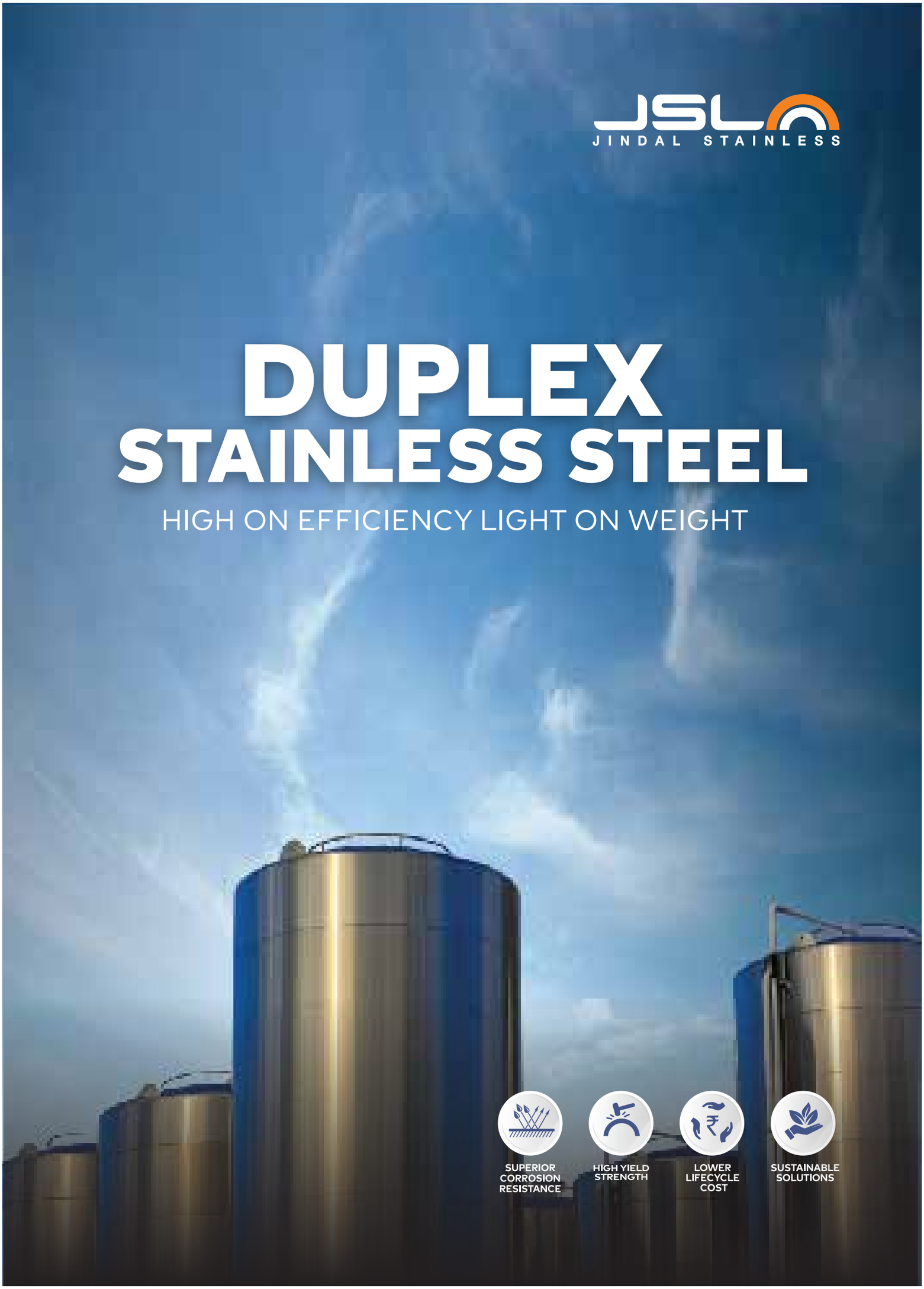
JSL
JINDAL STAINLESS

DUPLEX STAINLESS STEEL

HIGH ON EFFICIENCY LIGHT ON WEIGHT



A LEGACY
BUILT ON SAFETY & TRUST

Founded by Shri O.P. Jindal in 1970, Jindal Stainless is one of the largest stainless steel conglomerates in India and ranks amongst the top 10 stainless steel conglomerates in the world. Jindal Stainless Group has an annual crude steel capacity of 3 MTPA and an annual turnover of $4.2 billion USD (as on Mar'2023).

Our growth has been backed by the excellence of our people, value driven business operations, customer centricity, adoption of one of the best safety practices in the stainless steel industry and a commitment for social responsibility.

DUPLEX
STAINLESS STEELS

As industries are evolved and encountered more demanding applications, the limitations of conventional stainless steels became apparent. While austenitic stainless steels offered excellent corrosion resistance, they often lacked the necessary strength for certain applications. Ferritic stainless steels, on the other hand, provided better strength but exhibited lower corrosion resistance in aggressive environments, especially those containing chlorides.

Duplex stainless steel is a unique class of stainless steel that offers a combination of excellent mechanical properties and superior corrosion resistance. This family of alloys is known for its exceptional strength, ductility, and resistance to a wide range of corrosive environments, making it a preferred choice for various applications in industries such as oil and gas, chemical processing, marine engineering, and more.

