corrosion better than 316 in the as-supplied condition. It is far superior after spot welding. The crevice corrosion resistance of an untreated, oxidised TIG weld in 445M2 is equivalent to that of 316.	**7**
7.3 Intergranular Corrosion	Very low carbon content and stabilisation with titanium give 445M2 excellent resistance to intergranular corrosion after sensitising thermal cycles, superior to 316.	**8**
7.4 Stress Corrosion Cracking	In common with all ferritic stainless steels, 445M2 is substantially immune from stress corrosion cracking in chloride containing waters, unlike grade 316.	**8**
7.5 Rust Resistance		
7.5.1 Rooftop	A laboratory test simulating an exposed roof in a marine environment, where frequent rain would wash away salt particles, showed minimal rust staining on 445M2 – much less than 316.	**9**
7.5.2 Eaves	A laboratory test simulating an even more severe marine environment – a sheltered area, where salt particles concentrate, again showed minimal rust staining on 445M2 – much less than 316 which was badly stained.	**11**
7.5.3 Atmospheric exposure tests	In atmospheric exposure tests in a severe marine sub-tropical area 445M2 was almost completely free of rusting (or tea staining) after 2 years exposure. 316 was uniformly tea stained. The tests were done on a Japanese island near Taiwan, at an equivalent latitude to Fraser Island in Queensland.	**12**
7.6 General Corrosion (Acid Resistance)	Sulphuric acid is very aggressive to stainless steels, as it interferes with the formation of the passive surface film. 445M2 has about 1/5 the corrosion rate of 316 in low concentrations of sulphuric acid at elevated temperatures.	**14**
8. WELDABILITY		
8.1 TIG Weldability	The window of successful combinations of TIG welding current and speed is only slightly smaller for 445M2 than for 316, but is substantially larger than for 444.	**15**
8.2 Seam Weldability	The welded tensile strength of resistance seam welded 445M2 is slightly lower than that of 316, because of the lower tensile strength of the grade, but the strength is consistent over a broad range of welding current.	**16**

1. FEATURES

NSS445M2 is a ferritic stainless steel having superior antirust and weld anticorrosion characteristics which has been developed as a material suited for roofing and facing applications and for applications where high resistance to hot water containing chloride is required.

The main constituent of this steel is 22Cr-1.2Mo. By adding Nb, Ti, and Al, the surface film of this steel is reinforced to improve its rust resistance. Further, the loss of Cr through oxidation at the time of welding is suppressed to prevent the weld from degrading in corrosion resistance.

In addition to these features, its thermal expansion coefficient is nearly equal to that of common steel and smaller than that of austenitic stainless steel, so that this steel is also suitable for long-size roofing applications.

2. CHEMICAL COMPOSITION

Table 1. Chemical Composition of NSS 445M2 (mass%)

	C	Si	Mn	Cr	Mo	Nb	Ti	Al
Typical example	0.01	0.18	0.20	22.1	1.20	0.23	0.19	0.09

3. MICRO STRUCTURE

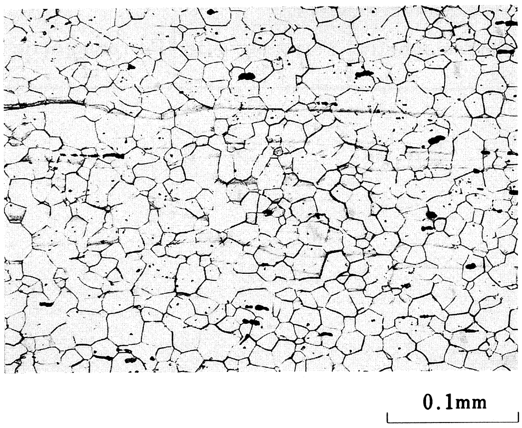


Photo 1. Optical Micro Structure of Cold-Rolled Annealed NSS 445M2

4. PHYSICAL PROPERTIES

Major physical properties of NSS 445M2 are shown in Table 2. NSS 445M2, a ferritic stainless steel, has a smaller thermal expansion coefficient than SUS304 and SUS316 which are of the austenitic kind, so that it is better suited for long-size roofing and other applications where a repetitive cycle of thermal expansion and contraction is unavoidable.

Table 2. Physical Properties of NSS 445M2

Item \ Type of Steel		NSS 445M2	22Cr-0.7Mo-Nb	SUS444	SUS304	SUS316
Density (kg/m^3)		7.75×10^3	7.75×10^3	7.75×10^3	7.93×10^3	7.98×10^3
Young's modulus (N/mm^2) (20°C)		199,000	200,000	200,000	193,000	193,000
Specific heat (J/(kg·°C)) (20°C)		0.46×10^3	0.46×10^3	0.46×10^3	0.50×10^3	0.50×10^3
Thermal expansion coefficient ($°C^{-1}$)	20-100°C	10.0×10^{-6}	10.0×10^{-6}	10.4×10^{-6}	17.3×10^{-6}	16.0×10^{-6}
	20-300°C	10.5×10^{-6}	10.5×10^{-6}	10.9×10^{-6}	18.8×10^{-6}	17.5×10^{-6}
	20-500°C	11.1×10^{-6}	11.1×10^{-6}	11.3×10^{-6}	18.3×10^{-6}	18.0×10^{-6}
Thermal conductivity (W/m·°C)	100°C	22.5	22.5	22.5	14.0	13.9
	500°C	22.6	22.6	22.6	18.4	18.4
Specific electric resistance (μΩ·m) (20°C)		0.60	0.60	0.60	0.72	0.74
Magnetism		Ferromagnetic	Ferromagnetic	Ferromagnetic	Non-magnetic	Non-magnetic

