



# Steels used onboard ships and how to perform maintenance welding

Despite many new materials being introduced into shipbuilding, steel is still what most ships are built from and is the most common metal that the welder onboard will encounter during maintenance welding. In below article the different kind of steels found onboard are briefly mentioned followed by application area and type of welding consumable to be used.

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### Classification of steel

Steel can be generally classified as an alloy of Ferrum (Fe), better known as iron, and carbon (C). Ferrum is the main component in most types of steel. Steel is classified in three grades:

- Unalloyed steel containing up to 1% alloy elements. This type of steel is also termed mild steel, black steel, carbon steel, low carbon steel, non-alloyed steel and carbon manganese steel. In the following Unalloyed steel will be used as name to describe this type of steels.
- Low alloy steel containing 1–5% alloy elements.
- High alloy steel containing more than 5% alloy elements.

Alloy elements are metals such as manganese (Mn), silicon (Si), chrome (Cr), nickel (Ni), molybdenum (Mo). Carbon (C) is not an alloy element.

For information on pre-heating and Interpass temperature for steel see separate Technical Update:

[www.teandersen.com](http://www.teandersen.com)

Welding Library under Practical welding and cutting>

Technical update-The need for pre-heating when welding.

Technical update- Heat input and interpass temperature during welding.



### Unalloyed steel (mild steel)

Unalloyed steel is a type of carbon steel with a low amount of carbon. Although ranges vary depending on the source, the amount of carbon (C) typically found in mild steel is 0.05% to 0.25% by weight, whereas higher carbon steels are typically described as having a carbon content from 0.30% to 2.0%. If any more carbon than that is added, the steel would be classified as cast iron. Unalloyed steel is not an alloy steel and therefore does not contain large amounts of other elements.

**Weldability of unalloyed steels:** With regard to the content of phosphorus and sulphur, weldability of unalloyed steels will usually be classified according to carbon content. Localised increases in hardness may occur inside these heat-affected zones as a consequence of rapid cooling. Therefore, as a rule, it is possible to weld unalloyed steels with carbon contents up to approx. 0.22 % without problems. Rutile, acid and organic type electrodes might be used. With higher carbon contents it is necessary to preheat the parent metal and care must be taken to ensure correct control of heat in the welded sections so as to reduce the cooling rate. However, it is not only carbon that determines the weldability of unalloyed steels. The wall thickness will also play an important role. Steels with wall thicknesses exceeding 25 mm (1") must be preheated to 100 - 150°C (210 - 300°F) and basic-type electrodes must be used. On board a ship, unalloyed steel will normally be found in the superstructure. Angle iron and flat are usually also unalloyed steel.

### Low alloy steel

Low alloy steel includes construction steel and high tensile ship building steel (sometimes referred to as ship quality steel), heat resistant steel, low temperature steel and weathering steel.

**Weldability of low alloy steels:** Low alloy steels often require proper control of heat prior to, during and after welding in order to achieve welds with the properties required. The chemical composition with regard to the type and quantity of alloying constituents and the microstructure has a significant effect. It is possible to improve the strength and ductility of high-tensile low-alloy steels by quenching and tempering\*. The total alloy content does not usually exceed 5 %. As a rule, the carbon (C) content lies between 0.2 and 0.6 %. Important alloying elements are chrome (Cr), nickel (Ni) and molybdenum (Mo), as well as manganese (Mn), silicon (Si) and vanadium (V).

\* Quenching or quench hardening involves heating the material and then rapidly cooling in water, oil, forced air or inert gases such as nitrogen.

**High tensile shipbuilding steels** differ from structural steels in terms of stricter tolerances. Most of the shipbuilding steels are approved by classification societies like Det Norske Veritas Germanischer Lloyds (DNV/GL), American Bureau of Shipping (ABS), Lloyds Register (LR) or Russian Maritime Register (RMRS). Normal high-strength ship building steels are manufactured by either hot rolling and normalization\* or normalization rolling. The quality standards of the steels are indicated by the letters A, B, D, E or F. Plate products are according to the standard EN10029 and the thickness tolerance class B. The shipbuilding steels are delivered with the certificate 3.2 which issued in accordance with the requirements of the classification society. On board a ship we find high tensile steel in hull plates, frames, deck plates, deck beams and bulkheads.

\* Normalization removes impurities in steel and improves its strength and hardness. This happens by changing the size of the grain, making it more uniform throughout the piece of steel. The steel is first heated up to a temperature between 810° C to 930° C (1490°F to 1706°F), then cooled by air.



Normal strength steels Grades A, B, D and E.

Higher strength steels Grades A32, D32, E32, A36, D36 and E36.

Higher strength steels with minimum yield strength 390 MPa\*: Grades A40, D40 and E40.

Higher strength steels for low temperature application: Grades F32, F36 and F40 (Not in below list).

\*1 MPa (Megapascal) = 1 N/mm<sup>2</sup> (Newton per square millimetre).

High tensile shipbuilding steel (hull structural steel grades):

Property	Grade A (32,36,40)	Grade B	Grade D (32,36,40)	Grade E (32,36,40)
% of Carbon	0.21 max	0.21 max	0.21 max	0.18 max
% of Manganese	2.5 times %C min	0.8 times %C min	0.6 times %C min	0.7 times %C min
% of Silicon	0.5 max	0.35 max	0.1 – 0.35	0.1 – 0.35
% of Phosphorous	0.035 max	0.035 max	0.035 max	0.035 max
% of Sulphur	0.035 max	0.035 max	0.035 max	0.035 max
% of Aluminium	–	–	0.015 min	–
Ultimate Tensile Strength* MPa	400-520 (58015-75420 psi**)			
Yield Strength***MPa	235 (34084 psi)			
% Elongation	22			
Temperature at which Impact test is done (°C)	NA	0	-20	-40

\*Tensile strength: the resistance of the material to forces trying to pull it apart.

\*\*psi: Pound force per square inch

\*\*\*Yield Strength: The stress at which a material begins to deform plastically.

High Tensile Steels (HTS) <

- HTS can be used effectively in highly stressed areas of the ship.
- They have less thickness for same strength compared to normal steel.



- Strength is increased by adding grain refining elements such as (% Aluminium (Al): 0.015 min, % Niobium (Nb): 0.02 – 0.05, % Vanadium (V): 0.05 – 0.10, % Titanium (Ti): 0.02).
- High tensile steels are expressed as AH 36, BH 40, etc.
- AH stands for High tensile steel of Grade A.
- The number represents minimum yield strength in N/mm<sup>2</sup>:  
 32 means minimum 315 MPa (45687 psi)  
 36 means minimum 355 MPa (51488 psi)  
 40 means minimum 390 MPa (56565 psi)
- Ultimate Tensile Strength for the above three numbers are:  
 32 means 440 – 590 MPa (63817-85572 psi)  
 36 means 490 – 620 MPa (71068-89923 psi)  
 40 means 510 – 650 MPa (73969-94275 psi)
- It should be noted that for Grade A steel temperature for impact test is not applicable. For Grade AH steel impact test to be carried out at zero degree Celsius.

## Comparable steel grades to Classification Societies

Grade	ISO 630-80 4950/2/3/ 1981	EN EN 10025-93 EN 10113-93	ASTM A 131	JIS G 3106
A B D E	Fe 360B Fe 360C Fe 360D -	S235JRG2 S235J0 S235J2G3 S275NL/ML	A B D E	SM41B SM41B (SM41C) -
A 27 D 27 E 27	Fe 430C Fe 430D —	S275J0G3 S275N/M S275NL/ML	- - -	- - -
A 32 D 32 E 32	- - -	- - -	AH32 DH32 EH32	SM50B (SM53C) -
A 36 D 36 E 36	Fe 510C Fe 510D E355E	S355N/M S355N/M S355NL/ML	AH36 DH36 EH36	SM53B (SM53C)
A 40 D 40 E 40	E390CC E390DD E390E	S420N/M S420N/M S420NL/ML	AH40 DH40 EH40	(SM58) - -

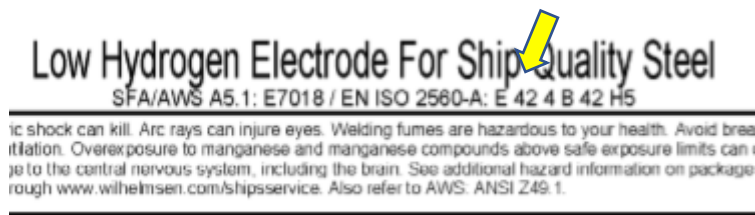


### Electrodes for unalloyed and low alloyed steels

**1** First step in choosing an electrode for a job is to determine your base metal composition. The goal is to match the electrode metal composition to the base metal composition, and make sure the mechanical properties are close to the same or better. If you're in doubt about the type of base material always start checking out the available documentation onboard. For some parts the documentation even informs towards welding procedures including recommending type of consumable. If no documentation available go to TE Andersen consulting > Welding Library > Methods of Identifying Metals.