There are several varieties of duplex stainless steels, each with its own unique composition and properties tailored to specific applications. The following are some of the most common types of duplex stainless steels:

	UNS	EN 10088	PREN
LEAN DUPLEX	UNS S32101	EN 1.4162	26
	UNS S32304	EN 1.4362	26
REGULAR DUPLEX	UNS S31803	EN 1.4462	34
	UNS S32205	EN 1.4462	35
SUPER DUPLEX	UNS S32760	EN 1.4501	41
	UNS S32750	EN 1.4410	41

THE DUPLEX STRUCTURE
GIVES A COMBINATION OF ATTRACTIVE PROPERTIES

Corrosion Resistance: Duplex stainless steels offer excellent resistance to various corrosive environments, including chloride-induced pitting and crevice corrosion. This makes them suitable for applications in offshore oil and gas platforms, chemical processing plants, and marine environments.

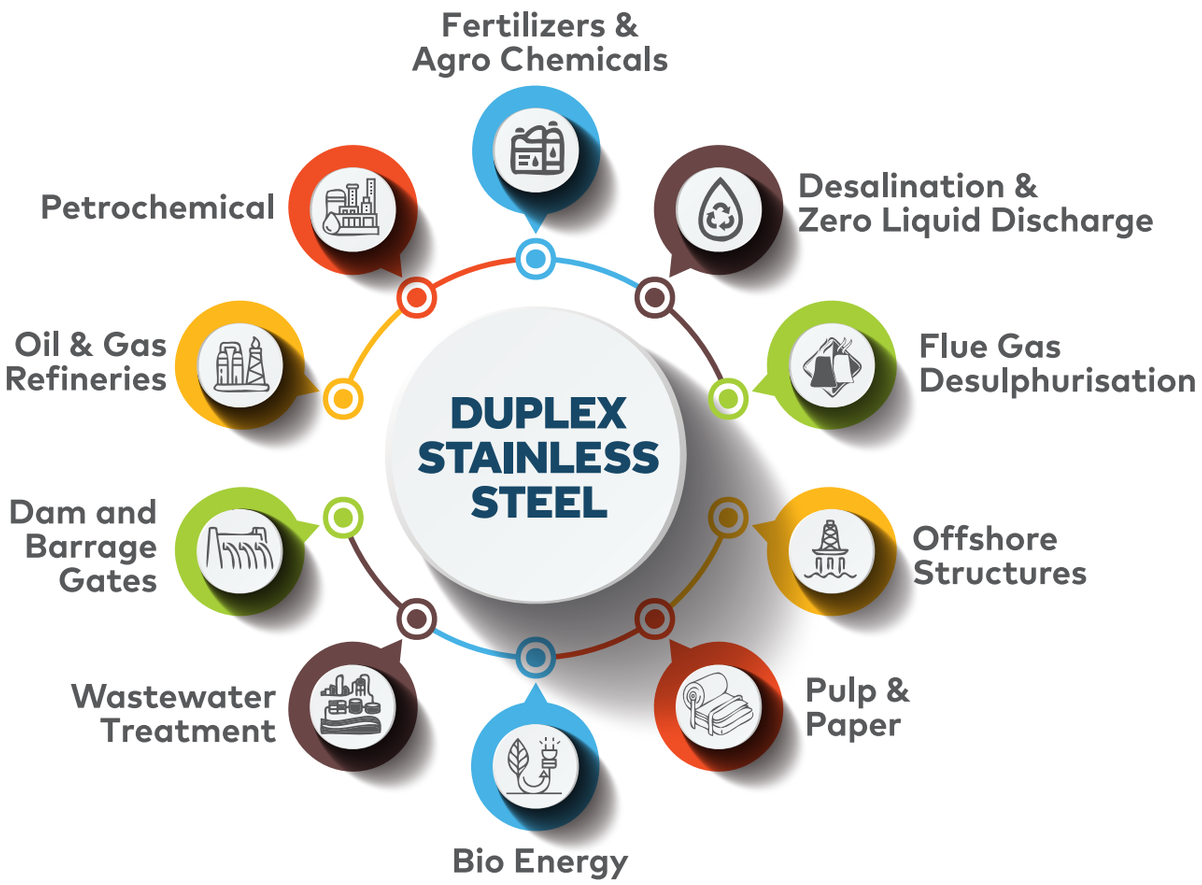
Strength: With higher mechanical strength compared to austenitic stainless steels, duplex stainless steels allow for thinner sections while maintaining structural integrity. This property is advantageous for reducing material costs and weight in engineering applications.

Toughness: The combination of ferrite and austenite phases results in improved toughness and ductility. This makes duplex stainless steel more resistant to brittleness and fracture under impact or sudden temperature changes.

Stress Corrosion Cracking Resistance: Duplex stainless steels exhibit better resistance to stress corrosion cracking compared to austenitic stainless steels, particularly in chloride-containing environments. This makes them suitable for applications where high tensile stresses are present, such as in pipelines and pressure vessels.

Weldability: While welding can potentially alter the balance between austenite and ferrite phases, leading to reduced corrosion resistance or toughness, modern welding techniques and filler materials have improved the weldability of duplex stainless steels.

Cost-Efficiency: While duplex stainless steels are more expensive than conventional austenitic stainless steels, they often provide cost savings due to their superior strength, which allows for reduced material thickness and weight.



