Atlas TechNotes

Revised : November 2011

Atlas Steels
Technical Department

www.atlassteels.com.au

FOREWORD

This compilation of TechNotes has been produced by Atlas Steels Technical Services Department as a companion to the Atlas Technical Handbook of Stainless Steels and the Atlas Grade Datasheets. Any suggestions for improvements, additions or corrections would be very welcome; these should be directed to:

Technical Manager, Atlas Steels
Telephone +61 3 9272 9999, E-mail peter.moore@atlassteels.com.au

Individual TechNotes are available from the Atlas Steels website. Information from any Atlas publication may be freely copied, but it is requested that the source be acknowledged.

Limitation of Liability

The information contained in these documents is not an exhaustive statement of all relevant information. It is a general guide for customers to the products and services available from Atlas Steels and no representation is made or warranty given in relation to this information or the products or processes it describes.

Published by Atlas Steels Technical Services Department

Atlas TechNotes Published

ATLAS TECH NOTE
No. 1

revised October 2008

QUALITATIVE SORTING TESTS FOR STEELS

These tests are intended for rapid, inexpensive and usually non-destructive and on-site sorting of grades of stainless steel. They are particularly useful for sorting products when, for example, bars of grades 304 and 303 have been accidentally stored together, or grade 304 and 316 sheet offcuts mixed.

LIMITATIONS

These tests are extremely useful, but it is important to realise that they have limitations; they cannot sort one heat from another of the same grade, and there is no easy way of sorting certain grades from each other. For instance, it is not possible to readily sort 304 from 321, 316 from 316L or 304 from 304L. The Molybdenum spot test therefore indicates that a piece of steel contains Mo, but does not alone indicate 316 .... in the absence of other knowledge the steel could be 316L, 2205 or 904L etc. It is possible to use tests in combination, so an item that is shown to contain Mo, and also to be attracted to a magnet is possibly grade 2205, and unlikely to be either 316L or 904L. But is it 444 or 18-2?

SOME OTHER OPTIONS

The simple tests described in this Note may assist in grade identification and product sorting. Other, more complex tests can also be carried out; these can involve several chemical reagents, hardness tests or checking response to heat treatment. Proprietary kits can be purchased to carry out some of these tests. In most cases, however, if these simple tests are not sufficient to identify the product it is best to have a full spectrometric analysis carried out by a competent laboratory. Another option is the use of portable analysis equipment, based on spark emission or X-ray fluorescence spectroscopy. This quite sophisticated equipment is used for some PMI (Positive Material Identification) testing wherein items are 100% checked for correct composition; this is sometimes a requirement of end users, particularly in the petrochemical or oil and gas project areas.

There are other less common qualitative spot tests available. A manganese spot test is available with specific relevance in sorting “200-series” Cr-Mn-(Ni)-(Cu) austenitic stainless steels from the more usual Cr-Ni “300-series” grades such as 304. The 200-series steels are non-magnetic and otherwise indistinguishable from the 300-series, but do have reduced corrosion resistance and have considerably less value as scrap.

Although this Tech Note is primarily aimed at sorting of stainless steels, some of the tests are also relevant to sorting carbon and low alloy steels. The sulphur spot test is equally relevant to sorting free-machining carbon steels (eg 1214 or 12L14) from low-sulphur alternative grades (eg M1020, 1045 or 4140).

PREVENTION

The need for these sorting tests can be reduced if original product identification is retained. Product tags and stickers, and stamped or stencilled Batch/Heat/Grade markings should be retained as much as possible. All product distributed by Atlas Steels has this identification, in line with requirements of our ISO 9001 quality system. Atlas also colour code many steel products; details of this coding system including a chart of colours are available for download from the Atlas Steels website.

Magnetic Response

What Can Be Sorted

Austenitic (both 300-Series and 200-series) stainless steels from other steels. All other steels are attracted to a magnet, including all the ferritic, duplex, martensitic and precipitation hardening stainless steels. The only other non-magnetic steels are the austenitic 13% manganese steels (eg “P8”).

Method

Note response, if any, when a permanent magnet is brought close to the steel.

Tips & Traps

Some austenitic grades, particularly 304, are to some degree attracted to a magnet when cold worked, eg by bending, forming, drawing or rolling. Stress relieving at cherry-red heat will remove this response due to cold work, but this stress relief may sensitise the steel and should not be performed on an item which is later to be used in a corrosive environment. A full anneal is acceptable, however.

Even although duplex grades have only half the amount of the magnetic ferrite phase compared to fully ferritic grades such as 430, the difference in “feel” of a manual test is unlikely to be enough to enable sorting duplex steels from ferritic, martensitic or precipitation hardening grades.

Austenitic stainless steel castings and welds are also usually slightly magnetic due to a deliberate inclusion of a small percentage of ferrite in the austenitic deposit. The % ferrite can be measured by the amount of magnetic response, and special instruments are available for this.

Safety Precautions

No hazards associated with this test

Nitric Acid Reaction

What Can Be Sorted

Stainless steels from non-stainless steels.

Method

1. Place a piece of the steel in strong nitric acid (20% to 50%) at room temperature, or a drop of the acid on a cleaned surface of the steel.
2. Test standard samples in the same way, ie stainless and non-stainless steel samples.
3. Non-stainless steels will quickly be attacked; a pungent brown fume is produced. Stainless steels are not affected. Compare result with standards.
4. Wash samples thoroughly afterwards.

Tips & Traps

Grease or similar contaminants will prevent the acid contacting the steel surface, so the surfaces should be clean – use detergent or an organic solvent to remove these contaminants. Surface oxide layers such as mill scale will also interfere … these should be filed or ground off, or removed by pickling.

Very lean stainless steels, such as AtlasCR12 and other 12%Cr grades, are not totally immune from nitric acid attack. They can show some minor reaction, but much less violently than on a carbon or low alloy steel.

If the product being tested is not stainless steel there is likely to be significant attack and hence a significant change in appearance. Carry out the test on a surface where any appearance change can be tolerated.

Safety Precautions

Consult the MSDS for nitric acid and follow directions. Personal protective equipment should be used as directed. Strong nitric acid attacks skin and is very corrosive. Use minimum quantities. Wash off immediately if skin contact occurs. Do not breathe brown fume.

Molybdenum (Mo) Spot Test

<u>What Can Be Sorted</u>

Stainless steels which contain significant Molybdenum from those which do not. The most common use is to sort 304 from 316, but the following grades also contain sufficient Mo to give a positive response to this test – 316, 316L, 317, 317L, 444, 904L, 2205, "6-Mo" grades and all "super duplex" grades (e.g. S32760, S32750, S32550, S32520).
Other similar grades with deliberate Molybdenum additions will also respond.

<u>Method I</u>

1. Clean the steel surface; use abrasive paper, and if necessary degrease and dry.
2. Use test solution "Decapoli 304/316", "Moly Drop 960" or similar – shake well.
3. Place one drop on the steel of interest, and similar drops on known 304 and 316 samples.
4. Darkening of the test drop in 2 to 4 minutes indicates significant Mo. Compare with indications on the known 304 and 316 samples.
5. Wash or wipe samples clean.

<u>Method II</u>

Prepare as for Method I, but the test is an electrochemical one based on kit "1542C" available from Koslow Scientific Co, USA. Instructions provided with the kit. A very quick and accurate test.

<u>Tips & Traps</u>

Reliable results are only obtained if standard comparison samples and test samples are all the same temperature and freshly cleaned. Avoid very low sample temperatures as this slows reactions.
Some Heats of "Mo-free" stainless steels, such as 304, contain enough Mo to give a slight reaction; up to about 0.5% is not unusual. Standard comparison samples <u>must</u> be used.

<u>Safety Precautions</u>

Consult the MSDS for the product and follow directions. Avoid contact of test solution on skin, and particularly eyes. Wash off immediately if contacted.

Sulphur (S) Spot Test

<u>What Can Be Sorted</u>

Free machining grades of stainless and plain carbon steels, which typically contain about 0.25-0.35% sulphur (eg 1214, 12L14, 303, 416, 430F), from non-free machining steels, which typically contain up to 0.03% sulphur.

Ugima 303 contains high sulphur (the same as standard Grade 303) so will give a positive reaction, but Ugima 304 and Ugima 316 have the same low sulphur contents as their standard (non-Ugima) equivalents, so will not give positive reactions.

<u>Method</u>

1. Clean the steel surface; use abrasive paper, and if necessary degrease. A flat area is preferred.
2. Prepare standard high and low sulphur samples in the same way, eg known M1020 and 1214, or 304 and 303.
3. Soak photographic paper in 3% sulphuric acid for about 3 minutes.
4. Press the prepared steel surfaces on the face of the photographic paper for 10 seconds.
5. A dark brown stain indicates significant sulphur. Compare with indications from standard samples.
6. Wash samples thoroughly.

<u>Tips & Traps</u>

Reliable results depend on good contact with the paper, and consistent time of contact. Standard comparison samples <u>must</u> be tested in conjunction with the unknown samples. This test also shows the distribution of sulphur across the tested section, which is useful in some cases.

<u>Precautions</u>

Consult the MSDS for sulphuric acid and follow directions. Wear personal protective equipment as directed. Avoid contact of acid with skin and eyes. Wash immediately if contacted.

This "Tech Note" is the first of a series of brief notes covering technical matters related to the selection, application, fabrication and use of special steels. It is hoped that these notes will be of assistance to all those with an interest in special steels. Copies are freely available to all in the engineering community. Copies of this or other Tech Notes can be freely downloaded from the Atlas website.

Any questions relating to this Note, or suggestions for further issues would be very welcome; these could be addressed either to your Atlas branch, or directly to the Atlas Steels Technical Department.

REFERENCES & FURTHER INFORMATION

Atlas Steels Technical Handbook, available from the Atlas website.

Material Safety Data Sheets for each of the test products.

ATLAS STEELS TECHNICAL SERVICES DEPARTMENT

Atlas Steels maintains a Technical Services Department to assist customers and the engineering community generally on correct selection, fabrication and application of special steels. Our metallurgists are supported by our laboratory and have a wealth of experience and readily available information. For information contact our Materials Engineer.

Telephone 1800 818 599 (Australia) or +61 3 9272 9963 e-mail: tech@atlassteels.com.au

Further information is also given on the Atlas website at **www.atlassteels.com.au**

Contact details for the extensive Atlas branch network are also listed on this website.

LIMITATION OF LIABILITY

ATLAS TECH NOTE No. 2

revised July 2010

PITTING & CREVICE CORROSION OF STAINLESS STEELS

Stainless Steels are a family of alloys exhibiting good resistance to attack by many of the environments encountered in industry and in domestic, commercial and marine exposure. Their resistance is not perfect, however, and the large number of grades of stainless steel now available is largely because of this challenge of finding cost-effective resistance to these various environments.

The resistance of stainless steels to some environments can be described by corrosion resistance tables, as the corrosion which does occur is a fairly uniform metal thinning over time. This is termed "General Corrosion" and most commonly occurs in strongly acidic conditions. "Localised Corrosion" by contrast results in attack at certain specific sites while other parts of the metal may remain totally unaffected.

This Atlas Tech Note describes two closely related forms of localised corrosion of stainless steels – **Pitting Corrosion** and **Crevice Corrosion**.

Studies of corrosion failures of stainless steel have indicated that pitting and crevice corrosion are major problems, and together account for perhaps 25% of all corrosion failures.

WHAT IS PITTING CORROSION?

Under certain specific conditions, particularly involving chlorides (such as sodium chloride in sea water) and exacerbated by elevated temperatures, small pits can form in the surface of the steel.

Dependent upon both the environment and the steel itself these small pits may continue to grow, and if they do can lead to perforation, while the majority of the steel surface may still be totally unaffected.

A common corrosion form encountered particularly on stainless steel in coastal areas is "tea staining". This appears to be a form of pitting corrosion although it rarely proceeds beyond initiation of multiple minute pits, so the result is largely superficial but unsightly staining of the surface.

WHAT IS CREVICE CORROSION?

Crevice Corrosion can be thought of as a special case of pitting corrosion, but one where the initial "pit" is provided by an external feature; examples of these features are sharp re-entrant corners, overlapping metal surfaces, non-metallic gaskets or incomplete weld penetration.

To function as a corrosion site a crevice has to be of sufficient width to permit entry of the corrodent, but sufficiently narrow to ensure that the corrodent remains stagnant. Accordingly crevice corrosion usually occurs in gaps a few micrometres wide, and is not found in grooves or slots in which circulation of the corrodent is possible.

ENVIRONMENTAL FACTORS

The severity of the environment is very largely dependent upon two factors - the chloride (Cl^-) content and the temperature – and the resistance of a particular steel to pitting and crevice corrosion is usually described in terms of what % Cl^- (or ppm Cl^-) and °C it can resist. It should be noted that the most common grade of stainless steel, 304, may be considered susceptible to pitting corrosion in sea water (2% or 20,000 ppm = 20,000mg/L chloride) above about 10°C, and even in low chloride content water may be susceptible at only slightly elevated temperatures. A safe chloride level for warm ambient temperatures is generally about 200mg/L, reducing to about 150mg/L at 60°C. Grade 316 is more resistant and is commonly used near ambient sea water, but its resistance is marginal so it can be attacked in crevices or if the temperature increases even slightly. The safe chloride level for 316 is about 1000mg/L at ambient, reducing to around 300mg/L at 60°C

The velocity of the liquid is also significant; a stagnant solution is more likely to result in pitting and crevice attack, particularly if there are particles to settle out of the liquid. Liquids that pool and can then evaporate over time result in the chlorides becoming more concentrated in the liquid residue, and hence more highly corrosive. This is a particular problem in intermittently used piping or tanks and has caused serious pitting problems when hydrostatic test water containing quite low chlorides has been left to pool in piping and tanks.

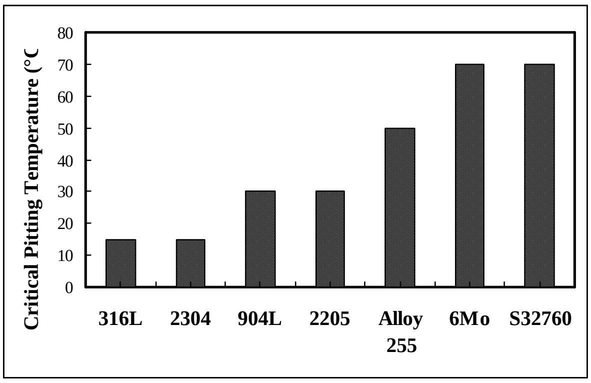
Note that there may also be a problem from stress corrosion cracking if austenitic stainless steels are used in chloride containing water at temperatures over about 60°C.

WHICH STEELS ARE SUSCEPTIBLE?

All stainless steels can be considered susceptible, but their resistances vary widely. Their resistance to attack is largely a measure of their content of chromium, molybdenum and nitrogen. Another factor of importance is the presence of certain metallurgical phases (in particular the grades 303, 416 and 430F containing many and large inclusions of manganese sulphide have very low resistances). A clean and smooth surface finish improves the resistance to attack. Contamination by mild steel or other "free iron" greatly accelerates attack initiation.

MEASUREMENT OF RESISTANCE TO ATTACK

Laboratory tests have been developed to measure the resistance of metals to both pitting and crevice corrosion. This testing has two main aims – firstly to enable ranking of each alloy in order of resistance, and secondly as a quality control measure, to ensure that particular batches of steel have been produced not just with correct composition, but also have been properly rolled and heat treated.



A commonly used test is that in ASTM G48, which measures resistance to a solution of 6% ferric chloride, at a temperature appropriate for the alloy, shown in the graph above. If an artificial crevice is added to the sample the test measures crevice corrosion resistance rather than pitting resistance. The temperature which is just high enough to cause failure of this test is termed the Critical Pitting Temperature (CPT) or the Critical Crevice Temperature (CCT).