To prevent cracking or other weld imperfections, make sure that the minimum tensile strength of the electrode matches the tensile strength of the base metal to be welded. You can identify an electrode's tensile strength by referring to the first two symbols in the EN-ISO\* 2560-A classification informed on the electrode's tech page or label. The first letter "E" indicates Electrode (stick electrode). The next two symbols (digest) stand for the electrode's tensile strength. For example, the symbol "42" in the electrode tech page or label classification (E**42** 4 B 42 H5) indicates that the filler metal (weld deposit) produces a weld bead with a minimum tensile strength of 500 to 640 MPa (72519 to 92824 psi). The 500 MPa will in this example be the minimum value.

\*EN-ISO Euronorm-International Organization for Standardization



Symbol	Tensile strength MPa	Yield strength MPa	Elongation min%
35	440 – 570 (63817-82671 psi)	355 (51488 psi)	22
38	470 – 600 (68168-87023 psi)	380 (55114 psi)	20
<b>42</b>	<b>500 – 640 (72519-92824 psi)</b>	420 (60916psi)	20
46	530 – 680 (76870-98626 psi)	460 (66717psi)	20
50	560 – 720 (81221-104427 psi)	500 (72519 psi)	18

You can also identify the electrodes tensile strength by referring to the first two digits of the AWS\* classification imprint on the electrode coating. For example, the symbol "70" on an E7018 electrode imprint indicates that the filler metal produces a weld bead with a minimum tensile strength of 70,000 psi (483 MPa). This will then be the perfect electrode for welding a steel with similar tensile strength.



\*AWS American Welding Society

In the following it will be referred to the EN-ISO classification of electrodes because it is more precise than the older AWS classification. Exception is Hardox, Manganese and "Problem steel".



**2** Some steels like grade D and E also specify minimum Impact properties in Joule at a specific temperature. If that is the case the electrode will have to match this value. You can identify an electrode's impact properties by referring to the third digit (symbol) in the EN-ISO classification informed on the electrode's tech page or label. For example, the symbol "4" in the electrode tech page or label classification (EN-ISO: E42 **4** B 42 H5) indicates that the filler metal (weld deposit) produces a weld bead with minimum impact properties 47J at -40°C (-40°F).

Symbol	Impact energy Charpy-V Temp °C for <b>47J</b> minimum
Z	No requirements
A	+20 (68°F)
0	0 (32°F)
2	-20 (-4°F)
3	-30 (-22°F)
<b>4</b>	<b>-40</b> (-40°F)
5	-50 (-58°F)
6	-60 (-76°F)

NB. If the electrode is an electrode for low temperature steel or weathering steel it will also have an alloy symbol like for example E 46 6 **2Ni** B 32 H5. This part of the code will be explained later when you come to low temperature and weathering steel



3 There are a number of different electrode coatings that can provide a number of different possibilities and advantages for the job at hand. To determine the type of electrode coating, refer to the letter symbol in EN-ISO: E42 4 **B** 42 H5. Here's how you decipher the type of electrode coating:

Symbol	Coating type	Details
A	Acid	Acid electrodes provides good fusion, stable arc and slag is very easy to remove even if it is first bead in a V- groove weld. The weld deposit will have a smooth surface. For welding of steel with tensile strength up to 440 MPa (63817 psi)
<b>B</b>	<b>Basic</b>	These electrode coatings are baked at a higher temperature and are therefore also referred to as low hydrogen electrodes. The basic low hydrogen electrode family has superior weld metal properties. They provide the highest ductility of any of the deposits. These electrodes have a medium arc with medium or moderate penetration. They have a medium speed of deposition.
C	Cellulose	Cellulose electrodes tend to produce a digging arc that provides deep penetration. The weld deposit is somewhat rough, and the spatter is at a higher level than other electrodes. Cellulose electrodes are widely used for pipe welding using the vertical down welding technique. The cellulose electrodes have very high hydrogen level that means that any steel welded with these electrodes should have a very high resistance to hydrogen cracking (cold cracking). These electrodes are mainly used on unalloyed mild steel (low-carbon, non-alloyed steel). Also, for root run (first run) only. They should be used only with due consideration of the steel composition, restraint and need for preheat.
R	Rutile	Electrodes with rutile coating have easy striking/ re striking, a quiet arc, an easily controlled slag, and a low level of spatter. The weld deposit will have a smooth surface and the penetration will be less than with the cellulose electrode. These electrodes produce relatively high levels of hydrogen: up to 25ml/100gm weld metal. This restricts their use to unalloyed mild steels with a thickness lower than 25mm. The weld metal properties will be slightly lower than the cellulosic types. Typical yield strength 330MPa (47862 psi). Typical tensile strength 430MPa (62366 psi).
RR	Rutile thick coated	This coating is very similar to the rutile coatings mentioned above, except that iron powder is added. With lower percentage of iron powder, the electrode can be used in all positions except vertical down. With the higher percentage of iron powder, it can only be used in the flat position or for making horizontal fillet welds. The increased amount of iron power greatly increases the deposition rate.
RC	Rutile- Cellulosic	Used as replacement for rutile electrodes, in order to do vertical down welding.
RA	Rutile- Acid	These electrodes have in most cases a thick coting and can therefore be utilized for welding in all positions, except the vertical down position.
RB	Rutile-Basic	Due to its somewhat thinner coating and special characteristics, the rutile-basic electrode is particularly well suited for root passes and welding in the vertical up position. For this reason, small and medium-diameter pipe construction is a preferred field of application for rutile basic electrodes.

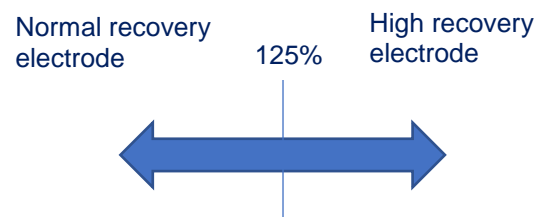
In general: Use Organic electrodes with caution. For unalloyed mild steel use Rutile, Acid or Basic low hydrogen electrodes. For high tensile steel use Basic low hydrogen electrodes.





**4** Some electrodes can be used with only Alternating Current (AC) or Direct Current (DC) power sources while other electrodes are compatible with both. One must obviously select an electrode compatible to the power source onboard. Transformers will deliver AC current, rectifiers or inverters DC current. Likewise, it is important to select an electrode with a metal recovery corresponding to the welding position. Select a normal recovery electrode with recovery max 120% if to weld in position welding. In flat (horizontal) you can select a high recovery electrode with more than 120% recovery. This will improve the amount of weld deposit per hour. To determine the correct current type and the electrodes metal recovery for a particular electrode, refer to the fourth digit in the EN-ISO: E42 4 B **4**2 H5 classification, which represents the type of recovery and type of current the electrode can be welded with.

Symbol	Metal recovery %	Type of current
1	<105	AC + DC
2	<105	DC
3	>105-125	AC + DC
<b>4</b>	<b>&gt;105-125</b>	<b>DC</b>
5	>125-160	AC + DC
6	>125-160	DC
7	>160	AC + DC
8	>160	DC



The recovery rate for an electrode can be improved by adding iron powder to the coating. If an electrode has less than 125% recovery it is referred to as normal recovery. If more, it is referred to as high recovery. If more than 150% it will normally only be able to weld in the flat (horizontal) position.

**5** A weld repair will have to be performed in a specific position. It can be horizontal, vertical, overhead, inclined position or a combination of different positions. It is therefore important to select an electrode that conform according to the actual repair position.

To determine what positions a particular electrode is qualified for, refer to the fifth digit in EN-ISO: E42 4 B **4**2 H5. Here's how you decipher the qualified electrode position:

1 = All positions.

**2 = All positions, except vertical down.**

3 = Flat butt weld, Flat fillet weld, horizontal-vertical fillet weld.

4 = Flat butt weld, flat fillet weld.

5 = Vertical down and positions according to symbol 3.



**6** If the weld repair involves high severity locations, and always if specified in welding procedures, the electrode might need to be approved by a classification society in order to be used on a specific steel. It is important to understand the difference between Classification and Approvals. A classification is a statement from the electrode manufacturer giving technical information about the electrode. An approval is a statement from a society that the electrode has passed a specific test and has been approved. Approval of a welding electrode may be carried out by the following societies:

Bureau Veritas (BV)  
Det Norske Veritas- Germanischer Lloyd (DNV-GL)  
Lloyds Register (LR)  
American Bureau of Shipping (ABS)

The electrode's approval will be stated on the electrode's tech page and/ or label in the form of a grading. For example, "3YH5". The 3Y in this example informs that the electrode is approved for higher tensile steel. The H5 informs that the hydrogen level in the weld metal deposit will be less than 5ml H<sub>2</sub>/ 100g deposit (5 millilitre hydrogen per 100 gram). For critical repairs, or if it is stated in the welding procedure, it is important that the electrode has the right grading and that the certificate is up to date. The information regarding the electrode's hydrogen level is also reflected in the electrode's classification. For example, EN-ISO: E42 4 B 42 **H5**

The water level in an electrode coating is very important. If water enters the arc that has a temperature of 7000°C (°F) the water will be transformed into hydrogen gas that again will form into hydrogen porosity in the Heat Affected Zone (HAZ) that again can develop into hydrogen cracking also referred to as cold cracking. Electrodes for repair of high tensile ship building steels should therefore have grading:

H15= hydrogen level in weld metal < 10ml H<sub>2</sub>/100g (glycerine method\*) or <15ml H<sub>2</sub>/100g (mercury method\*).

