Ferritic Stainless Steels Sheet, Coil & Plate

Providing Solutions in Specialty Metals

Atlas Steels

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Characteristics of “Ferritic” stainless steels

What are Ferritic stainless steels?

- They are straight chromium steels, containing little or no nickel.
- Their crystal structure is “Body Centred Cubic” (bcc), as for ferritic carbon steels (ie. mild steel,galvanised steel etc).
- They resist corrosion and oxidation; they are true stainless steels.
- They are highly resistant to stress corrosion cracking.
- They are fully magnetic.
- They can in many instances be more easily fabricated than austenitic stainless steels such as 304 and 316 grades.
- Their application and fabrication performance can be significantly improved with the addition of the alloying elements of molybdenum, titanium and/or niobium.
- They often prove better value over the product life span than carbon steels and are significantly less costly than nickel-containing, austenitic grades of stainless steel.

What do alloying elements do in stainless steel?

The effect of Chomium

Chromium is the indispensable element that makes stainless steels “stainless”. In amounts of at least 10.5% it forms a very thin, hard self-repairing chromium oxide surface layer which resists corrosive attack. Higher chromium contents give more corrosion resistance. The same chromium oxide layer is also effective in resisting high temperature scaling.

The effect of Nickel

Nickel is added in amounts of 8% or more to all the common austenitic stainless steel grades, such as 304 and 316. The nickel has only a minor effect on the corrosion resistance. The principal reason for adding nickel is to change the crystal structure of the metal from Body Centred Cubic (bcc) to Face Centred Cubic (fcc); this structure is called austenite. Austenitic steels are characterised by very high ductility which improves formability. The austenitic steels also have excellent weldablity, and both good toughness at cryogenic temperatures and strength at very high temperatures and they are also non magnetic.

The effect of Molybdenum

Molybdenum is added to stainless steels because it greatly improves the resistance to pitting and crevice corrosion, particularly from chlorides. An amount of 2% Mo or more is commonly added to steels intended to resist corrosion in marine environments. The higher the molybdenum contents the greater is the corrosion resistance.

The effect of Titanium and Niobium

Titanium and Niobium (also called Columbium) are added to stainless steels because they are very strong carbide formers. They bind the carbon which could otherwise cause sensitisation and intergranular corrosion and thus improve the weldability of stainless steel.

Ferritic compared to Austenitic stainless steel

Ferritic Stainless Steel	Austenitic Stainless Steel
Magnetic	Non-magnetic
Low thermal expansion (similar to carbon steel)	Higher thermal expansion
Excellent high temperature oxidation resistance	Good high temperature oxidation resistance
Higher thermal conductivity	Lower thermal conductivity
Excellent creep resistance when stabilised with niobium	Good cheap resistance
Easier to cut and work, less tool wear	Higher strength, requiring more force to manipulate, and increased tool wear
Less prone to spring back during cold forming	Greater spring back
High yield strength (similar to carbon steel)	Lower yield strength than Ferritic grades
Virtually immune from stress corrosion cracking	Highly susceptible to stress corrosion cracking

Ferritic compared to Duplex stainless steel

Duplex grades have compositions balanced to give a structure of about 50% ferrite and 50% austenite and therefore have some properties that are mid-way between the two types. Their thermal expansion for instance is between that of the ferritic and austenitic grades, and their resistance to stress corrosion cracking is higher than that of an austenitic but not quite as good as for the ferritic. The duplex grades do however tend to have higher strengths than either of the other types. As for all stainless steel grades the pitting resistance is very largely determined by the content of chromium, molybdenum and nitrogen – the actual structure is not important.

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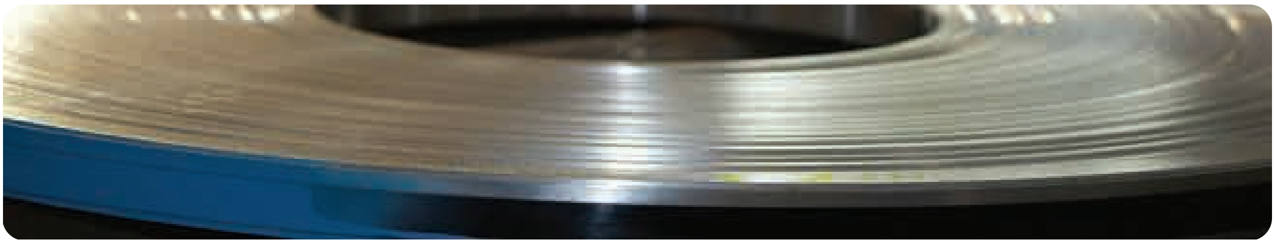

