

ASTM A 516 Pressure Vessel Quality Plate

ASTM A516 is a specification for carbon steel plates for moderate and low temperature service. The plates are generally used for the construction of welded pressure vessels when an improvement in notch toughness is required.

ASTM A516 (or ASME SA516) is available in four grades: 55, 60, 65 and 70. Tensile strengths range from 380MPa to 620MPa depending on the grade. Oakley Steel supplies Grade 60 and Grade 70.

Whilst it is possible for very thick plates (200mm) to be produced that meet the requirements of the standard the thickest generally available plates are 150mm.

A516 steel plate is killed and has a fine austenitic grain size. Plates less than 40mm thick can be supplied as rolled or normalised, whereas plates over 40mm thick are normalised.

- Thickness:
4 - 200mm
- Width:
1500mm, 2000mm, 2055mm, 2500mm, 3000mm, 4000mm*
- Length:
6000mm, 8000mm, 10000mm, 12000mm, 14000mm*

Chemical Properties

	Composition (%)		
	A516 Grade 60	A 516 Grade 65**	A16 Grade 70
Carbon (C) (Max)			
≤12.5mm Thick	0.21	0.24	0.27
>12.5mm - ≤50mm Thick	0.23	0.26	0.28
>50mm - ≤100mm Thick	0.25	0.28	0.30
>100mm - ≤200mm Thick	0.27	0.29	0.31
>200mm Thick	0.27	0.29	0.31
Manganese (Mn)			
≤12.5mm Thick			
Heat Analysis	0.6-0.9	0.85-1.2	0.85-1.2
Product Analysis	0.55-0.98	0.79-1.3	0.79-1.3
>12.5mm Thick			
Heat Analysis	0.85-1.2	0.85-1.2	0.85-1.2
Product Analysis	0.79-1.3	0.79-1.3	0.79-1.3
Phosphorous (P)(max)	0.035	0.035	0.035
Sulphur (S) (max)	0.035	0.035	0.035
Silicon (Si)			
Heat Analysis	0.15-0.4	0.15-0.4	0.15-0.4
Product Analysis	0.13-0.45	0.13-0.45	0.13-0.45
Product Analysis	0.13-0.45	0.13-0.45	0.13-0.45

Mechanical Properties

	A516 Grade 60	A 516 Grade 65**	A16 Grade 70
Tensile Strength (ksi)	60-80	65-85	70-90
Tensile Strength (MPa)	415-550	450-585	485-620
Yield Strength (ksi)	32	35	38
Yield Strength (MPa)	220	240	260
Elongation in 200mm (%)	21	19	17
Elongation in 50mm (%)	25	23	21
Max Thickness (mm)	205	205	205

*subject to availability

**A516 Grade 65 is only supplied with HIC resistance



Carbon and low alloy boiler and pressure vessel steel plate

quality steel supplied for: oil & gas, petrochemical & process, construction & shipbuilding industries

Oakley Steel supplies carbon steel boiler plates for use where Sulphide Stress Cracking (SSC) is an issue. The incidence of SSC can be limited by setting a maximum limit on the hardness of plates.

Sulphide stress cracking generally occurs in environments that have a high concentration of H₂S and which are acidic. Hydrogen is absorbed into the steel where it expands causing cracks that can damage or reduce the integrity of the steel structure.

A number of factors affect the likelihood of a steel being effected by SSC. These include: the grade, hardness, form and heat treatment of the steel being used, the H₂S partial pressure, the acidity and the presence of sulphur and chloride ions. Also important is the temperature, the tensile stress applied and the length of time of exposure.

An option for improving SSC resistance (as opposed to HIC, SOHIC or SZC resistance) is to select plates with a maximum hardness

Carbon steel plates with a maximum 22 HRC (according to NACE MR0175:2) are qualified for use in SSC environments. They must however have a maximum of 1% nickel content and require heat treatment (hot-rolled; annealed; normalised, normalised and tempered; normalised, austenitised, quenched and tempered; and, austenitised, quenched and tempered)

Welds are also susceptible to SSC and need to be hardness tested – meeting similar requirements and potentially requiring PWHT if the hardness is too high.