Note: N/mm^2 (newtons per square millimetre) is the same unit as MPa (megapascal), which is normally used in Australia

5. MECHANICAL PROPERTIES

Table 3. Mechanical Properties of NSS 445M2

Type of Steel	Finish	Plate Thickness (mm)	Yield Stress (N/mm^2)	Tensile Strength (N/mm^2)	Elongation (%)	Hardness (HV)	Contact Bending
NSS 445M2	2B	1.0	348	519	30	170	Good
	2D	0.8	343	510	29	166	Good
	2DR	0.4	387	536	27	178	Good
22Cr-0.7Mo-Nb	2B	1.0	353	529	31	162	Good
SUS444	2B	1.0	353	568	29	173	Good
SUS304	2B	1.0	265	657	60	159	Good
	2DR	0.4	–	642	59	164	Good
SUS316	2B	1.0	314	578	55	154	Good
	2DR	0.4	–	602	53	156	Good

6. FORMABILITY

Table 4. Formability of NSS 445M2

Type of Steel	Finish	Plate Thickness (mm)	Work Hardening Coefficient (n Value)	Plastic Deformation (r Value)	CCV (mm)	Erichsen (mm)	Ring Forging Ratio (Punched Hole)
NSS 445M2	2B	1.0	0.18	1.307	47.4	10.0	1.29
22Cr-0.7Mo-Nb	2B	1.0	0.20	1.351	47.1	10.5	1.22
SUS444	2B	1.0	0.21	1.340	46.5	10.2	1.02
SUS304	2B	0.8	0.50	1.033	27.8	13.2	0.51
SUS316	2B	0.8	0.50	1.033	27.5	12.8	0.51

NOTE: The average plastic deformation ratio is calculated from the following formula.

$$\text{Average value } \bar{r} = \frac{(r_0° + 2 \cdot r_{45}° + r_{90}°)}{4}$$

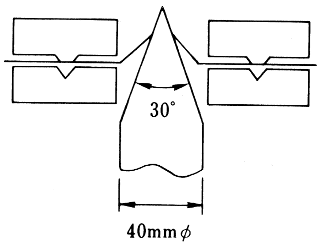
The Erichsen value is determined by the JIS B method.

For ring forging ratio determination, a 10 mm-diam. punched hole is referenced. It is calculated from the following formula.

$$\text{Ring forging ratio} = \frac{d - d_0}{d_0}$$

where d_0 = hole diameter before testing
d = hole diameter after testing

Testing tool



Wrinkle pressure: 4.5 t
Punch lifting speed: 5 mm/min

7. CORROSION RESISTANCE

7-1. Pitting Corrosion Resistance

The pitting potential is shown in Fig. 1.

Generally, the pitting potential decreases with increasing Cl^- concentration. However, this steel always exhibits high pitting potential due to the action of its surface film.

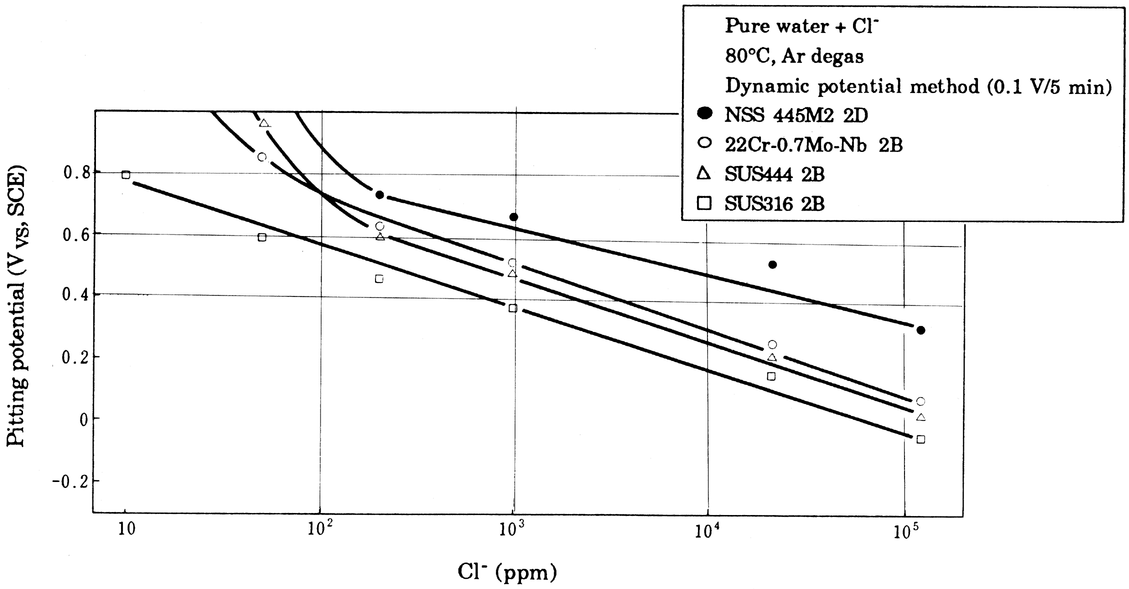


Fig. 1. Pitting Potential (Dynamic Potential Method)

7-2. Crevice Corrosion Resistance

The relationship between crevice corrosion potential and Cl^- concentration is shown in Fig. 2.

