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DUPLEX STAINLESS STEEL  
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# STAINLESS STEEL

## DUPLEX STAINLESS STEEL

EXPERIENCE  
KNOWLEDGE  
INNOVATION

# DUPLEX



**NIPPON STEEL CORPORATION**

# NSSC DUPLEX

## Stainless Steel

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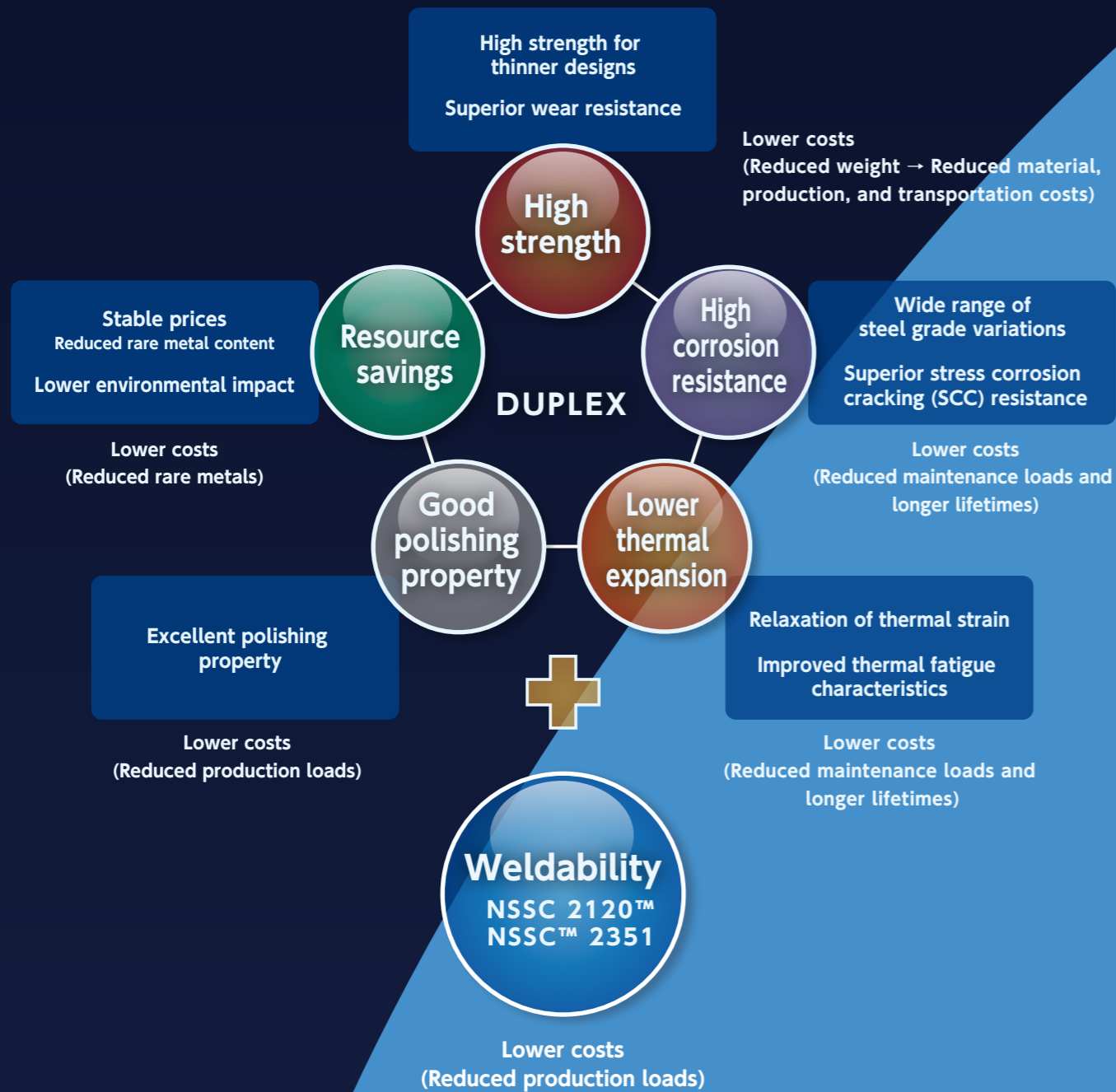


## Real Innovation

New value is added to society by a fusion between cutting edge materials developed entirely from the user perspective and the creativity required to make best use of them.

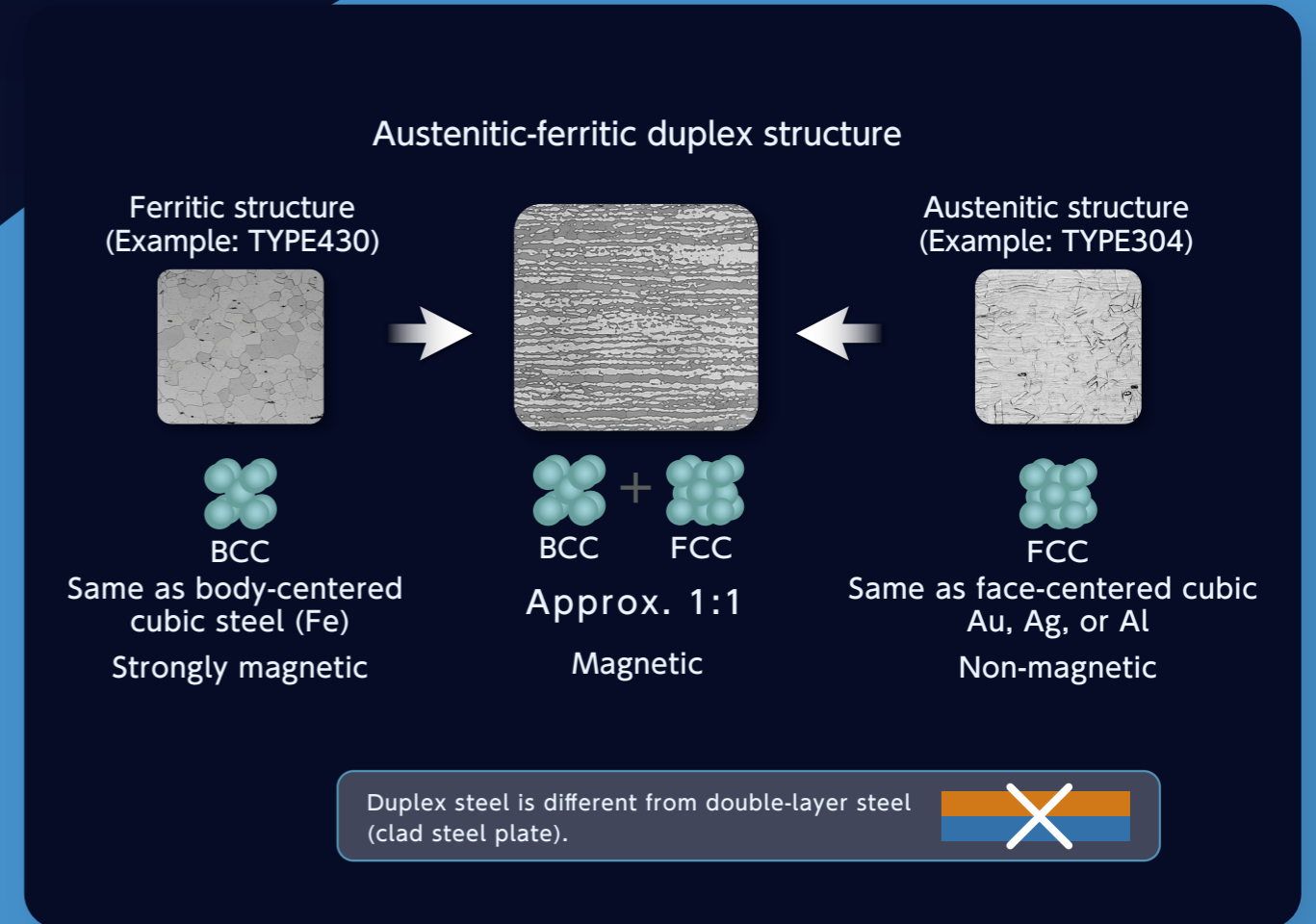
## Features of NIPPON STEEL's original duplex stainless steel