Most carbon steel in pressure vessel quality grades sold by Oakley Steel are suitable for use in an SSC environment providing that they are hardness tested. NACE MR0175 allows for individual results to exceed the 22 HRC so long as the tests are taken in close proximity to each other, that the average is below 22HRC and that no individual value is above 24 HRC.

The following grades are suitable for SSC use with hardness testing:

- A516 60
- A516 70
- Thickness: 5 - 150mm
- Width: 1500, 2055, 2500, 3000mm
- Length: up to 12000mm

NACE Characteristics

Carbon steels with a hardness of less than 22 HRC (in accordance with NACE MR0175:2 Section 7 and Appendix A) are qualified for SSC resistance. They are not necessarily resistant to HIC or other forms of corrosion caused by high levels of H₂S.



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ASTM A 516 Pressure Vessel Quality Plate with HIC resistance

HIC plate or Hydrogen Induced Cracking resistant plate is carbon steel plate, such as A516, which has been further tested to demonstrate that it is resistant to hydrogen induced cracking.

The steel plate must meet all the standard requirements of the grade – such as chemical composition and have the same mechanical properties – but the manufacturing process has been developed so that when the steel is tested in a synthetic sour service environment the cracks that form have certain maxima. This gives designers the confidence to use carbon steel boiler plate in sour service avoiding much more expensive stainless steel plate.

It is mainly used for pressure vessel and boiler manufacture in the oil and gas and petrochemical industries where the oil has high sulphur content – known as sour service. The improved crack resistance helps to reduce maintenance and full life costs – as well as improved safety over standard boiler plate.

When steels are evaluated for resistance (not immunity) to HIC one of the key factors is the level of sulphur in the steel and typically maximum allowable levels are 0.003% in plates if the acceptance tests in TM0284 are to be met.

Oakley Steel offers HIC plate in the following ASTM grades A516 grades 60, 65 and 70.

- Thickness:
8 - 80mm
- Width:
1500, 2055, 2500, 3000
- Length:
up to 12000mm

All plates come with certification according to EN10204 3.2.

European (EN) and American (ASTM/ASME) pressure vessel quality steel grades can both be produced with HIC resistance. EN10028 specifies the acceptance requirements for

the EN grades (starting with P) and the test requirements are specified in EN10229.

American grades are specified in NACE MR0175 and the testing requirements in NACE TM0284. Generally we offer A516 plate in grades 60, 65 and 70 which have been tested to TM0284 and which meet acceptance class I of EN 10028-3.

There are three acceptance classes for HIC plates under EN 10028-3. Each acceptance class sets requirements for the maximum permissible % of the crack to length ratio (CLR), the crack to thickness ratio (CTR) and the crack sensitivity ratio (CSR). Acceptance class I is the most resistant, followed by II and then III.

The table below shows the acceptable test results using Test Solution A (pH3).

Acceptance Class	CLR %	CTR %	CSR %
I	≤5	≤1.5	≤0.5
II	≤10	≤3	≤1
III	≤15	≤5	≤2

Oakley Steel offer HIC resistant plate that meets acceptance class I.



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ASTM A 387 Chrome Molybdenum Pressure Vessel Quality Plate

A387 is a steel grade intended for use in boilers and pressure vessels designed for high temperature use. The grade is a chrome molybdenum low alloy steel and is available in plate form from Oakley Steel.

The ASTM A387 standard covers 10 grades of A387 – 2, 5, 9, 11, 12, 21, 21L, 22, 22L, and 91. These grades are differentiated by the amount of Chromium and Molybdenum in the alloy. The Molybdenum component is either 0.5% or 1% whilst the Chromium content ranges from 0.5% for grade 2 to 9% for grade 91.

Oakley Steel offers grades 5, 11, 12 and 22. Grade 91 isn't generally produced in Europe.

To satisfy the various engineering requirements of boiler manufacturers the different grades can be supplied as Class 1 or Class 2. Class 2 offers a higher yield and tensile strength but the chemical composition is the same for both classes. We only offer Class 2 as, generally, it will meet the design requirements of customers needing both Class 1 and Class 2 A 387 plate. Tensile strengths range from 485 - 620 MPa for grade 2 to 515-690 MPa for Grade 9.