The crevice corrosion resistance of a steel varies with the shape of its crevice and the weld condition. Not only the material of this steel itself but also the weld crevice features excellent crevice corrosion resistance when the crevice spacing is wide as in spot welding material.

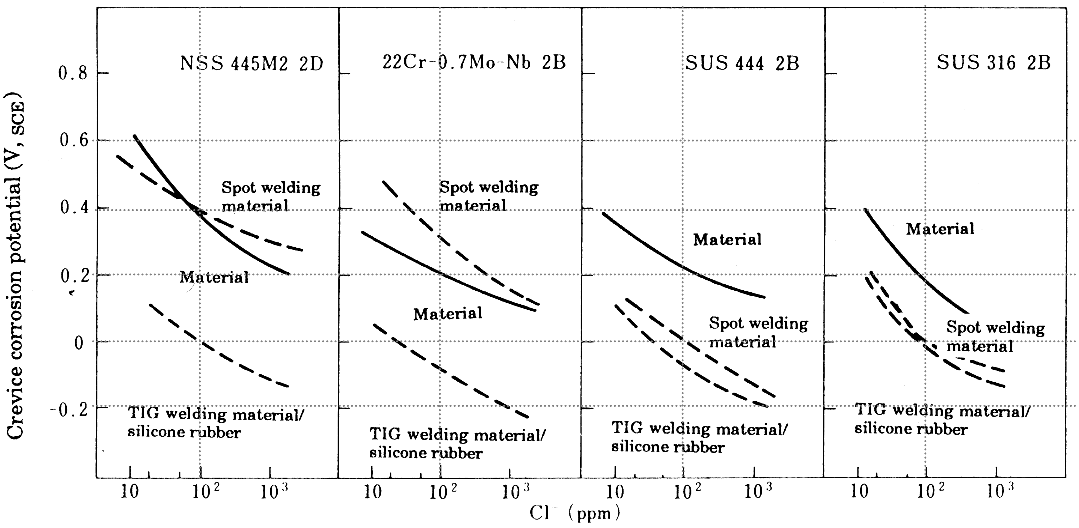
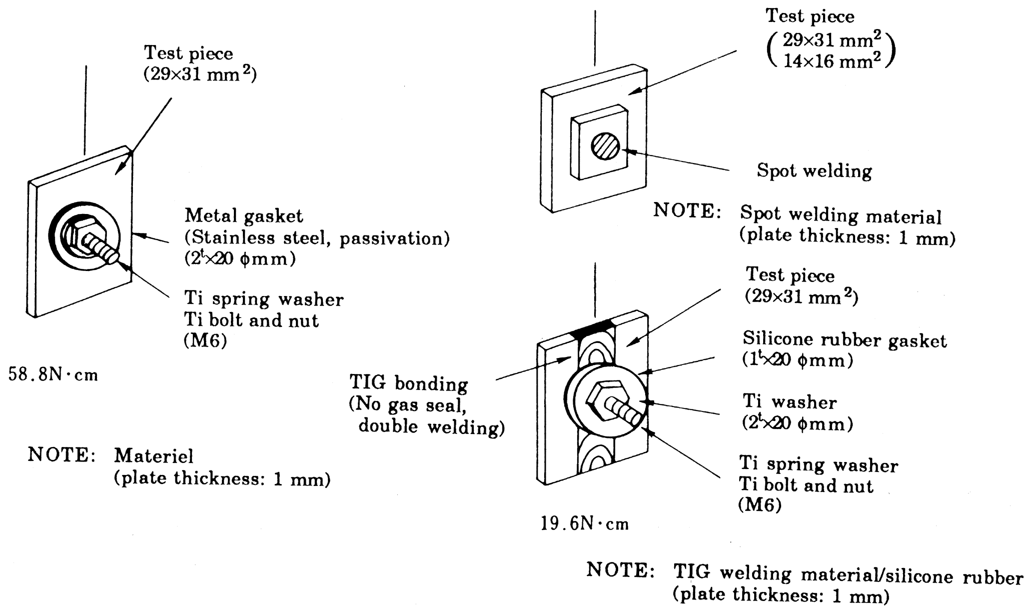


Fig. 2. Relationship between Crevice Corrosion Potential and Cl^- Concentration in Diluted Salt Solution (at 80°C)



7-3. Intergranular Corrosion Resistance

The results of a sulfuric acid-copper sulfate intergranular corrosion resistance test are shown in Table 5.

Adequate amounts of Nb and Ti are contained in this steel as stabilizers to suppress its intergranular corrosion sensitivity.