### NIPPON STEEL's original duplex stainless steel achieves a large improvement in weldability! ※

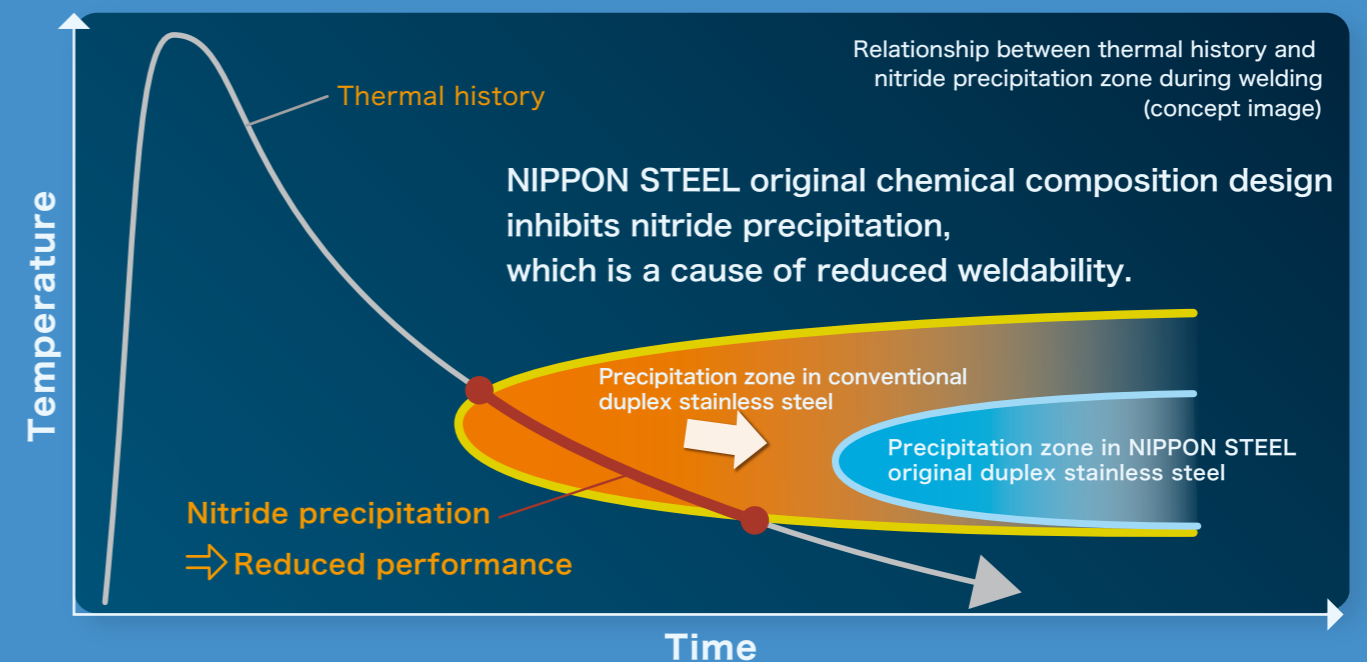


※Compared to conventional duplex stainless steel

## Metal structure of duplex stainless steel

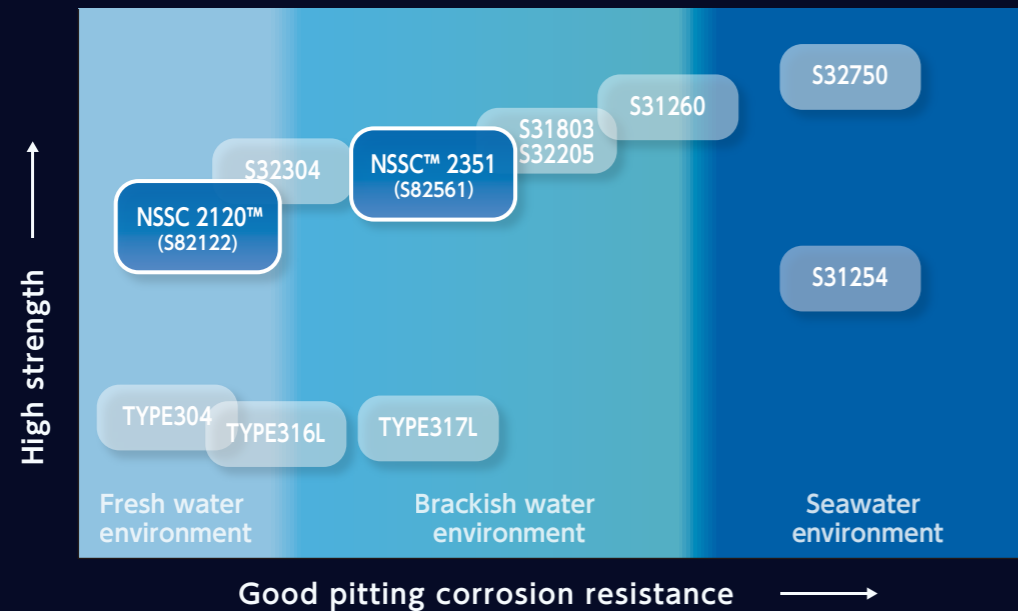


### NIPPON STEEL's original stainless duplex stainless steel features greatly improved welding workability. ※



### Duplex stainless steel lineup

A wide lineup is available ranging from resource-saving Lean grade to the Super grade which can withstand seawater. Users can choose the steel grade that is most suitable for the service environment.



Classification	NSSC standard/ JIS standard	ASTM standard (UNS)	Main chemical composition (wt%)	PREN <sup>*1)</sup>	CI <sup>*2)</sup>	Products that can be provided
Lean Duplex	NSSC 2120™ (SUS821L1)	S82122 <sup>*3)</sup>	21Cr-2Ni-3Mn-Cu-0.17N	25	26	Coil&Sheets, Plates, rods
	SUS323L	S32304	23Cr-4Ni-0.15N	27	27	Coil&Sheets, Plates, rods
Standard Duplex	NSSC™ 2351 (SUS329J1)	S82561 <sup>*3)</sup>	23Cr-5Ni-1Mo-0.17N	30	32	Coil&Sheets, Plates, rods
	SUS329J3L	S31803 S32205	22Cr-5Ni-3Mo-0.15N	34	38	Coil&Sheets, Plates, rods
	SUS329J4L	S31260	25Cr-6Ni-3Mo-0.15N	36	41	Coil&Sheets, Plates, rods
Super Duplex	SUS327L1	S32750	25Cr-7Ni-4Mo-0.28N	42	49	Coil&Sheets, Plates, rods
Austenitic	SUS304	S30400	18Cr-8Ni-Low N	19	19	Coil&Sheets, Plates, rods
	SUS316L	S31603	18Cr-12Ni-2.5Mo-Low C-N	26	28	Coil&Sheets, Plates, rods
	SUS317L	S31703	18Cr-12Ni-3.5Mo-Low C-N	30	32	Coil&Sheets, Plates, rods
	SUS312L	S31254	20Cr-18Ni-6Mo-0.2N	43	50	Coil&Sheets, Plates

<sup>\*1)</sup> PREN= Cr%+3.3xMo%+16N%(pitting resistance equivalent number)  
<sup>\*2)</sup> CI=Cr%+4.1Mo%+27N%(crevice corrosion index)  
<sup>\*3)</sup> Flat products