H10= hydrogen level in weld metal < 5ml H<sub>2</sub>/100g (glycerine method) or <10ml H<sub>2</sub>/100g (mercury method).

**H5= hydrogen level in weld metal < 5ml H<sub>2</sub>/100g (mercury method).**

\*The glycerine and mercury methods are test methods to measure hydrogen levels in weld deposit.



### 7 Storing and re-drying.

Electrodes are hygroscopic and attract moisture from the atmosphere and must therefore be stored properly. Welding consumables should be stored in their original packing. Some electrode manufacturers deliver their products in vacuum packing. If that is not the case, we recommend the following temperatures in the storage room:

Max relative humidity in storage location depends on temperature.

°C	°F	Max relative humidity in %
5 - 15	41 - 59	60
15 - 25	59 - 77	50
Above 25	Above 77	40

Re-drying of electrodes is recommended before use whenever there are application requirements relating to weld metal hydrogen content and / or radiographic soundness. This information is given on the box label for the individual electrodes. Failure to follow these recommendations may produce pores and weld failure. Re-drying temperatures for most low hydrogen electrodes are 350°C (572°F) for 2 hours.

### 8 Specification and Service Conditions

Make sure to assess the conditions that the welded part will encounter throughout its service. If it will be used in high heat or low temperature environments, subjected to repetitive shock loading, a low hydrogen electrode with higher ductility will reduce the chance of weld cracking. Also, be certain to check for welding specifications if you're working on critical applications such as pressure vessel or boiler. In most cases, these welding specifications will require you to use specific types of electrodes.

An effective way to avoid cold cracking is preheating before welding and close control of the interpass temperature (temperature during welding). It delays the cooling of the weld region and thereby slows the hydrogen effusion. For information on pre-heating and interpass temperature see:

[www.teandersen.com](http://www.teandersen.com)

Welding Library > Practical welding and cutting >

Technical update-The need for pre-heating when welding.

Technical update- Heat input and interpass temperature during welding.

### Cast steel

Cast steels are used when cast irons cannot deliver enough strength or shock resistance. Items that are made in cast steel include: valve bodies, pump casings, turbocharger turbines and engine cylinder blocks. Alloy steel castings are broken down into two categories: low-alloy cast steels and high-alloy cast steels. Low-alloy cast steels contain less than 8% alloying elements and high-alloy steels have 8% or more. There is further Heat resistant cast steel per ASTM A297-1981 and Corrosion resistant cast steel per ASTM A743-1981a. Most cast steels are similar to unalloyed or low-alloyed steel in composition, and can be welded with ease. Edge preparation is to follow the same procedure as for heavy gauge steel. The same applies for preheating. Preferably basic low hydrogen electrodes should be used.



Basic low hydrogen electrode brands to consider for unalloyed, low alloyed and cast steel:

There are a large number of electrode manufacturers and an even bigger number of brands to consider. Below find some of the brands that are the most easily available to vessels. Also consider high recovery electrodes if welding takes place in down hand position:

Normal recovery basic coated electrodes:

Lincoln Electric	Esab	Bohler	Unitor	Drew Marine	Kobe steel
Baso 120	OK 48.00	FOX EV 50	LH-314 N	LH Plus	LB-52-18

Elga	Kjellberg	BOC (Linde)	Philarc	Oerlikon (Air Liquide)	Hyundai
Maxeta 24	Garant S	Smootarc 18	PA-18	Tenax 58S	S 7018 GH

High recovery basic coated electrodes:

Lincoln Electric	Esab	Bohler	Unitor	Oerlikon (Air Liquide)	Kobe steel
Conarc V180	OK 38.65	Phoenix ROT BR 160	LHH-314H	Febamatic 160S	LT-B50

Elga	Philarc	Hyundai
Maxeta 21	PA-7028	S 7028 F

There are also basic coated electrodes specifically developed for vertical down welding

Lincoln Electric	Esab	Bohler	Unitor	Drew Marine	Kobe steel
Baso 26V	Filarc 27P	FOX BVD 85	LHV-316 N	LV Plus	LB-26V

Please make sure that the particular brand selected is according to the EN-ISO classification in case changes have taken place. Also check that the electrodes mechanical properties match the base material to be welded and that the selected electrode have the class societies approval. It might well be that you need to select an electrode with higher yield and tensile strength and /or impact values than the one mentioned above.



### Low temperature steel (cryogenic steels)

#### Background

The use of natural petroleum gases in industrial supply and also in the chemical industry has increased significantly in recent years. With the increase in the use of these gases transporting and storing them has become more and more important. The gases pass over into the liquid state when cooled to very low temperatures and at the same time their volume decreases considerably. This behaviour is utilised for storage and transport by vessels. However, it is only possible to utilise this behaviour if suitable base metals and filler metals, which possess adequate mechanical properties and toughness at the low temperatures of the liquid gases, are available for construction of the transport and storage tanks required.

Un-alloy, low-alloy or high-alloy steels that are still tough at low temperatures below approx.  $-50^{\circ}\text{C}$  ( $-58^{\circ}\text{F}$ ) are known as cryogenic steels. Non-alloy and low-alloy steels may be used in all cases for temperatures down to  $-50^{\circ}\text{C}$  ( $-58^{\circ}\text{F}$ ) as long as they are killed\*. The steel groups may be differentiated as follows:

1. Un-alloy and low-alloy cryogenic and fine-grain constructional steels for operating temperatures in the range of approx.  $-50^{\circ}\text{C}$  ( $-58^{\circ}\text{F}$ ) in the normalised condition\*\* and down to approx.  $-60^{\circ}\text{C}$  ( $-76^{\circ}\text{F}$ ) in the quenched and tempered condition\*\*\*.
2. Nickel-alloy tempering steels with 1.5 to 9 % nickel (Ni) for operating temperatures from  $-80^{\circ}\text{C}$  to approx.  $200^{\circ}\text{C}$  ( $-112$  to  $-328^{\circ}\text{F}$ ).
3. Austenitic chrome nickel steels for operating temperatures down to approx.  $-269^{\circ}\text{C}$  ( $-500^{\circ}\text{F}$ ).

In relation to ships, low temperature steels can be found in Ice class hull plates. Filler metals of the same or similar composition as the parent metal with 2.0 to 3.5 % Ni are used when welding nickel-alloy tempering steels. Filler metals of the same composition as the parent metal are to be preferred if it is necessary to guarantee the mechanical and technological (strength, toughness) and physical (heat expansion coefficient) properties of the parent metal in the weld metal in addition to satisfying the minimum temperature required.

\*Killed steel is steel that's been completely deoxidized so that all oxygen is removed from the melt during the steelmaking process.

\*\* Normalising is a heat treatment of steel to change the grain size to improve the physical properties of the steel.

\*\*\* Quenching or quench hardening involves heating the material and then rapidly cooling in water, oil, forced air or inert gases such as nitrogen.





Higher strength steels for low temperature application: Grades F32, F36 and F40.

In order to select the right electrode, make use of the previously explained EN-ISO 2560-A. classification. You will find the information on electrodes tech page or on the label. As an example: E 46 6 2Ni B 32 H5.

E: Electrode.

46: Tensile strength 530-680 MPa (76870- 98626 psi).

6: Impact energy Charpy-V Temp - 60°C (-76°F) 47J minimum.

Then comes an alloy short symbol for alloying elements. In our example 2Ni.

Alloy short symbol	Alloying element		
	Mn	Mo	Ni
No short symbol	2.0	-	-
Mo	1.4	0.3-0.6	-
Mn Mo	>1.4-2.0	0.3-0.6	-
1 Ni	1.4	-	0.6-1.2
2 Ni	1.4	-	1.8-2.6
3 Ni	1.4	-	2.6-3.8
Mn 1 Ni	>1.4-2.0	-	0.6-1.2
1 Ni Mo	1.4	0.3-0.6	0.6-1.2
Z	Any other composition		

B: Basic electrode.

3: Recovery >105-125 and type of current AC and DC.

2: All positions except vertical down.

H5: hydrogen level in weld metal < 5ml H<sub>2</sub>/100g (mercury method).