Alternative laboratory tests can be carried out using electrochemical cells with a variety of test solutions. The results obtained in laboratory tests are approximate only, as factors such as surface finish, water velocity, water contaminants and metallurgical condition of the steel are all important.

PITTING RESISTANCE EQUIVALENT NUMBER (PRE)

From experience it has been found that an estimate of resistance to pitting can be made by calculation from the steel's composition as the Pitting Resistance Equivalent Number (PRE or PREN):

$$PRE = \%Cr + 3.3 \times \%Mo + 16 \times \%N$$

Various multipliers (up to 30) for Nitrogen have been used in this equation; with the higher values often used for the austenitic stainless steel grades; in any case the effect of nitrogen is very important. Hence the emergence of the more highly resistant 2205 grade S32205 with a minimum nitrogen content of 0.14%, plus higher minimum contents of chromium and molybdenum compared to the original S31803 variant. This also explains the trend in extremely high pitting resistant alloys for even higher nitrogen levels. The super duplex grade 2507 (UNS S32750) typically contains 0.26% nitrogen, while the super austenitic grade 4565S (UNS S34565) typically contains 0.45% nitrogen.

Typical PRE for Common Grades				
Grade	**%Cr**	**%Mo**	**%N**	**PRE**
AtlasCR12	11			11
430	17	0		17
304	18			18
2304	23	0.3		24
444	18	1.8		24
316	17	2.2		24
904L	20	4.2		34
2205	22	3	0.15	34
2507	25	4	0.26	42
6Mo	20	6.1	0.20	43

NACE specification MR0175 recognises the positive effect on pitting corrosion resistance of the element tungsten, and adds a factor at half the rate of molybdenum. The PRE formula is therefore:

$$PRE = \%Cr + 3.3 \times (\%Mo + 0.5 \times \%W) + 16 \times \%N$$

It must be kept in mind that the PRE calculation is only a convenient way to compare grades; it is an approximation and should not be used to differentiate between grades that have close PRE values.

EFFECT OF WELDING

The welding process results in metallurgical changes in both fusion zone and heat affected zone. In most alloy systems some degradation in pitting and crevice corrosion resistance occurs in welding, but these effects can be minimised if proper materials and practices are used. Proper materials are often over-alloyed consumables and proper practices include appropriate heat inputs. It is important that correct information be sought from suppliers.

MEASURES TO REDUCE PITTING AND CREVICE CORROSION

1. Control the environment to low chloride content and low temperature if possible. Fully understand the environment.
2. Use alloys sufficiently high in chromium, molybdenum and/or nitrogen to ensure resistance.
3. Prepare surfaces to best possible finish. Mirror-finish resists pitting best.
4. Remove all contaminants, especially free-iron, by passivation or by pickling (refer Atlas Tech Note 5).
5. Design and fabricate to avoid crevices.
6. Design, fabricate, commission and operate to avoid trapped and pooled liquids.
7. Weld with correct consumables and practices and inspect to check for inadvertent crevices.
8. Pickle to remove all weld scale (refer Atlas Tech Note 5).

REFERENCES & FURTHER INFORMATION

1. Atlas website has information covering many of the grades and products mentioned in this Tech Note.
2. ASSDA Technical Bulletin, "Preventing coastal corrosion (tea staining)".
3. Gümpel, P. and Ladwein, T., "High Strength Austenitic Stainless Steels for Use in Marine Environments". Eighth International Conference on Offshore Mechanics and Arctic Engineering. The Hague, March 1989.
4. Sedriks, A.J., "Corrosion of Stainless Steels", John Wiley & Sons, New York, 1996.
5. Turnbull, B.W., "A Guide to the Corrosion Resistance of Stainless Steel and Nickel Based Alloys", Australian Defence Industries, 1991.
6. Watts, M.R., "Material Development to Meet Today's Demands", Inspection, Repair and Maintenance Conference, Aberdeen, November 1988.
7. NACE MR0175 / ISO 15156-3 "Materials for use in H_2S-containing environments in oil and gas production – Part 3 – Cracking-resistant corrosion resistant alloys and other alloys".

ATLAS STEELS TECHNICAL SERVICES DEPARTMENT

Atlas Steels maintains a Technical Services Department to assist customers and the engineering community generally on correct selection, fabrication and application of special steels. Our metallurgists are supported by our laboratory and have a wealth of experience and readily available information. For information contact our Materials Engineer.

Freecall (in Australia only): 1800 818 599 or telephone +61 3 9272 9963
e-mail: tech@atlassteels.com.au

Further information is also given on the Atlas website at **www.atlassteels.com.au**

Contact details for the extensive Atlas branch network are also listed on this website.

LIMITATION OF LIABILITY

The information contained in this Atlas Steels Tech Note is not an exhaustive statement of all relevant information. It is a general guide for customers to the products and services available from Atlas Steels and no representation is made or warranty given in relation to this information or the products or processes it describes.

STAINLESS STEELS – PROPERTIES AND EQUIVALENT GRADES

Comparison of Grade Specifications of Stainless Steels

Type	Grade	UNS No	Old British BS	Old British En	Euronorm No	Euronorm Name	Swedish SS	Japanese JIS
Austenitic	201	S20100	-	-	1.4372	X12CrMnNiN17-7-5	-	SUS 201
	202	S20200	-	-	1.4373	X12CrMnNiN18-9-5	-	SUS 202
	301	S30100	301S21	-	1.4310	X10CrNi18-8	2331	SUS 301
	302HQ	S30430	394S17	-	1.4567	X3CrNiCu18-9-4	-	SUS XM7
	303	S30300	303S31	58M	1.4305	X8CrNiS18-9	2346	SUS 303
	304	S30400	304S31	58E	1.4301	X5CrNi18-10	2332	SUS 304
	304L	S30403	304S11	-	1.4307	X2CrNi18-9	2352	SUS 304L
	304H	S30409	-	-	1.4948	X6CrNi18-10	-	-
	304N	S30451	-	-	-	-	2371	SUS 304N1
	309S	S30908	309S24	-	1.4833	X12CrNi23-13	-	SUS 309S
	310H	S31009	310S24	-	-	-	-	SUH 310
	310S	S31008	310S16	-	1.4845	X8CrNi25-21	2361	SUS 310S
	316	S31600	316S31	58H,58J	1.4401	X5CrNiMo17-12-2	2347	SUS 316
	316L	S31603	316S11	-	1.4404	X2CrNiMo17-12-2	2348	SUS 316L
	316H	S31609	316S51	-	1.4919	-	-	-
	316N	S31651	-	-	1.4406	X2CrNiMoN17-11-2	2375	SUS 316N
	316Ti	S31635	320S31	-	1.4571	X10CrNiMoTi18-10	2350	SUS 316Ti
	317L	S31703	317S12	-	1.4438	X2CrNiMo18-16	2367	SUS 317L
	321	S32100	321S31	58B,58C	1.4541	X6CrNiTi18-10	2337	SUS 321
	347	S34700	347S31	58G	1.4550	X6CrNiNb18-10	2338	SUS 347
	904L	N08904	904S13	-	1.4539	X1NiCrMoCuN25-20-5	2562	-
	253MA	S30815	-	-	1.4835	X9CrNiSiNCe21-11-2	2368	-
	4565S	S34565	-	-	1.4565	X2CrNiMnMoN24-17-6-4	-	-
Ferritic	409	S40900	409S19	-	1.4512	X6CrTi12	-	SUH 409
	AtlasCr12	S41003	-	-	1.4003	X2CrNi12	-	-
	430	S43000	430S17	60	1.4016	X8Cr17	2320	SUS 430
	430F	S43020	-	-	1.4104	X12CrMoS17	2383	SUS 430F
	Atlas F20S	-	-	-	-	-	-	-
	444	S44400	-	-	1.4521	X1CrMoTi18-2	2326	SUS 444
	446	S44600	-	-	1.4749	X18CrN28	2322	SUH 446
Duplex	2101	S32101	-	-	1.4162	-	-	-
	2304	S32304	-	-	1.4362	X2CrNiN23-4	2327	-
	2205	S32250	318S13	-	1.4462	X2CrNiMoN22-5-3	2377	SUS 329J3L
	329	S32900	-	-	1.4460	X8CrNiMo27-5	2324	SUS 329J1
	2507	S32750	-	-	1.4410	X2CrNiMoN25-7-4	2328	-
	2507Cu	S32520	-	-	1.4507	X2CrNiMoCuN25-6-3	-	-
	Zeron100	S32760	-	-	1.4501	X2CrNiMoCuWN25-7-4	-	-
Martensitic	410	S41000	410S21	56A	1.4006	X12Cr13	2302	SUS 410
	416	S41600	416S21	56AM	1.4005	X12CrS13	2380	SUS 416
	420	S42000	420S37	56C	1.4021	X20Cr13	2303	SUS 420J1
	431	S43100	431S29	57	1.4057	X17CrNi16-2	2321	SUS 431
	440C	S44004	-	-	1.4125	X105CrMo17	-	SUS 440C
P.H	630	S17400	-	-	1.4542	X5CrNiCuNb16-4	-	SUS 630
	631	S17700	460S52	-	1.4568	X7CrNiAl17-7	2388	SUS 631

The above comparisons are approximate only - in some instances they are very close, in others much less so. The list is intended as a comparison of functionally similar materials not as a schedule of contractual equivalents. If exact equivalents are needed original specifications must be consulted.

Typical Physical Properties

Grade	UNS No.	Density kg/m³	Elastic Modulus (a) GPa	Mean Coefficient of Thermal Expansion (b)			Thermal Conductivity		Specific Heat	Elect. Resis-tivity
				0-100°C µm/m/°C	0-315°C µm/m/°C	0-538°C µm/m/°C	at 100°C W/m.K	at 500°C W/m.K	0-100°C J/kg.K	nΩ.m
201	S20100	7800	197	15.7	17.5	18.4	16.2	21.5	500	690
202	S20200	7800	-	17.5	18.4	19.2	16.2	21.6	500	690
301	S30100	8000	193	17.0	17.2	18.2	16.2	21.5	500	720
302HQ	S30430	8000	193	17.2	17.8	18.8	16.3	21.5	500	720
303	S30300	8000	193	17.3	17.8	18.4	16.2	21.5	500	720
304	S30400	8000	193	17.2	17.8	18.4	16.2	21.5	500	720
304L	S30403	8000	193	17.2	17.8	18.4	16.2	21.5	500	720
304H	S30409	8000	193	17.2	17.8	18.4	16.2	21.5	500	720
304N	S30451	8000	196	17.2	17.8	18.4	16.3	21.5	500	720
309S	S30908	8000	200	15.0	16.6	17.2	15.6	18.7	500	780
310H	S31009	7750	200	15.9	16.2	17.0	14.2	18.7	500	720
310S	S31008	7750	200	15.9	16.2	17.0	14.2	18.7	500	720
316	S31600	8000	193	15.9	16.2	17.5	16.3	21.5	500	740
316L	S31603	8000	193	15.9	16.2	17.5	16.3	21.5	500	740
316H	S31609	8000	193	15.9	16.2	17.5	16.3	21.5	500	740
316N	S31651	8000	196	15.9	16.2	17.5	14.4	-	500	740
316Ti	S31635	8000	193	15.9	16.2	17.5	16.3	21.5	500	740
317L	S31703	8000	200	16.5	17.0	18.1	14.4	-	500	790
321	S32100	8000	193	16.6	17.2	18.6	16.1	22.2	500	720
347	S34700	8000	193	16.6	17.2	18.6	16.1	22.2	500	720
904L	N08904	8000	200	15.0	-	-	13.0	-	500	850
253MA	S30815	7800	200	17.0	17.2	18.0	14.0	18.0	500	850
4565S	S34565	8000	190	14.5	16.3	17.2	14.5	-	510	920
409	S40900	7600	208	11.0	11.7	12.4	25.8	27.5	460	600
AtlasCR12	S41003	7740	200	10.8	11.3	12.5	30.5	40.0	480	570
430	S43000	7750	200	10.4	11.0	11.4	23.9	26.0	460	600
430F	S43020	7750	200	10.4	11.0	11.4	26.1	26.3	460	600
Atlas F20S	-	7700	210	11.5	12.0	12.5	21.3	-	450	700
444	S44400	7800	200	10.0	10.6	11.4	26.8	-	420	620
446	S44600	7800	200	10.4	10.8	11.2	20.9	24.4	500	670
2101	S32101	7800	200	13.0	14.0	-	16.0	-	500	800
2304	S32304	7800	200	13.0	-	-	16.0	-	470	850
2205	S32205	7805	200	13.7	14.7	-	19.0	-	450	850
329	S32900	7800	186	10.1	11.5	-	-	-	460	750
2507	S32750	7800	200	13.0	14.0	-	17.0	-	470	-
2507Cu	S32520	7810	205	13.5	14.0	14.5	17.0	-	450	850
Zeron100	S32760	7840	190	12.6	13.9	-	14.4	-	480	850
410	S41000	7750	200	9.9	11.4	11.6	24.9	28.7	460	570
416	S41600	7750	200	9.9	11.0	11.6	24.9	28.7	460	570
420	S42000	7750	200	10.3	10.8	11.7	24.9	-	460	550
431	S43100	7750	200	10.2	12.1	-	20.2	-	460	720
440C	S44004	7650	200	10.1	10.3	11.7	24.2	-	460	600
630	S17400	7750	196	10.8	11.6	-	18.4	22.7	460	800
631	S17700	7800	204	11.0	11.6	-	16.4	21.8	460	830

Notes:
(a) 1 GPa = 1000 MPa (b) µm/m/°C = microns/metre/°C = $\times 10^{-6}$/°C

Properties given are typical for the annealed condition.

Magnetic Permeability of all 300 series austenitic steels in the annealed condition is approximately 1.02.

Specified Mechanical Properties

Type	Grade	UNS No	Tensile Strength (MPa) min	Yield Strength (MPa) min	Elongation (% in 50mm) min	Hardness max Rockwell (HR B)	Hardness max Brinell (HB)
Austenitic	201	S20100	515	260	40	95	217
	202	S20200	620	260	40	-	241
	301	S30100	515	205	40	95	217
	302HQ	S30430	(450)	(205)	(70)	-	-
	303	S30300	-	-	-	-	262
	304	S30400	515	205	40	92	201
	304L	S30403	485	170	40	92	201
	304H	S30409	515	205	40	92	201
	304N	S30451	550	240	30	95	217
	309S	S30908	515	205	40	95	217
	310H	S31009	515	205	40	95	217
	310S	S31008	515	205	40	95	217
	316	S31600	515	205	40	95	217
	316L	S31603	485	170	40	95	217
	316H	S31609	515	205	40	95	217
	316N	S31651	550	240	35	95	217
	316Ti	S31635	515	205	40	95	217
	317L	S31703	515	205	40	95	217
	321	S32100	515	205	40	95	217
	347	S34700	515	205	40	92	201
	904L	N08904	490	220	35	90	-
	253MA	S30815	600	310	40	95	217
	4565S	S34565	795	415	35	100	241
Ferritic	409	S40900	380	207	20	95	207
	AtlasCR12	S41003	455	275	18	20HRC	223
	430	S43000	450	205	22	89	180
	430F	S43020	(552)	(380)	(25)	-	262
	Atlas F20S	-	(510)	(360)	(29)	(78)	-
	444	S44400	415	275	20	96	217
	446	S44600	450	276	20	-	219
Duplex	2101	S32101	680	480	30	-	290
	2304	S32304	600	400	25	32HRC	290
	2205	S32205	620	450	25	31HRC	293
	329	S32900	620	485	15	28HRC	269
	2507	S32750	795	550	15	32HRC	310
	2507Cu	S32520	770	550	25	-	310
	Zeron100	S32760	750	550	25	-	270
Martensitic	410	S41000	480	275	16	-	-
	416	S41600	(517)	(276)	(30)	-	262
	420	S42000	(655)	(345)	(25)	-	241
	431	S43100	(862)	(655)	(20)	-	285
	440C	S44004	(758)	(448)	(14)	-	269
P.H	630 (H900)	S17400	1310	1170	10	40HRC min	388 min
	631 (CH900)	S17700	1585	-	-	-	-

The above properties are specified for each grade's most common product - generally plate or bar in the solution treated condition. Different limits apply to some other products.