### Physical properties (reference values)

Classification	NSSC standard/ JIS standard	Density <sup>*1)</sup> (g/cm <sup>3</sup> )	Modulus of longitudinal elasticity (kN/mm <sup>2</sup> )	Specific heat (kJ/kg/°C)	Specific electric resistivity (10 <sup>-8</sup> Ωm)	Thermal conductivity (W/m/°C)	Coefficient of linear expansion (×10 <sup>-6</sup> /°C)
Lean Duplex	NSSC 2120™ (SUS821L1)	7.80	200	0.5	80	16.0	13.7
	SUS323L	7.80	200	0.5	80	16.0	13.0
Standard Duplex	NSSC™ 2351 (SUS329J1)	7.80	200	0.5	80	15.2	13.1
	SUS329J3L	7.80	200	0.5	80	12.5	13.7
	SUS329J4L	7.80	200	0.5	80	13.4	13.4
Super Duplex	SUS327L1	7.80	200	0.5	80	14.0	13.0
Austenitic	SUS304	7.93	193	0.5	72	16.3	17.3
	SUS316L	7.98	193	0.5	74	16.3	16.0

<sup>\*1)</sup> Density values reference the JIS standard.

Sources: Duplex Stainless Steel Machining Manual (IMOJA)  
 Best Uses of Duplex Stainless Steel (The Society of Materials Science, Japan)  
 Information for NSSC 2120™ and NSSC™ 2351 are sample measurements by  
 our company.

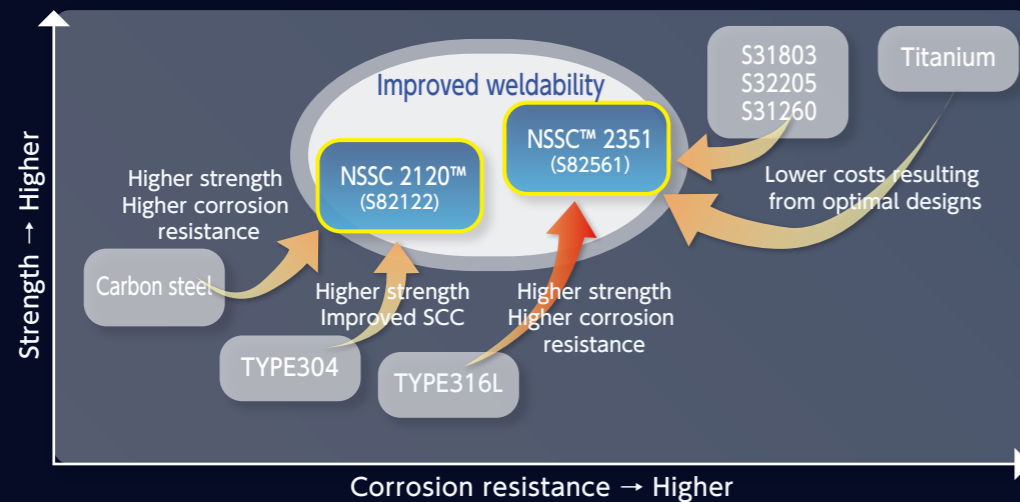
### Mechanical properties (reference values)

Classification	NSSC standard/ JIS standard	Finish	Thickness (mm)	0.2% yield strength (MPa)	Tensile strength (MPa)	Elongation (%)	Hardness HV
Lean Duplex	NSSC 2120™ (SUS821L1)	2B	1.5	570	792	31	256
		2B	3.0	544	759	35	244
Standard Duplex	NSSC™ 2351 (SUS329J1)	2B	1.5	613	830	29	264
		2B	3.0	608	809	31	255
		SUS329J3L	2B	1.5	641	867	28
Super Duplex	SUS327L1	2B	1.5	725	955	26	313
		SUS329J4L	2B	1.5	686	868	25
Austenitic	SUS304	2B	1.5	300	654	56	170
		2B	1.5	281	561	53	143

NIPPON STEEL's Duplex Series

Utilizing the high strength and high corrosion resistance makes possible VE by changing from regular stainless steel and other materials.

Positioning of NSSC 2120™ and NSSC™ 2351

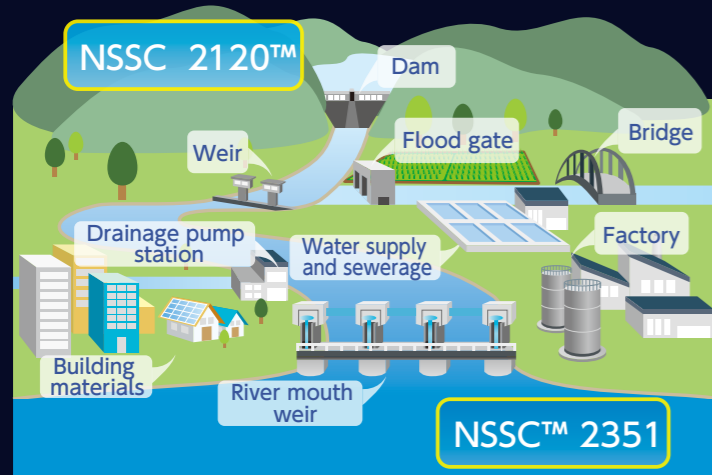


NSSC 2120™

- 1 Corrosion resistance is equal to or better than TYPE304.
- 2 SCC resistance is largely superior to TYPE304.
- 3 Utilizing the higher strength makes thinner and lighter-weight designs possible.
- 4 When switching from carbon steel, there is a limited initial increase in cost, however the overall life cycle costs are reduced.

NSSC™ 2351

- 1 Corrosion resistance is equal to or better than TYPE316L.
- 2 SCC resistance is largely superior to TYPE316L.
- 3 When used as a replacement for TYPE316L, thinner and lighter-weight designs are possible and life cycle costs can be reduced.
- 4 Changing from high-grade materials (avoiding excessively high specifications) can achieve a large reduction in cost.



Possible applications

- River facilities  
Fresh water environment: NSSC 2120™  
Brackish water environment: NSSC™ 2351
- Buildings and civil engineering  
Inland environment: NSSC 2120™  
Coastal environment: NSSC™ 2351
- Tanks and other factory equipment  
Equipment using TYPE304: NSSC 2120™  
Equipment using TYPE316L: NSSC™ 2351

※For a full seawater environment, S31260 or Super Duplex S32750 is recommended.

NSSC 2120™ and NSSC™ 2351 weldability

High heat-input welding is possible.

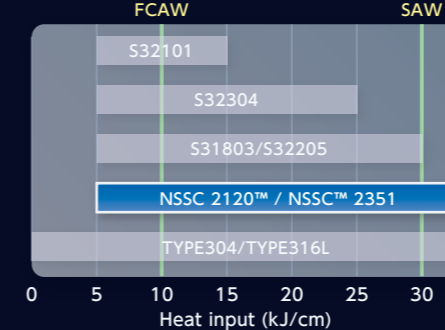
The recommended heat input range for NSSC 2120™ and NSSC™ 2351 is larger than conventional duplex stainless steel, allowing high heat-input welding.

Welding efficiency is greatly increased by the use of high heat-input welding.

Because SAW high heat-input welding can be used, efficient welding is possible (2× or more compared to ordinary welding). It is particularly suitable for construction of large-size structures.