CERTIFICATIONS

LEAN DUPLEX
UNS S32101, UNS S32304

Lean Duplex Stainless Steel offers high strength coupled with corrosion resistance as compared to austenitic grade like 316L. This grade has a stable cost owing to low nickel and molybdenum content.

Lean Duplex can substitute standard austenitic grade like 304/304L, 316/ 316L in most environments.

CHEMISTRY

UNS	EN	C%	Cr%	Ni%	Mo%	N%	Mn%	Cu%
S32101	1.4162	≤0.04	21.0-22.0	1.35-1.70	0.10-0.80	0.20-0.25	4.00-6.00	0.10-0.80
S32304	1.4362	≤0.03	21.5-24.5	3.0-5.5	0.05-0.60	0.05-0.20	≤2.50	0.05-0.60

MECHANICAL PROPERTIES (AS PER ASTM 240):

UNS	YS(MPa)	UTS(MPa)	%Elongation	Hardness(BHN)
S32101 (t>5mm)	450 min	650 min	30 min	290 max
S32101 (t<5mm)	530 min	700 min	30 min	290 max
S32304	400 min	600 min	25 min	290 max

TYPICAL VALUE OF MECHANICAL PROPERTIES

UNS	YS(MPa)	UTS(MPa)	%Elongation	Hardness (BHN)
S32101	**550**	**750**	**35**	**220**
S32304	**480**	**665**	**30**	**215**

LEAN DUPLEX
IN WATER AND WASTEWATER

Lean duplex stainless steel can offer several advantages over SS316 in terms of corrosion resistance, strength, and cost-effectiveness, making it a potentially superior choice for certain applications with in a waste water treatment plant.

Lean duplex stainless steel typically provides better corrosion resistance than SS316, especially in environments with higher levels of chlorides and aggressive chemicals commonly found in waste water. The enhanced corrosion resistance can result in longer service life and reduced maintenance costs.

Lean duplex stainless steel generally has higher mechanical strength compared to SS316. This can be beneficial for structural components and equipment that need to withstand mechanical stresses and pressures in a wastewater treatment plant.

Being a price stable grades owing to low nickel and molybdenum contents, along with its superior mechanical properties and good corrosion resistance, Lean Duplex is ideal for use in various applications thus providing durability and long-term cost efficiency.

GIVEN THEIR LOW NICKEL CONTENT, HOW DO LEAN DUPLEXES WORK SO WELL?

The behaviour of stainless steel in terms of corrosion is mostly influenced by its chromium concentration. The stronger the chromium oxide layer is and the more it is able to shield the metal from the start of corrosion, the higher it is. Industrial stainless steel production techniques have improved, allowing us to combine the finest qualities of both worlds: great corrosion resistance due to the possibility of raising the chromium percentage while maintaining excellent mechanical properties.

LEAN DUPLEX
IN PETROCHEMICAL
GREATER WEIGHT SAVINGS!

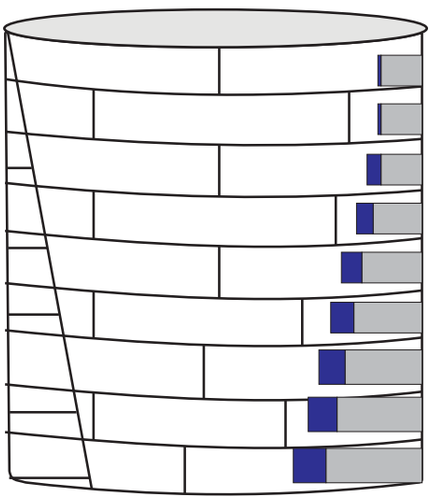
Allowable stress plays a significant role in determining the weight savings that can be achieved in a silo construction, regardless of the material used, including lean duplex stainless steel. Lean duplex stainless steel are preferred material for the silo for its higher strength compared to some other materials.

Combined with its corrosion resistance, allows for the possibility of designing with higher stress levels while still maintaining safety. This can result in weight savings due to reduced material usage.

Lean duplex stainless steels are generally more resistant to stress corrosion cracking (SCC) than standard austenitic stainless steels. This property is crucial in applications where materials are subjected to both corrosion and mechanical stress, which is common in the petrochemical industry.

A sample calculation have been shown to compare the weight reduction in the shell plate of an API tank. The Allowable stress tank shells of SS304L is 44% less than that of the lean duplex UNS S32101 which would offer considerable weight saving as illustrated.

It's important to note that while weight savings can be a significant consideration, other factors must also be taken into account. A comprehensive engineering analysis, possibly involving finite element analysis (FEA) and consultation with materials experts, will provide a clearer understanding of the potential weight savings achievable with lean duplex stainless steel in a given silo application.



Lean Duplex UNS S 32101
Design stress = 260 MPa

Austenitic SS304L
Design stress = 145 MPa

REGULAR DUPLEX
UNS S31803, UNS S32205

Duplex, also known as UNS S31803/S32205, is one of the most commonly used grades of duplex stainless steel. It is highly regarded for its excellent combination of corrosion resistance, high strength, and good weldability.

While Duplex 2205 may be more expensive than 316/316L upfront however its superior corrosion resistance and strength can result in cost savings over time by reducing maintenance and replacement costs.

Duplex stainless steel is employed in various components, including pressure vessels, piping, heat exchangers, and reaction vessels. Proper material selection, fabrication, and maintenance practices are essential to ensure the reliability and performance of equipment.