Values in parentheses are typical; no values are specified. Original specifications must be consulted for definitive values.

SPECIFICATIONS & GRADE DESIGNATIONS

Australian "common usage" grades are based upon the ASTM (American Society for Testing and Materials) designations; variations of this system have also been adopted in many other countries, including USA, Canada and Japan, and are well-recognised throughout the rest of the world. Certain grades of stainless steel have no equivalents in this system, particularly some European and newer grades. All metals in regular production have been allocated UNS (Unified Numbering System) designations by ASTM and SAE; these are often referred to in ASTM and other national specifications. "Euronorms" are increasingly used across the European Union; the grades are usually functionally compatible with ASTM / UNS grades, but may vary in their details.

Note that "AISI" was the organisation that first codified the three digit designation system, and steels are still widely referred to as eg "AISI 304", but AISI is not a standards-writing body – such designations are well recognised but should not be used as specifications for products. Product specifications (such as ASTM A240M for stainless steel flat rolled) do use the same grade designations but have clear requirements for composition limits, and also for mechanical properties, dimensions, testing procedures etc.

REFERENCES & FURTHER INFORMATION

- Stahlschlüssel "Key to Steel"
- Iron and Steel Society "Steel Products Manual – Stainless Steels", 1999 edition.
- ASM Alloy Digest Sourcebook – Stainless Steels.
- ASTM A240/A240M-10a "Chromium and Chromium-Nickel Stainless Steel Plate, Sheet and Strip for Pressure Vessels and for General Applications"
- EN 10088-1:2005 "Stainless steels – Part 1: List of stainless steels"

ATLAS STEELS TECHNICAL DEPARTMENT

Atlas Steels maintains a Technical Department to assist customers and the engineering community generally on correct selection, fabrication and application of specialty metals. Our metallurgists have a wealth of experience and readily available information.

Telephone 1800 818 599 (Australia) or +61 3 9272 9963
e-mail: tech@atlassteels.com.au or tech@atlassteels.co.nz

Further information is given on the Atlas website at **www.atlassteels.com.au**

Contact details for the extensive Atlas branch network are also listed on this website.

LIMITATION OF LIABILITY

ATLAS TECH NOTE
No. 4

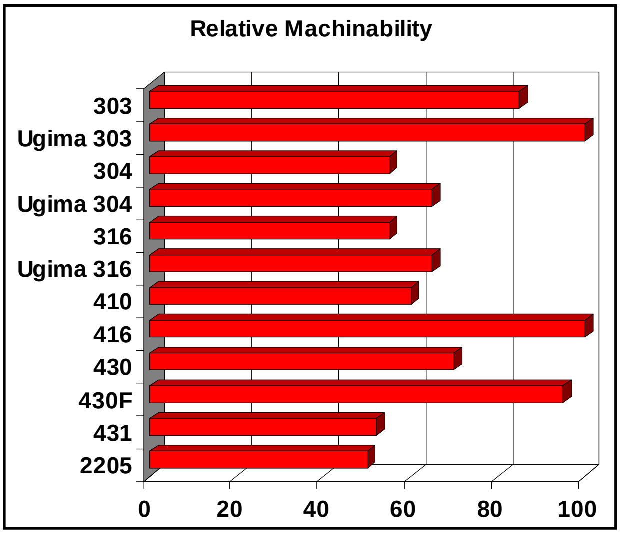
revised November 2011

MACHINING OF STAINLESS STEELS

The stainless steels are in general more difficult to machine than carbon or low alloy steels, although there are very wide differences between different grades and conditions. The common austenitic (300-series) stainless steels in particular are often regarded as having poor machinability; this is due to their relatively high strength (particularly hot strength), low thermal conductivity, high thermal expansion and high work hardening rate. These often useful properties can be a negative factor in respect of their ability to be fabricated – by other techniques as well as machining. Those organisations that understand these properties usually have very few problems in machining modern stainless steels.

MACHINABILITY OF STAINLESS STEELS

When considering non-free machining steels, the ferritic grades such as 430 are in general the easiest to machine as they are relatively low strength and also work harden at a low rate. The martensitic grades (410 and 431 for example) are also fairly readily machined if in the annealed condition, and can also be machined if hardened so long as they are tempered back to around 30HR C; this is a commonly supplied condition. The austenitic grades give most problems due to their "gummy" behaviour. Duplex grades do not have such high work hardening rates as the austenitics, but have substantially higher strengths, and so also have relatively poor machinabilities. The graph shows approximate machinabilities of grades, relative to Grade 416 free-machining stainless steel.



In general terms the three most important contributors to machinability of stainless steels are –

Sulphur content – a steel with less than about 0.015%S will be more difficult to machine; almost all plate, sheet and pipe has this very low sulphur content. Round and hexagonal bar steels in common grades 304 and 316 are usually made with between 0.02 and 0.03% sulphur. Free machining stainless steels (eg grade 303) have about ten times this amount.

Hardness – harder steels will be more difficult to machine. Smaller diameter round bars (up to about 26mm) that are drawn to final size are likely to be slightly less readily machined compared to larger, bars that are produced by annealing then turning to final size.

Improved Machinability – the "Ugima factor" gives a significant increase in machinability compared to the same grade in non-Ugima form.

FREE-MACHINING STAINLESS STEELS

"Free Machining" variants of austenitic, ferritic and martensitic grades exist – Grade 303 is a free machining version of Grade 304 and Grades 430F and 416 are free machining variants of 430 and 410 respectively. In each case the free machining version is created by the addition of Sulphur (about 0.2 to 0.3%) which is present in the steel as "stringers" of manganese sulphide running along the length of the material. These sulphides act as chip breakers and also reduce build-up of metal on tool edges, and enable significantly higher cutting speeds. Unfortunately these sulphides also have some negative effects – they substantially reduce the corrosion resistance of the steel, in particular pitting resistance. The free machining grades also have reduced ductility and hence have limited capacity for cold heading and bending. They also have very poor weldability – structural welding is not recommended.

"UGIMA" IMPROVED MACHINABILITY STAINLESS STEELS

A new generation of "Improved Machinability" stainless steels is available, under proprietary designations such as "Ugima". This exciting breakthrough has seen austenitic stainless steels with workability (weldability, formability) and corrosion resistances identical to their standard grade equivalents but with machinabilities substantially higher. In most instances the improvement in achievable cutting speed is about 20%. Other advantages are a substantial increase in tool life and improvement in workpiece surface finish. For many machine shops the improvement in tool life is the most valuable benefit. Ugima is stocked by Atlas in grades 304 and 316 and also in a super-machinable Ugima 303.

CUTTING FLUIDS

These are necessary to:-

- provide lubrication, reducing tool wear
- cool the work piece and tool – very important for stainless steels
- minimise edge build-up on the tool
- flush away chips

Both mineral oils and water soluble oils are used in machining stainless steels; the mineral oils are more usual for heavy loads at low speeds when using high speed steel tooling, whereas water soluble oils tend to be used for higher speed machining with carbide tooling. Recommendations for exact cutting fluid selection should be sought from specialist suppliers of these products. No matter what cutting fluid is used it should subsequently be removed from the finished component. Lubricant left on can stain the component surface, can prevent wetting by later passivation treatment and may lead to carburisation in later welding or heat treatment operations.

RULES TO OPTIMISE MACHINING OF STAINLESS STEELS

1. Both tool and work-piece must be held firmly. A very rigid machine tool is preferred.
2. A positive cut must be made at all times to ensure that work hardened material is removed.
3. Coolant / lubrication will almost always be necessary; this must be effectively applied.
4. A more powerful machine tool should be used; perhaps 50% above that required for carbon steels.
5. Tools such as drills and reamers should be kept as short and as rigid as possible to reduce tendency for chatter. Heavy tools will also help conduct heat away.

MAINTAINING CORROSION RESISTANCE OF MACHINED COMPONENTS

Some simple rules to maintain corrosion resistance of machined products :-

- Cutting lubricants should be removed, especially if subsequent welding or heat treatment are to be carried out.
- Passivation treatment, usually by nitric acid solution, is strongly recommended to remove all traces of metal contamination and surface sulphide inclusions. Passivation is recommended after any surface cutting process if the item is to see service in an aggressively corrosive environment. Pickling is recommended to remove weld or heat treatment scale.
- Components should be machined with internal corners radiused and with all surfaces as smooth as possible so that crevice corrosion sites are minimised. This also improves resistance to fatigue fracture initiation.

GUIDE TO MACHINING SPEEDS AND FEEDS

The following tables give some general guidance on machining of stainless steel bars. Much more detailed information is available from Atlas, particularly on the Ugima range of grades.

Drilling

Grade	Speed (m/min) and Feed (mm/rev) for Drilling Hole Sizes as Below							
	3mm□		6mm□		12mm□		15mm□	
	Speed	Feed	Speed	Feed	Speed	Feed	Speed	Feed
303	22	0.07	24	0.10	26	0.20	29	0.20
Ugima 303	25	0.07	27	0.10	29	0.20	31	0.20
304,316	11	0.07	13	0.10	13	0.20	15	0.20
Ugima 304,316	12	0.07	14	0.10	14	0.20	17	0.20
416	18	0.07	26	0.10	26	0.20	28	0.20
410	11	0.07	14	0.10	14	0.20	16	0.20
431	7	0.07	8	0.10	9	0.15	10	0.15
430	15	0.07	17	0.10	17	0.20	19	0.20
430F	22	0.07	25	0.10	25	0.20	27	0.20

Notes: 1. High speed steel grade M1 drills of indicated diameter.
2. Lubricant assumed for all operations.
3. All work material in annealed (solution treated) condition. Lower cutting speeds apply for Cold Drawn or Hardened and Tempered condition.

Turning

Grade	Speed (m/min) and Feed (mm/rev) for Turning with Tool Materials Listed							
	High Speed Steel		Carbide-Brazed		Carbide-Indexed		Carbide-Coated	
	Speed	Feed	Speed	Feed	Speed	Feed	Speed	Feed
303	21	0.4	122	0.4	197	0.4	247	0.4
Ugima 303	21	0.4	147	0.4	247	0.4	297	0.4
304,316	15	0.4	87	0.4	117	0.4	147	0.4
Ugima 304,316	16	0.4	108	0.4	157	0.4	202	0.4
416	39	0.4	137	0.4	177	0.4	197	0.4
410	24	0.4	107	0.4	157	0.4	177	0.4
431	13	0.2	75	0.2	111	0.2	126	0.2
430	27	0.4	112	0.4	127	0.4	187	0.4
430F	40	0.4	172	0.4	192	0.4	242	0.4

Notes: 1. This data is for roughing turning at 25mm diameter, with 3mm depth of cut.
For finishing typical parameters would be :- Depth of Cut = 0.5 - 1.0mm, with Feed approximately 0.2mm/rev and Speeds increased by about 20% on above data.
2. Cutting tool materials P10 Carbide of each construction or M1/M2 High Speed Steel.
3. Lubricant assumed for all operations.
4. All work material in annealed (solution treated) condition. Lower cutting speeds apply for Cold Drawn or Hardened and Tempered condition.

REFERENCES AND FURTHER INFORMATION

Datasheets for all the usual grades of stainless steels are available on the Atlas website; these give more general data on each grade.

Specific machining questions can be referred to engineers at Ugitech. Such enquiries should be discussed with Atlas Technical Department.

ATLAS STEELS TECHNICAL DEPARTMENT

Atlas Steels maintains a Technical Department to assist customers and the engineering community generally on correct selection, fabrication and application of specialty metals. Our metallurgists have a wealth of experience and readily available information.

Telephone 1800 818 599 (Australia) or +61 3 9272 9963
e-mail: tech@atlassteels.com.au or tech@atlassteels.co.nz

Further information is given on the Atlas website at **www.atlassteels.com.au**

Contact details for the extensive Atlas branch network are also listed on this website.

LIMITATION OF LIABILITY

ATLAS TECH NOTE
No. 5

revised November 2011

CLEANING, CARE & MAINTENANCE OF STAINLESS STEELS

The attractive and hygienic surface appearance of stainless steel products cannot be regarded as completely maintenance free. All grades and finishes of stainless steel may in fact stain, discolour or attain an adhering layer of grime in normal service. To achieve maximum corrosion resistance the surface of the stainless steel must be kept clean. Provided the grade, condition and surface finish were correctly selected for the particular service environment, fabrication and installation procedures were correct and that cleaning schedules are carried out regularly, good performance and long life will be achieved. Frequency and cost of cleaning of stainless steel is lower than for many other materials and this will often out-weigh higher acquisition costs.

These principles apply whether the item concerned is a simple kitchen utensil or a large and complex architectural installation.

WHY MAINTENANCE IS NECESSARY

Surface contamination and the formation of deposits are critical factors which may lead to drastically reduced life. These contaminants may be minute particles of iron or rust from other non-stainless steels used in nearby construction and not subsequently removed. Industrial, commercial and even domestic and naturally occurring atmospheric conditions can result in deposits which can be quite corrosive. An example is salt deposits from marine conditions.

Working environments can also create more aggressive conditions, such as the warm, high humidity atmosphere above indoor swimming pools. This particular environment has in a small number of instances been found to be highly aggressive, and specialist advice should be obtained.

Aggressive operating environments can increase the speed of corrosion and therefore require more frequent maintenance. Modern processes use many cleaners, sterilisers and bleaches for hygienic purposes. These proprietary solutions, if appropriate for use with stainless steel and when used in accordance with their makers' instructions are safe, but if used incorrectly (e.g. warm or concentrated) can cause discolouration and corrosion on the surface of stainless steels.

MAINTENANCE DURING INSTALLATION

Cleaning of new fabrications should present no special problems, although more attention may be required if the installation period has been prolonged. Where surface contamination is suspected, immediate attention to cleaning will promote a trouble-free service life. Food handling, pharmaceutical and aerospace applications may require extremely high levels of cleanliness.

Strong acid solutions (e.g. hydrochloric acid or “spirits of salts”) are sometimes used to clean masonry and tiling during building construction but they should never be permitted to come into contact with metals, including stainless steel. If this should happen the acid solution must be removed immediately by copious water flushing, but even if promptly removed the appearance of the steel may be unacceptably changed.

ON-GOING MAINTENANCE

Advice is often sought concerning the frequency of cleaning of products made of stainless steel, and the answer is quite simply “clean the metal when it is dirty in order to restore its original appearance”. A rule of thumb for many exterior building installations is to clean the stainless steel whenever the nearby glass needs cleaning. This may vary from once to four times a year for external applications or it may be once a day for an item in hygienic or aggressive situations. In many applications the cleaning frequency is after each use. Suggested cleaning intervals are as in this table – these should be modified by experience. Note that natural rain is an effective cleaner – those items that are not washed by rain water are likely to need more frequent maintenance cleaning.

Environment	Grade 304	Grade 316
Clean inland	3 – 6 months	6 – 12 months
Polluted urban or industrial	Not suitable	6 – 12 months
Coastal / Marine (not splashed)	Not suitable	3 – 6 months

GOOD HOUSEKEEPING DURING MANUFACTURE

Stainless steel can be contaminated by pick-up of carbon steel (“free iron”) and this is likely to lead to rapid localised corrosion. The ideal is to have workshops and machinery dedicated to only stainless steel work, but in a workshop also processing other steels avoid pick-up from:

- Tooling used with other metals
- Steel storage racks
- Handling Equipment
- Grinding wheels, wire brushes, linishing belts
- Contamination by grinding or welding sparks from adjacent carbon steel fabrication

CLEANING METHODS

Sections below give **passivation** treatments for removal of free iron and other contamination resulting from handling, fabrication, or exposure to contaminated atmospheres, and **pickling** treatments for removal of high temperature scale from heat treatment or welding operations.