Recommended heat input during welding Suitable range

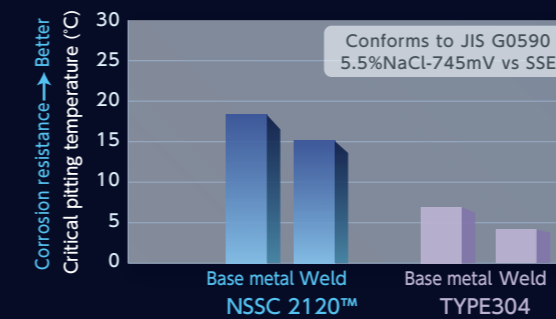


Welding method	Groove shape and laminating procedure	Macroscopic cross-section image	Number of passes	Welding heat input kJ/cm	Applicability
Ordinary welding FCAW Flux Cored Arc Welding			8	10	○
High heat-input welding SAW Submerged Arc Welding			4	35	○

NSSC 2120™ and NSSC™ 2351 weld corrosion resistance

NSSC 2120™ weld corrosion resistance is equal to or greater than that of TYPE304 welds.

Corrosion resistance in a neutral high-salinity environment (Critical pitting temperature)



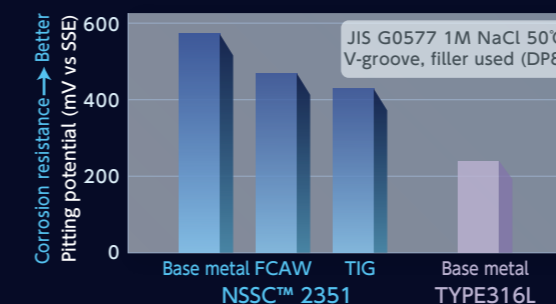
Exposure test results

Exposed for 1 year approximately 30 m from the ocean on the coast of Yamaguchi Prefecture. TIG welding was performed at the center, followed by pickling.



NSSC™ 2351 weld corrosion resistance is equal to or greater than that of TYPE316L welds.

Sample pitting potentials of base metal and welds



Ferric chloride test results

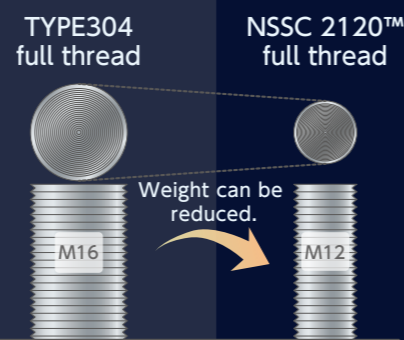
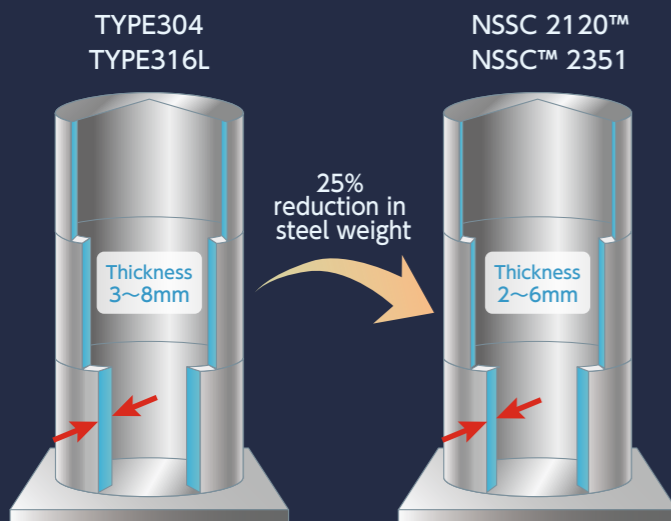
JIS G 0578-B 72 h 15°C TIG welding, 3 mmt, V-groove, 2 passes, Ar shield Filler used (YM-DP8/2351, YM-316L/316L)



## Characteristics of duplex stainless steel

Utilizing the material high strength makes thinner and lighter-weight designs possible. ※Concept image

High strength



Typical examples of mechanical properties

Product type	0.2% yield strength N/mm <sup>2</sup>	Tensile strength N/mm <sup>2</sup>
NSSC 2120™ full thread	600	801
TYPE304 full thread	486	643

### Comparison of design standard strengths

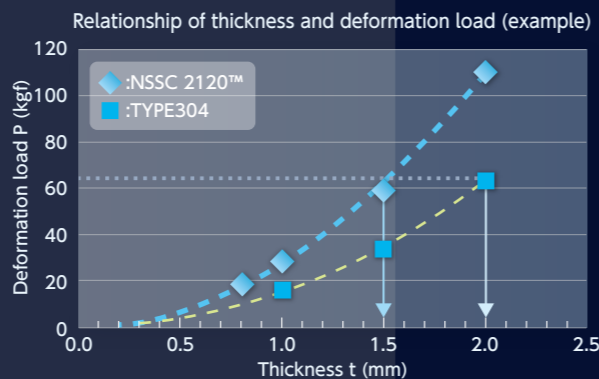
[ Design strength ] ※When designed for yield strength

NSSC™ 2351	400N/mm <sup>2</sup>
NSSC 2120™	400N/mm <sup>2</sup>
SMA490	355N/mm <sup>2</sup>
SM490	315N/mm <sup>2</sup>
SS400	235N/mm <sup>2</sup>
TYPE304	205N/mm <sup>2</sup>
TYPE316L	175N/mm <sup>2</sup>

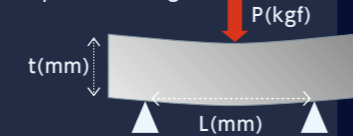
High strength

### Potential for reduced thickness at bending tests (trial calculations)

Compared with TYPE304, thickness can be reduced by 25%.



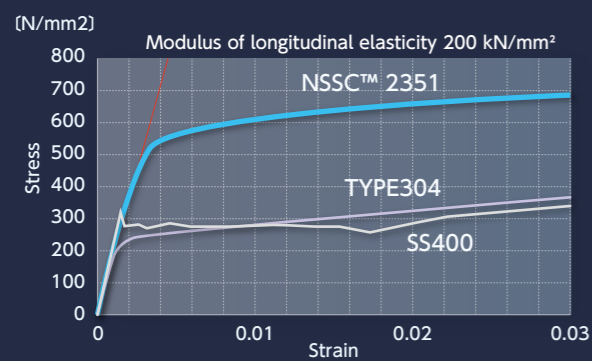
Calculation basis conditions (3-point bending)



$$P = \frac{2b\sigma_y}{3L} t^2$$

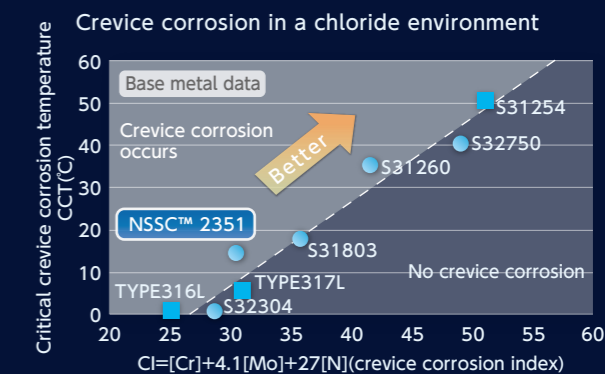
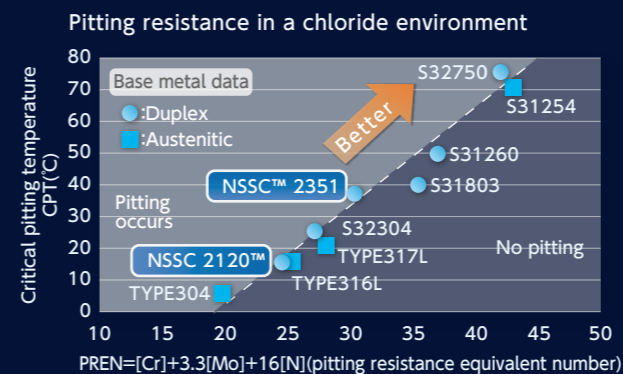
Deformation load: P (kgf)  
Distance between support points: L (mm)  
Thickness: t (mm)  
Width: b (mm)