CHEMISTRY

UNS	EN	C%	Cr%	Ni%	Mo%	N%	Mn%
S31803	1.4462	≤0.03	21.0-23.0	4.50-6.50	2.50-3.50	0.08-0.20	≤2.00
S32205	1.4462	≤0.03	22.0-23.0	4.50-6.50	3.00-3.50	0.14-0.20	≤2.00

MECHANICAL PROPERTIES (AS PER ASTM 240):

UNS	YS(MPa)	UTS(MPa)	%Elongation	Hardness(BHN)
S31803	450 min	620 min	25 min	293 max
S32205	450 min	650 min	25 min	293 max

TYPICAL VALUE OF MECHANICAL PROPERTIES

UNS	YS(MPa)	UTS(MPa)	%Elongation	Hardness (BHN)
S31803	**625**	**775**	**30**	**228**
S32205	**625**	**775**	**30**	**228**

DUPLEX IN HIGH
PRESSURE UREA SYNTHESIS

Due to the high pressures and temperatures involved in urea production as well as the extremely corrosive process environment that necessitates

oxygen to prevent active corrosion, the urea production is complicated and corrosive in nature.

In urea stripping the carbamate is decomposed into ammonia and carbondioxide. This separation is carried out under harsh and unfavourable circumstances, including high pressure, high temperature, a solution with a high degree of corrosion potential, and the existence of both liquid and vapour phases, which is always a potential source of corrosion, at nearly the same pressure as in the reactor.

Austenitic like 316L and 310 have been used in urea production and is still practised widely however the austenitic are susceptible to SCC by chlorides.

The choice of material is crucial from the beginning of the design process onward. Poor material choice can result in catastrophic failures and plant outages. In view of the corrosion challenges the designers have begun to refer the use of Duplex 2205 and Super Duplex Grades in view of suitable material that could offer price optimisation.

SUPER DUPLEX
UNS S32750, UNS S32760

Super duplex stainless steels typically contain higher levels of alloying elements compared to standard duplex stainless steels like Duplex 2205.

Super Duplex excellent corrosion resistance makes it a suitable application for highly corrosive application like brine, seawater and is the designer's choice for material for higher reliability with optimised cost.

CHEMISTRY

UNS No.	EN	C%	Cr%	Ni%	Mo%	N%	Mn%	Cu%	W%
S32750	1.4410	<0.03	24.0-26.0	6.0-8.0	3.0-5.0	0.24-0.32	<1.20	<0.50	-
S32760	1.4501	<0.03	24.0-26.0	6.0-8.0	3.0-4.0	0.20-0.30	<1.00	0.50-1.00	0.5-1.0

MECHANICAL PROPERTIES (AS PER ASTM 240):

UNS	YS (MPa)	UTS (MPa)	% Elongation	Hardness(BHN)
S32750	550 min.	795 min.	15 min.	310 max.
S32760	550 min.	750 min.	25min.	310 max.

TYPICAL VALUE OF MECHANICAL PROPERTIES

UNS	YS (MPa)	UTS (MPa)	% Elongation	Hardness(BHN)
S32750	585	826	25	260
S32760	640	820	35	240

SUPER DUPLEX
IN DESALINATION & ZERO LIQUID DISCHARGE

Creating a green and environmentally friendly environment without relying on chemical paints and plastics involves adopting sustainable alternatives like Super Duplex that assures reliability, longevity, safety offering plant owners and operators achieve their greener goals.

Super duplex stainless steel can be used in various Desalination and Zero Liquid Discharge components, including:

Reverse Osmosis (RO) Systems: Components such as high-pressure piping, RO membrane housings, and high-pressure pumps, valves

Multi-Effect Distillation (MED) and Multi-Stage Flash (MSF) Systems: Heat exchangers, evaporators, and distillation chambers.

Brine Concentrators: Components handling concentrated brine streams.

Evaporators: These are used to concentrate the waste solution by removing water through evaporation. Super duplex stainless steel is suitable for the construction of evaporator tubes, heat exchanger plates, and vessels.

Crystallizers: Crystallization processes are used to precipitate solids from the concentrated solution. Super duplex can be used for crystallizer vessels and associated piping.

Solvent recovery strippers: Used for recovering solvents by providing air. Super duplex stainless steel's resistance to corrosion and high temperatures makes it suitable for constructing distillation columns used in the separation and recovery of solvents.

Raw Effluent or Seawater: Intake Pipelines, Inlet screens are used in Super Duplex Stainless Steel. Super Duplex does not breakdown or degrades in UV.

Offshore Structures: Structural components, platforms, and supports in desalination plants located near the coastline

DUPLEX IN PRESSURE
VESSELS & EQUIPMENT

Manufactures of chemicals, petrochemicals, Fertilizers and oil & gas production often exposes the processing equipment to highly corrosive fluids. Analyses of the fluids, pressures, and process temperatures have shown Duplex Stainless Steel Pressure Vessels to be highly corrosion-resistant in many of these extreme environments.

In these applications, aggressive fluids come into contact with interior surfaces of the equipment used in the process. Consideration must be given to the effects of process chemistry on the material of construction. Otherwise, manufacturing conditions will rapidly decline, leading to corrosion, and ultimately compromising equipment usefulness and endangering the entirety of the process line. When this occurs, proper action requires repair and/or replacement of equipment, causing expensive and disruptive downtime of the process.