PASSIVATION TREATMENTS

- Grades with at least 16% chromium (except free machining grade such as 303) :
  20-50% nitric acid, at room temperature to 40°C for 30-60 minutes.
- Grades with less than 16% chromium (except free machining grades such as 416) :
  20-50% nitric acid, at room temperature to 40°C for 60 minutes.
- Free machining grades such as 303, 416 and 430F :
  20-50% nitric acid + 2-6% sodium dichromate, at room temperature to 50°C for 25-40 minutes.

PICKLING TREATMENTS

- All stainless steels (except free machining grades) :
  8-11% sulphuric acid, at 65 to 80°C for 5-45 minutes.
  ***Note** – Sulphuric acid treatment is only needed as a pre-treatment of significantly scaled items, to loosen the scale for subsequent HF/nitric acid.*
- Grades with at least 16% chromium (except free machining grades) :
  15-25% nitric acid + 1-8% hydrofluoric acid, at 20 to 60°C for 5-30 minutes.
- Free machining grades and grades with less than 16% chromium such as 303, 410 and 416 :
  10-15% nitric acid + 0.5-1.5% hydrofluoric acid, at 20 to 60°C for 5-30 minutes.

"Pickling Paste" is a commercial product of hydrofluoric and nitric acids in a thickener - this is useful for pickling welds and spot contamination, even on vertical and overhanging surfaces.

RECOMMENDATIONS FOR CLEANING OF SPECIFIC PRODUCTS

Stainless steel is easy to clean compared to many other materials. Washing with soap or a mild detergent and warm water followed by a clean water rinse is usually quite adequate for domestic and architectural equipment. An enhanced appearance will be achieved if the cleaned surface is finally wiped dry. Specific methods of cleaning are as in the table. These are recommendations only; there are uncertainties in all cleaning operations. All such treatments must be evaluated by the user; a trial clean of an inconspicuous location is strongly recommended to prove both effectiveness and acceptability of appearance.

PROBLEM	CLEANING AGENT	COMMENTS
Routine cleaning All finishes	Soap or mild detergent and water. (preferably warm)	Sponge, rinse with clean water, wipe dry if necessary. Follow polish lines.
Fingerprints All finishes	Soap and warm water or organic solvent (eg acetone, alcohol, methylated spirits)	Rinse with clean water and wipe dry. Follow polish lines.
Stubborn stains and discolouration. All finishes.	Mild cleaning solutions. Ensure any proprietary cleaners state compatibility with stainless steel. Phosphoric acid cleaners may also be effective.	Use rag, sponge or fibre brush (soft nylon or natural bristle. An old toothbrush can be useful). Rinse well with clean water and wipe dry. Follow polish lines.
Lime deposits from hard water.	Solution of one part vinegar to three parts water.	Soak in solution then brush to loosen. Rinse well with clean water.
Oil or grease marks. All finishes.	Organic solvents (eg. acetone, alcohol, methylated spirits, proprietary "safety solvents"). Baked-on grease can be softened beforehand with ammonia.	Clean after with soap and water, rinse with clean water and dry. Follow polish lines.
Rust and other corrosion products. Embedded or adhering "free iron".	Very light rust stains can be removed by 10% nitric acid. More significant rust or embedded iron will require pickling. See also previous sections on Passivating and Pickling. Sand or glass-bead blasting is another option.	Wear PPE as appropriate. Afterwards rinse well with clean water. Mix in acid-proof container, and be very careful with the acid. (see Precautions for acid cleaners)
Routine cleaning of boat fittings.	Frequent washing down with fresh water.	Recommended after each time the boat is used in salt water.
Cooking pot boiled dry.	Remove burnt food by soaking in hot water with detergent, baking soda or ammonia.	Afterwards clean and polish, with a mild abrasive if necessary. See comments re steel wool.
Dark oxide from welding or heat treatment.	"Pickling Paste" or pickling solutions given on previous page.	Must be carefully rinsed, and use care in handling (see Precautions for acid cleaners).
Scratches on polished (satin or brushed) finish.	Slight scratches - use impregnated nylon pads. Polish with polishing wheel dressed with iron-free abrasives for deeper scratches. Follow polish lines. Then clean with soap or detergent as for routine cleaning.	Do not use ordinary steel wool - iron particles can become embedded in stainless steel and cause further surface problems. Stainless steel and "Scotch-brite" scouring pads are satisfactory.

PRECAUTIONS

Acids should only be handled using personal protective equipment as detailed in relevant MSDS and other product-specific information. Care must be taken that acids are not spilt over adjacent areas. All residues must be flushed to a treated waste stream (refer to local water authorities for regulations and assistance). Always dilute by adding acid to water, not water to acid. Use acid-resistant containers, such as glass or plastics. If no dulling of the surface can be tolerated a trial treatment should be carried out; especially for pickling operations. All treatments must be followed by thorough rinsing.
Solvents should not be used in confined spaces. Smoking must be avoided when using solvents.
Chlorides are present in many cleaning agents. This entails risk of pitting corrosion of stainless steel. If a cleaner containing chlorine, chlorides, bleaches or hypochlorites is used it must afterwards be promptly and thoroughly cleaned off.

REFERENCES FOR FURTHER READING

- ASTM A380, "Standard Practice for Cleaning and Descaling Stainless Steel Parts, Equipment, and Systems", American Society for Testing and Materials.
- ASTM A967, "Chemical passivation treatments for stainless steel parts" American Society for Testing and Materials.
- "Successful use of Stainless Steel Building Materials", Japan Stainless Steel Association (Nickel Institute publication 12 013).
- "Cleaning of Stainless Steels", Outokumpu Information 17800GB.
- ASSDA Technical Bulletin 2, "Preventing coastal corrosion (tea staining)", Australian Stainless Steel Development Association.

ATLAS STEELS TECHNICAL DEPARTMENT

Atlas Steels maintains a Technical Department to assist customers and the engineering community generally on correct selection, fabrication and application of specialty metals. Our metallurgists have a wealth of experience and readily available information.

Telephone 1800 818 599 (Australia) or +61 3 9272 9963
e-mail: tech@atlassteels.com.au or tech@atlassteels.co.nz

Further information is given on the Atlas website at **www.atlassteels.com.au**

Contact details for the extensive Atlas branch network are also listed on this website.

LIMITATION OF LIABILITY

The information contained in this Atlas Steels Tech Note is not an exhaustive statement of all relevant information. It is a general guide for customers to the products and services available from Atlas Steels and no representation is made or warranty given in relation to this information or the products or processes it describes.

ATLAS TECH NOTE No. 6

revised November 2011

LIFE CYCLE COSTING

Traditionally the selection of a material for a given application has been on the basis of the cheapest purchase price. It is now recognised that the cheapest purchase price may not be the most economic choice if account is taken of the very real additional costs due to installation, regular maintenance and for periodic replacement should the material's life be less than that required for the product or construction. In the case of equipment installed in factories or processing plants a further cost which must be included for each possible alternative material is that caused by lost time – the time for which production is lost because of unscheduled down-time of the equipment. In many industries this lost time cost far outweighs all other costs, and must certainly be included. The total of these considerations is the “Life Cycle Cost” (LCC), “Total Cost of Ownership” (TCO) or “Whole of Life Cost” (WoL).

In general terms the total LCC can be broken down into components:

LCC =	Acquisition Cost	+	Fabrication and Installation Cost	+	Maintenance Costs (periodic)	+	Replacement Costs (periodic)	+	Cost of Lost Production (periodic)	–	Residual (Scrap) Value

Each of these terms must be known if a realistic result is to be calculated.

EVALUATION OF LIFE CYCLE COST

The calculation of LCC relies upon the concept of the "time value of money" – the notion that a dollar spent next year costs less than a dollar spent today, because the money could in the interim be invested and hence be generating income of its own. Future expenditures can therefore be discounted by a factor which depends upon several inputs, including the cost of funds to the organisation, the prevailing inflation rate and the time period for which the expenditure is delayed. Calculation by manual methods is quite complex, so in the past this valuable tool has been left to the accounting specialists. Using spreadsheets the calculation of LCC has become much easier, but a further step towards ease of use has been made with the implementation of computer programs specifically for this task.

LCC CALCULATION BY COMPUTER PROGRAM

A program has been produced by the International Chromium Development Association (ICDA), Euro Inox and Southern Africa Stainless Steel Development Association (SASSDA) and is available for download from the Euro-Inox website at http://www.euro-inox.org/LCC/flash.html. This website also includes full instructions and a worked example.

The LCC computer program has been written to ensure ease of use; all inputs are keyed into appropriate simple screens, and the resulting changes are reflected immediately in the calculated LCC, giving comparative costs for up to three alternative materials.

This program is intended primarily as a teaching tool – some limitations mean that the most accurate forward projections are best made by the more complex route of a very specific spreadsheet. In particular this simple program cannot account for variations in cost of capital or inflation rates … these are assumed constant for the life of the component. Maintenance events can only be set down at regular intervals, whereas in practice there may be none for the first few years and then increased frequency and increasing amount required.

EVALUATION OF AN EXAMPLE LIFE CYCLE COST ANALYSIS

An example of the use of LCC analysis using the ICDA LCC software is for a simple rectangular mixing tank. The requirement is for a 20 year tank life, to coincide with the requirement for other components of the water treatment plant.

The design brief requested evaluation of three alternative materials:

a) stainless steel – austenitic Grade 304
b) stainless steel – duplex Grade 2205
c) mild steel with applied fibreglass lining

As the 2205 was not readily available in the angle and channel products required for reinforcement of the tank, these were substituted by Grade 304 in the 2205 design; these components were not to be in regular contact with the corrosive environment, so no corrosion problem was anticipated, and welding the grades together is usually not a problem.

Experience suggested that both the 304 and 2205 would survive without replacement for the full twenty years in the stated environment. The 2205 stainless steel was expected to require inspection and cleaning at three yearly intervals, compared to the same minimal regime at yearly intervals for the 304. The mild steel however was expected to require fairly extensive patching of the steel and its lining at yearly intervals, plus full replacement after each eight years.

The "Life cycle summary of a WTP Mixing Tank" table on the next page shows the resulting LCC analysis. The top *Description* section summarises inputs and gives the calculated Total LCC for each option. The following sections break out details for the *Material Costs*, *Operating Costs* and the assumed *Cost Rates and Project Duration*.

This hypothetical example shows the 304 and 2205 as almost identical life cycle costs but with the mild steel substantially more expensive due to its higher maintenance and replacement costs. The Material Cost (acquisition cost) of the mild steel construction is of course by far the cheapest despite the additional need to apply the protective lining.

The negative Replacement Costs for the two stainless steel alternatives reflect the expected significant residual scrap value of the metal at the end of 20 years, discounted from the initial material costs because it is a deferred income. The mild steel option includes a removal cost each time the tank is replaced and for the stainless steels removal at the end of their required service life.

The "Value of Lost Production" in this example is shown as zero - this implies all maintenance and replacement is carried out in scheduled shut-downs for other plant maintenance. Unexpected shut-downs causing lost production could substantially add to the Total Operating Cost of the option requiring this unscheduled maintenance. This would of course radically alter the LCC outcome, in favour of the more durable options.

“What if” questions can be easily answered … What if the 304 fails to survive the full 20 years as expected? What would be the outcome of using a higher cost but longer life coating on the mild steel?

Note: All values are in "Mu" - Monetary units - to enable use of the software with any currency.

Life cycle summary of a WTP Mixing Tank

Description	304	2205	Mild Steel
Material costs	5185	6833	2320
Fabrication costs	2780	2780	2780
Other installation costs	0	0	1500
Initial costs	**7965**	**9613**	**6600**
Maintenance	2572	793	12858
Replacement	-126	-100	7362
Lost production	0	0	0
Material related	0	0	0
Operating costs	**2446**	**693**	**20220**
Total LCC	**10411**	**10306**	**26820**

Initial costs

Material costs (MU)			
Plate, sheet:	3560	4750	1620
Pipe, fittings:	1062	1520	450
Bar & other (fixings, consumables):	563	563	250
Fabrication & install. costs (MU)			
Cutting, welding, forming, etc. :	1280	1280	1280
Assembly & installation:	1500	1500	1500
Other installation costs (MU)			
Surface protection:	0	0	1500
Special labour skills, etc. :	0	0	0

Operating costs

Maintenance costs			
Cost per event (MU):	200	200	1000
Elapsed time between events (years):	1	3	1
Replacement costs			
Removal costs per event (MU):	500	500	500
Material & install. costs per event:	0	0	6600
Residual value of material per event:	290	229	90
Elapsed time between events (years):	20	20	8
Annual material-related costs			
Annual cost (MU):	0	0	0

Rates & duration

Cost of capital:	7.9	%
Inflation rate:	3.5	%
Desired life cycle duration:	20	years
Downtime per maintaince/replacement event:	0	days
Value of lost production:	0	MU/day
Real interest rate	**4.25**	**%**

LCC PC PROGRAM - USER ASSISTANCE

The LCC program is simple in operation, but a number of on-line Help screens are available which give assistance.

REFERENCES & FURTHER INFORMATION

1. Moore, P.J. and Matheson, P.J., "Life Cycle Costing & Stainless Steel", Architectural Review, Vol 10, No. 3.
2. "Life Cycle Costing and Stainless Steel", Australian Stainless, No. 1, July 1993, Editorial.
3. von Matérn, S., "Demonstration of a LCC Calculation Program on a PC", Applications of Stainless Steel '92, Stockholm, June 1992.
4. Life Cycle Costing software with on-line instructions, produced by ICDA, SASSDA and Euro-Inox. Refer to the Euro-Inox website at http://www.euro-inox.org/LCC/flash.html.

ATLAS STEELS TECHNICAL DEPARTMENT

Atlas Steels maintains a Technical Department to assist customers and the engineering community generally on correct selection, fabrication and application of specialty metals. Our metallurgists have a wealth of experience and readily available information.

Telephone 1800 818 599 (Australia) or +61 3 9272 9963
e-mail: tech@atlassteels.com.au or tech@atlassteels.co.nz

Further information is given on the Atlas website at **www.atlassteels.com.au**

Contact details for the extensive Atlas branch network are also listed on this website.

LIMITATION OF LIABILITY

ATLAS TECH NOTE No. 7

revised Aug 2010

GALVANIC CORROSION

WHAT GALVANIC CORROSION IS

Galvanic corrosion is a localised mechanism by which metals can be preferentially corroded. This form of corrosion has the potential to attack junctions of metals, or regions where one construction metal contacts another. Frequently this condition arises because different metals are more easily fabricated into certain forms; an example might be a door frame manufactured from aluminium extrusions (aluminium extrudes extremely well into architectural sections), but with a door handle fabricated from stainless steel tube to exploit its higher strength and abrasion resistance. Galvanic corrosion is well known to most designers, specifiers and fabricators, but often the only rule in force is "don't mix metals".

WHAT CONDITIONS ARE NEEDED

For galvanic corrosion to occur there are three conditions which must be met ... and some qualifications to these conditions as well:-

Condition 1. Metals must be far apart on the galvanic series

The galvanic or electrochemical series ranks metals according to their potential, generally measured with reference to the Standard Calomel Electrode (S.C.E.). The results are often viewed as a chart similar to that on the third page of this Atlas TechNote. This chart says that the "anodic" or "less noble" metals at the negative end of the series – at the right of this diagram, such as magnesium, zinc and aluminium - are more likely to be attacked than those at the “cathodic" or "noble" end of the series such as gold and graphite. The critical point is the difference in potential of the two materials being considered as a joined pair. A difference of hundreds of millivolts is likely to result in galvanic corrosion, but only a few tens of millivolts is unlikely to be a problem. A rule of thumb is that differences over about 200mV (0.2 Volts) suggest galvanic corrosion could be a concern.