The range of Ferritic stainless steel grades and codes

Five "groups" of Ferritic stainless steels

Ferritic stainless steels can be divided into five "groups", generally segmented by chemical composition which determines the characteristics of the grades such as corrosion resistance and the appropriate applications they can potentially be applied to.

The Atlas range of ferritic grades has been chosen to incorporate at least one grade that is suitable for each of the first four groups. The fifth group is highly specialised in application and therefore may require technical input to make the correct grade selection. Please contact Atlas Technical Services for assistance.

Within Australia:
Telephone Free Call 1800 818 599

Group	Characteristics	Ferritic Grades	Typical Applications
1	10-14% chromium, for non or low corrosive environments, or for non-aesthetic applications	409, AtlasCR12, AtlasCR12Ti	Rail wagons, shipping containers, automotive exhausts, bus and coach frames
2	14-18% chromium content and greater resistance to corrosion over group 1	430	Domestic appliances, indoor panels
3	14-21% chromium content and stabilised to improve weldability and formability. Often an acceptable substitute for grade 304	439, Atlas F20S	Sinks, heat exchangers (sugar industry), automotive exhausts
4	Molybdenum added for extra corrosion resistance. Often an acceptable substitute for grade 316	444	Hot water tanks, solar water heaters, outdoor panels and trims
5	Greater than 21% chromium and added molybdenum for extra corrosion resistance	Refer Atlas Technical Services for assistance in grade selection	Highly corrosive environments

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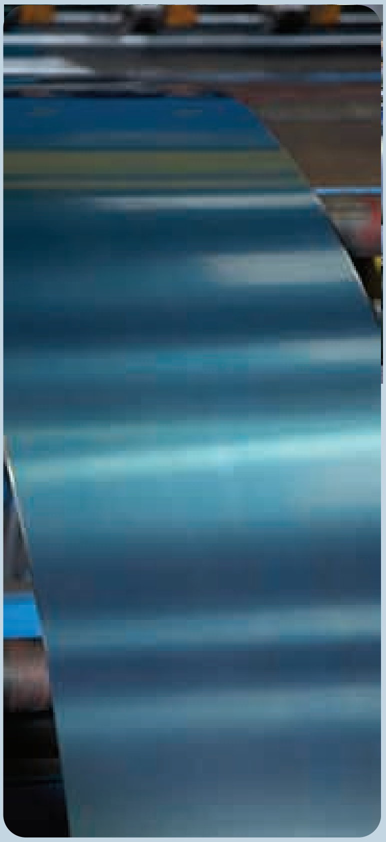
Photo courtesy of Atlas Metal Processors



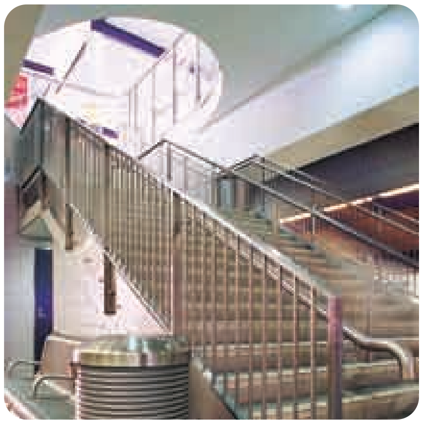
The Atlas range of Ferritic stainless steel flat products

The following table shows the product range of standard ferritic stainless steel sheets, coil and plate available from Atlas.