Electrode brands to consider:

BOHLER FOX 2.5Ni (AWS A5.5-06: E8018-C1H4R) (EN ISO 2560-A:2010: E 46 8 2Ni B 42 H5)

ESAB OK 73.68 (AWS A5.5; E8018-C1) (EN ISO 2560-A: E 46 6 2Ni B 32 H5)

UNITOR LHL-319 (AWS A5.5: E8018-C1) (EN ISO 2560-A: E 46 6 2Ni B 32 H5)





### Weathering steel

Weathering steel can be exposed to the weather without being painted. They contain small amounts of copper (Cu) 0.45%, chromium (Cr) 0.6%, Nickel (Ni) 0.6%. This will create a steel which weather by acquiring a stable, rusted surface, and so can be used un-painted. Weathering steel such as Corten\*, Patinax (355 and 355P), Coraldur and Korralpin steels are typical weathering steel trade names.

\*Corten: corrosion resistance and tensile strength.



The corrosion resistance of weathering steels is four to six times that of normal structural carbon steels, and two to three times that of many of the low-alloy structural steels. Areas of application onboard will be locations in need of good corrosion resistance to sea-water and flue gases.



Electrodes for weathering steel are also classified according to EN-ISO 2560-A. You will find the information on electrodes tech page or on the label. As an example:

E 46 5 Z B 32

E: Electrode.

46: Tensile strength 530-680 MPa (76870- 98626 psi).

5: Impact energy Charpy-V Temp - 50°C (-58°F) 47J minimum.

Then comes an alloy short symbol for alloying elements. In our example Z.

Alloy short symbol	Alloying element		
	Mn	Mo	Ni
No short symbol	2.0	-	-
Mo	1.4	0.3-0.6	-
Mn Mo	>1.4-2.0	0.3-0.6	-
1 Ni	1.4	-	0.6-1.2
2 Ni	1.4	-	1.8-2.6
3 Ni	1.4	-	2.6-3.8
Mn 1 Ni	>1.4-2.0	-	0.6-1.2
1 Ni Mo	1.4	0.3-0.6	0.6-1.2
Z	Any other composition		

The Z for an electrode for weathering steel informs Copper (Cu), Nickel (Ni) and sometimes Chromium (Cr).

B: Basic electrode.

3: Recovery >105-125 and type of current AC and DC.

2: All positions except vertical down.

Electrode brands to consider:

BOHLER FOX NiCuCr (AWS A5.5-06: E8018-W2H4R) (EN ISO 2560-A:2010: E 46 4 ZNiCrCu B 42 H5)

ESAB OK 73.08 (AWS A5.5 E8018-G) (EN ISO 2560-A: E 46 5 Z B 32)

UNITOR LHR-320N (AWS A5.5 E8018-G) (EN ISO 2560-A: E 46 5 Z B 32)





### Heat resistant steel (High temperature steel/ Heat- Creep resistant steel)

#### Background

The high temperature properties of ordinary steels are no longer adequate at operating temperatures above 350°C (662°F). Creep and flow processes occur in the steel at high temperatures under load as a result of which the steel loses its mechanical properties. Therefore, steels alloyed with Molybdenum (Mo), Chromium (Cr) – Mo and Cr-Mo-Vanadium (V) are used. Small additions of Mo, Cr and V are sufficient up to 550°C (1022°F) operating temperature. Above 550°C (1022°F) increased scale resistance is also necessary. Up to approx. 600°C (1112°F) it is possible to use quenched and tempered 9 % and 12 % Cr steels with additions of Mo, V, Niobium (Nb) and Wolfram (W) respectively. Above this temperature special austenitic Cr-Ni steels are used. The basic type contains 16 % Cr and 13 % Ni with additions of Nb. To be precise: Only steels that stand out for their special resistance to the oxidising effect of gases at temperatures above approximately 600°C (1112°F) are deemed to be referred to as creep-resistant. At temperatures above 700°C (1292°F) only nickel-base alloys with additions of Mo, W and Nb exhibit adequate creep properties.

In relation to ships the heat resistant steel in boiler pipes and plates will normally be steel that can take operating temperatures up to 550°C (1022°F). Heat resistant steel is a low alloy steel, alloyed with a certain percentage of Mo and Cr. The addition of these alloying elements gives heat resistant characteristics and the steel retains its strength at high temperatures. On board we find this steel in boiler tubes, boiler plates and high-pressure pipes. For welding of heat resistant steel, only filler material with heat resistant deposit may be used. Selection of the correct electrode for the job will depend on the percentage of Mo and Cr in the alloy.





### Electrodes for Heat resistant steel

For welding of heat resistant steel, only filler material with heat resistant deposit may be used. Selection of the correct electrode for the job will depend on the percentage of Mo and Cr in the alloy. Make use of the electrodes EN-ISO classification to select the right type for the job at hand.

The standard that relates to Heat resistant steel is EN ISO 3581-A (Filler material for stainless and heat resistant steel). You will find the information on electrodes tech page or on the label. As an example:  
E CrMo 1B 42 H5.

The first letter “E” indicates Electrode (stick electrode). The next symbols (digest) informs by short names the alloy components.

Short name for chemical structure of weld metal. The alloy components (approximate values) are listed in the order **Cr, Ni, Mo** numerically one after the other without their chemical symbol. Alloy components like niob, mangan, nitrogen and copper are added as chemical symbol without specification of their contents. The addition **L** indicates a very low carbon content. In addition to the alloy structure, the mechanical properties laid down in the standards have to be achieved.

In our example EN-ISO: E **CrMo 1**B 42 H5 the alloying elements are **CrMo 1**.

To determine the type of electrode coating, refer to the letter symbol in EN-ISO: E CrMo 1**B** 42 H5. Here's how you decipher the type of electrode coating:

Symbol	Coating type
R	Rutile
<b>B</b>	<b>Basic</b>



To determine the correct current type and the electrodes metal recovery for a particular electrode, refer to the classification EN-ISO: E CrMo 1B 42 H5, which represents the type of recovery and type of current the electrode can be welded with.

Symbol	Metal recovery %	Type of current
1	<105	AC + DC
2	<105	DC
3	>105-125	AC + DC
4	>105-125	DC
5	>125-160	AC + DC
6	>125-160	DC
7	>160	AC + DC
8	>160	DC

To determine what positions a particular electrode is qualified for, refer to the EN-ISO: E CrMo 1B 42 H5. Here's how you decipher the qualified electrode position:

1 = All positions.

2 = All positions, except vertical down.

3 = Flat butt weld, Flat fillet weld, horizontal-vertical fillet weld.

4 = Flat butt weld, flat fillet weld.

5 = Vertical down and positions according to symbol 3.

The information regarding the electrode's hydrogen level is also reflected in the electrode's classification. For example, EN-ISO: E CrMo 1B 42 H5.

H15= hydrogen level in weld metal < 10ml H<sub>2</sub>/100g (glycerine method\*) or <15ml H<sub>2</sub>/100g (mercury method\*).

H10= hydrogen level in weld metal < 5ml H<sub>2</sub>/100g (glycerine method) or <10ml H<sub>2</sub>/100g (mercury method).

H5= hydrogen level in weld metal < 5ml H<sub>2</sub>/100g (mercury method).



Electrode brands to consider:

BOHLER FOX DMV 83 Kb (AWS A5.5-06: E9018-G) (EN ISO 3580-A:2008: E MoV B 4 2 H5)  
BOHLER FOX CM 2Kb (AWS A5.5-06: E9018-B3H4R) (EN ISO 3580-A:2008: E CrMo2 B 4 2 H5)  
BOHLER FOX DCMV (AWS A5.5-06: E9018-G) (EN ISO 3580-A:2008: E ZCrMoV1 B 4 2 H5)  
BOHLER FOX DCMS Kb (AWS A5.5-06: E8018-B2H4R) (EN ISO 3580-A:2008: E CrMo1 B 4 2 H5)  
BOHLER FOX DMO Kb (AWS A5.5-06: E7018-A1H4R) (EN ISO 3580-A:2008: E Mo B 4 2 H5)  
ESAB OK 76.18 (AWS A5.5-06; E8018-B2) (EN ISO 3580-A: E CrMo1 B 4 2 H5)  
UNITOR LHT 318N (AWS A5.5-06; E8018-B2) (EN ISO 3580-A: E CrMo1 B 4 2 H5)  
DREW MARINE Amerarc CrMo ((AWS A5.5-06; E8018-B2) (EN ISO 3580-A: E CrMo1 B 4 2 H5)

NB. Wrong welding procedure and/or wrong choice of welding consumable can be catastrophic when dealing with boiler tubes and plates. Therefore, always consult the consumable manufacturer and class society before commencing. Approved procedures and approved welder by class society is often the case.