Table 5. Intergranular Corrosion Test Results

Heat Treatment \ Type of Steel	NSS 445M2	22Cr-0.7Mo-Nb	SUS444	SUS304	SUS316
Material	○	○	○	○	○
1200°C×10 min, A.C.	○	○	○	–	–
650°C×2 hr, A.C.	○	○	○	×	×

Test conditions: Conforming to the sulfuric acid-copper sulfate test requirements (JIS-G-0575).
Bending radius = 0.5 t

Evaluation: ○ : No intergranular corrosion observed, ×: Intergranular corrosion observed

7-4. Stress Corrosion Cracking Resistance

One notable feature of ferritic stainless steel is very low stress corrosion cracking susceptibility.

The results of a stress corrosion cracking test are shown in Table 6. In the U-shape bending test in high-concentration oxidizer-containing chloride solution, cracking was found in SUS304 and SUS316. However, as with 22Cr-0.7Mo-Nb steel and SUS444, this steel suffered no cracking.

Table 6. Stress Corrosion Cracking Test Results

Heat Treatment \ Type of Steel	NSS 445M2	22Cr-0.7Mo-Nb	SUS444	SUS304	SUS316
Material	○	○	○	×	×

Test conditions: 20% NaCl + 1% $Na_2Cr_2O_7$, B.P, 240 hrs.
U-shape bending test (bending radius = 8 t)

Evaluation: ○ : No cracking observed, ×: Cracking observed

7-5. Rust Resistance

7-5-1. Accelerated Tests

A problem encountered with stainless steel used as a roofing material is corrosion due to deposition of sea salt particles on it. The degree of corrosion differs depending on whether the material is used for the rooftop from which sea salt particles are easily washed away by rainwater or for the portion of the roof under the eaves from which they are not easily washed away.

The results of accelerated tests modeling a rooftop and the portion of a roof under eaves are shown below.

(1) Weather simulated corrosion test

The appearance of test samples after testing is shown in Photo 2 and the variation in red rust area with time in Fig. 3.

In this accelerated test, a washing process is introduced for each cycle to simulate a rooftop from which sea salt particles are easily washed away by rainwater. In this test, NSS 445M2 gathered little rust, exhibiting superior weatherability.

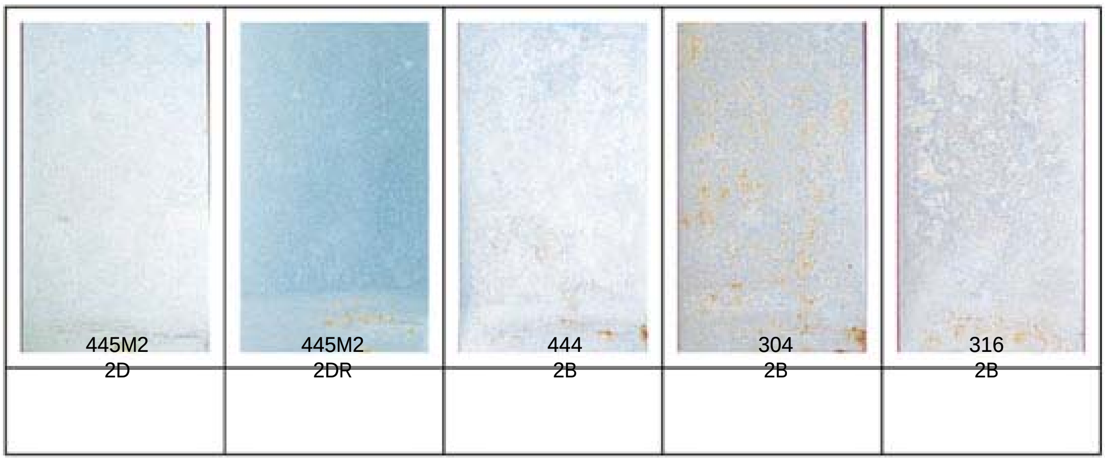


Photo 2. Rust Appearance After Weather Simulated Corrosion Test (1000 Cycles)

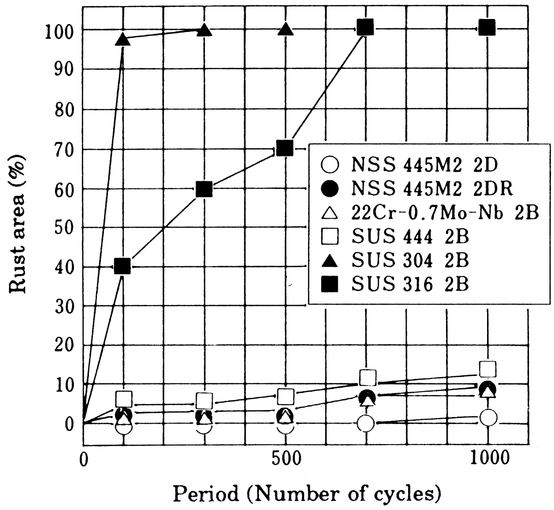
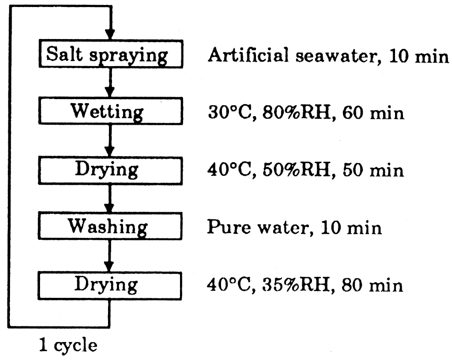


Fig. 3. Variation in Rust Area with Time After Weather Simulated Corrosion Test



Test Conditions

(2) Cyclic corrosion test

The appearance of test samples after testing is shown in Photo 3 and the variation in red rust occurrence rate with time in Fig. 4.