Ferritic Grade	Group Type	Form	Rolling	Width (mm)	Thickness (mm)	Finish
409	1	Sheet & Coil	CR	On application		
AtlasCR12		Sheet & Coil	CR	1250	1.2, 1.5, 2.0, 2.5	2B
	1	Plate	HR	1500, 2000	8.0, 10.0, 12.0, 16.0, 20.0, 25.0	No.1
AtlasCR12Ti	1	Sheet, Coil & Plate	CR, HR	1250, 1500	3.0, 5.0, 6.0	2B, No1
430	2	Sheet & Coil	CR	914, 1219	0.7, 0.9, 1.2	2B, BA
439	3	Sheet & Coil	CR	On application		
AtlasF20S	3	Sheet & Coil	CR	1219	0.7, 0.9, 1.2. 1.5. 2.0	2B, No.4
444	4	Sheet & Coil	CR	1219, 1500	0.7, 0.9, 1.2. 1.5. 2.0	2B, No.4

Please contact Atlas for enquiries about less common thicknesses and finishes.

Photos courtesy of Atlas Metal Processors and United Group Rail



Considerations in selecting a Ferritic grade to suit an application

Corrosion resistance

Corrosion resistance of stainless steels is determined more by chemical composition than by austenitic or ferritic crystalline structure. Stainless steels are "stainless" because their chromium content gives them exceptional resistance to corrosion. A comparison of the corrosion resistance properties of ferritic and austenitic grades shows that the corrosion resistance of most nickel containing (austenitic) grades can be matched by ferritic grades. In most cases there are also duplex grade alternatives.

These are not covered in this publication, but enquiries are invited.

The following are some useful guidelines for improving the grade selection of ferritic stainless steels in corrosive environments.

- In the case of an aggressive environment, select a grade with a higher chromium and/or molybdenum content.
- The stainless steel grade PRE (pitting resistance equivalent) is a useful guide to its corrosion resistance. The higher the number the more corrosion resistance the steel.
- Avoid rough surface finishes and favour a fine-polished finish with a low Ra value.
- Optimise design for "washability" e.g. min 15° slope on upward facing surfaces.
- Avoid "crevice like" geometries.
- Keep surfaces clean by regular washing to avoid staining and dust accumulation.

Typical Chemical Composition %						PRE
Ferritic Grade	C	Cr	Ni	Mo	Ti + Nb	
409	0.01	11			0.20	11
AtlasCR12	0.02	11.5	0.4			11.5
AtlasCR12Ti	0.02	11.5	0.4		0.20	11.5
430	0.05	16.5				17
439	0.02	17.5			0.35	17.5
AtlasF20S	0.02	21			0.40	21
444	0.02	18		2	0.45	25

PRE = %Cr + 3.3xMo + 16x%N

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Photos courtesy of Cookon and Stoddart.

Mechanical properties

The mechanical properties of a metallic alloy are those that describe the material's ability to compress, stretch, bend, dent and break, and above all the ability of the metal to safely carry a load, pressure or stress in service. Therefore common criteria for evaluating mechanical characteristics are: strength (yield and tensile) hardness, toughness and ductility.

Ferritic stainless steels have:

- Stress-strain curves fairly similar to those of plain carbon steels.
- Moderately high yield strengths (generally higher than austenitic grades).
- Moderately high tensile strengths.
- Good total elongation, but lower than those of the austenitic grades.
- Good ductility, but as for ferritic carbon steels ductility drops at low temperature.

Specified Mechanical Properties %						
Ferritic Grade	Tensile Strength (MPa) min	Yield Strength 0.2% Proof (MPa) min	Elongation (% in 50mm) min	Hardness		Cold Blend Transverse direction bend radius = 1T
				Rockwell B (HR B) max	Brinell (HB) min	
409	380	170	22	88	179	180°
AtlasCR12	455	275	18	HRC20	223	–
AtlasCR12Ti	427	205	22	–	–	–
430	450	205	22	89	183	180°
439	415	205	22	89	183	180°
AtlasF20S	427	205	22	–	–	–
444	415	275	20	96	217	180°

These values are as listed for flat rolled product in ASTM A240M.
Different limits apply to other products such as bar or tube.
Values for F20S are given for ASTM A240M grade UNS S44500.

Physical properties

The physical properties of a metallic alloy concern the material's ability to conduct heat, conduct electricity, expand or shrink etc.

Ferritic stainless steels:

- Are fully ferro–magnetic – they are attracted strongly to a magnet.
- Have good thermal conductivity (better than austenitic).
- Have a thermal coefficient of expansion similar to that of carbon steel.
- Are less prone to heat distortion compared to austenitic grades.