### Hardox steel

Hardox steel is typically used onboard dredgers, bulk carriers and cement carriers that experience abrasive wear from the cargo they are processing and carrying. Often, a Hardox wear plate will be welded to a plain carbon steel structure only in the areas that experience abrasive wear. Since wear does occur, wear plates need to be replaced frequently, which makes this a very common welding application.

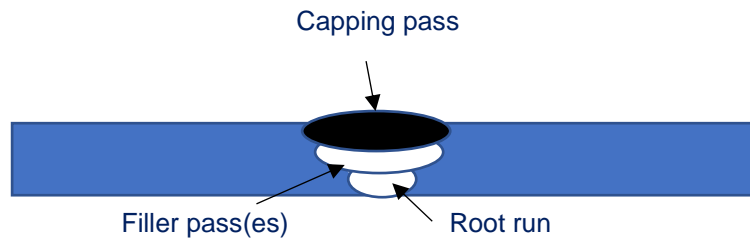
There are a number of different types of Hardox steel, ranging from Hardox Hi Temp, Hi Tuf, 400, 450, 500, 550, 600 and Extreme. The number indicate the approximate Brinell Hardness (HB)\*. They are very wearing resistant and contain from 0.25 to 0.80% Molybdenum (Mo), 0.10 to 2.5% Nickel (Ni), 0.10 to 1.5% Chromium (Cr) all depending on type of alloy.



\* The Brinell hardness test is commonly used to determine the hardness of materials like metals. Unalloyed steel Brinell hardness is approximately 130 HB.



To avoid weld cracking, the joint needs a welding procedure that need to be followed rather strictly. It is important to use an electrode with lower strength than the Hardox base metal for the root and filler passes, and then hardface only on the capping pass to obtain abrasion resistance of the weld surface.



Preheating and interpass temperature (temperature during welding) depend on type of Hardox and the plate thickness.

Maximum preheating and interpass temperature

Hardox Hi Temp	300°C (572°F)
Hardox Hi Tuf*	300°C (572°F)
Hardox 400	225°C (437°F)
Hardox 450	225°C (437°F)
Hardox 500	225°C (437°F)
Hardox 550	225°C (437°F)
Hardox 600	225°C (437°F)
Hardox Extreme	100°C (212°F)

Interpass temperatures up to approx. 400°C (752°F) can be used in certain cases for Hardox Hi Tuf.

For further information on pre heating and interpass temperature go to:

[www.teandersen.com](http://www.teandersen.com)>

Welding Library > Practical welding and cutting.

Technical update-The need for pre-heating when welding.

Technical update- Heat input and interpass temperature during welding.





### Type of electrodes:

It is important to use an electrode with lower strength than the Hardox base metal for the root and filler passes, and then hardface only on the cover pass to obtain abrasion resistance of the weld surface. Unalloyed and low-alloyed electrodes with a maximum tensile strength of 500 MPa (72519 psi) are generally recommended for Hardox steel in general. Electrodes of higher strength max. 900 MPa (130534 psi) may be used for Hardox 400 and 450 in the thickness range 0.7 – 6.0 mm (0.028” – 0.236”).

### A better solution to consider:

Consumables of austenitic stainless steels can be used for welding all types of Hardox. They allow welding at room temperature 5 – 20°C (41 – 68 °F) without preheating, except for Hardox 600 and Hardox Extreme. The manufacturer of Hardox recommends giving first preference to consumables in accordance with AWS 307 and second preference to those in accordance with AWS 309. These types of consumables have a yield strength of up to approximately 500 MPa (72519 psi) in all weld metal. The AWS 307 type can withstand hot cracking better than AWS 309. Manufacturers seldom specify the hydrogen content of stainless steel consumables, since hydrogen does not affect the performance as much as it does in unalloyed and low-alloyed consumables.

### Electrodes AWS 5.4 E307-X

Recommended: EN ISO 3581-A: 18 18 Mn/

EN ISO 3581-B: 307

Suitable: EN ISO 3581-A: 22 12 X/

EN ISO 3581-B: 309X

Note: X stands for one or more characters.

In general, about AWS 5.4 E307-X electrodes: Joining of wear plates like Hardox to each other and to their supports. Welding of 14% Mn steel, armour steel, hardenable steel and generally all hard-to-weld steels. Joining of stainless steels to carbon steels. Building up of rails and buttering layers before hardfacing on 14%Mn steel or on steels of unknown composition or on carbon steels. An important electrode to have onboard a vessel.

### Electrode brands to consider:

LINCOLN ELECTRIC Arosta 307 (AWS 5.4 E307-16)

PHILARC Philstain 307 (AWS 5.4 E307-16)

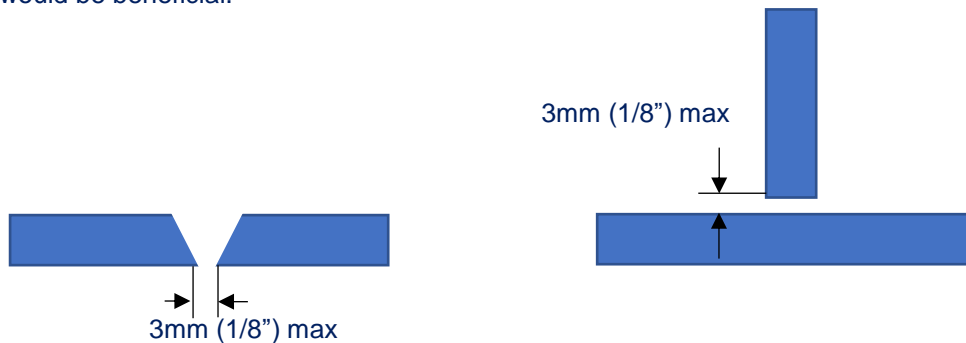
ESAB OK 67.43 (AWS 5.4 E307-16)

BOHLER FOX A7-A (AWS 5.4 E307-16)

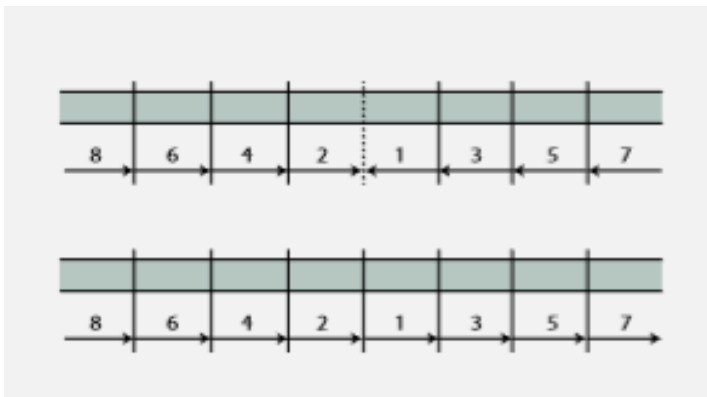
BOHLER Thermanit XW (AWS 5.4 E307-16)



Before tack welding, it is important to maintain a root opening between base plates not exceeding 3 mm (1/8"). Aim for as uniform a gap size along the joint as possible. Also, avoid weld start and weld stops in highly stressed areas. Make multiple smaller weld beads maintaining the base materials interpass temperature as mentioned above. If possible, the start and stop procedures should be at least 50 – 100 mm (2" – 4") from a corner. When welding to the edge of plates, a runoff weld tab (steel plate) would be beneficial.



Use a symmetrical weld sequence.



If the weld joint is located in an area with the expectation of high wear, one can employ hardfacing with special consumables to increase the wear resistance of the weld metal.

Electrode brands to consider for hard surfacing:

BHOLER UTP DUR 600 (AWS A5.13: EFe3) (EN ISO 14700: EFe8)

AFROX Afrox 600 (AWS A5.13: EFe3)

NIKKO STEEL HV-600 B (AWS A5.13: EFe3)





### High alloy steel

In this group we find **Stainless steel**. For detailed information on how to weld stainless steel see: [www.teandersen.com](http://www.teandersen.com) >Welding Library> Practical welding and cutting >Technical update-How to weld stainless steel.

**Manganese steel** also called Hadfield steel (after its inventor) or mangalloy steel is used for very rugged service involving high impact and abrasion. It is a nonmagnetic alloy that contain 1-1.4% carbon (C) and 12–14% manganese (Mn) which when abraded strain-hardens to form an incredibly hard skin which resists wearing. Brinell hardness (HB) of manganese steel according to the original Hadfield specification is 220 HB but that with impact wear the surface hardness will increase to over 550 HB.

Area of application:

Because of its self-hardening properties, manganese steel is used onboard dredger vessels and cement carriers. Bulk carriers with elevator and shovel buckets and bucket teeth's as well as rail crane tracks onboard.