This accelerated test, which contains no washing process, simulates the portion of a roof under eaves from which sea salt particles are not easily washed away by rainwater. The degree of corrosion was higher than in the weather simulated corrosion test.

In this test, NSS 455M2 also gathered only a little red rust, showing excellent resistance to atmospheric corrosion.

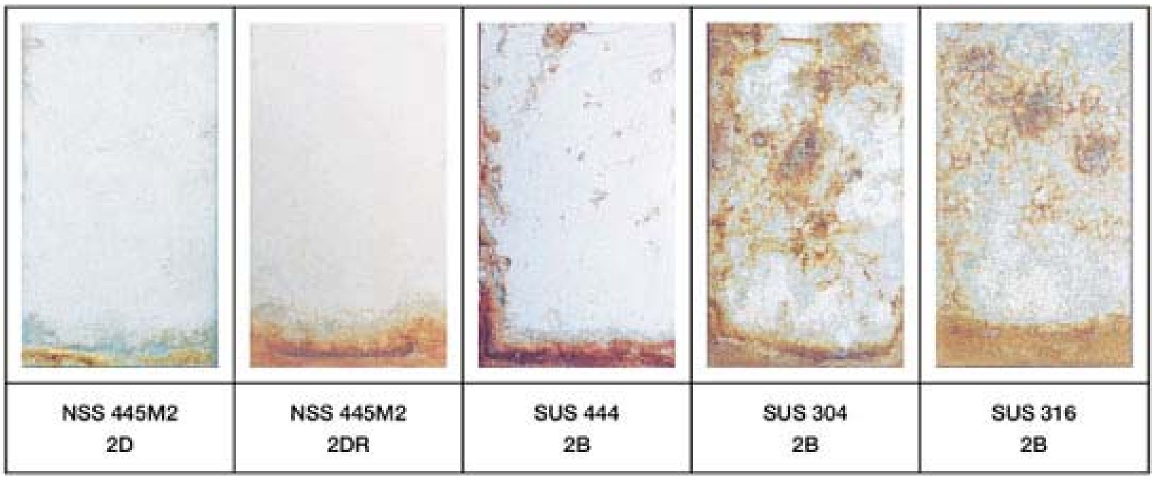


Photo 3. Rust Appearance After Cyclic Corrosion Test (1000 Cycles)

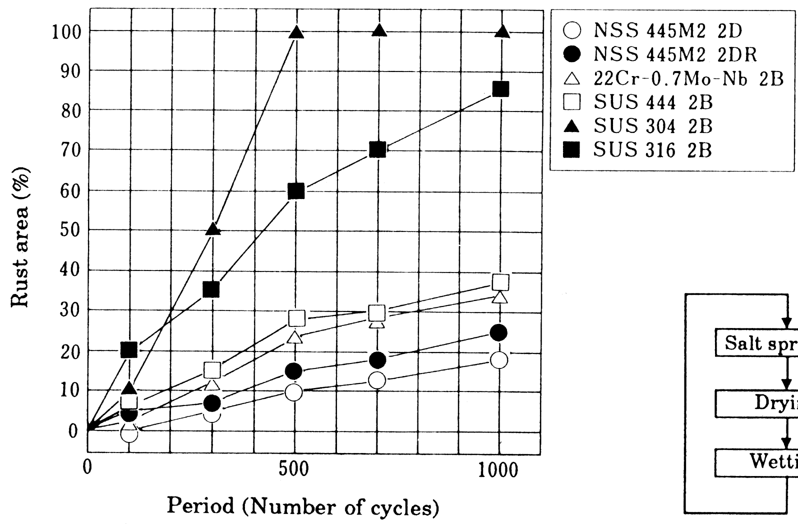
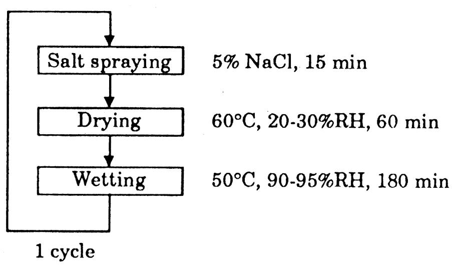