Although stainless steels are rightly considered to be towards the noble end of the spectrum, other materials are even more noble. Note particularly the position of graphite – galvanic coupling between stainless steels and graphite should be avoided. Graphite-containing gaskets, seals, packing and lubricants should not be used in contact with stainless steels in contact with sea water. Carbon black in rubber is a common source of this graphite; significant variations in the galvanic effect occur due to the use of different rubbers containing various amounts and types of carbon black filler.

Condition 2. The metals must be in electrical contact

The two different metals must be in electrical contact with each other. This is of course very common. The two metals can be bolted, welded or clamped together, or even just resting against each other.

Condition 3. The metal junction must be bridged by an electrolyte

An electrolyte is simply an electrically conducting fluid. Almost any fluid falls into this category, with distilled water as an exception. Even rain water is likely to become sufficiently conducting after contact with common environmental contaminants. If the conductivity of the liquid is high (a common example is sea water) the galvanic corrosion of the less noble metal will be spread over a larger area; in low conductivity liquids the corrosion will be localised to the part of the less noble metal near to the junction. Different ions in the fluid also behave differently; chloride ions (such as in sea water) are particularly aggressive while hydroxide ions are often passive. The concentration of ions is relevant but the effect can be changed due to dissolution of ions from the corroding metal and to variable solubility of oxygen, among other effects.

THE AREA EFFECT

The relative area of the anode and cathode has a pronounced effect upon the amount of corrosion that occurs. A small anode (the less noble metal, such as aluminium) joined to a large cathode (the more noble metal, such as stainless steel) will result in a high current density on the aluminium, and hence a high rate of corrosion. The corrosion is concentrated by the area difference. Conversely if the area of the anode is large compared to that of the cathode this dilutes the corrosive effect, in many cases to the extent that no problem occurs. It is common practice to use stainless steel fasteners to fix aluminium sheeting or signs, but if aluminium screws were used to fix stainless steel sheet the screws may rapidly corrode.

An apparent contradiction of the area effect occurs when the component comprised of the two metals is only partly wetted. Consider for instance a stainless steel bolt in an aluminium plate; if water collects in the corner at the edge of the bolt but the remainder of the plate remains dry, the effective area of the less noble aluminium is only the wetted region, which may be only a similar size to that section of the bolt that is wetted .... thus it is quite possible for the aluminium plate to be galvanically attacked in the region immediately surrounding the bolt. Only the wet "area" counts.

CREVICES & STAGNANT CONDITIONS

As shown in the electrochemical series chart on the next page there are two different potentials associated with each stainless steel grade. The less noble value shown in outlined boxes is that which applies inside a crevice formed between the two dissimilar metals or such as beneath bio-fouling. Such a crevice could be from the design or fabrication of the component, and formation of biological films is more likely in stagnant or slow-flowing sea water. The result of these stagnant conditions is oxygen depletion and the less noble potential which can make the stainless steel susceptible to corrosion in conditions that might otherwise be considered non-corrosive.

PASSIVE SURFACE FILMS

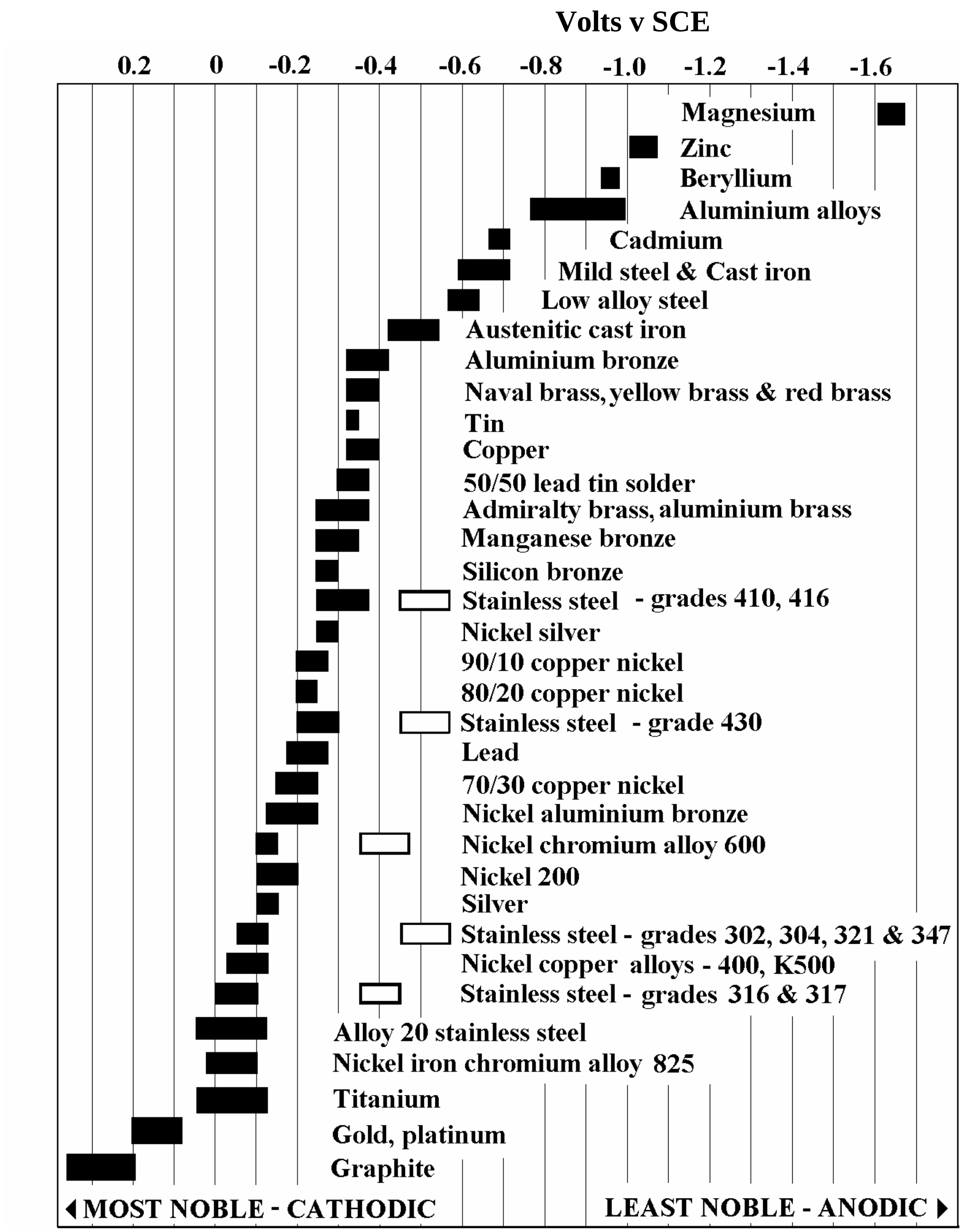
Stainless steels naturally form passive surface films – this is what makes them "stainless". This film also reduces the amount of current available for corrosion, so slows the corrosion rate down compared to some other galvanic pairs.

AVOIDANCE OF GALVANIC CORROSION

The methods for avoidance of galvanic corrosion are in general suggested by the above descriptions of the conditions necessary for its occurrence.

Don't Mix Metals. If only one material is used in a construction the problem is avoided (Condition 1 is not present – no mixed metals). Be particularly aware of zinc plated or galvanised fasteners in stainless steel sheets – a common substitution because of perceived cost savings, better availability or just incorrect material identification. These less noble fasteners look fine when installed but are likely to be rapidly attacked.

Prevent Electrical Contact. It is often practical to prevent electrical contact between the (…cont'd page 4)



Corrosion potentials in flowing sea water at ambient temperature. The unshaded symbols show ranges exhibited by stainless steels in acidic water such as may exist in crevices or in stagnant or low velocity or poorly aerated water. The more Noble materials at the left side tend to be cathodic and hence protected; those at the right are less Noble and tend to be anodic and hence corroded in a galvanic couple.

dissimilar metals (removal of Condition 2). This may be achieved by the use of non-conducting (eg rubber or plastic) spacers, spool pieces or gaskets, perhaps in conjunction with sleeves around bolts. For the same reason a gap may be left between galvanised roofing and a stainless steel down-pipe.

Prevent the Wetted Junction. The third Condition can be removed by ensuring that no electrolyte remains at the intermetallic junction - this may require extra attention to drainage or to protection from the weather. A good covering of paint or sealant over the junction can be effective.

Use the Area Effect. The area effect should also be considered in avoiding corrosion damage, particularly in selection of fastener materials. Stainless steel fasteners can be used to hold aluminium structures, but the area effect will not apply if the wetted area shrinks over time due to evaporation.

Positively Use Galvanic Protection. The galvanic effect can also be used to provide corrosion protection. For example it is prudent to guard against possible crevices, perhaps associated with marine fouling, or simply under bolt heads, by specifying slightly more noble bolt materials. An example is the use of 316 fasteners in conjunction with 304 structural materials – the minor galvanic protection afforded the fasteners improves their corrosion resistance.

REFERENCES FOR FURTHER READING

1. Atlas Tech Note 2, "Pitting and Crevice Corrosion of Stainless Steels".
2. Sedriks, A.J., "Corrosion of Stainless Steels", Wiley Interscience, 2nd Edition, 1996.
3. ASM Specialty Handbook "Stainless Steels", ASM International, 1994.
4. AS 4036-2006 “Corrosion of metals – dissimilar metals in contact with seawater”
5. ASSDA Technical FAQ No1 “Galvanic / dissimilar metal corrosion”
6. AS HB39-1997 “Installation code for metal roof and wall cladding”

ATLAS STEELS TECHNICAL SERVICES DEPARTMENT

Atlas Steels maintains a Technical Services Department to assist customers and the engineering community generally on correct selection, fabrication and application of specialty metals. Our metallurgists are supported by our laboratory and have a wealth of experience and readily available information.

Telephone 1800 818 599 (Australia) or +61 3 9272 9963
e-mail: tech@atlassteels.com.au or tech@atlassteels.co.nz

Further information is given on the Atlas website at **www.atlassteels.com.au**
Contact details for the extensive Atlas branch network are also listed on this website.

LIMITATION OF LIABILITY

ATLAS TECH NOTE
No. 8

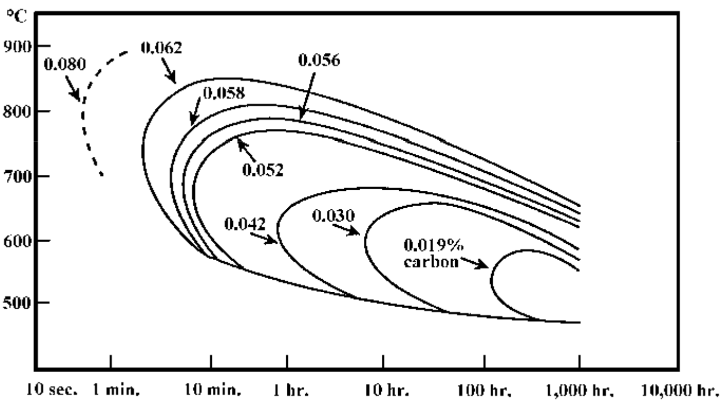
revised August 2011

"L", "H" AND STANDARD GRADES OF STAINLESS STEELS

Within the usual designations of the common austenitic grades of stainless steel, such as 304 and 316, there are "sub-grades" – "L" and "H" variants – with particular applications.

WHAT "L" GRADES ARE & WHY THEY ARE USED

The low carbon "L" grades are useful where welding or other high temperature exposure will occur, particularly welding of medium or heavy sections. The low carbon is one way of delaying or preventing grain boundary chromium carbide precipitation (often referred to as "sensitisation") which can result in intergranular corrosion in many service environments. As shown in the time-temperature-sensitisation curves at right, the precipitation of chromium carbides occurs over time at temperatures in the range of about 450-850°C and most rapidly between 600 and 700°C. The time for damaging precipitation to occur is highly dependant upon the amount of carbon present in the steel, so low carbon content increases resistance to this problem. Because of their application area the "L" grades are most readily available in plate and pipe, but often also in round bar. By the same logic sheet and tube are routinely supplied as 304 or 316 without necessarily having low carbon content; as sensitisation is due to time at temperature even higher carbon content 304 or 316 can be welded without risk by normal processes in sections up to about 3 to 5mm.



Time-Temperature-Sensitisation curves

In the absence of sensitisation the corrosion resistances of the standard and "L" grades are usually identical.

Another approach to solving the sensitisation problem is to add a "stabiliser" element to the steel, usually titanium (Ti) but sometimes niobium (Nb). The grades that are stabilised by addition of titanium (eg 321 or 316Ti) or niobium (eg 347) do not suffer from sensitisation even after exposure at 450 – 850°C because the Ti or Nb combines preferentially with the carbon, leaving chromium free to resist corrosion. Stabilised ferritic stainless steels are also very common, such as grade 444 (ferritics are not stabilised by low carbon).

WHAT "H" GRADES ARE & WHY THEY ARE USED

"H" grades are the higher carbon versions of each of the standard grades. The high carbon results in increased strength of the steel, particularly at elevated temperatures (generally above about 500°C). Both short term tensile strengths and long term creep strengths are higher for these high carbon grades. "H" grades are produced primarily in plate and pipe, but may be available in some other products. Applicable grades are most commonly 304H and 316H, but high carbon versions of 309, 310, 321 and 347 are also specified in ASTM A240/A240M. The specialist high temperature grade 253MA (S30815) has no low or standard carbon version at all. As discussed above, these high carbon content grades are susceptible to sensitisation if held in the temperature range of about 450-850°C. If it occurs this sensitisation will result in impaired aqueous corrosion resistance. In general however, this is not a concern for a steel that is primarily intended for high temperature applications.

WHAT THE DIFFERENCES ARE

1. Composition limits for 304 and 304L are identical in all respects except for carbon content (304L does permit up to 12.0%Ni, compared to 10.5% max for 304 – but given the cost of nickel it is usual for both grades to have close to the minimum of 8.0%, so there is no practical difference). Neither 304 nor 304L has a minimum carbon content specified. A carbon content of 0.02% therefore fully complies with both 304 and 304L specifications.

2. The high carbon version of 304 is 304H, as detailed in the table below (for flat rolled product). The differences between 304 and 304H are the carbon content, a slightly higher chromium minimum and removal of the 0.10% upper limit on nitrogen which applies to both standard and "L" grades. In addition all austenitic "H" grades must have a grain size of ASTM No 7 or coarser.

3. The three grades 316, 316L and 316H are exact counterparts to the 304 series. Again only the carbon contents differentiate these grades (and the nitrogen and grain size limits mentioned above). Compositions of the alternatives are therefore as in the following table (again for flat rolled products, from ASTM A240/A240M-10a; for full compositions refer to the standard).

Grade	UNS Number	Carbon (%)	Chromium (%)	Nickel (%)	Molybdenum (%)	Nitrogen (%)
304	S30400	0.07 max	17.5 – 19.5	8.0 – 10.5	-	0.10 max
304L	S30403	0.030 max	17.5 – 19.5	8.0 – 12.0	-	0.10 max
304H	S30409	0.04 – 0.10	18.0 – 20.0	8.0 – 10.5	-	-
316	S31600	0.08 max	16.0 – 18.0	10.0 – 14.0	2.00 – 3.00	0.10 max
316L	S31603	0.030 max	16.0 – 18.0	10.0 – 14.0	2.00 – 3.00	0.10 max
316H	S31609	0.04 – 0.10	16.0 – 18.0	10.0 – 14.0	2.00 – 3.00	-
Note that long-standing C and Cr limits for 304 and 304L were revised in ASTM A240/A240M-07 to achieve harmonisation with the European specification EN 10088-2. Chromium content of 304 and 304L in ASTM specifications other than A240 (eg A312 for pipe) still give 18.0% minimum and carbon is 0.08% maximum as of the 2009 revisions.						

Specifications for some other products, particularly tube and pipe, have a carbon limit of 0.035% or 0.040% maximum for 304L and 316L. There can also be minor differences in other elements.