Welding: Manganese steel can be weld repaired if wear and tear have caused defects in the surface. Manganese steel can also be welded to carbon and alloy steels. Manganese steel can be prepared for welding by flame cutting, plasma cutting or by ACA (Air Carbon Arc) gouging; however, every effort should be made to keep the base metal as cool as possible. If the part is small it is recommended that it be frequently cooled in water or, if possible, partially submerged in water during the flame cutting and welding operation. The base metal must be kept cool. Cracks should be completely removed to sound metal prior to rewelding. Grinding can be employed to smooth up these surfaces. No pre-heating. The welding procedures should be such as to maintain local temperatures below 250°C (482°F) measured close to the weld. It is therefore recommended to weld short beads and to allow for continuous cooling during welding or to place the workpiece in a cold-water bath with only the welding area sticking out of water. There are two types of manganese steel electrodes available. Both are similar in analysis to the base metal but with the addition of elements which maintain the toughness of the weld deposit without quenching. The AWS: EFeMn-A electrode is known as the nickel manganese electrode and contains from 3-5% nickel in addition to the 12-14% manganese. The carbon is lower than normal manganese ranging from 0.50 to 0.90%. The weld deposits of this electrode on large manganese castings will result in a tough deposit due to the rapid cooling of the weld metal. The other electrode used is a molybdenum-manganese steel type AWS: EFeMn-B. This electrode contains 0.6-1.4% molybdenum (Mo) instead of the nickel. This electrode is less often used for repair welding of manganese steel or for joining manganese steel itself or to carbon steel. The manganese nickel steel is more often used as a build-up deposit to maintain the characteristics of manganese steel when surfacing is required. Stainless steel electrodes can also be used for welding manganese steels and for welding them to carbon and low-alloy steels. The 18-8 chrome-nickel types are popular; however, in some cases when welding to alloy steels the 29-9 nickel is sometimes used. These electrodes are considerably more expensive than the manganese steel electrode and for this reason are not popular. Because of the toxic nature of the weld fumes it's vitally important that the welder protect himself accordingly.



Electrode brands to consider:

LINCOLN ELECTRIC Wearshield (AWS A5.13-8: EFMn-A)  
PHILARC Philhard Ni Mn (AWS A5.13-8: EFMn-A)  
PHILARC Philhard Mn (AWS A5.13-8: EFMn-B)  
ESAB Wear-arc nickel manganese (AWS A5.13-8: EFMn-A)  
BOHLER UTP 7200 (AWS A5.13-8: EFMn-A)

### Problem steel/difficult to weld steel

Onboard a vessel there will be a number of steel parts and items of unknown chemical composition. Steels containing carbon in excess of 0,25%, chromium and molybdenum over 1,5% and manganese over 1,5% exhibit increased strength and hardenability and decreased weldability. Additional elements such as vanadium, silicon, nickel, boron, niobium and titanium also influence hardenability and weldability. Problem steels fall into two categories, i.e. ferritic types which require preheat and austenitic steels such as 11–14% manganese steels, which require minimum heat input. Manganese steel we have previously explained.

Problem steel electrodes are suitable for welding combinations of dissimilar steels such as chromium, molybdenum, creep resistant steels and stainless steels to mild and low alloy steels. Care should be taken when welding such combinations to ensure that excessive dilution between the base and weld metal do not occur.

Electrodes for welding problem steels/ difficult to weld steel are according to AWS A 5.4: E 312-17 (EN ISO 3581-A E29 9 R26). They have a rutile basic coating, low carbon content and contain approx. 29% chromium and 9% nickel. The structure is highly resistant to hot cracking and extremely tolerant of dilution from medium and high carbon steels. These electrodes are suitable for welding medium and high carbon hardenable steels, tool steel, high speed steel, armour steel, spring steel, gear wheels, rocker arms, push rods and shafts which may be of unknown composition. These electrodes can be used for joining as well as building up. They can also be used as buffer layer before hard surfacing.

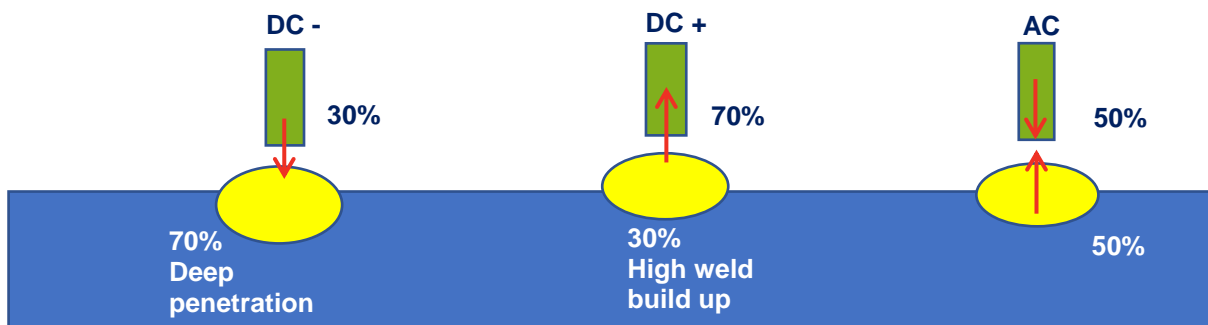
Electrode brands to consider for Problem steels:

AFROX Superweld 312 (AWS A 5.4: E 312-17)  
UNITOR Tensile-328N (AWS A 5.4: E 312-17)  
ESAB OK 68.81 (AWS A 5.4: E 312-17)  
LINCOLN ELECTRIC Limarosta 312 (AWS A 5.4: E 312-17)  
CASTOLIN EUTECTIC Eutectrode E 312-17 (AWS A 5.4: E 312-17)  
BOHLER FOX 29/9-A (AWS A 5.4: E 312-17)  
DREW MARINE Amerarc TE (AWS A 5.4: E 312-16)



### Type of current and Amperage setting

If your welding machine is a transformer delivering Alternating Current (AC), polarity to the electrode (electrode holder) does not matter. If your welding machine is an inverter or a rectifier delivering Direct Current (DC) you must consider connecting the electrode (electrode holder) to either + (reverse) or – (straight) polarity. Electrons runs from – to +. They will have a heat impact on the electrode tip and on the base material according to below drawing:

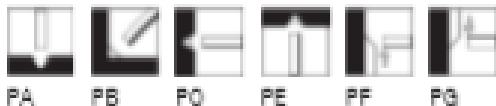


Connecting to minus polarity will deliver 70% of the heat of 7000°C (12632°F) in the arc to the base material and 30% to the electrode tip resulting in deeper penetration and more heat to the base material. This can with good result be to an advantage when doing the root run. For filler passes and capping runs + polarity will be an advantage. Hard facing will in most cases be performed with the electrode connected to + polarity. For stainless steel welding electrodes should always be connect to + polarity simply because of less heat to the base material. The electrode coating (rutile, organic, acid or basic) will also influence on penetration and weld build up.

For Amperage setting consult the parameter setting informed on the electrode's tech page or electrode package label. They will in most cases be given as a minimum value and maximum value. In below example for a 3,2mm (1/8") electrode 95 Amp is minimum, 155 Amp maximum.

Diameter mm	Current range Ampere
2,5 (3/32")	75- 105
3,2 (1/8")	95-155
4,0 (5/32")	125-210

- Use maximum value (155 Amp) if you are welding vertically down or T-joints
- Use minimum value (95 Amp) if you are welding vertically up.
- Use middel value (125 Amp) if you are welding overhead or downhand (flat).



During welding observe the molten pool and slag in order to fine tune your amperage. It is also important to take plate thickness and joint configuration into consideration.

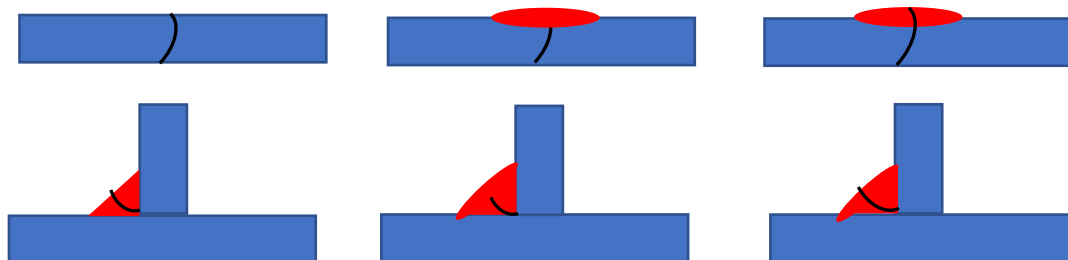


### Edge preparation and weld sequence

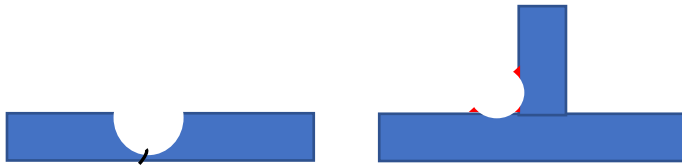
Edge preparation is 50% of the job when welding. If you do proper edge preparation the welding itself will become much easier with a high possibility of success.