Whilst it is possible for very thick plates to be produced that meet the requirements of the standard these usually have to be specially rolled to your requirements. For high availability the thickest plates usually on hand are 150mm thick for grade 12 and less for the other grades.

A387 is killed and plates require heat treatment before use. Generally annealing, normalising and tempering is undertaken by the mill, but where plates are supplied without heat treatment they are annealed and stress relieved.

SA 387 Grade 5

- Thickness:
5 - 80mm
- Width:
1500, 2000, 2500, 3000mm
- Length:
up to 12000mm

SA 387 Grade 11

- Thickness:
6 - 60mm
- Width:
1500, 2000, 2500, 3000mm
- Length:
up to 12000mm

SA 387 Grade 12

- Thickness:
3 - 150mm
- Width:
1500, 2000, 2500, 3000mm
- Length:
up to 12000mm

SA 387 Grade 22

- Thickness:
4 - 120mm
- Width:
1500, 2000, 2500, 3000mm
- Length:
up to 12000mm

16 Mo 3

- Thickness:
1, 5 - 300mm
- Width:
2000, 2500, 3000mm
- Length:
up to 12000mm



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Mechanical Properties

	A 387 Grade 5		A 387 Grade 11		A 387 Grade 12		A 387 Grade 22	
	Class 1	Class 2	Class 1	Class 2	Class 1	Class 2	Class 1	Class 2
Tensile Strength (ksi)	60 – 85	75 – 100	60 – 85	70 – 90	50 – 80	65 – 85	60 – 85	75 – 100
Tensile Strength (MPa)	415 – 585	515 – 690	415 – 585	485 – 620	380 – 550	450 – 585	415 – 585	515 – 690
Yield Strength (ksi)	30	45	35	45	33	40	30	45
Yield Strength (MPa)	205	310	240	310	230	275	205	310
Elongation in 200mm (%)	-	-	19	18	18	19	-	-
Elongation in 50mm (%)	18	18	22	22	22	22	18	18
Reduction of area in %	45	45	-	-	-	-	45	45

Chemical Properties

	Grade 5	Grade 11	Grade 12	Grade 22
Carbon				
Heat Analysis	0.15 max	0.05 – 0.17	0.05 – 0.17	0.05 – 0.15
Product Analysis	0.15 max	0.04 – 0.17	0.04 – 0.17	0.04 – 0.15
Manganese				
Heat Analysis	0.3 – 0.6	0.4 – 0.65	0.4 – 0.65	0.3 – 0.6
Product Analysis	0.25 – 0.66	0.35 – 0.73	0.35 – 0.73	0.25 – 0.66
Phosphorous				
Heat Analysis	0.035	0.035	0.035	0.035
Product Analysis	0.035	0.035	0.035	0.035
Sulphur				
Heat Analysis	0.030	0.035	0.035	0.035
Product Analysis	0.030	0.035	0.035	0.035
Silicon				
Heat Analysis	0.5 max	0.5 – 0.80	0.15 – 0.4	0.5 max
Product Analysis	0.55 max	0.44 – 0.86	0.13 – 0.45	0.5 max
Chromium				
Heat Analysis	4.00 – 6.00	1.0 – 1.5	0.8 – 1.15	2.0 – 2.5
Product Analysis	3.9 – 6.1	0.94 – 1.56	0.74 – 1.21	1.88 – 2.62
Molybdenum				
Heat Analysis	0.45 – 0.65	0.45 – 0.65	0.45 – 0.6	0.9 – 1.1
Product Analysis	0.40 – 0.7	0.40 – 0.7	0.4 – 0.65	0.85 – 1.15

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We are also able to offer the following steel:

- **Wear and abrasion resistant steel plate – to 400 and 500HB**
- **High yield steel plate S690QL, S890QL and S960QL**
- **Shipbuilding plate to AH36, DH36 and EH36.**

Wear Resistant Plate

Wear resistant steel is used in areas where there is likely to be a high degree of abrasion or wear of the steel plate. Typical applications are in truck beds, attachments to diggers and earth movers and in processing applications in the mining industry.