4. There are also mechanical property specification differences (ASTM A240/A240M-09b):

Grade	UNS Number	Tensile Strength (MPa) min	Yield Strength (MPa) min	Elongation (%) min	Brinell Hardness (HB) max	Rockwell Hardness (HRB) max
304	S30400	515	205	40	201	92
304L	S30403	485	170	40	201	92
304H	S30409	515	205	40	201	92
316	S31600	515	205	40	217	95
316L	S31603	485	170	40	217	95
316H	S31609	515	205	40	217	95

In practice, steel mills generally ensure that all “L” grade heats meet the strength requirements of the standard grades, ie. 304L and 316L will almost always have yield and tensile strengths above 205MPa and 515MPa respectively, so will meet both standard and “L” grade requirements.

5. There are no dimensional or other differences between standard, “L” and “H” grades.

6. Pressure vessel codes (e.g. AS 1210) and pressure piping codes (e.g. AS 4041) give allowable working pressures for each of the grades at nominated elevated temperatures and give higher pressure ratings for standard grades than for “L” grades, at all temperatures. AS 1210 does not permit the use of “L” grades above 550°C and also includes a clause stating that for use above 550°C the standard grades must contain at least 0.04% carbon. Grades 304 or 316 with 0.03% carbon or less are therefore not permitted for these elevated temperatures, whether called “L” or not. At temperatures from ambient up to this high temperature cut-off it would be permitted to use “L” grade heats with the standard grade pressure ratings, so long as the material was in full compliance with the standard grade composition and mechanical property specifications. As discussed above, it is normal practice for this condition to be met. ASME Codes do permit use of “L” grades at elevated temperatures under some conditions (refer for instance to ASTM A240 Supplementary Requirement S2). AS 4041 permits use of “L” grades up to 800°C but subject to design constraints. This is a complex topic requiring professional engineering input.

7. The pressure vessel and pressure piping codes give the same allowable pressure rating for “H” grades as for standard grades - this is logical as the “H” grades are simply the standard grades with their carbon contents controlled to the top half of the range, or slightly above.

ALTERNATIVE GRADE USAGE

Because of availability issues it is sometimes desirable to be able to use a product labelled as a standard grade when an “L” or “H” grade has been specified, or vice versa. Such substitution can be made under the following conditions.

1. “L” grades can be used as standard grades at ambient temperatures and up to around 500°C so long as the mechanical properties (tensile and yield) conform to the standard grade requirements. “L” grades virtually always do fully comply with standard grade requirements, but this would need to be checked on a case by case basis. Mills' inspection certificates give this information.

2. Australian pressure codes generally preclude use of “L” grades at high temperature (over about 500°C). Supplementary Requirement S2.3 of ASTM A240M-09b enables use of “L” grades at temperatures above 540° subject to certain conditions – the original specifications and ASME Code should be consulted.

3. Standard grades can be used as “L” grades so long as their carbon content meets the “L” grade limit of 0.030% maximum (or 0.035 or 0.040% as noted previously).

4. Standard grades can often be used in place of “H” grades so long as their composition (carbon and chromium) meet the “H” limits. The grain size requirement may be satisfied by extra testing.

5. “H” grades can be used as standard grades so long as their carbon contents are 0.07% (304) or 0.08% (316) maximum, and nitrogen 0.10% maximum. This is highly likely, but would need to be checked. It is also highly likely that 304H will have chromium not exceeding the 19.5% maximum for 304, but again this should be checked.

6. It has become quite common for steel mills to supply “L” heats when standard grades have been

ordered. Sometimes the product and inspection certificates are "dual certified" as 304/304L or 316/316L, and sometimes the marking is only as standard or as "L". In any case the practice is legitimate and should generally present no problems to fabricators or to end users unless a high temperature application is intended. Again the full details given on the mill inspection certificate will show whether compliance with the alternative grade is achieved.

7. If an application requires an "H" grade - generally for high temperature applications - this must be specified at time of order. Atlas may be able to supply the required high carbon content steel from standard grade stock, but full compliance with "H" grade specification will require additional measurement of grain size. The product and its test certificate may describe it as a standard 304 or 316 unless it was originally manufactured as an "H" grade. Details of the inspection certificate will confirm grade compliance.

8. All product is unambiguously traced through the Atlas Steels stock management system and marked with full identification. Certification can therefore be provided, which may enable alternative grade usage.

DUAL CERTIFICATION

It is common practice for certain products including plate, pipe and some bar to be stocked as "dual certified". Such product is certified by the manufacturer as fully compliant with both 304 and 304L or 316 and 316L. It thus has the resistance to sensitisation expected of an "L" grade plus the higher strength of a standard grade. Dual certified products are generally precluded from use at high temperatures (over about 500°C) because of their low carbon content, the same as other "L" products, but refer to preceding comments. There is also a dual certified 321 / 321H, but there is no "L" version of 321.

REFERENCES

AS 1210-2010 "Pressure Vessels"
AS 4041-2006 "Pressure Piping"
ASTM A240/A240M-10a "Chromium and Chromium-Nickel Stainless Steel Plate, Sheet and Strip for Pressure Vessels and for General Applications"

ATLAS STEELS TECHNICAL DEPARTMENT

Atlas Steels maintains a Technical Department to assist customers and the engineering community generally on correct selection, fabrication and application of specialty metals. Our metallurgists have a wealth of experience and readily available information.

Telephone 1800 818 599 (Australia) or +61 3 9272 9963
e-mail: tech@atlassteels.com.au or tech@atlassteels.co.nz

Further information is given on the Atlas website at **www.atlassteels.com.au**

Contact details for the extensive Atlas branch network are also listed on this website.

LIMITATION OF LIABILITY

ATLAS TECH NOTE No. 9

revised August 2010

STAINLESS STEEL TUBE FOR THE FOOD INDUSTRY

This commentary note compares the various specifications, all of which are from time to time considered alternatives for food process line service -

AS 1528.1-2001	"Specification for tubes (stainless steel) for the food industry"
ASTM A249M-08	"Specification for welded austenitic steel boiler, superheater, heat exchanger, and condenser tubes"
ASTM A269-08	"Specification for seamless & welded austenitic stainless steel tubing for general service"
ASTM A270-03a	"Specification for seamless & welded austenitic and ferritic/austenitic stainless steel sanitary tubing"
ASTM A554-08a	"Specification for welded stainless steel mechanical tubing"

The revision years noted above are those used for this comparison; ASTM specifications are revised very regularly and changes both major and minor are made. The comparisons are all based on the metric unit versions of each standard. Some reference is also made to the general specification ASTM A1016M-08.

AS1528 was revised in 2001 (after many years of disuse) by key stake-holders in the Australian tube industry and food manufacturing industries, under the auspices of the Australian Stainless Steel Development Association (ASSDA). AS 1528 is unique in that it covers all the associated fittings, in addition to the tube …

AS1528.1 - "Tubes"
AS1528.2 - "Screwed Couplings"
AS1528.3 - "Butt Weld Tube Fittings"
AS1528.4 - "Clamp Liners with Gaskets"

At time of writing AS 1528 is in the process of a timely revision, expected to include endorsement as a joint AS/NZS standard.

SPECIFICATION COMPARISON

1. Material

All specifications call for the common grades 304, 304L, 316 and 316L. Most specifications allow a number of other stainless steel grades as well. AS1528.1 permits all grades of austenitic and duplex stainless steel listed in ASTM A240, so the possibilities are very extensive.

2. Manufacture

All specifications require fusion welded tube without filler metal (in practice this permits standard tube production using TIG, plasma or other processes such as laser welding). AS 1528, A269 and A270 also cover seamless product, if requested, although this is rarely required.

3. Dimensional Tolerances

3.1 Wall Thickness

A249M requires ±10% of nominal - no standard nominal thicknesses are stipulated.
A269 requires ±10% of nominal for sizes over ½" - no nominal thicknesses are stipulated.
A270 requires ±12.5% of nominal - no nominal thicknesses are stipulated.

A554 requires ±10% of nominal - no nominal thicknesses are stipulated.
AS 1528.1 specifies standard nominal thicknesses of 1.6mm for all ODs except 2.0mm for 203.2mm OD; other non-standard thicknesses can be specified by purchasers. The standard tolerance is +nil, -0.10mm. The all-minus tolerance recognises the usual practice for tube, to all specifications, to be produced towards the lower limit of the tolerance range. A range of between 1.52 and 1.58mm is typical. Slightly wider tolerances apply to the complimentary tube fittings covered by the other parts of AS 1528.

3.2 Outside Diameter

for standard inch series OD tube sizes, each specification requires -

Outside Diameter Tolerances (mm)					
Diameter	**A249M**	**A269**	**A270**	**A554**	**AS 1528.1**
25.4	±0.15	±0.13	±0.13	±0.13	±0.13
38.1	±0.15	±0.25	±0.20	±0.20	±0.25
50.8	±0.25	±0.25	±0.20	±0.28	±0.25
63.5	±0.25	±0.25	±0.25	±0.30	±0.25
76.2	±0.38	±0.25	±0.25	±0.36	±0.25
101.6	+0.38/-0.64	±0.38	±0.38	±0.51	±0.38

- A249M tolerances for OD given in ASTM A1016M
- A554 tolerances for the standard "AW" condition of weld bead not removed.
- AS1528.1 also covers OD sizes 12.7, 19.0, 31.8, 127.0, 152.4 and 203.2mm

Ovality is a measure of the out-of-round, usually measured as the difference between the largest and smallest OD dimensions at a single cross-section of the tube; for most products there is no ovality allowance beyond the OD tolerance. The ASTM specifications do however make provision for extra ovality in "thin walled" tube, defined differently in each standard, as follows.
A249M Tubes with WT <3% of OD (OD 63.5mm and over for 1.6mm WT) can have ovality of 2.0%.
A269 1.6mm WT tube in all above sizes can have ovality twice the diameter tolerance.
A270 Extra provision for ovality only for diameters over 101.6mm.
A554 Ovality tolerance of double OD tolerance applies to tubes 63.5mm OD and above for 1.6mm WT.
AS 1528.1 allows ovality of up to double the OD tolerance for all sizes.
All the above specifications that allow extra ovality for thin wall tube still require the mean OD to be within their respective OD tolerances.

All these tube specifications give limits for OD and Wall Thickness – the Inside Diameter is not separately specified, even although from the hygiene point of view there may be some logic in doing so.

4. Surface Finish

A249 and A269 both require surfaces "free of scale" – the mandatory annealing of the tube is normally done in a controlled atmosphere and this "bright annealed" finish is stated to be acceptable.

A270 requires selection of both internal and external surfaces. The possible conditions range from a "mill finish" (ie. the strip's 2B finish, without any subsequent polishing), to abrasive polishing with 80, 120, 180 or 240 grit, to special polishing and electropolishing. Surface finishes may also be specified in terms of Ra values, but no limits are given in the specification.

A554 requires only "free of scale" and implies a "direct off mill" finish as standard. Clause 12.2 does allow - "If special surface conditioning is required, they shall be stated in the order". Thus a large proportion of A554 tube used in the Australian market is supplied in the externally abrasive polished condition, in the range of about 180 - 320#, or with a very highly buffed surface, typically stated as 600#, or proprietary finishes such as the highly reflective "Ultrabrite".

AS1528.1 specifies the external surface "as-produced" or "buff polished", as agreed. The internal surface is required to be 2B finish, quoted as typically 0.3µm Ra. Work done by Atlas Steels indicates that for 1.6mm 2B coil (the starting material for welded tube) the typical roughness is 0.10 - 0.20 µm Ra; this would be expected to be degraded slightly in the manufacture of tube. With weld bead rolling it would be expected that the finish of the weld would also be similar to that of the parent tube.

5. Weld Bead

The food industry generally requires a tube with no weld bead remnant on the inside surface if the intended service is handling product.

A249M requires that at least the weld be cold worked after welding and before final heat treatment.

A269 does not require or allow for any weld bead control or cold working.

A270 makes no mention of weld bead, other than for “heavily cold worked” tube.

A554 can be supplied with the weld bead left on, but in recent years Australasian manufacturers of As Welded tube have made internal weld bead rolling a fairly routine procedure; this therefore complies with the "Bead Removed" option of A554. (Weld bead rolling is not generally possible in sizes below about 31.8mm, although sizes down to 20mm or even smaller can be hammer swaged by some manufacturers). Despite this practice “bead removed” is not a requirement for standard “AW” tube to ASTM A554.

AS1528.1 requires removal of the weld bead (except in the small sizes where the procedure is not possible). There is also a requirement that the internal surface be smooth, with no lack of weld penetration and no crevices adjacent to welds. This requirement addresses the heart of the issue - freedom from sites for product or bacterial build-up.

6. Heat Treatment

A249M, A269 and A270 all require that ... “all material shall be furnished in the heat treated condition”. Heat treatment is annealing (also referred to as solution treatment or solution annealing). In practice this is not a common requirement for food industry tube unless it requires significant bending or flaring.

A554 is normally supplied “as welded”, ie. no heat treatment after tube forming (although the tube will be produced from strip which has itself been annealed just prior to the final cold roll). There is the possibility of calling for A554 tube in the annealed condition, but this is never done - annealed tube (“As Welded Annealed” or AWA) is more usually specified to ASTM A269.

AS1528.1 allows either annealed or un-annealed conditions to be specified by the purchaser, although in practice un-annealed is standard.

7. Mechanical Properties

A249M is intended for critical environments in boilers or heat exchangers, so extensive mechanical testing is required. Full tensile and hardness testing is standard, as are flattening, flange and reverse bend.

A269 requires no tensile testing, but does require hardness tests, plus flange and reverse flattening.

A270 requires a reverse flattening test only.

A554 requires no mechanical testing as standard.

AS1528.1 requires no mechanical testing, but does require the tube to be made from strip compliant with ASTM A240 - which itself has tensile test requirements.

8. Non-Destructive Inspection

A249, A269, A270 and AS1528.1 all require 100% hydrostatic or eddy current testing.

A554 includes the possibility of NDT as a supplementary requirement, but this is not usual for A554 tube.

WHICH SPECIFICATION?

ASTM A249/A249M is written for heat exchangers. It does specify weld bead removal, but this can be met from other standards, without unnecessarily calling up the stringent mechanical testing of A249. The annealing mandatory in A249 will not be required for most food applications. A high cost option.

ASTM A269 again requires tube in the annealed condition. Conversely, it does not specify internal weld bead removal, which generally is a food industry requirement. A269's main positive aspect is that it is frequently a stock item. It will prove uncompetitive against un-annealed tube.

ASTM A270 also has problems in that it requires the tube in the annealed condition, and says nothing about weld bead. Not normally stocked in Australasia.

ASTM A554 in its usual supply condition is intended for mechanical or structural applications, not for pressure containment and not for sanitary use. The lack of weld non-destructive testing reduces the reliability and lack of weld bead removal reduces cleanability vital for food applications.

AS1528.1 is by far the safest option … and the most cost-effective. It is specifically directed at food industry applications, specifying the features necessary to ensure high integrity lines for hygienic applications without requiring high cost additional mechanical testing. Annealing is possible if required and surface finishes can be further specified. Batch traceability marking – considered essential to validate many food and pharmaceutical plants - is mandatory. Another key benefit is the existence of matching specifications for associated tube fittings.

REFERENCES FOR FURTHER READING

Refer to the individual specifications for full details of requirements. Note that ASTM specifications are revised frequently; current revisions should be checked. ASTM specifications can be purchased through their website at www.astm.org. Australian Standards are available at www.saiglobal.com.

ATLAS STEELS TECHNICAL SERVICES DEPARTMENT

Atlas Steels maintains a Technical Services Department to assist customers and the engineering community generally on correct selection, fabrication and application of specialty metals. Our metallurgists are supported by our laboratory and have a wealth of experience and readily available information.

Telephone 1800 818 599 (Australia) or +61 3 9272 9963
e-mail: tech@atlassteels.com.au or tech@atlassteels.co.nz

Further information is given on the Atlas website at **www.atlassteels.com.au**

Contact details for the extensive Atlas branch network are also listed on this website.