Fig. 4. Variation in Rust Area with Time After Cyclic Corrosion Test



Test Conditions

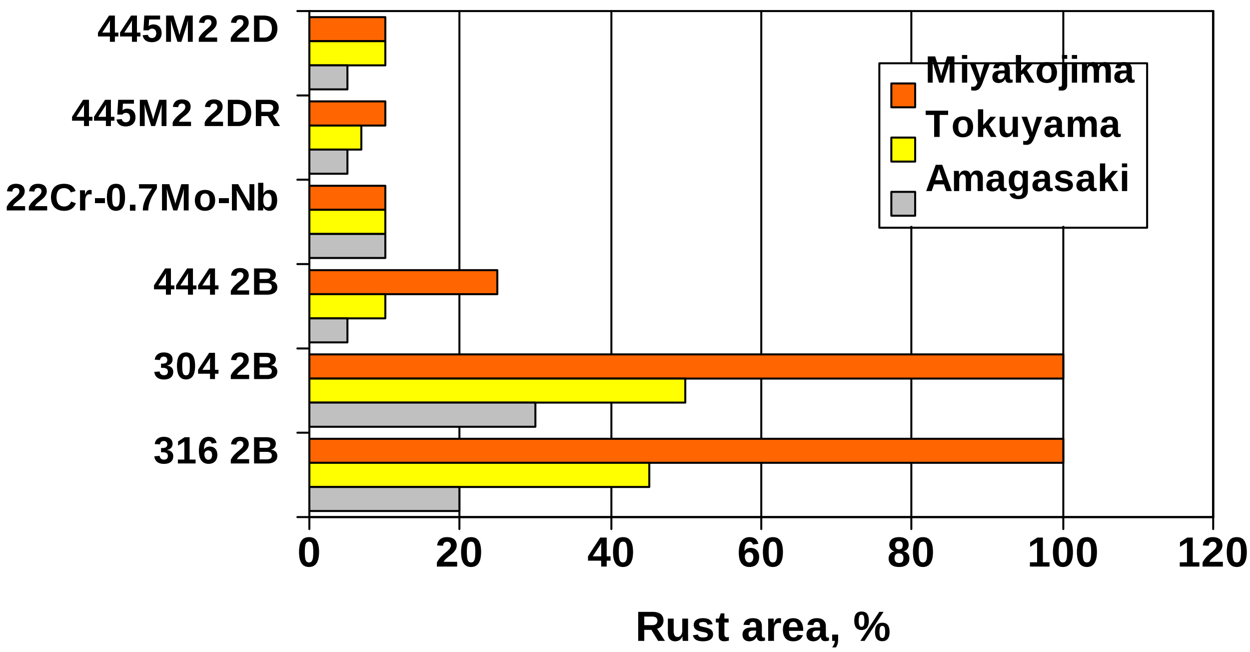
7-5-2 Atmospheric Exposure Test

The rust area of test samples after two-year exposure in various areas are shown in Fig. 5.

As can be seen from the figure, this steel exhibits superior weatherability even in highly corrosive environments such as Miyakojima.

Location	Environment	Direction of and Distance from the Sea
Miyakojima	Seashore (open sea), subtropics	1.5 km south
Tokuyama	Industrial area, seashore (inland sea)	5 m north
Amagasaki	Industrial area, seashore (inland sea)	1.5 km south

NOTE: Atmospheric exposure test locations and environments



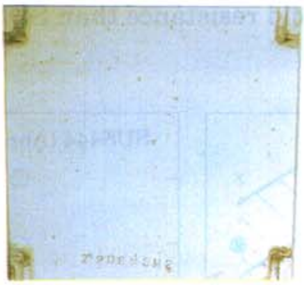
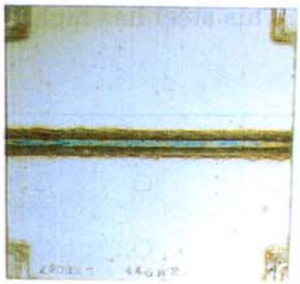
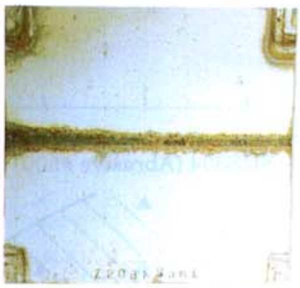
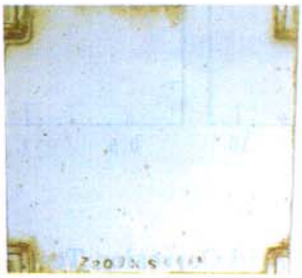
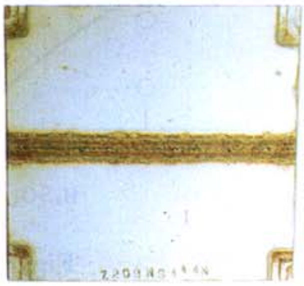
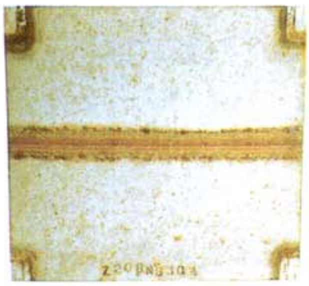
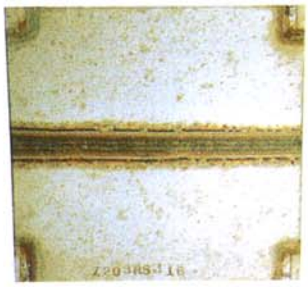
Type of Steel	Material	TIG Welding Material
NSS 445M2 2DR		
22Cr-0.7Mo-Nb 2B		
SUS 444 2B		
SUS 304 2B		
SUS 316 2B		

Photo 4. Rust Appearance After Atmospheric Exposure Test (2 Years at Miyakojima)

7-6. General Corrosion Resistance (Acid Resistance)

The results of a sulfuric acid corrosion test are shown in Fig. 6.
This steel has higher sulfuric acid resistance than SUS444, SUS304, and SUS316.