### [ Stress-strain curve ]



### Wide range of steel grade variations

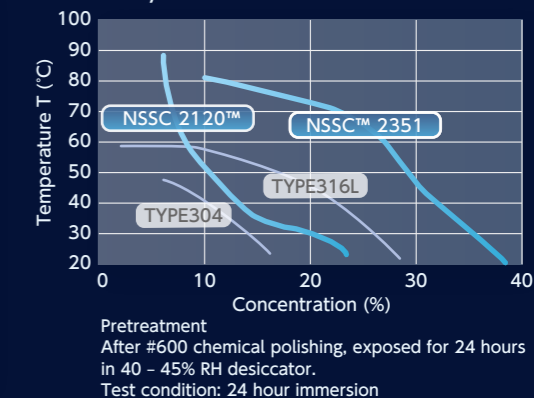
High corrosion resistance



Exposure test Results from exposure for 1 year in SE Asia ocean



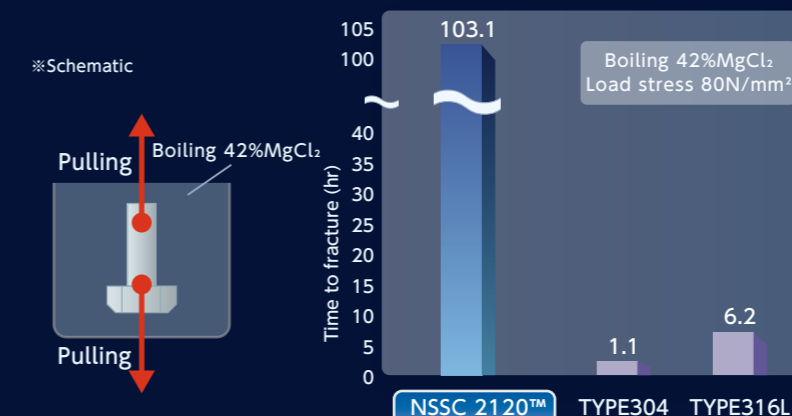
### Sulfuric acid resistance limit of application (≤0.1 mm/y)



### Excellent stress corrosion cracking resistance (SCC resistance)

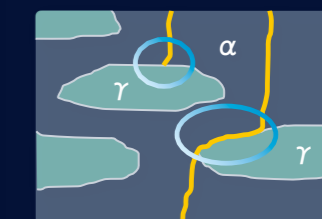
Compared to austenitic stainless steel in the same class, duplex stainless steel has superior stress corrosion cracking resistance (SCC resistance) in a chloride environment.

High corrosion resistance



### SCC resistance improvement mechanism

It was confirmed that the crack end branches at the αγ interface.



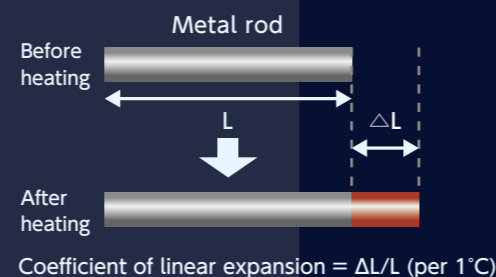
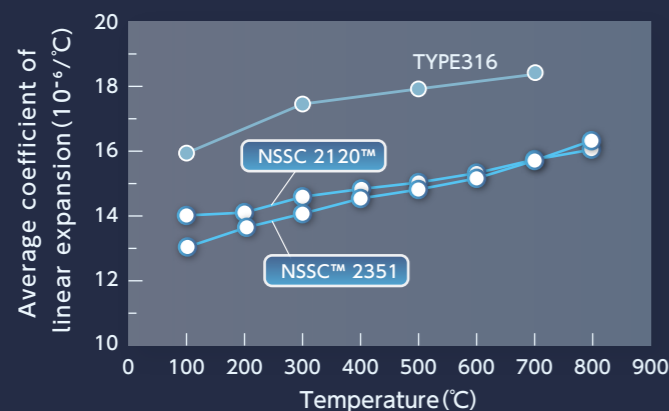
α=Ferrite phase  
γ=Austenite phase

## Characteristics of duplex stainless steel

### Relaxing of thermal strain

Compared to austenitic stainless steel, the coefficient of linear expansion is lower. This can be expected to produce longer lifetimes in equipment where thermal strain is a problem.

Low thermal expansion

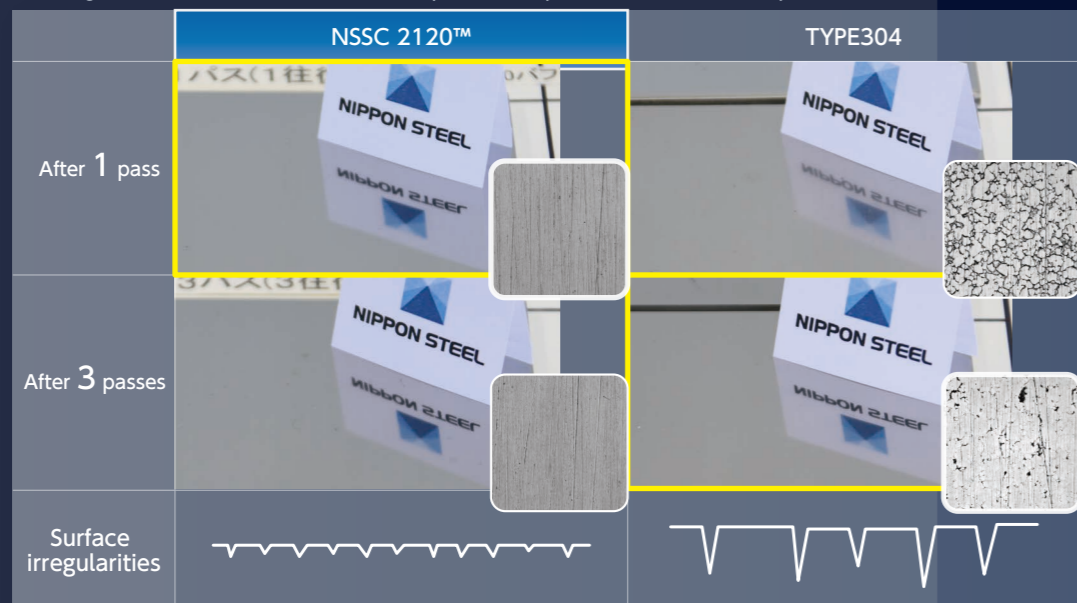


### Excellent polishing property

NSSC 2120™ provides superior polishing property, with the finish (yellow box) after 1 pass equivalent to the finish after 3 passes with TYPE304, making it possible to reduce the man-hours required for polishing.

Good polishing property

Polishing conditions  
 Material before polishing: Cold-rolled 3.0 mm, No. 2B finish  
 Polishing powder: #400 alumina based powder  
 Polishing conditions: Buff diameter 400 mm, speed 2000 rpm, material movement speed 286 mm/s



It is thought that buffing performance is affected by the differences in the grain boundary depth that can be seen in the material surface after pickling.