LIMITATION OF LIABILITY

ATLAS TECH NOTE No. 10

revised July 2006

RESTRICTIONS OF HAZARDOUS SUBSTANCES (RoHS)

BACKGROUND

The European Union has introduced a directive that restricts the use of certain substances. Called Restriction of Hazardous Substances (RoHS) Directive (Directive 2002/95/EC, dated 27/01/2003), it restricts some specific hazardous substances in electrical and electronic products. Effective July 1st 2006, the RoHS Directive identifies Lead, Mercury, Cadmium, Hexavalent Chromium, Polybrominated Biphenyls (PBB) and Polybrominated Diphenyl Ethers (PBDE) – these are banned from electrical and electronic products sold in Europe. An Annex to the Directive lists certain exemptions from the ban.

The reason for the ban is stated as "… to contribute to the protection of human health and the environmentally sound recovery and disposal of waste electrical and electronic equipment."
The Directive also states that the list of restricted substances is not fixed and final – there is an assumption that the Directive will be regularly reviewed in the light of new scientific evidence so that other substances may be included in future revisions. Many other countries are now implementing similar laws, so it can be expected that similar but perhaps not identical restrictions will apply to products imported to these other areas in the near future.

The present EU Directive applies specifically to items of electrical or electronic equipment imported into the European Union.

Dangerous substances restricted by the RoHS Directive

Substance	Examples of Applications
Lead	Addition to some metal products to improve machinability, solder (SnPb), thermal stabilizers of PVC (lead stearate...), yellow pigments for polymers (lead chromate)
Mercury	Switches (mercury whetted), lamps, displays
Cadmium	Electroplated coatings (with hexavalent chromium passivation), high temperature brazing alloys (eg Ag-Cu-Zn-Cd), thermal stabilizers of PVC (cadmium stearate), yellow pigments for polymers (cadmium sulphide)
Hexavalent Chromium	Contained in some passivations of zinc, copper, aluminium alloys, silver and galvanized sheet steel
Polybrominated Biphenyls (PBB)	Flame retardant, cables, plastics
Polybrominated Diphenyl Ethers (PBDE	Flame retardant, cables, plastics

MAXIMUM ALLOWABLE LEVELS

The Annex to the Directive states that there is a maximum level of 0.1% allowed for all of the above with the exception of cadmium, which is limited to 0.01%. The allowable level is for any "homogeneous compound". This is defined as any compound that can be removed through mechanical means including abrasion i.e. if you can grind it off then it is an homogenous compound. This means that a layer of paint or a passivation is classified as a homogenous compound and must not have more than 0.1% of any of the above substances in it. This rules out substances such as lead oxide as colorant or dye in paint.

There are a number of exemptions allowed, for example:

1. Batteries – these are covered by directive 95/157/EEC.
2. Mercury in specific types of lamps.
3. Lead in the glass of cathode ray tubes, electronic components, and fluorescent tubes.
4. Lead as an alloying element in steel containing up to 0.35% by weight, aluminium containing up to 0.4% lead by weight and as a copper alloy containing up to 4% lead by weight.
5. Lead in high melting temperature type solders (i.e. tin-lead solder alloys containing more than 85% lead).
6. Lead in solder in certain other specific applications.
7. Lead in electronic ceramic parts (e.g. piezo electronic devices).
8. Cadmium plating with some exceptions.
9. Hexavalent chromium in some corrosion inhibitors.

The full text of the Directive can be downloaded from http://europa.eu/eur-lex/pri/en/oj/dat/2003/l_037/l_03720030213en00190023.pdf

ATLAS STANDARD PRODUCTS

Atlas Steels believes that the standard stocked products set out in the following schedule comply with the RoHS directive except as noted. If you require formal validation however please contact Atlas Steels on a case by case basis. Please note the specific exclusion from the list of galvanised carbon steel product that has been passivated with a chromate compound – we do not believe that this product complies with the RoHS directive.

For further details related to Atlas stock or indent products please contact any Atlas Steels branch, or the central contact below.

Peter Moore
Technical Manager
Atlas Steels
telephone +61 3 9272 9963
email peter.moore@atlassteels.com.au
internet www.atlassteels.com.au

Schedule of Standard Atlas Products	
Product	**Comments**
Stainless steel flat rolled product (plate, sheet, coil and strip).	PVC (polyvinyl chloride) plastic film is applied to certain products, particularly intended for deep drawing; there is no information on the compliance of this film. PE (polyethylene) plastic film is used on standard products and does not contain objectionable amounts of banned substances. It is presumed in any case that all protective plastic films would be removed prior to the finished product entering service.
Stainless steel tube, pipe and associated fittings.	All of these products comply with the directive. Rubber seals and similar non-metallic components are exceptions that would need to be validated on a case-by-case basis.
Stainless steel sections and bar.	None of the free machining grades of stainless steel contain deliberate lead additions, so all stainless steel bars will comply with the directive.
Carbon steel and low alloy steel bars.	Leaded free machining grades of carbon steel are listed in the table below. All carbon steel and low alloy steel bars comply.
Carbon steel tube, pipe and associated fittings.	All of these products comply with the directive.
Galvanised, electrogalvanised and zinc-aluminium coated sheet steel.	Chromate conversion coatings on these products may not comply. Electroplated or hot-dipped coatings without the chromate conversion do comply.
Aluminium alloy flat rolled product (plate, sheet, coil and strip).	All of these products comply with the directive.
Copper alloy bars.	Alloy 385 complies as its lead content is specified 3.8% maximum, as shown in the table below. All standard non-free machining copper alloys comply.
Cast iron fittings.	Cast iron complies with the directive, but any items coated with paint or similar products are exceptions that would need to be validated on a case-by-case basis..
A note on stainless steel and chromium Stainless steels all by definition contain at least 10.5% chromium. The chromium is not present in the banned hexavalent form, it is all present as solid metal. The British Stainless Steel Association's website gives a more complete explanation for the statement of compliance for all stainless steels.	

The commonly stocked "leaded" free machining grades of steel and copper alloy have lead contents as follows, and hence are permitted under the exceptions clause …

Leaded Free Machining Carbon Steel and Copper Alloy Bars		
Product	**Lead content specified**	**Comment**
12L14 bright carbon steel bar	0.15 – 0.35% Pb	Complies with 0.35% maximum
Alloy 385 (UNS C38500)	2.5 – 3.8% Pb	Complies with 4% maximum

FURTHER REFERENCES

- EU Directive 2002/95/EC "Restriction of Hazardous Substances", dated 27/01/2003.
- BSSA statements re Hexavalent Chromium, and the relationship of this to chromium-containing steels. See http://www.bssa.org.uk/index.htm
- Mill inspection certificates for each product – available on request from Atlas Steels.

ATLAS STEELS TECHNICAL SERVICES DEPARTMENT

Atlas Steels maintains a Technical Services Department to assist customers and the engineering community generally on correct selection, fabrication and application of specialty metals. Our metallurgists are supported by our laboratory and have a wealth of experience and readily available information.

Telephone 1800 818 599 (Australia) or +61 3 9272 9963
e-mail: tech@atlassteels.com.au or tech@atlassteels.co.nz

Further information is given on the Atlas website at **www.atlassteels.com.au**

Contact details for the extensive Atlas branch network are also listed on this website.

LIMITATION OF LIABILITY

The information contained in this Atlas Steels Tech Note is not an exhaustive statement of all relevant information. It is a general guide for customers to the products and services available from Atlas Steels and no representation is made or warranty given in relation to this information or the products or processes it describes.

ATLAS TECH NOTE No. 11

July 2010

MAGNETIC RESPONSE OF STAINLESS STEELS

Magnetic response – or the lack of it – is often one of the first things that people think of as a basic property of stainless steels. The response of stainless steels to a magnet is an interesting physical property and can be a useful sorting test but it is not as clear-cut as is often thought.

WHAT ARE THE BASIC MAGNETIC PROPERTIES OF MATERIALS?

Ferromagnetic Materials
Materials that are strongly attracted to a magnet (either permanent or electro) and that can themselves form permanent magnets. This is the usual property when a material is said to be "magnetic".

Magnetic Permeability
The ease by which a magnetic material can be magnetised is expressed by the Magnetic Permeability. Values close to 1.0 show the material is non-magnetic.

Hard or Soft Magnetic Characteristics
Magnetic materials can be classified as "Hard" or "Soft". Hard magnetic materials retain a large amount of residual magnetism after exposure to a magnetic field. Soft magnetic materials can be magnetised by a relatively small magnetic field and when this is removed they revert to low residual magnetism.

Non-magnetic Materials
Materials that show no response to a magnet.

Curie Temperature
Some metals have a temperature at which they change from ferromagnetic to non-magnetic. For common carbon steels this happens at about 768°C.

WHICH METALS ARE MAGNETIC?

All common carbon steels (including mild steel), low alloy steels and tool steels are ferromagnetic. Some other metals such as nickel and cobalt are also ferromagnetic. All stainless steels with the exception of the austenitic grades are also magnetic – all ferritic grades (eg 430, AtlasCR12, 444, F20S), all duplex grades (eg 2205, 2304, 2101, 2507), all martensitic grades (eg 431, 416, 420, 440C) and all precipitation hardening grades (eg 630/17-4PH). Even although the duplex grades are mixtures of austenite and ferrite they are still strongly attracted to a magnet.

WHICH METALS ARE NON-MAGNETIC?

Most non-ferrous metals such as aluminium and copper and their alloys are non-magnetic. Austenitic stainless steels, both the common 300-series (Cr-Ni) and the lower nickel 200-series (Cr-Mn-Ni) are non-magnetic. It is common for wrought austenitic stainless steels to contain a very small amount of ferrite, but this is not sufficient to significantly affect magnetic performance except in very critical applications.

WELDS AND CASTINGS

Castings in austenitic stainless steels have slightly different compositions compared to their wrought counterparts. The cast version of 316L for instance is grade CF-3M. Most "austenitic" cast alloys are very deliberately made so that they have a few percent of ferrite – this helps prevent hot cracking during casting.

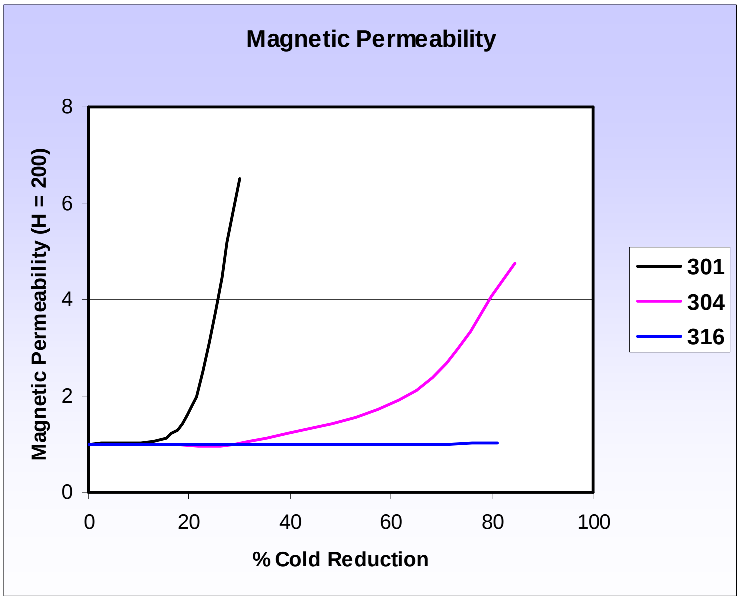
A weld can be viewed as a small, long casting, and for the same reason as detailed above austenitic welds have about 4 – 8% ferrite. In the case of both welds and castings the small amount of ferrite results in a small amount of magnetic response, but it can be readily detected with a good hand-held magnet. With a suitable "ferrite meter" this magnetic response can in fact be used to measure the amount of ferrite in a weld.

FERRITE-FREE AUSTENITIC STAINLESS STEELS

If a weld is required to be zero ferrite content special consumables are available. "Ferrite-free" 316L plate can also be sourced (it has a higher content of nickel than standard 316L), or existing stock 316L plate can be tested to confirm ferrite level. "Ferrite-free" products are specially produced for a few specific corrosive conditions, not usually for their magnetic properties.

THE EFFECT OF COLD WORK

Even although wrought austenitic stainless steels are non-magnetic in the annealed condition they may develop magnetic response when cold worked. Cold work can transform some austenite to martensite. This has a dramatic effect on tensile strength and even more so on yield strength; a heavily cold drawn grade 304 wire can achieve a tensile strength of up to around 2000MPa. Such a highly worked 304 will also be very strongly attracted to a magnet.



Grades with higher amounts of austenite forming elements – nickel, manganese, carbon, copper and nitrogen – form less martensite when cold worked, so do not become so strongly magnetic. This can be evaluated as the ratio of austenite former elements divided by ferrite former elements, or simply as the Ni/Cr ratio. Grade 316 products usually only become slightly magnetic and 310 and 904L are almost totally non-magnetic no matter how severely cold worked. Grade 301 on the other hand has a lesser amount of nickel and work hardens even more rapidly than does 304 …. and becomes strongly magnetic after even a small amount of cold work.

These comparisons are shown in the graph above. Note that different heats of steels of the same grade may exhibit different magnetic responses because of minor differences in the amounts of each element.

HEAT TREATMENT

If a piece of austenitic stainless steel has been made to respond to a magnet by cold work this can be removed by a solution treatment – the standard treatment of heating to about 1050°C (depending on the grade) followed by water quenching or other rapid cooling. The high temperature allows the "strain-induced martensite" to re-form as austenite and the steel returns to being non-magnetic. It is also returned to being low strength.

DOES MAGNETIC RESPONSE MATTER?

Magnetic response has no effect on any other property. Cold drawn 304 (and to a lesser degree 316) is attracted to a magnet, but this has no effect on the corrosion resistance. Some of the most highly corrosion resistant stainless steels are strongly magnetic … examples are the duplex and super duplex grades and highly alloyed ferritic grades such as 29-4C. Cold drawn 304 also has high tensile strength, but this is not due to the magnetic response – both the magnetic response and the high strength are due to the cold work.

Applications where absence of magnetic response may be required include MRI equipment and in naval mine-hunter vessels. Specialist guaranteed low magnetic response stainless steels can be sourced for such applications.

MAGNETICALLY SOFT STAINLESS STEELS

Magnetically soft steels are used in electrical applications involving changing electromagnetic induction. Solenoids and relays are typical examples: the magnetic field must be able to collapse when the electric current is shut off, releasing the solenoid plunger. Where these components also need to have corrosion resistance a ferritic stainless steel can be a good choice. For critical applications specialist ferritic bar grades are available (subject to mill enquiry) with guaranteed magnetic properties.

SORTING OF STEELS

The magnetic response of a piece of steel is a quick and qualitative test that can be useful for sorting grades of steel. Other qualitative tests are listed in Atlas TechNote 1.

Grade Sorting by Magnetic Response
What Can Be Sorted Austenitic (both 300-Series and 200-series) stainless steels from other steels. All other steels are attracted to a magnet, including all the ferritic, duplex, martensitic and precipitation hardening stainless steels. The only other non-magnetic steels are the austenitic 13% manganese steels (eg "P8").
Method Note response, if any, when a permanent magnet is brought close to the steel.
Tips & Traps Some austenitic grades, particularly 304, are to some degree attracted to a magnet when cold worked, eg by bending, forming, drawing or rolling. Stress relieving at cherry-red heat will remove this response due to cold work, but this stress relief may sensitise the steel and should not be performed on an item which is later to be used in a corrosive environment. A full anneal is acceptable, however. Even although duplex grades have only half the amount of the magnetic ferrite phase compared to fully ferritic grades such as 430, the difference in "feel" of a manual test is unlikely to be enough to enable sorting duplex steels from ferritic, martensitic or precipitation hardening grades. Austenitic stainless steel castings and welds are also usually slightly magnetic due to a deliberate inclusion of a small percentage of ferrite in the austenitic deposit. The % ferrite can be measured by the amount of magnetic response, and special instruments are available for this.
Safety Precautions No hazards associated with this test

REFERENCES & FURTHER INFORMATION

Atlas TechNote 1 “Qualitative sorting tests”
Nickel Institute Publication 2978 “Mechanical & physical properties of austenitic chromium-nickel stainless steels at ambient temperatures”
ASM Specialty Handbook “Stainless steels”
ASSDA Technical FAQ No 3 “Magnetic effects of stainless steels”.