With their multitude of applications, the process industries are always in pursuit of the most cost-effective and reliable materials. Duplex Stainless Steel pressure vessels are widely endorsed by plant operations management and maintenance specialists who acknowledge their durability and corrosion resistance against very aggressive fluids.

Specification of Duplex Stainless Steel as the material of construction for pressure vessels offers a long term, cost effective method to prevent damaging corrosion, thus eliminating leaks to the process.

A Duplex Stainless Steel Pressure Vessel will possess strong corrosive resistance to localized corrosion, cracking, and stress corrosion.

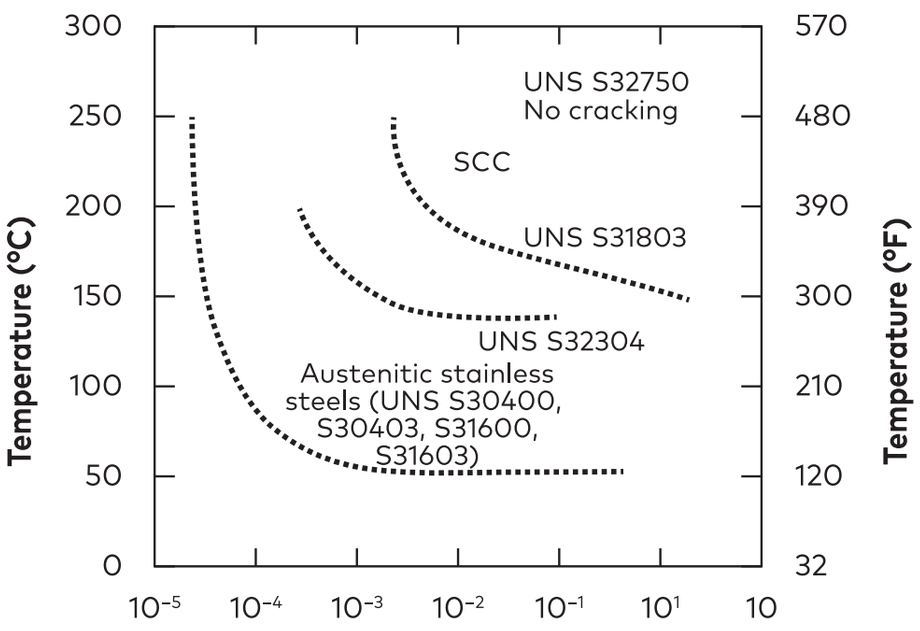
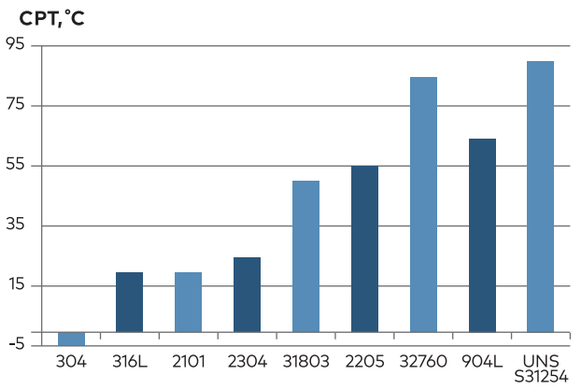


Figure 5: Stress corrosion cracking resistance of Duplex Stainless Steels

Critical Pitting Temperature (CPT)

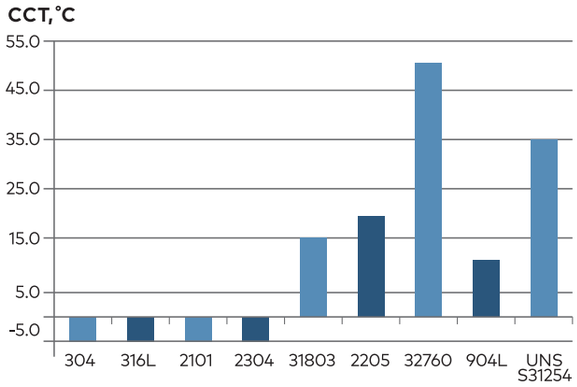
Pitting corrosion has to be taken into account for applications involving chloride ions. The CPT is defined as the minimum temperature to produce pitting attack generally measured in a ferric chloride solution according to ASTM G48E. The lean duplex S32201 is more resistant to pitting corrosion than the standard austenitic grades 304L and 316L. S32205 has an equivalent resistance to 904L, while the 25%Cr super-duplex grades present the same pitting resistance as some of the more alloyed UNS S31254 (6% MOLY) super-austenitic materials.