### Price stability

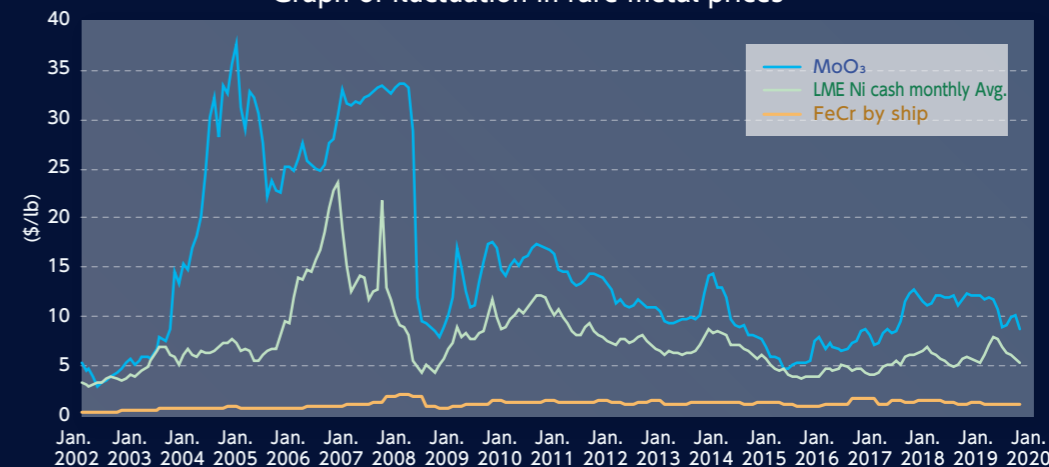
Uses much smaller amounts of Ni and Mo - expensive materials that are subject to price fluctuations.

Resource conservation

Comparison of main components

	TYPE304	NSSC 2120™	TYPE316L	NSSC™ 2351
Ni	8%	2%	12%	5%
Mo	0%	0%	2.5%	1%
Cr	18%	21%	18%	23%

Graph of fluctuation in rare metal prices

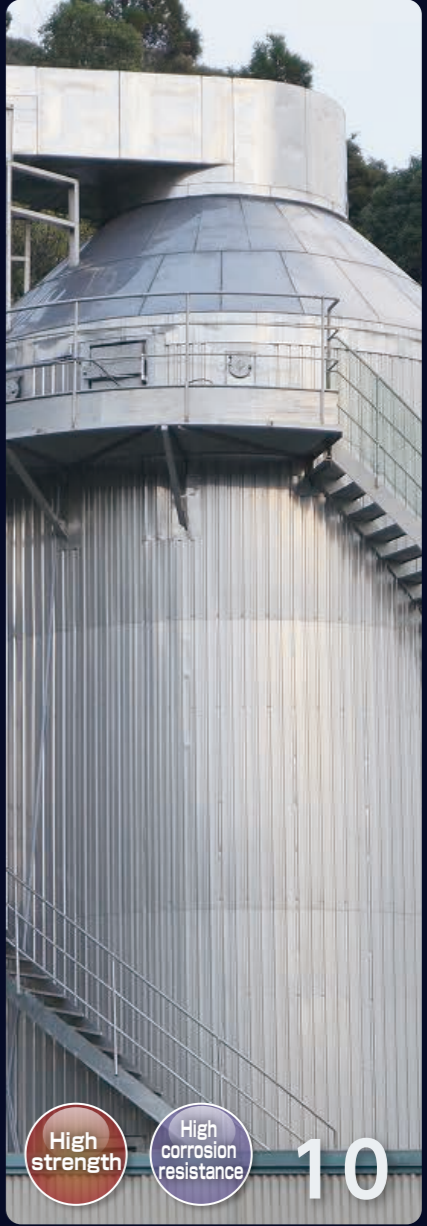


Examples of Applications



- 01. Pedestrian overpass (SUS821L1)
- 02. NS Smart Inspection Walkway (SUS821L1)
- 03. Underwater beam (SUS821L1)  
Duplex stainless steel, bolts (NSSC 2120™)
- 04. Dam discharge facility (SUS821L1)

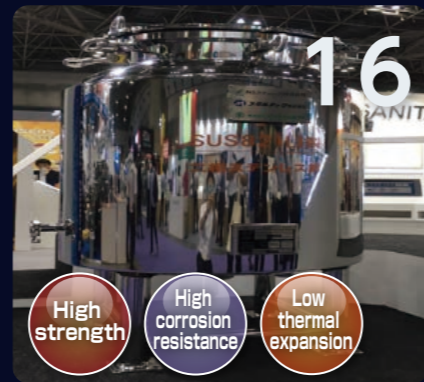
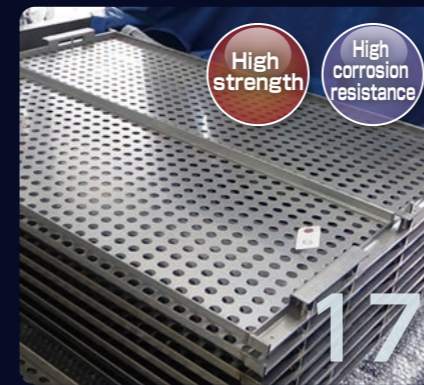
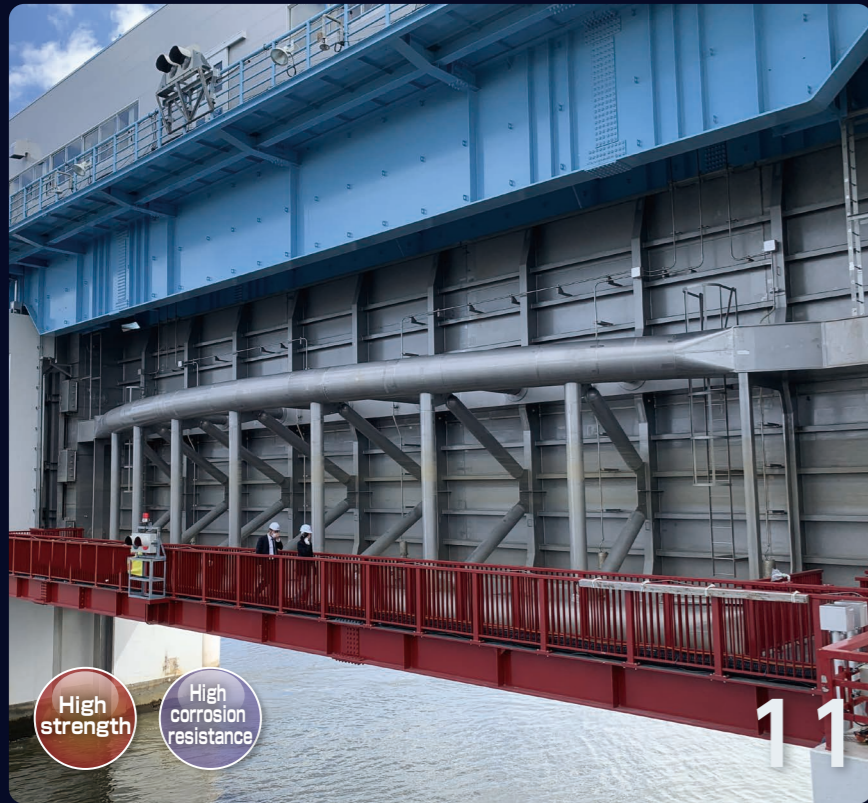
- 05. Dust remover (SUS821L1)
- 06. Drain sluice (SUS323L)
- 07. Seawater-resistant screen (SUS327L1)
- 08. Tide embankment floodwall gate (SUS821L1)
- 09. Mega-scale solar panel frame (SUS821L1)
- 10. Spray dryer (SUS821L1)



Examples of Applications

- 11. Storm surge gate (SUS323L)
- 12. Cargo hold of general cargo ship (SUS821L1)
- 13. Cylindrical tank (SUS821L1)
- 14. Steelmaking service reservoir (SUS329J4L or other)
- 15. Food product tank (SUS329J1)
- 16. Sanitary tank (SUS821L1, SUS329J1, or other)

- 17. Sterile tray (SUS821L1)
- 18. Home door frame (SUS821L1)
- 19. Disaster supply storage facility (SUS821L1 or other) (Including bolts, nuts, and washers) Duplex stainless steel, full-thread bolts (NSSC 2120™)
- 20. Truck cargo bed (SUS821L1, SUS329J1)
- 21. Balcony railings for high-rise apartment building "Skyplex" (SUS821L1)
- 22. Stainless pipe (SUS821L1)
- 23. Swimming pool (SUS821L1)



Precautions for Use

(1)Forming

- Because these are high-strength stainless steels, formability is not the same as austenitic stainless steel .
- Although drawing is possible to the same shape as austenitic stainless steel , because the deformation load is approximately 10% higher, check the equipment capacity. It may be necessary to adjust dies, lubricating conditions, or other factors.
- Adjustment is necessary when bending due to the large spring-back.
- Cutting performance and drilling performance are equal to or better than austenitic stainless steel .