The key quality for wear resistant steels is their hardness. We sell wear plate according to its hardness measured on the Brinnell Hardness Test – usually in 400HB and 500HB grades. If your specification is to the Rockwell Test we can also advise.

Steels with a high HB rating (Brinell Hardness) are intended for applications where wear or abrasion resistance is important. The benefit of using an abrasion resistant steel is that the working life of the plant, machinery or construction can be considerably extended. This can significantly improve the reliability, durability and safety of structures and equipment. It also helps to reduce the maintenance costs associated with wear and breakdown of plant.

400 HB steel is over 3 times harder than mild steel (120HB), but only a third as hard as stainless steel (1250HB). Example uses are for construction machinery, skips, bulldozers and excavators, buckets and conveyors.

The steel is quenched which provides wear resistance; in order to improve hardness it may also be tempered. Lower HB's generally provide good cold bending properties and good weldability. Weldability is not generally reduced as the hardness increases.

Wear resistant steels are not appropriate for use at temperatures over 250°C as the heat can cause changes to the material properties.

Testing is undertaken by firing a 10mm steel or tungsten carbide ball at 29kN and the size of the resulting indentation is measured. Tests are carried out according to EN ISO 6506 or ASTM E10.

400 HB

- Thickness: 3 - 120mm
- Width: 1500, 2000, 2055, 3000mm
- Length: up to 12000mm

500 HB

- Thickness: 5 – 100mm
- Width: 1500, 2000, 2055, 3000mm
- Length: up to 12000mm



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High Yield Plate

High yield quenched and tempered steel plate to EN10025 Part 6 is available for construction purposes from Oakley Steel. We offer plates with yields of 690 MPa, 890 MPa and 960 MPa with thicknesses up to 200mm.

	S690QL (t=16mm)	S890QL (t=16mm)	S960QL (t=16mm)
Tensile Strength (MPa)	770 - 940	910 - 1100	980 - 1150
Yield Point (MPa)	690	890	960
Charpy V-Notch Test Temperature °C	0	0	0
Charpy V-Notch Test Energy J	50	50	50

S690 QL

- Thickness: 3 - 200mm
- Width: 1500, 2000, 2055, 3000mm
- Length: up to 12000mm

S890 QL

- Thickness: 4 - 120mm
- Width: 1500, 2000, 2055, 3000mm
- Length: up to 12000mm

S960 QL

- Thickness: 4 - 100mm
- Width: 1500, 2000, 2055, 3000mm
- Length: up to 12000mm

Shipbuilding Plate

Steel plates to ASTM A131 for shipbuilding are available from Oakley Steel.

A131 covers a number of different grades – some are ordinary strength A, B, D, CS and E, whilst others are higher strength – AH, DH, EH and FH. Oakley Steel supplies AH36, DH36 and EH36 which are chemically similar but which are tested as different temperatures for the Charpy V-Notch test.

The standard composition is as below for AH36, DH36 and EH36:

Element	% Composition
C	0.18
Mn	0.90 – 1.60
Si	0.1 – 0.5
P	0.035
S	0.035
Al	0.015
Nb	0.02 – 0.05
V	0.05 – 0.1
Ti	0.02
Cu	0.35
Cr	0.2
Ni	0.4
Mo	0.08

Maximum carbon equivalent values are 0.38 for plates less than 50mm thick and 0.4 for plates between 50mm and 100mm thick.

	AH36	DH36	EH36
Tensile Strength (ksi)	71 – 90	71 – 90	71 – 90
Tensile Strength (MPa)	490 – 620	490 – 620	490 – 620
Yield Point (ksi)	51	51	51
Yield Point (MPa)	355	355	355
Elongation in 200mm (%)	19	19	19
Elongation in 50mm (%)	22	22	22
Charpy V-Notch Test Temperature	0°C	-20°C	-40°C

AH36

- Thickness: 5 - 150mm
- Width: 1500, 2000, 2055, 3000mm
- Length: up to 12000mm

DH36

- Thickness: 5 - 150mm
- Width: 1500, 2000, 2055, 3000mm
- Length: up to 12000mm

EH36

- Thickness: 5 - 150mm
- Width: 1500, 2000, 2055, 3000mm
- Length: up to 12000mm

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