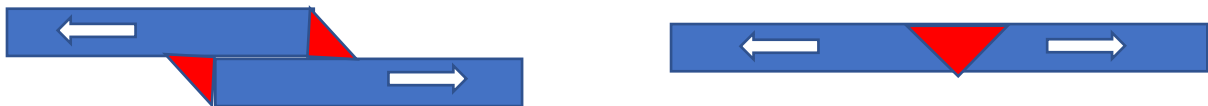
If you weld on top of a crack without grinding or gouging it out it will crack again when it goes into service. An electrode does not penetrate more than a couple of millimetres into the base material even if you drive up the amperage.



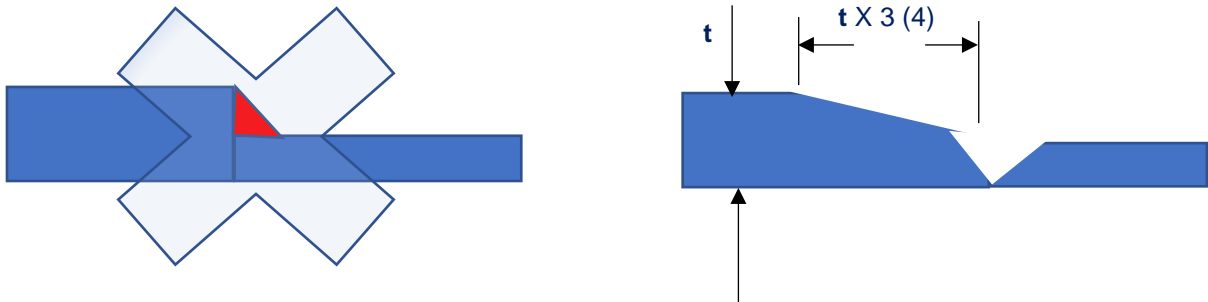
The crack will still be there. As soon as there are vibration and stain it will re appear



Make sure to grind or gouge out the crack to its full dept and length. For further information on gouging options go to: [www.teandersen.com](http://www.teandersen.com) > Welding Library> Practical welding and cutting> Technical update-Methods for removal of welds and opening of cracks.



Avoid overlap joints. Whenever possible make use of butt joints. I, V, U or X preparation depend on plate thickness.



If difference in plate thickness of butt welds exceeding 4mm (5/32") the thicker plate shall be tapered not steeper than 1: 3 of thickest member generally. Butt joints, which are prone to fatigue loading shall be tapered not steeper than 1: 4 of thickness.

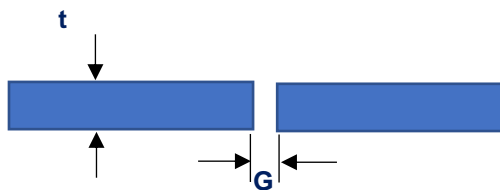


## No.47 Shipbuilding & Repair Quality Standard. Rev.7 June 2013.

It is intended that the below suggestions provide guidance where established and recognized shipbuilding or national standards accepted by the Classification Society do not exist.

### Plate fit up tolerances Butt -joints:

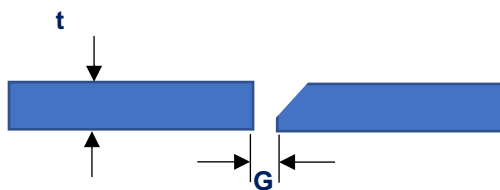
#### Square butt



If **G** is less or equal to 10mm (25/64") chamfer to 45° and build up by welding.

If **G** is more than 10mm (25/64") build up using backing strip. Remove backing strip. Back gouge and make sealing weld or insert plate with minimum width 300mm (12").

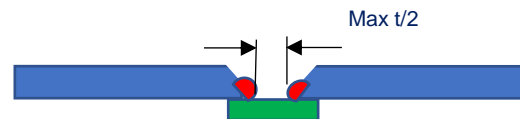
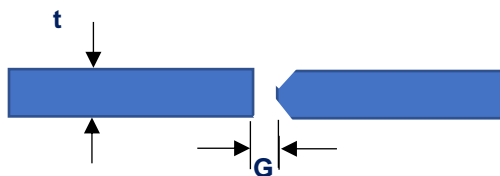
#### Single bevel butt



If **G** is less than 5mm (13/64") or less or equal to 1.5 X **t** (maximum 25mm (1")) build up gap with welding on one or both edges to maximum of 0.5 X **t** using backing strip if necessary.

Where a backing strip is used, the backing strip is to be removed, the weld back gouged, and a sealing weld made.

#### Double bevel butt

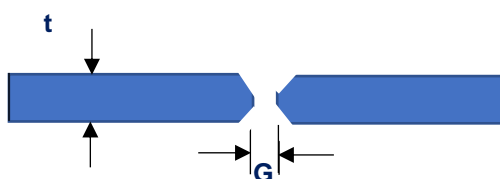


If **G** is less than 5mm (13/64") or less or equal to 1.5 X **t** (maximum 25mm (1")) build up gap with welding on one or both edges to maximum of 0.5 X **t** using backing strip if necessary.

Different welding arrangements by using backing materials approved by classification societies may be accepted on basis on appropriate welding procedure specification.

When **G** is more than 25mm (1") or 1.5 X **t**, whichever is smaller, use insert plate of minimum length 300mm (12").

#### Double vee butt

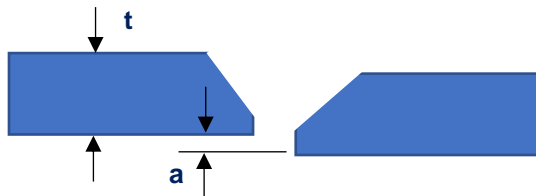


300mm (12") minimum

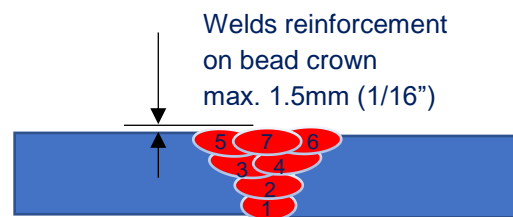
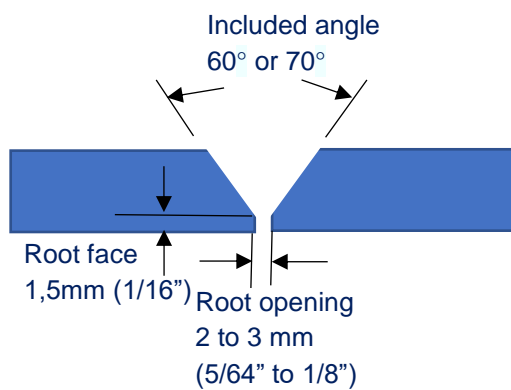




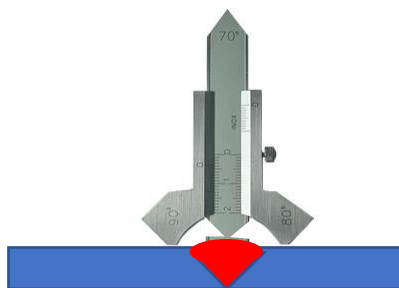
Alignment of butt welds



Limit	Remarks
<p><b>a</b>, less or equal <math>0.15 \times t</math> for strength member.</p> <p><b>a</b>, less or equal <math>0.2 \times t</math> for other, but maximum 4.0 mm (5/32").</p>	<p><b>t</b>, is the lesser thickness.</p>



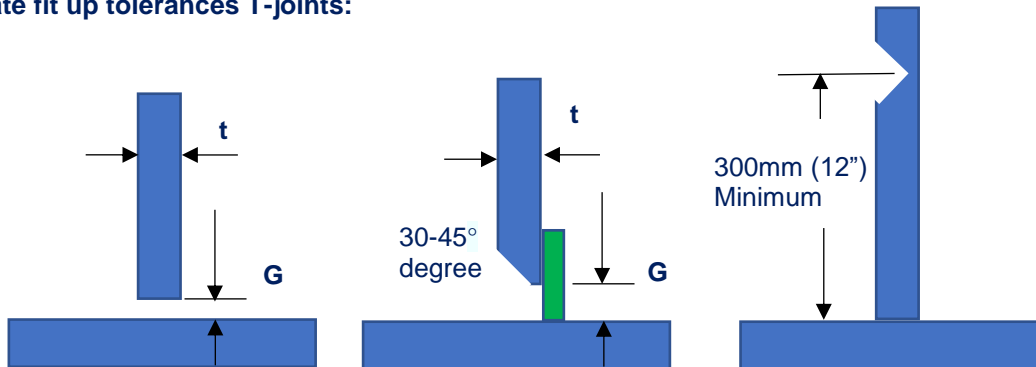
- 1 Root run. Normally done using – polarity.
- 2 Hot pass. + polarity (also part of filler runs).
- 3-4 Filler runs. + polarity. Number of runs depend on plate thickness.
- 5-7 Capping runs. + polarity. Better do straight runs than weaving.