(2)Welding

- NSSC original duplex stainless steel features greatly improved weldability and allows welding under approximately the same conditions as austenitic stainless steel.
- However special welding material is recommended. Although welding without welding material is possible, it is necessary to check the weld characteristics in advance.

(3)Recommended service temperature

- The recommended service temperature range is -50 to 300°C, narrower than that of austenitic stainless steel (-196 to 850°C).

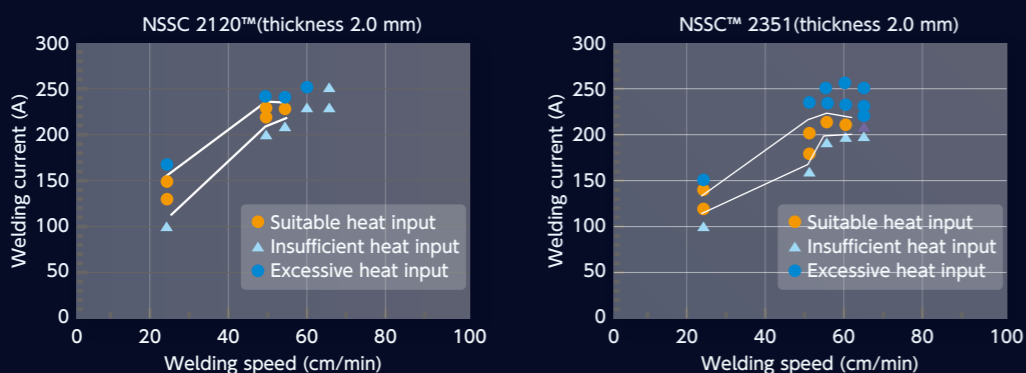
Precautions when welding duplex stainless steel

1. In order to suppress the precipitation of carbonitrides and structural changes, avoid excessive or insufficient welding heat input.
2. Limit the interpass temperature to 100 to 150°C.
3. Because low-temperature cracking caused by hydrogen is possible, avoid the use of H2 in the shield gas.
4. Be sure to fully remove the welding scale.

Welding materials for carbon steel and different stainless steels

		Lean Duplex	Standard Duplex		Super Duplex
		NSSC 2120™ S82122 S32304	NSSC™ 2351 S31803 S32205	S31260	S32750
Lean Duplex	NSSC 2120™ S82122 S32304	Similar metal (lean duplex steel) TYPE2209	TYPE2209	TYPE2209	TYPE2209
Standard Duplex	NSSC™ 2351 S31803 S32205	TYPE2209	TYPE2209	TYPE2594	Similar metal (super duplex steel)
	S31260	TYPE2209	TYPE2594	TYPE2594	Similar metal (super duplex steel)
Super Duplex	S32750	TYPE2209	Similar metal (super duplex steel)	Similar metal (super duplex steel)	Similar metal (super duplex steel)
Austenitic stainless steel	TYPE304	Type2209 309L/309 309LMo/309Mo	TYPE2209 309LMo/309Mo	TYPE2209 309LMo/309Mo	TYPE2209 309LMo/309Mo
	TYPE316L	TYPE2209 309LMo	TYPE2209 309LMo	TYPE2209 309LMo	TYPE2209 309LMo
Carbon steel Low-alloy steel	SS400 SM490 Others	TYPE2209 309L/309 309LMo/309Mo	TYPE2209 309L/309 309LMo/309Mo	TYPE2209 309L/309 309LMo/309Mo	TYPE2209 309L/309 309LMo/309Mo

Example of suitable TIG welding conditions



Applicable Standards and Other Official Standards

M-650 ED.4

NORSOK certification

The following duplex stainless steels have been certified as steel suitable for marine structures.

- S31803 (MDS D45)
- S32205 (MDS D45)
- S32750 (MDS D55)

Public standards that can be provided

	NSSC 2120™	SUS323L	NSSC™ 2351	SUS329J3L	SUS329J4L	SUS327L1
JIS G 4304: Hot-rolled stainless steel plate, sheet and strip	○ SUS821L1	○	○ SUS329J1 (≥2mm thickness)	○	○	○
JIS G 4305: Cold-rolled stainless steel plate, sheet and strip	○	○	○	○	○	○
JIS G 4303: Stainless steel bars	○	○	○	○	○	○
JIS G 4308: Stainless steel wire rods	○ (JIS G 4303)	○ (JIS G 4303)	○ SUS329J1	○	○	○ (JIS G 4303)
JIS B 8265: Construction of pressure vessel – General principles (safety factor 4)	○ (JIS B 8267)	○ (JIS B 8267)	○ SUS329J1 (≥2mm thickness)	○	○	○ (JIS B 8267)
JIS B 8267: Construction of pressure vessel (safety factor 3.5)	○	○	○	○	○	○
NK ship class	○ KSUS821L1	○	○ KSUS329J1	○ KSUS329J3L	○	○
ASTM A240/240M: Standard Specification for Chromium and Chromium-Nickel Stainless Steel Plate, Sheet, and Strip for Pressure Vessels and for General Applications	○ S82122	○ S32304	○ S82561	○ S31803 S32205	○ S31260	○ S32750

Awards

NSSC 2120™

6th Monodzukuri Nippon Grand Awards Received the Minister of Economy, Trade and Industry Award.

Specifications

Hot-rolled plate (4Hi)

Classification	Grade	0.2% yield strength (MPa)	Tensile strength (MPa)	Elongation (%)	Hardness	
					HB	HRC
Lean Duplex	NSSC 2120™	≥400	≥600	≥30	≤290	≤32
	S82122	≥400	≥600	≥30	≤290	≤32
	S32304	≥400	≥600	≥25	≤290	≤32
Standard Duplex	NSSC™ 2351	≥400	≥600	≥25	≤277	≤29
	S82561	≥485	≥690	≥18	≤302	≤32
	S31803	≥450	≥620	≥25	≤293	≤31
	S32205	≥450	≥655	≥25	≤293	≤31
Super Duplex	S32750	≥550	≥795	≥15	≤310	≤32
Austenitic	TYPE304	≥205	≥515	≥40	≤201	-
	TYPE316L	≥170	≥485	≥40	≤217	-
	TYPE317L	≥205	≥515	≥40	≤217	-
	S31254	≥310	≥655	≥35	≤223	-

(1MPa=1N/mm<sup>2</sup>)