ATLAS STEELS TECHNICAL SERVICES DEPARTMENT

Atlas Steels maintains a Technical Services Department to assist customers and the engineering community generally on correct selection, fabrication and application of specialty metals. Our metallurgists are supported by our laboratory and have a wealth of experience and readily available information.

Telephone 1800 818 599 (Australia) or +61 3 9272 9963
e-mail: tech@atlassteels.com.au or tech@atlassteels.co.nz

Further information is given on the Atlas website at **www.atlassteels.com.au**

Contact details for the extensive Atlas branch network are also listed on this website.

LIMITATION OF LIABILITY

The information contained in this Atlas Steels Tech Note is not an exhaustive statement of all relevant information. It is a general guide for customers to the products and services available from Atlas Steels and no representation is made or warranty given in relation to this information or the products or processes it describes.

ATLAS TECH NOTE
No. 12

January 2011

PIPE DIMENSIONS

The dimensions of pipe – carbon steel and stainless steel – are shrouded in the mystery of an arcane designation system; its origins go back to ASME recommendations of 1886!

SPECIFICATIONS

Pipe used in Australia and New Zealand is almost exclusively specified to American standards; carbon steel "hollow sections" are additionally specified to AS/NZS 1163. The usual specifications are …

ASTM A53M	standard ERW welded carbon steel pipe
ASTM A106M	standard seamless carbon steel pipe
ASTM A333M	seamless and welded carbon steel pipe for low temperature service
ASTM A312M	most stainless steel pipe produced on continuous pipe mills and seamless pipe
ASTM A358M	larger diameter welded stainless steel pipe
ASTM A790M	welded and seamless duplex stainless steel pipe
API 5L / ISO 3183	carbon steel line pipe for the petroleum and natural gas industries
AS/NZS 1163	carbon steel structural steel "hollow sections"

The American standards all refer to ASME B36.10M or ASME B36.19M for nominal dimensions of carbon steel and stainless steel respectively, but dimensional tolerances are in the ASTM or API standards.

Pipe produced to multiple specifications is common; Atlas ERW carbon steel is generally to API 5L Grade B & X42 PSL1 / ASTM A53M GR B / AS/NZS1163 C350 and 0.23% carbon maximum.

OUTSIDE DIAMETER

The outside diameters of pipes are described by the "Nominal Pipe Size", shown in specifications as NPS and often incorrectly called "inches". In more recent times with the introduction of the metric system and with the usage of the same pipes in Europe, a metric version has been developed called DN, or "Diameter Nominal", often incorrectly called "millimetres" and also incorrectly referred to as Nominal Bore or NB. The pipe sizing system did originate with an understanding that then standard pipe sizes when used at the then most typical wall thickness gave an internal diameter approximately equal to the nominal size. With the current multiplicity of wall thicknesses available the Nominal Bore concept has long since ceased to be relevant, and in fact is now misleading. All pipe is specified by outside diameter, never by inside diameter.

WALL THICKNESS

Wall thicknesses of carbon steel and stainless steel pipe are most commonly (but not exclusively; see later comments) described by a "Schedule Number". The wall thickness for a schedule varies according to the pipe size and is given in tables in the relevant specifications; refer to the table on page 3 of this TechNote. These schedules are derived from two different specifications, for carbon steels and for stainless steels, so although they share much there are some important differences. "S" schedules are specific to stainless steels and schedules without the "S" are intended for carbon steels. Carbon steel pipe to AS/NZS 1163 is also specified to hard millimetre thicknesses; these are close enough to the ASME schedules that multiple compliance product is possible.

WHERE CARBON STEEL SCHEDULES EQUAL STAINLESS SCHEDULES

Up to DN 300 (NPS 12) all Sch 10 and Sch 10S wall thicknesses are the same.
Up to DN 250 (NPS 10) all Sch 40, Std Wt and Sch 40S wall thicknesses are the same.
Up to DN 200 (NPS 8) all Sch 80, XS and Sch 80S wall thicknesses are the same.

THE DIFFERENCES BETWEEN CARBON STEEL AND STAINLESS PIPE

In larger nominal sizes Std Wt and XS schedules remain constant, but schedules 10, 40 and 80 continue to increase with larger pipe sizes. (The ASME committee had hoped that these older Std Wt, XS and XXS wall thicknesses would gradually disappear, when the standard was revised – in 1939!) The stainless steel "S" schedules are aligned with the Std Wt and XS series …

- Sch 40S matches Std Wt and Sch 80S matches XS, throughout the full size range.
- Sch 10S deviates from Sch 10 above DN 300 – there is no carbon steel equivalent to 10S.

In carbon steels there is a very rich range of schedules, including a thin wall Sch 5 (identical to stainless steel Sch 5S) and many other wall thicknesses not in the list on page 3. Only the common pipe sizes and schedules are held in stock.

STAINLESS STEEL PIPE WITH SCH 80?

Occasionally specifiers require larger size (over DN 200) stainless steel pipe with a heavier wall than Sch 80S. This can be covered by calling for Sch 80. This is an uncommon but legitimate deviation and the dimensions are covered by ASME B36.10M. Stainless pipe to Sch 80 is a "special" that is not commonly stocked. There will be a price premium.

In most instances, when a stainless steel pipe is requested with a Sch 40, Sch 80 etc, this is due to somebody taking a short-cut – what they really want is standard Sch 40S or Sch 80S. This must be confirmed for all contracts involving larger sized stainless steel pipe.

TOLERANCES

Outside Diameter

Nominal Pipe Size		Carbon Steel		Stainless Steel
DN	**NPS**	**ASTM A53M**	**ASTM A106M**	**ASTM A999M**
6 to 40	⅛ to 1½	±0.4mm	±0.4mm	+0.4 / -0.8mm
Over 40 to 100	Over 1½ to 4	±1%	±0.8mm	±0.8mm
Over 100 to 200	Over 4 to 8	±1%	+1.6 / -0.8mm	+1.6 / -0.8mm
Over 200 to 450	Over 8 to 18	±1%	+2.4 / -0.8mm	+2.4 / -0.8mm
Over 450 to 650	Over 18 to 26	±1%	+3.2 / -0.8mm	+3.2 / -0.8mm
Over 650 to 850	Over 26 to 34	±1%	+4.0 / -0.8mm	+4.0 / -0.8mm
Over 850 to 1200	Over 34 to 48	±1%	+4.8 / -0.8mm	+4.8 / -0.8mm

Wall Thickness

Nominal Pipe Size		Carbon Steel	Stainless Steel
DN	**NPS**	**ASTM A53M & 106M**	**ASTM A312M**
6 to 65	⅛ to 2½	-12.5% minimum	+20.0 / -12.5%
80 to 450, t/D ≤ 5% t/D > 5%	3 to 18, t/D ≤ 5% t/D > 5%	-12.5% minimum	+22.5 / -12.5% +15.0 / -12.5%
500 and over … • welded • seamless, t/D ≤ 5% • seamless, t/D > 5%	20 and over … • welded • seamless, t/D ≤ 5% • seamless, t/D > 5%	-12.5% minimum *(maximum wall thickness limited only by mass – see below)*	 +17.5 / -12.5% +22.5 / -12.5% +15.0 / -12.5%
t = nominal wall thickness, D = ordered outside diameter. Refer to next page for these values. The mass of all carbon steel pipe and seamless stainless steel pipe is limited to +10% and a minus limit that varies depending on size – refer to standards for details.			

Straightness

The carbon steel pipe standards require only that "the finished pipe shall be reasonably straight". ASTM A312M (in ASTM A999M) requires welded stainless steel pipe to be straight to within 3.2mm over 3.0m length.

Nominal Pipe Size		**Outside Diameter (mm)**	**Wall Thickness (mm)**																
			Stainless Steel				**Carbon Steel**												
DN	**NPS**		**Sch 5S**	**Sch 10S**	**Sch 40S**	**Sch 80S**	**Sch 10**	**Sch 20**	**Sch 30**	**Sch 40**	**STD**	**Sch 60**	**Sch 80**	**XS**	**Sch 100**	**Sch 120**	**Sch 140**	**Sch 160**	**XXS**
6	⅛	10.3		1.24	1.73	2.41	1.24		1.45	1.73	1.73		2.41	2.41					
8	¼	13.7		1.65	2.24	3.02	1.65		1.85	2.24	2.24		3.02	3.02					
10	⅜	17.1		1.65	2.31	3.20	1.65		1.85	2.31	2.31		3.20	3.20					
15	½	21.3	1.65	2.11	2.77	3.73	2.11		2.41	2.77	2.77		3.73	3.73				4.78	7.47
20	¾	26.7	1.65	2.11	2.87	3.91	2.11		2.41	2.87	2.87		3.91	3.91				5.56	7.82
25	1	33.4	1.65	2.77	3.38	4.55	2.77		2.90	3.38	3.38		4.55	4.55				6.35	9.09
32	1¼	42.2	1.65	2.77	3.56	4.85	2.77		2.97	3.56	3.56		4.85	4.85				6.35	9.70
40	1½	48.3	1.65	2.77	3.68	5.08	2.77		3.18	3.68	3.68		5.08	5.08				7.14	10.15
50	2	60.3	1.65	2.77	3.91	5.54	2.77		3.18	3.91	3.91		5.54	5.54				8.74	11.07
65	2½	73.0	2.11	3.05	5.16	7.01	3.05		4.78	5.16	5.16		7.01	7.01				9.53	14.02
80	3	88.9	2.11	3.05	5.49	7.62	3.05		4.78	5.49	5.49		7.62	7.62				11.13	15.24
90	3½	101.6	2.11	3.05	5.74	8.08	3.05		4.78	5.74	5.74		8.08	8.08					
100	4	114.3	2.11	3.05	6.02	8.56	3.05		4.78	6.02	6.02		8.56	8.56		11.13		13.49	17.12
125	5	141.3	2.77	3.40	6.55	9.53	3.40			6.55	6.55		9.53	9.53		12.70		15.88	19.05
150	6	168.3	2.77	3.40	7.11	10.97	3.40			7.11	7.11		10.97	10.97		14.27		18.26	21.95
200	8	219.1	2.77	3.76	8.18	12.70	3.76	6.35	7.04	8.18	8.18	10.31	12.70	12.70	15.09	18.26	20.62	23.01	22.23
250	10	273.1	3.40	4.19	9.27	12.70	4.19	6.35	7.80	9.27	9.27	12.70	15.09	12.70	18.26	21.44	25.40	28.58	25.40
300	12	323.9	3.96	4.57	9.53	12.70	4.57	6.35	8.38	10.31	9.53	14.27	17.48	12.70	21.44	25.40	28.58	33.32	25.40
350	14	355.6	3.96	4.78	9.53	12.70	6.35	7.92	9.53	11.13	9.53	15.09	19.05	12.70	23.83	27.79	31.75	35.71	
400	16	406.4	4.19	4.78	9.53	12.70	6.35	7.92	9.53	12.70	9.53	16.66	21.44	12.70	26.19	30.96	36.53	40.49	
450	18	457	4.19	4.78	9.53	12.70	6.35	7.92	11.13	14.27	9.53	19.05	23.83	12.70	29.36	34.93	39.67	45.24	
500	20	508	4.78	5.54	9.53	12.70	6.35	9.53	12.70	15.09	9.53	20.62	26.19	12.70	32.54	38.10	44.45	50.01	
550	22	559	4.78	5.54			6.35	9.53	12.70		9.53	22.23	28.58	12.70	34.93	41.28	47.63	53.98	
600	24	610	5.54	6.35	9.53	12.70	6.35	9.53	14.27	17.48	9.53	24.61	30.96	12.70	38.89	46.02	52.37	59.54	
650	26	660					7.92	12.70			9.53			12.70					
700	28	711					7.92	12.70	15.88		9.53			12.70					
750	30	762	6.35	7.92			7.92	12.70	15.88		9.53			12.70					

These dimensions are nominal – substantial tolerances apply to both OD and WT – refer to the standards for details.
Stainless steel pipe nominal dimensions based on ASTM A312M and ASME B36.19M-2004.
Carbon steel pipe nominal dimensions based on ASTM A106M and ASME B36.10M-2004. For other wall thicknesses and for sizes of carbon steel pipe above DN 750 consult ASME B36.10M.

THE OTHER PIPE SIZES – AUSTRALIAN STANDARD

There is a range of carbon steel "tube" covered by AS 1074 and AS 1579 that also has DN designations for nominal size. There are some differences between these and the ASTM / ASME pipes of the same designation as shown in the table of nominal outside diameters at right. The AS tubes do not have schedules of wall thickness but rather come in Light, Medium and Heavy wall.

Flanges intended for use with ASTM pipe or AS 1074 tube may need different internal bore sizes; note particularly DN 65, DN 125 and DN 150.

The AS/NZS 1163 product has the same outside diameters as these other Australian standards, but does not refer to DN sizes, only to nominal millimetres.

Nominal Size (DN)	ASME (mm)	AS 1074 / AS 1579 (mm)
15	21.3	21.3
20	26.7	26.9
25	33.4	33.7
32	42.2	42.4
40	48.3	48.3
50	60.3	60.3
65	73.0	76.2
80	88.9	88.9
90	101.6	101.6
100	114.3	114.3
125	141.3	139.7
150	168.3	165.1

PIPE DESIGNATED BY SIZE

Some manufacturers supply standard pipe to the usual DN / Schedule sizes, but they describe the size as OD x WT in millimetres. So an inspection certificate describes the pipe as 88.9 x 3.05mm for instance. This is still just a DN 80 Sch 10S. All Atlas products are designated by ASME DN and Sch or designator (eg STD, XS or XXS) unless clearly identified as compliant to Australian Standards.

REFERENCES & FURTHER INFORMATION

ASTM A53M-07 "Pipe, Steel, Black and Hot Dipped, Zinc-Coated, Welded and Seamless"
ASTM A106M-06a "Seamless Carbon Steel Pipe for High Temperature Service"
ASTM A312M "Seamless, Welded and Heavily Cold Worked Austenitic Stainless Steel Pipes"
ASTM A333M-05 "Seamless and Welded Steel Pipe for Low Temperature Service"
ASTM A358M-05 "Electric Fusion Welded Austenitic Chromium Nickel Stainless Steel Pipe for High Temperature Service and General Applications"
ASTM A790M-07 "Seamless and Welded Ferritic/Austenitic Stainless Steel Pipe"
API 5L/ISO 3183:2007 "Specification for Line Pipe"
ASME B36.10M-2000 "Welded and Seamless Wrought steel Pipe"
ASME B36.19M-2004 "Stainless Steel Pipe"
AS/NZS 1163-2009 "Cold-Formed Structural Steel Hollow Sections"

ATLAS STEELS TECHNICAL SERVICES DEPARTMENT

Atlas Steels maintains a Technical Services Department to assist customers and the engineering community generally on correct selection, fabrication and application of specialty metals. Our metallurgists are supported by our laboratory and have a wealth of experience and readily available information.

Telephone 1800 818 599 (Australia) or +61 3 9272 9963 e-mail: tech@atlassteels.com.au

Further information is given on the Atlas website at **www.atlassteels.com.au**

Contact details for the extensive Atlas branch network are also listed on this website.

LIMITATION OF LIABILITY

The information contained in this Atlas Steels Tech Note is not an exhaustive statement of all relevant information. It is a general guide for customers to the products and services available from Atlas Steels and no representation is made or warranty given in relation to this information or the products or processes it describes.