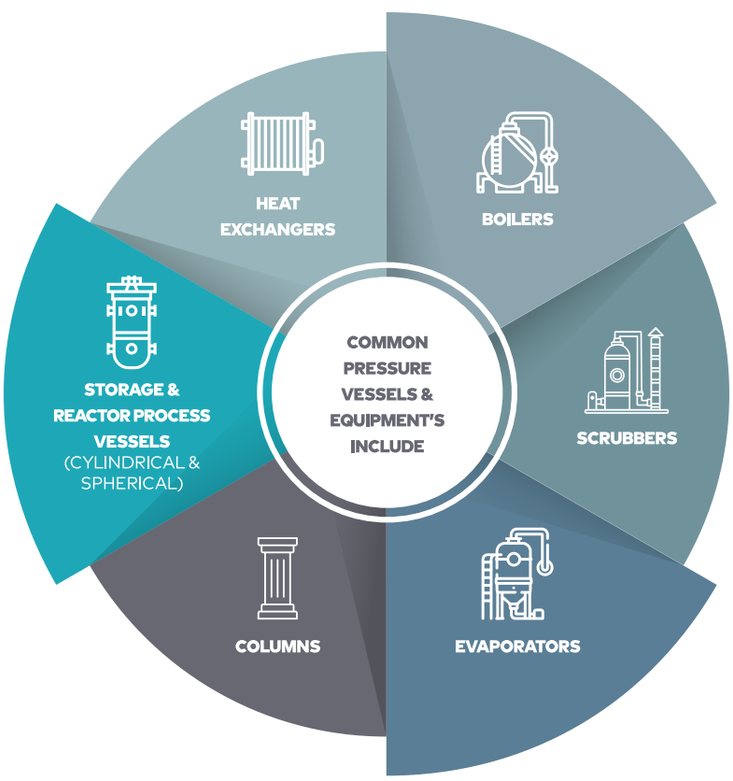
Critical Pitting Corrosion: (As per ASTM G150)

Critical Crevice Temperature (CCT)

Crevice corrosion has to be taken into account when confined areas are likely to be formed (for instance under deposit, flanges, gaskets. S32205 offers a significantly higher resistance to crevice corrosion than the standard austenitic steels including 904L. S32760 presents an equivalent resistance to some 6%Mo super-austenitic grades.



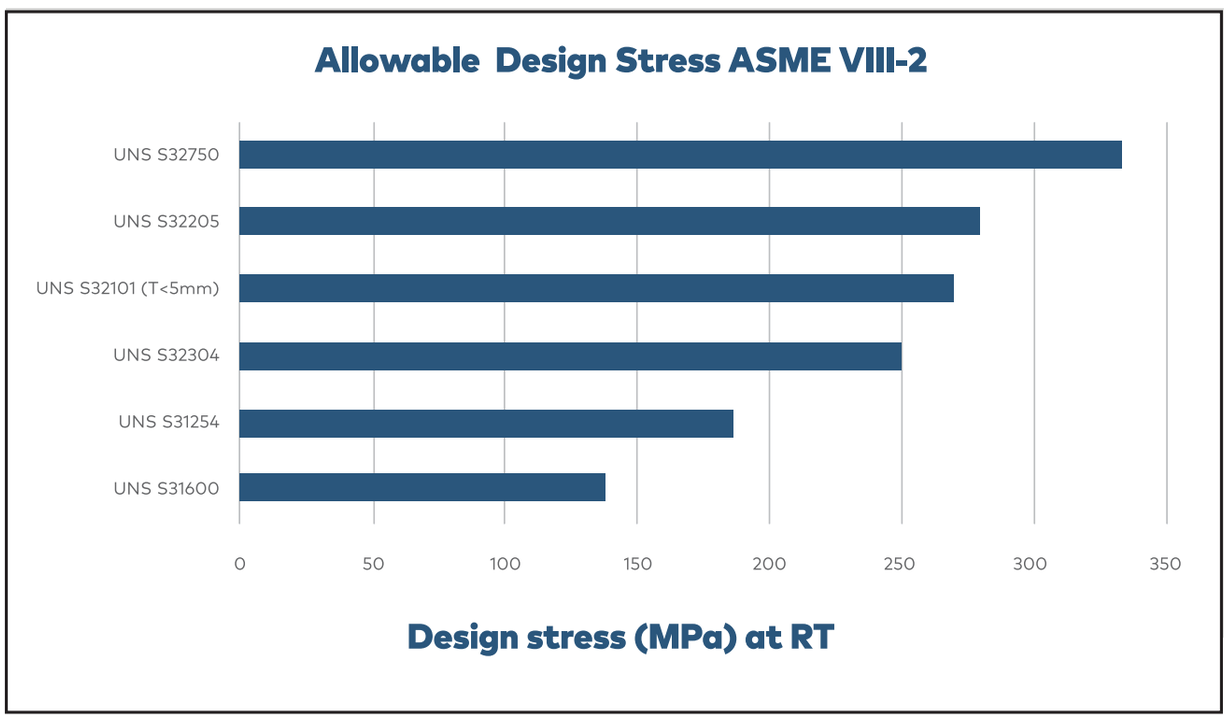
Critical Crevice Corrosion: (As per ASTM G48 Method F)



SNAPSHOT OF VARIOUS STANDARDS W.R.T DUPLEX GRADES

Global design codes and standards such as ASME VIII Div.1, PD5500, EN13445, API 650 and many others allow the use of Duplex Stainless Steels for fabrication of various Pressure Vessels & Equipment's. Snapshot of maximum Allowable Design stress.

Grade	ASME VIII (MPa) (At 20 °C)	PD 5500 (MPa) (At 20 °C)	EN13445 (MPa) (At 20 °C)	API 650 (MPa) (At 40 °C)
UNS S32101	186	-	271	260
UNS 32304	172	-	263	240
UNS S32205	187	289	267	262
UNS S31803	177	289	267	248
UNS S32750	228	319	304	318
UNS S32760	214	319	304	298
UNS S31603 (316L)	115	135	173	145
UNS S31600 (316)	138	160	173	155



WELDING OF DUPLEX STAINLESS STEELS

Welding conditions required for duplex stainless steels depends on thickness of the plates that is welded and also of their chemical composition. So the welding parameters should be set accordingly with following rules:

Heat input: Here an optimum value results comes in between need for rather slow cooling below melting point and that of fast cooling below of nearly 1000°C.