Cold-rolled sheet and strip

Classification	Grade	Thickness (mm)	0.2% yield strength (MPa)	Tensile strength (MPa)	Elongation (%)	Hardness		
						HB	HRC	HV
Lean Duplex	NSSC 2120™	<3.0	≥500	≥700	≥25	≤290	≤32	≤320
		≥3.0	≥400	≥600	≥30	≤290	≤32	≤320
	S82122	<3.0	≥500	≥700	≥25	≤290	≤32	-
		≥3.0	≥400	≥600	≥30	≤290	≤32	-
Standard Duplex	S32304	-	≥400	≥600	≥25	≤290	≤32	-
		-	≥400	≥600	≥25	≤290	≤32	-
	NSSC™ 2351	<2.0	≥400	≥600	≥20	≤302	≤32	≤320
		≥2.0	≥400	≥600	≥20	≤277	≤29	≤292
		-	≥485	≥690	≥18	≤302	≤32	-
Super Duplex	S32750	-	≥450	≥620	≥25	≤293	≤31	-
		-	≥450	≥655	≥25	≤293	≤31	-
		-	≥550	≥795	≥15	≤310	≤32	-
Austenitic	TYPE304	-	≥205	≥515	≥40	≤201	-	-
	TYPE316L	-	≥170	≥485	≥40	≤217	-	-
	TYPE317L	-	≥175	≥480	≥40	≤187	-	-
	S31254	<5.0	≥310	≥690	≥35	≤223	-	-

(1MPa=1N/mm<sup>2</sup>)

Hot-rolled sheet and strip

Classification	Grade	Thickness (mm)	0.2% yield strength (MPa)	Tensile strength (MPa)	Elongation (%)	Hardness		
						HB	HRC	HV
Lean Duplex	NSSC 2120™	>2.0	≥400	≥600	≥25	≤290	≤32	≤320
		≥3.0	≥400	≥600	≥30	≤290	≤32	-
		-	≥400	≥600	≥25	≤290	≤32	-
Standard Duplex	NSSC™ 2351	<6.0	≥400	≥600	≥20	≤277	≤29	≤292
		≥6.0	≥400	≥600	≥25	≤277	≤29	≤292
	S82561	-	≥485	≥690	≥18	≤302	≤32	-
		-	≥450	≥620	≥25	≤293	≤31	-
		-	≥450	≥655	≥25	≤293	≤31	-
Super Duplex	S32750	-	≥550	≥795	≥15	≤310	≤32	-
Austenitic	TYPE304	-	≥205	≥515	≥40	≤201	-	-
	TYPE316L	-	≥170	≥485	≥40	≤217	-	-
	TYPE317L	-	≥175	≥480	≥40	≤187	-	-
	S31254	<5.0	≥310	≥690	≥35	≤223	-	-

(1MPa=1N/mm<sup>2</sup>)

Wires and rods

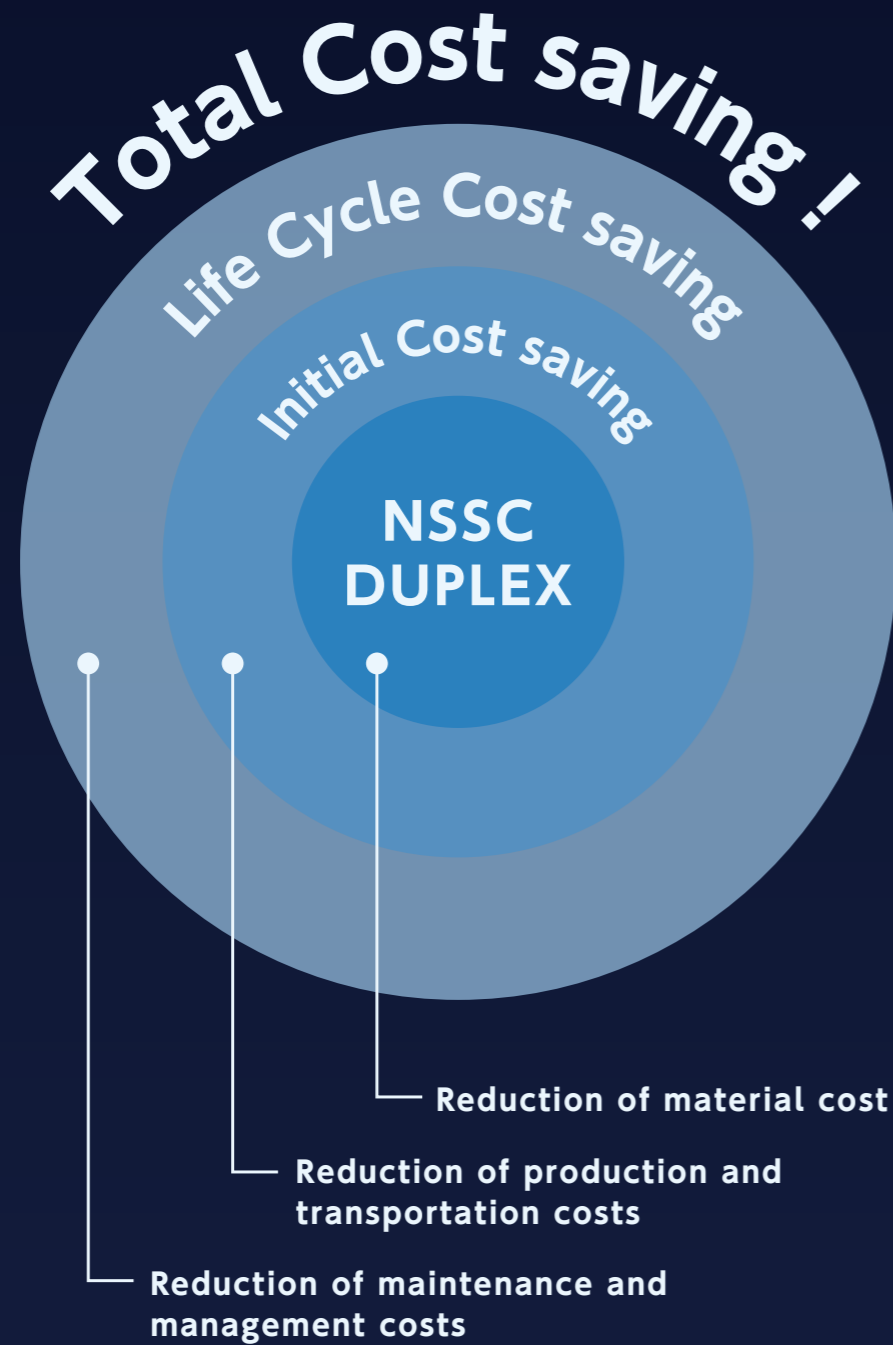
Classification	Grade/UNS	Diameter (mm)	0.2% yield strength (N/mm <sup>2</sup> )	Tensile strength (N/mm <sup>2</sup> )	Elongation (%)	Reduction of area(%)	Hardness		
							HB	HRC	HV
Lean Duplex	NSSC 2120™	≤φ75	≥400	≥600	≥25	≥40	≤290	≤32	≤310
	SUS821L1	≤φ75	≥400	≥600	≥25	≥40	≤290	≤32	≤310
	SUS323L	-	≥400	≥600	≥25	≥40	≤290	≤32	≤310
Standard Duplex	SUS329J1	-	≥390	≥590	≥18	≥40	≤277	≤29	≤292
	SUS329J3L	-	≥450	≥620	≥18	≥40	≤302	≤32	≤320
	TYPE31803	-	≥450	≥620	≥18	≥40	≤302	≤32	≤320
	TYPE32205	-	≥450	≥620	≥18	≥40	≤302	≤32	≤320
	SUS329J4L	-	≥450	≥620	≥18	≥40	≤302	≤32	≤320
Super Duplex	SUS327L1	≤φ50.8	≥550	≥800	≥15	≥40	≤310	≤32	≤330
		>φ50.8	≥515	≥760	≥15	≥40	≤310	≤32	≤330
Steel for welding	ER2209	-	-	-	-	-	-	-	-
Austenitic	TYPE304	-	≥205	≥520	≥40	≥60	≤187	-	≤200
	TYPE316L	-	≥175	≥480	≥40	≥60	≤187	-	≤200
	TYPE317L	-	≥175	≥480	≥40	≥60	≤187	-	≤200

(1MPa=1N/mm<sup>2</sup>)



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