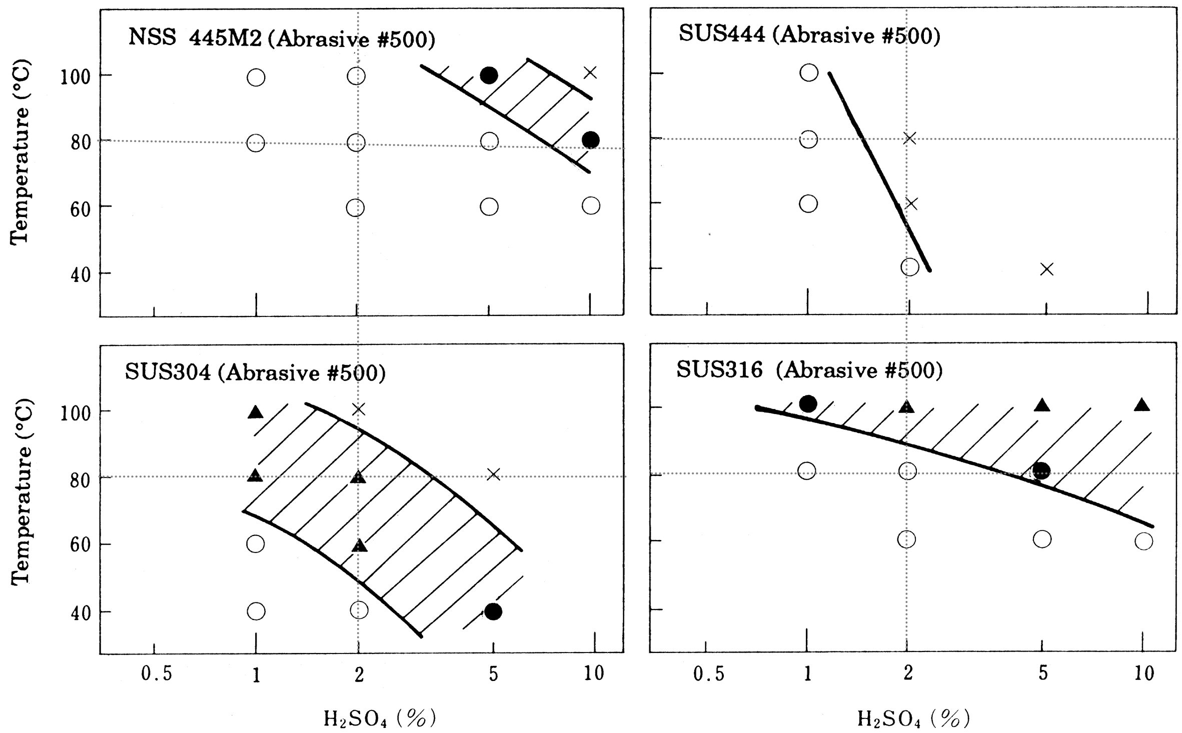


Fig. 6. Sulfuric Acid Corrosion Test Results

Evaluation

	Degree of corrosion (g/m²h)
○	< 0.1
●	0.1 – 1
▲	1 – 10
×	> 10

* Weight loss after 24 hours

8. WELDABILITY

8-1. TIG Weldability

The adequate condition range for TIG welding is shown in Fig. 7.

The TIG welding adequate condition range for this steel is narrower than that for SUS316 but wider than that of SUS444, so that it allows welding at lower current values than with SUS444.