Filler metal composition: In this, we have higher Ni content than base metal, so that it can help the formation of austenite. However nitrogen content is lower than base metal to reduce its potential for the precipitation of chromium nitrides.

Shielding gas: It can contain nitrogen but in all cases, moisture and hydrogen should be avoided.

Preheating should be avoided. If necessary, the temperature can be taken in about 100°C.

For lean and standard duplex, the requirement for maximum interpass temperature is mainly at 150°C. For super duplex maximum interpass temperature is at 100°C. Stress relief treatment at a low temperature of nearly 600-650°C must be avoided. For Post-weld heat treatment, solution annealing should be done followed by the fast cooling.

Processes without filler metal like spot welding should also be avoided.

TABLE 1: DUPLEX STAINLESS STEELS (DSS) WITH RECOMMENDED WELDING FILLER

Grade	ASTM	EN	Chemical composition (in wt%)					
			C	N	Cr	Ni	Mo	Mn
2101	S32101	1.4162	0.02	0.22	21.5	1.5	0.3	5
Filler 2101	-	-	0.03	0.16	23.5	7	<0.5	0.8
2304	S32304	1.4362	0.02	0.10	23	4	<0.3	1.5
Filler 2304	-	-	0.02	0.12	24.5	8	<0.3	0.8
2205	S32205	1.4462	0.02	0.17	22	5.5	3.1	1.5
Filler 2205	E2209	-	0.02	0.16	23	9.5	3.2	0.8
2507	S32750	1.4410	0.02	0.27	25	7	4	1.5
Filler 2507	E2594	-	0.03	0.23	25.5	10	4	1.2

TABLE 2: SHIELDING GASES IN DSS WELDING

Method	Grades	Shielding Gas
GMAW	2101, 2304, 2205	Ar + 1-2% CO^2 or Ar + 1-3% CO^2 Ar + 1-2% CO^2 or Ar + 2-3% CO^2
	2507	Ar + 1-2% CO^2 or Ar + 1-3% CO^2 Ar Ar + 30% He + 1-2%N2+1-2%CO^2
GTAW	2101, 2304, 2205, 2507	2101, 2304, 2205, 2507Ar + 10-30% He + 2% N_2 Ar
FCAW	2101, 2304, 2205	Ar + 16-25% CO^2 100% CO^2
Plasma	2101, 2304, 2205, 2507	Ar* Ar + 20-30% He + 1-2% N2* *also as plasma gas
Laser	2101, 2304, 2205, 2507	Ar

General guidelines:

- ✓ Gas flow should be MIG 12-16 l/min
- ✓ Gas flow of TIG 8-12 l/min
- ✓ A too low or too high flow may result in porosity

TABLE 3: RECOMMENDED PARAMETERS OF DSS AND SDSS FOR DIFFERENT PROCESSES:

Process	Material	Filler dia. (mm)	Bead	Current (A)	Voltage (V)	Speed (cm/min.)
MMA	2205	2.50	Root	50-60	20-22	4-6
		3.25	Cap	80-95	23-25	7-9
MMA	2507	4.00		125-135	24-26	15-25
MIG	2205	1.20		180-200	28-30	30-40
TIG	2205	1.60	Root	45-50	9-10	3-5
TIG	2205	2.40	Root	100-120	16-18	5-8
FCAW		1.20	Cap	190-210	28-30	17-22
SAW	2205	3.20		400-450	30-32	40-50
SAW	2507	2.40		350-400	28-30	40-50
FCAW	2205	1.20	Root	135-145	24-26	20-25
FCAW			Cap	200-220	28-30	30-45

Filler Material Selection in Dissimilar Welds

Duplex stainless steel can be welded with other duplex stainless steels, with austenitic stainless steels and with carbon and low alloy steels. To weld duplex stainless steels with other duplex grades, most frequently used method is duplex stainless steel filler material, in which nickel content is more as compared to its base metal. Adequate level of austenite formation in the weld during cooling is ensured through increased nickel content in filler material.

Welding to austenitic grades requires austenitic filler metals, which has low carbon and molybdenum content intermediate between two steels that are typically used. AWS E309LMo/ER309LMo is also used to join duplex stainless steels to carbon and with low alloy steels. Nickel –base filler metals can also be used when it is free of niobium (columbium). This is due to the fact that austenitic stainless steels have lower strength than the duplex. Hence, weld joints which is made with the austenitic filler metals will not be stronger then duplex base metal.

Welding of duplex stainless steels with other dissimilar metals requires following filler metals as shown in table 5. Depending on process, joint geometry and other possible considerations, bare wire (AWS designation ER) and flux cored wire can be considered. However the given examples show the usage of AWS SMAW electrode designation 'E'.

TABLE 4
WELDING CONSUMABLES USED FOR DISSIMILAR METAL WELDING

Type	Lean Duplex	Standard Duplex	Super Duplex
Lean Duplex	E2307 E2209 E309L	E2209	E2209
Standard Duplex	E2209	E2209	E2594
Super Duplex	E2209	E2594	E2594
304/304L	E2209 E309L E309LMo	E2209 E309LMo	E2209 E309LMo
316L	E2209 E309LMo	E2209 E309LMo	E2209 E309LMo
Carbon Steel Low Alloy Steel	E2209 E309L E309LMo	E2209 E309L E309LMo	E2209 E309L E309LMo

Jindal Stainless emphasizes on providing hands-on training to industrial and general stainless steel fabricators across the nation through its monthly fabrication training programmes and workshops.