Physical Properties						
Ferritic Grade	Density (kg/m^3)	Elastic Modulus (GPa)	Coefficient of Thermal Expansion 0-100°C (µm/m/°C)	Thermal Conductivity at 100° (W/m.K)	Specific Heat 0-100°C (J/kg.K)	Electrical Resistivity (nΩ.m)
409	7700	220	11.0	28	460	580
AtlasCR12	7700	220	10.8	23	460	580
AtlasCR12Ti	7700	220	10.8	23	460	580
430	7700	220	10.5	26	460	600
439	7700	220	10.5	26	460	600
AtlasF20S	7700	220	10.5	23	460	600
444	7700	220	10.5	26	460	600

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Surface finish – appearance

The surface finishes for ferritic grades of stainless steel are generally similar to those of austenitic and other grades. If anything, ferritic grades tend to be brighter and more reflective compared to an austenitic grade of the same nominal finish.

Finish	ASTM Designation	Description
Hot rolled	No.1	A relatively rough, dull surface produced by hot rolling to the specified thickness, followed by annealing and descaling. Commonly associated with plate product.
Cold rolled	2B	A general-purpose, cold rolled, smooth finish obtained as a result of a final light pass through polished rolls at the mill.
Bright annealed	BA	A bright, cold rolled, highly reflective finish retained by final annealing in a controlled atmosphere furnace. The brightness and reflectivity is a function of thickness and grade. Usually supplied with a PE or PVC coating as a surface protection.
General purpose polished	No.4	Produced from 2B finish often by a service centre. It is a general-purpose widely used ground polished finish. Usually supplied with a PE or PVC coating as a surface protection.
Bright polished	No.8	Highly reflective 'mirror' finish. Produced from 2B finish by polishing with successive finer abrasives followed by extensive buffing.
Other	Customer Specific	Atlas Metals Processors can provide customer-specific finishes for special applications.

Fabrication

Joining and Weldability

Ferritic grades are suited to most methods successfully used to join other stainless steels – welding, soldering, brazing, mechanical joining and adhesive bonding.

The welding characteristics of stainless steels are affected by chemical composition, metallurgical structure and physical properties. Ferritic grades have some useful advantages over austenitic grades when it comes to welding due to their lower thermal expansion, lower electrical resistivity and higher thermal conductivity. These physical properties mean that the fabrication is less likely to suffer distortion during welding, compared with austenitic grades.

But there are also some limitations that must be taken into account. The ferritic grades are more susceptible to sensitisation than are their austenitic alternatives. For this reason most ferritic grades are produced with very low carbon and nitrogen contents. Unlike the austenitic grades however low carbon content (i.e. an "L" grade) does not guarantee freedom from sensitisation. Ferritic grades intended for welding are additionally stabilised with titanium and / or niobium. This is particularly important in thin sections. It is also important that care is taken in welding to prevent the pick-up of carbon from other sources, such as from the filler wire or from carbonaceous contaminants on the steel surface. Cleanliness is important.

Another limitation is the ferritic structure is prone to grain growth at elevated temperatures. The heat affected zone (HAZ) of a weld can undergo grain growth, which may result in reduction of toughness. The thicker the steel being welded the more significant is the effect, while low heat input processes and practices minimise the effect. Most ferritic stainless steels are therefore only available in gauges up to about 3mm. Exceptions are the grades AtlasCR12 and AtlasCR12Ti. Both have been metallurgically optimised to limit grain growth, so these grades alone amongst ferritics are welded in heavy plate sections.

Processes

Ferritic grades of stainless steel can be welded using arc, resistance, laser and friction welding techniques. Like other stainless steels they cannot be gas welded. All these steels can be welded by GTAW / TIG, GMAW / MIG, manual, submerged arc, plasma and resistance processes. Autogenous TIG welding is possible in gauges up to about 1.5mm.

Heat input

Heat input should be kept low (approximately 0.25kJ/mm when TIG welding 1.5mm sheet, and lower for MIG welding) for all grades except AtlasCR12 and AtlasCR12Ti. The heat input should be the lowest that will achieve full penetration. AtlasCR12 and AtlasCR12Ti should be welded within the range 0.5 – 1.5J/mm.