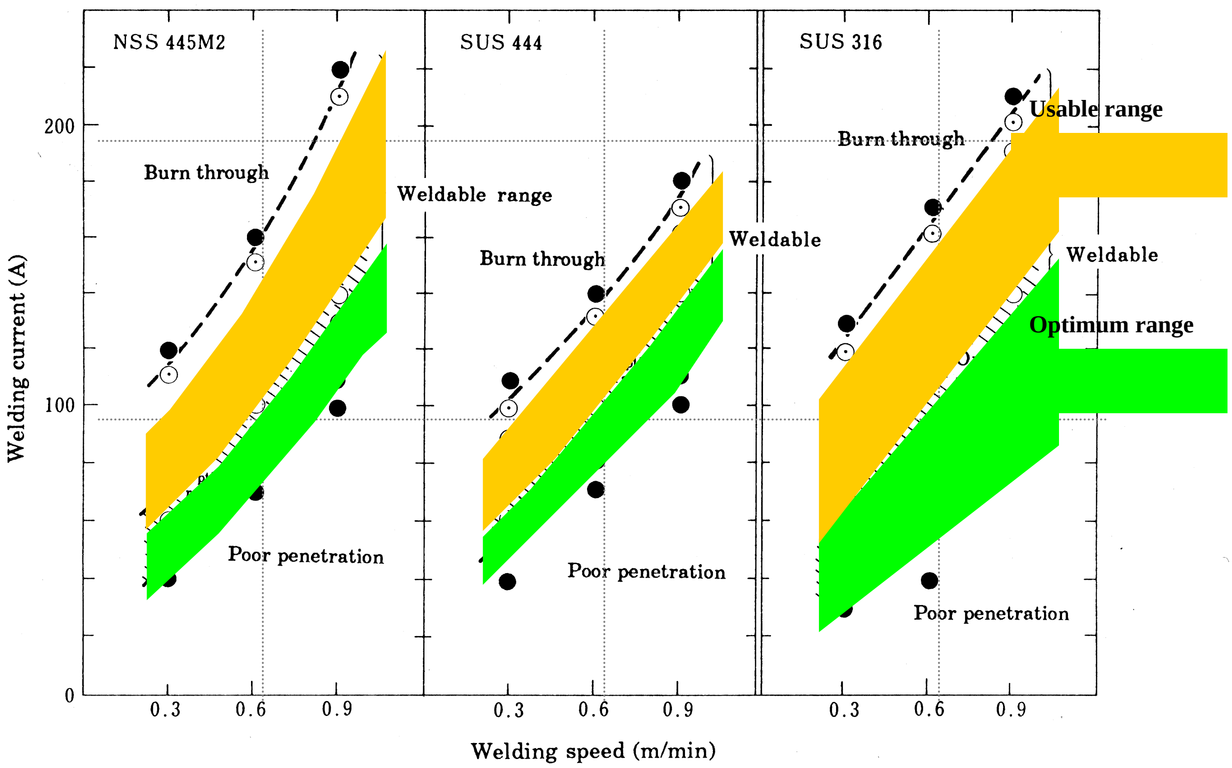


Fig. 7. Adequate Condition Ranges for TIG Welding

Welding Conditions

- Groove: I groove (butt)
- W electrode diameter: Welding current ≥100A: 1.6 mmϕ; >100A: 2.4 mmϕ
- Arc length: 1.0 mm
- Shielding gas: Ar 10 L/min
- Chiller (copper plate) used on the back side
- Plate thickness: 1.0 mm

<Evaluation>

- ○ : Proper welding
- ⊙ : Weldable
- ● : Poor welding

Note: these weld tests were made without the addition of filler metal. For MIG welding, or where the addition of filler metal in TIG welding is required, 316L or 316LSi filler metal should be used.

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8-2. Seam Weldability

The welding strengths of test pieces at various welding speeds and current values are shown in Fig. 8.

Although the maximum welding strength of this steel is slightly lower than that of SUS316 because of its low tensile strength, it offers stable welding strength over the wide current range of 1750 to 2300 A.

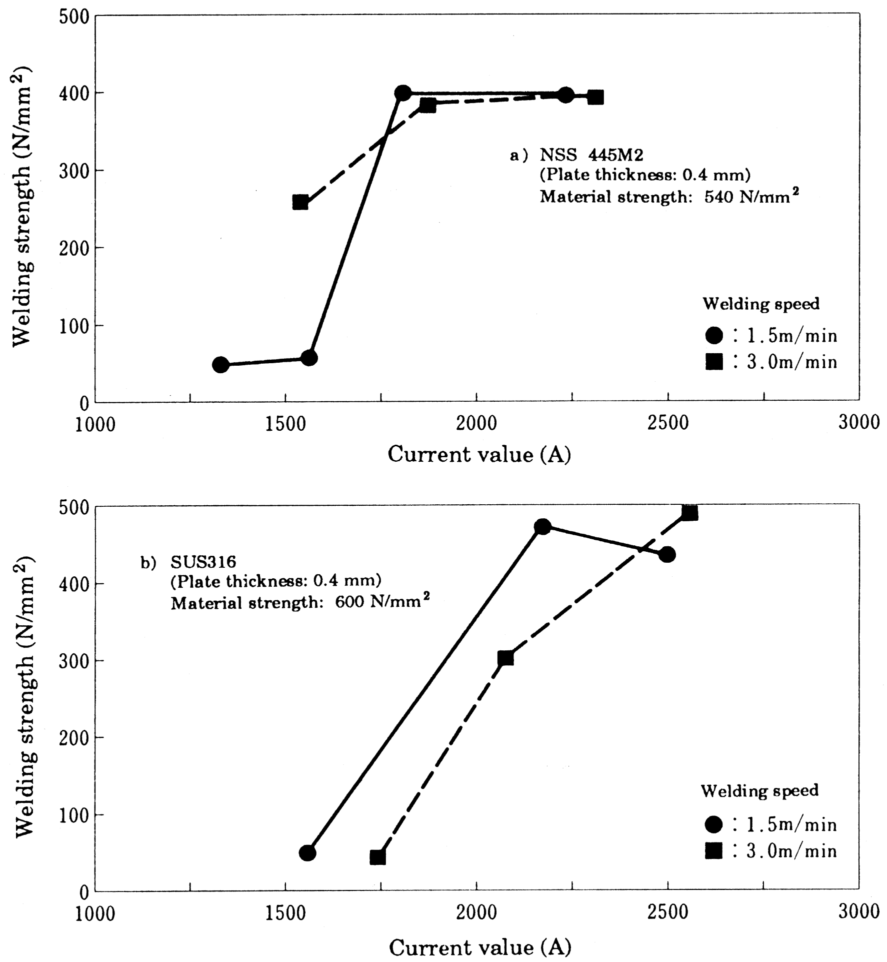

Fig. 8. Effect of Welding Speed and Current on Strength After Seam Welding

Welding Conditions

- Test piece: 10 mm-wide two-ply plate
- Electrode width: 4.5 mm
- Welding force: 150 kg
- Welding cycle: Continuous

Tension test method