# ATLAS TECH NOTE No. 8

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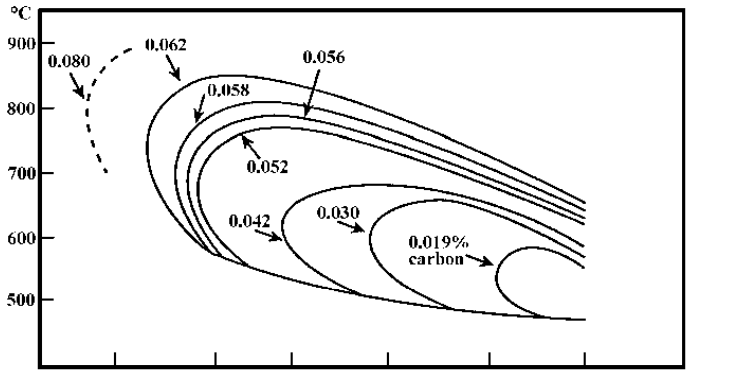
## "L", "H" AND STANDARD GRADES OF STAINLESS STEELS

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.

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