Use a welder's gauge to check the bead crowns reinforcement.



## Plate fit up tolerances T-joints:

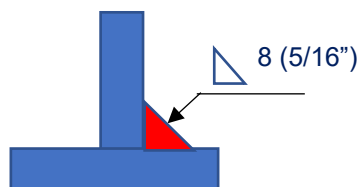


If **G** is 3mm (1/8") to less or equal to 5mm (13/64") the welds leg length is to increase to standard leg length calculation + **G**-2mm (3/64").

If **G** is more than 5mm (13/64") to less or equal to 16mm (5/8") or **G** is less or equal  $1.5 \times t$ , chamfer by 30° to 45°. Build up with welding on one side, with backing strip if necessary, grind and weld.

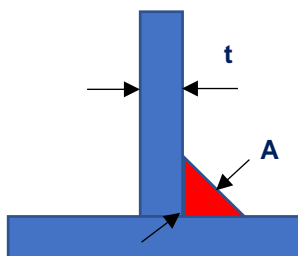
If distance **G** is over 16mm (5/8") or **G** is more than  $1.5 \times t$  use insert plate of minimum height (length) of 300mm (12").

The size of the weld done in a T-joint is referred to as the **A** measurement or trout thickness. If working according to a drawing it is indicated like this on the drawing:



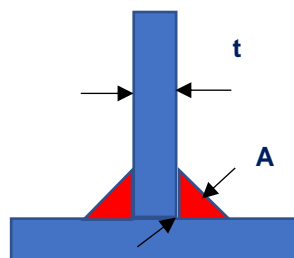
In this example the **A** measurement is to be 8mm (5/16").

If no information on **A** measurement:



If one side welding **A** =  $t \times 0,7$

NB. **t** is thinnest member in the joint.

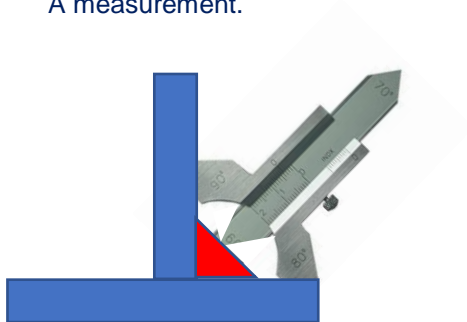


If both sides welded **A** =  $t \times 0,5$

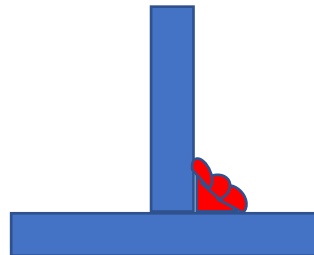




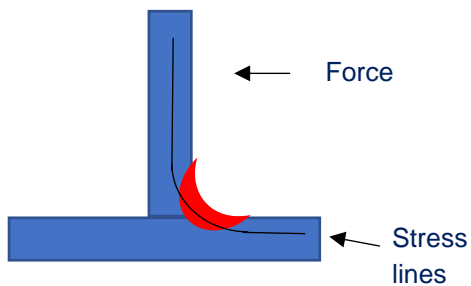
A welder's gauge is used to measure the A measurement.



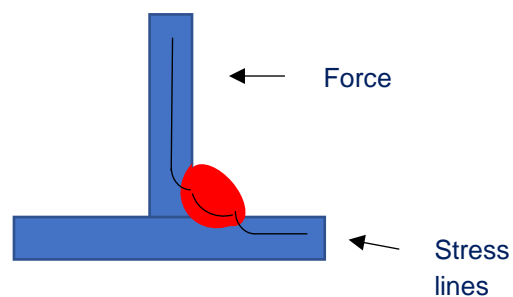
It might require a number of runs in order to build up to required measurement.



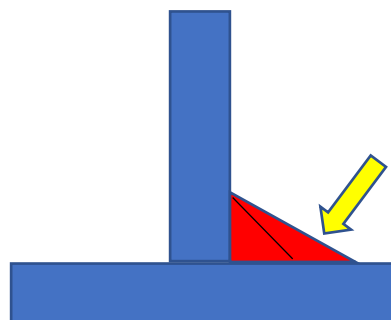
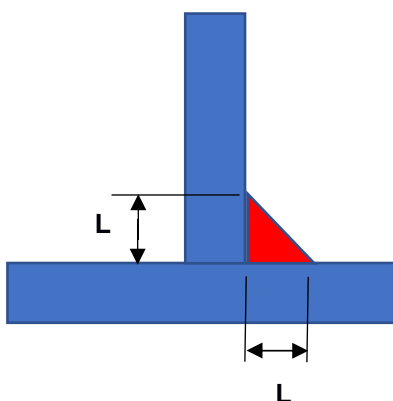
A flat or concave weld contour is preferred.



Avoid creating a convex weld contour.



Stresses are distributed more uniformly through a flat or concave fillet weld contour.



It is also of importance that the final weld has equal leg length (**L**). If not, there will be a waste of material without gaining any strength.

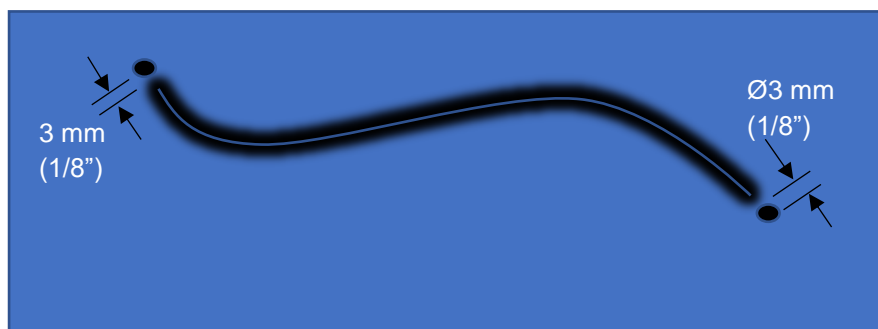


### Welding sequence, a way to reduce shrinkage stress

If the damage is in the form of a crack in the material, it may be difficult to determine where the crack actually ends. The use of a crack detector set to find the complete extent of the crack is absolutely recommended. If the crack has no free end do as follows:

When the true length of the crack has been established, drill 3mm (1/8") holes at a distance of 3mm (1/8") from the ends of the crack. This will prevent the crack from opening and spread further during welding.

Cracks should be "V-ed" or "U-ed" out, using either a grinding machine or by gouging electrodes.



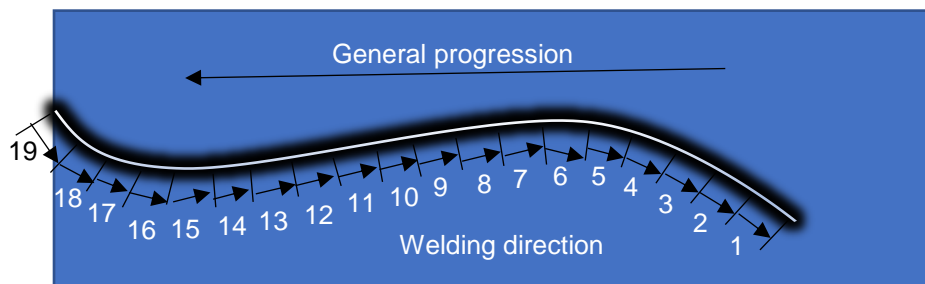
If free end:

The sequence or direction, of welding is important and should be towards the free end of the crack.



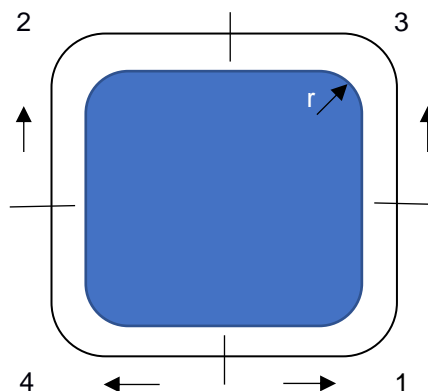


In order to reduce the shrinkage stresses that can develop into cracking, do not weld continually from starting point to the end point. The heat will build up and accumulate into one high shrinking point. Better do back step welding that will more evenly distribute the shrinking forces developed during welding. Back-step welding involves depositing short adjacent weld lengths in the opposite direction to the general progression.



### Renewal of plates (insert)

Size of insert plate to be minimum 300 X 300mm (12" X 12").  
The radius to be 5 X plate thickness.  
Circular inserts to be minimum diameter 200mm (8").



Material grade of insert to be same as original. Welding sequence: 1,2,3,4.

For pre- heating and interpass temperature see:

[www.teandersen.com](http://www.teandersen.com)

Welding Library > Practical welding and cutting:

Technical update-The need for pre-heating when welding.

Technical update- Heat input and interpass temperature during welding.