Please contact your Local Jindal Stainless Ltd. reprsentative for further details.

APPLICATIONS


SILOS


PRESSURE VESSEL


SUNSHINE SKYWAY BRIDGE


EVAPORATOR


DAM GATES


50 YEARS
USA
Germany
Belgium
Spain
Turkey
Italy
India
South Korea
Taiwan
UAE
Vietnam
Singapore
Indonesia
Brazil
International Sales Offices
Manufacturing Facilities
INDIA'S NO.1 STAINLESS STEEL BRAND WITH GLOBAL FOOTPRINT
Supplier to over 32 Sectors in India
Worldwide Presence
Trusted Export Partner for 21 Years

MANUFACTURING FACILITIES

COMMITTED TO NET ZERO

- Net Zero emission by 2050 and 50% reduction in emissions by 2035
- Committed to taking Science Bases Target Initiative (SBTi) in our net zero journey in compliance with the Paris Agreement
- Responsible steel site certification: JSL is well underway towards achieving site certification from responsible steel

EFFICIENCY

- Achieved ~3.1 lakh tCO_2e reduction over FY22–24through carbon-saving initiatives.
- Earned 30K+ E-Certificates by exceeding targets in PAT Cycles 1 & 2.
  - PAT Cycle 1: 12,687
  - PAT Cycle 2: 21,270

RENEWABLE

- 7.3 MWp floating solar plant installed in Jajpur
- 4.2 MWp roof-top solar plant installed in Hisar
- 28 MWp rooftop solar plant being installed in Jajpur and Hisar
- Replaced fossil fuels with biofuels at Hisar Hot Rolling Mill, enabling 45,000+ tCO_2e abatement

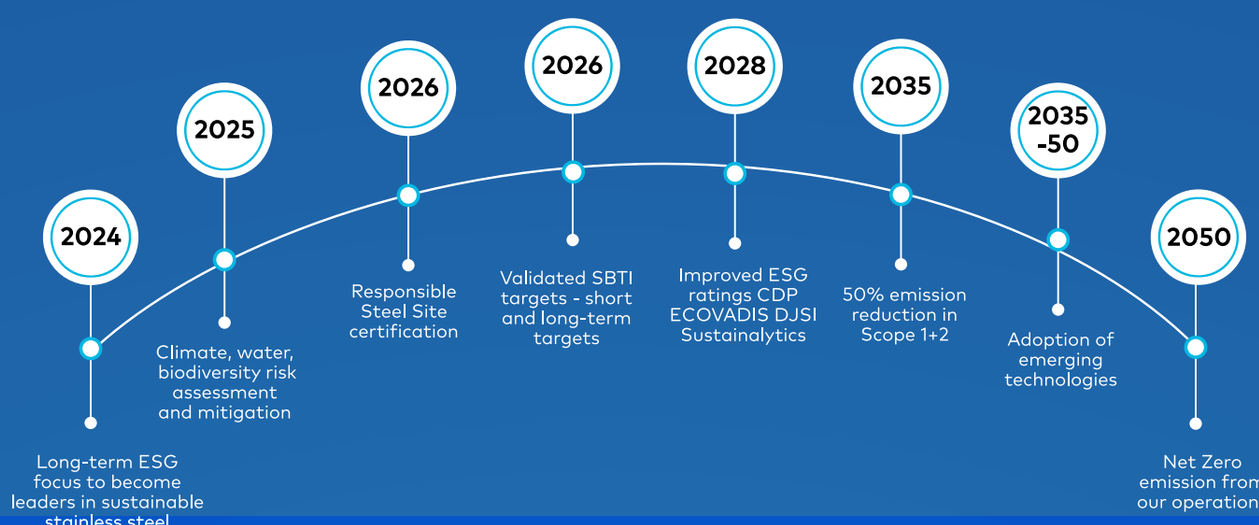
(ROUND THE CLOCK)

- MoU with ReNew Power for 100 MW RTC renewable energy at Jajpur, cutting 4.35+ lakh tCO_2e annually
- Second MoU signed for 100 MW RTC renewable power at Hisar, with similar CO_2 abatement.
- All future power needs at JSL to be met with renewable sources.

HYDROGEN

- JSL commissions domestic stainless steel industry's first green hydrogen project for captive use.
  - Currently used in one HBA line, with plans for full rollout.
  - CO2 reduction potential of 2700 tCO2 annually
  - All existing HBA lines to move to Green Hydrogen by FY28

OUR SUSTAINABILITY ROAD MAP



ENDLESS SUSTAINABLE STAINLESS STEEL SOLUTIONS

Odisha's 1st Fully Captive Floating Solar Power Plant (Capacity 7.3 MW)

300 MW of Hybrid Renewable Energy Projects

India's 1st Stainless Steel Company with a Green Hydrogen Plant

Electric Vehicles at Jajpur Plant

JINDAL STAINLESS

Jindal Stainless Centre
Plot No-50, Sector 32, Gurugram - 122001
www.jindalstainless.com