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Filler metals

Although matching ferritic filler wires are made, it is more common to use austenitic fillers. These should be selected to match or exceed the required corrosion resistance. Other filler can be used for specific applications.

Grade	409	Atlas CR12	Atlas CR12Ti	430	439	Atlas F20S	444
Filler Wire	308L	309L	309L	309L	308L	308L	316L

Protective gases

Shielding and backing gases should be argon or argon mixes, as below. CO_2 should only be present up to 3% and hydrogen and nitrogen must be avoided completely.

GTAW / TIG – Argon, Argon + Helium

GMAW / MIG – Argon + 2% CO_2, Argon + 2% O_2, Argon + 2% CO_2 + Helium

For further assistance on welding please contact Atlas Technical Services.

Formability (eg deep drawing or bending)

Cold forming operations change the shape of strip or sheet product by subjecting it to plastic strain. The forming operation involves complex tensile and compressive loading, using a combination of stretching and deep drawing performance.

Although the overall drawing capacity of austenitic grades is better than that of ferritic, some ferritic grades show excellent drawing performance and display higher LDR (Limiting Drawing Ratio) to austenitic. Ferritic grades are inferior to austenitic in pure stretch forming.

In practice, industrial forming operations usually involve a combination of both pure drawing and pure stretch deformation. Design, construction and fabrication parameters and the material properties of the ferritic grade concerned must be considered together, in order to get the best out of the drawing process.

The following chart is a general reference to the forming properties of the main steel groups.

	Carbon Steel	Ferritic Stainless Steel	Austenitic Stainless Steel
Structure	bcc	bcc	fcc
Work hardening	low	low	high
Spring back	low	low	high
Deep drawing	excellent	good	good
Stretch forming	good	good	excellent
Ridging	no	can occur	no

crystal structure of the steel: bcc = body-centred cubic fcc = face-centred cubic

For further assistance on applications involving drawing – stretching please contact Atlas Technical Services.

Cost

Ferritic grades of stainless steel are generally much lower in cost than the alternative austenitic grade. However, other factors beside price, such as familiarity with existing product, specification by a design engineer, asset owner's product preference, also contribute to the decision of selecting an appropriate steel for a product application. We therefore encourage our customers to seek the assistance of Atlas sales and technical staff who can provide support in evaluating the best specialty metals solution possible to suit a product application.

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Photo courtesy of Atlas Metal Processors

Typical product applications

The following is a list of typical applications and appropriate grades that may suit. The list is not exhaustive and users should trial product and assess product suitability based on their individual requirements.

Industry	Typical Product Application	Ferritic Grades
Automotive	• Exhaust systems • Decorative trims • Component parts	409, 430
Building & construction	• Hinges and fasteners • Guttering • Chimney flues • Roofing • Cladding and facades • Doors and balustrades • Lift panels	AtlasCR12, 430, 444, AtlasF20S
Urban furniture	•Ticket machines • Electrical boxes • Telephone housings • Bus shelters • Play ground equipment	AtlasCR12, 430, 444, AtlasF20S
Food commercial equipment	• Food preparation equipment • Commercial refrigerators • Catering trolleys • Display cabinets • Food handling equipment	430, 439, AtlasF20S
Home & office	• Stoves • Cookware and pots • Dishwashers • Electrical appliances • Range hoods • Kitchen ware • Domestic refrigerator panels • Washing machines • Sinks • Dryers • BBQ's • Hot water services	430, 439, 444, AtlasF20S
Industrial	• Cold and hot water tanks • Boilers • Heat exchangers • Solar water heaters	439, 444, AtlasF20S
Transportation	• Bus & coach body frames • Sea containers • Coal & ore wagons	AtlasCR12, AtlasCR12Ti, 439, AtlasF20S
Medical & hospital	• Tables • Trolleys • Sterilisation cabinets	444, AtlasF20S

Ferritic grades of stainless steel have been available for years and proven to be acceptable in many applications. They are not an inferior alternative to austenitic grades but a lower cost good alternative in the right application.

Atlas technical support and sales personnel can assist with stainless steel product selection specific for end application use.

Additional information to what has been provided in this brochure is available from the grade data sheet provided on the Atlas web site: **www.atlassteels.com.au**

Useful Reference:

"The Ferritic Solution" ISSF 2007. Available from the ISSF website **www.worldstainless.org**

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