HARDOX® WEAR PLATE

WELDING HARDOX

SSAB


WELD WITH EASE




Welding Hardox wear plate

Hardox® wear plate combines unique performance with exceptional weldability. Any conventional welding methods can be used for welding these steels to any type of weldable steel.

This brochure contains useful tips and information for anyone who wants to simplify and boost the efficiency of their welding processes. It offers advice on preheat and interpass temperatures, heat input, welding consumables and more. With this practical information, every user can gain the full benefit of the unique properties of Hardox steels.

CONTENTS

Hardox

Users all over the world place their trust in the Hardox wear plate family from SSAB when fighting wear. Hardox boosts performance and maximizes uptime in applications like excavators, front wheel loaders, tipper bodies, mining trucks, conveyors, chutes, containers, crushers, fragmentizers, mixers, sieves, demolition tools and barges. Hardox wear plates can withstand the challenges of any harsh climate, terrain or environment. During manufacturing and in the workshop, Hardox cuts lead times and production costs.

Hardox has come a long way from its early years. It comes in a much wider range, and the traditional Hardox wear plate is also available as wear-resistant tubes, round bars and even strip steel. For comprehensive information about the Hardox product program, including steel grades and qualities, delivery conditions, technical data, and application cases, visit ssab.com.

Getting the best welding results

Clean the weld area to remove moisture, oil, corrosion or any impurities prior to welding. In addition to good welding hygiene, make sure you consider the following aspects:

- Choice of welding consumables
- Preheat and interpass temperatures
- Heat input
- Weld sequence and size of root gap in the joint

Welding consumables

Strength of unalloyed and low-alloyed welding consumables

Unalloyed and low-alloyed consumables with a maximum tensile strength of 500 MPa (72 ksi) are generally recommended for Hardox. Consumables of higher strength (R_e max. 900 MPa/130 ksi) may be used for Hardox 400 and 450 in the thickness range 0.7 – 6.0 mm (0.028" – 0.236"). Low-alloyed consumables result in higher hardness of the weld metal which can reduce the wear rate of the weld metal. If the wear properties of the weld metal are essential, the top cap of the joint could be welded with consumables used for hardfacing; see the chapter "Hard facing" on page 15. In addition, recommended consumables for Hardox steels and their designations according to AWS and EN classifications can be found in Table 1 on page 6.

Table 1: Recommended consumables for Hardox wear plate

Welding method	AWS classification	EN classification
MAG/ GMAW, solid wire	AWS A5.28 ER70X-X	EN ISO 14341-A- G 38x
	AWS A5.28 ER80X-X	EN ISO 14341-A- G 42x
MAG/ MCAW, metal cored wire	AWS A5.28 E7XC-X	EN ISO 17632-A- T 42xH5
	AWS A5.28 E8XC-X	EN ISO 17632-A- T 46xH5
MAG/ FCAW, flux cored wire	AWS A5.29 E7XT-X	EN ISO 17632 -A- T 42xH5
	AWS A5.29 E8XT-X	EN ISO 17632 -A- T 46xH5
MMA (SMAW, stick)	AWS A5.5 E70X	EN ISO 2560-A- E 42xH5
	AWS A5.5 E80X	EN ISO 2560-A- E 46xH5
SAW	AWS A5.23 F49X	EN ISO 14171-A- S 42x
	AWS A5.23 F55X	EN ISO 14171-A- S 46x
TIG/ GTAW	AWS A5.18 ER70X	EN ISO 636-A- W 42x
	AWS A5.28 ER80X	EN ISO 636-A- W 46x

Note: X stands for one or more characters

Requirements on hydrogen content of unalloyed and low-alloyed welding consumables

The hydrogen content should be lower than or equal to 5 ml of hydrogen per 100 g of weld metal when welding with unalloyed or low-alloyed welding consumables.

Solid wire used in MAG/ GMA and TIG/ GTA welding can produce these low hydrogen contents in weld metal. Hydrogen content for other types of welding consumables should be obtained from the respective manufacturers.

If consumables are stored in accordance with the manufacturer's recommendations, the hydrogen content will be maintained to meet the requirement stated above. This also applies to all coated consumables and fluxes.

Stainless steel welding consumables

Consumables of austenitic stainless steels can be used for welding all Hardox products, as shown in Table 2. They allow welding at room temperature 5 – 20°C (41 – 68 °F) without preheating, except for Hardox 600 and Hardox Extreme.

SSAB 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 (72 ksi) in all weld metal.

The AWS 307 type can withstand hot cracking better than AWS 309. It should be noted that 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. SSAB does not impose any restrictions on the maximum hydrogen content for these types of consumables.

Table 2: Recommended stainless steel consumables for Hardox wear plate

Welding method	AWS classification	EN classification
MAG/ GMAW, solid wire	AWS 5.9 ER307	**Recommended:** EN ISO 14343-A: B 18 8 Mn/ EN ISO 14343-B: SS307 **Suitable:** EN ISO 14343-A: B 23 12 X/ EN ISO 14343-B: SS309X
MAG/ MCAW, metal cored wire	AWS 5.9 EC307	**Recommended:** EN ISO 17633-A: T 18 8 Mn/ EN ISO 17633-B: TS307 **Suitable:** EN ISO 17633-A: T 23 12 X/ EN ISO 17633-B: TS309X
MAG/ FCAW, flux cored wire	AWS 5.22 E307T-X	**Recommended:** EN ISO 17633-A: T 18 8 Mn/ EN ISO 17633-B: TS307 **Suitable:** EN ISO 17633-A: T 23 12 X/ EN ISO 17633-B: TS309X
MMA/ SMAW, stick	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
SAW	AWS 5.9 ER307	**Recommended:** EN ISO 14343-A: B 18 8 Mn/ EN ISO 14343-B: SS307 **Suitable:** EN ISO 14343-A: S 23 12 X/ EN ISO 14343-B: SS309X
TIG/ GTAW	AWS 5.9 ER307	**Recommended:** EN ISO 14343-A: W 18 8 Mn/ EN ISO 14343-B: SS307 **Suitable:** EN ISO 14343-A: W 23 12 X/ EN ISO 14343-B: SS309X

Note: X stands for one or more characters

Shielding gas

Shielding gases for Hardox wear plate are generally the same as usually selected for unalloyed and low-alloyed steels.

Shielding gases used for MAG/ GMA-welding of Hardox steels usually contain a mixture of argon (Ar) and carbon dioxide (CO_2). A small amount of oxygen (O_2) is sometimes used together with Ar and CO_2 in order to stabilize the arc and reduce the amount of spatter. A shielding gas mixture of about 18–20% CO_2 in argon is recommended for manual welding, which facilitates good penetration in the material with a reasonable amount of spatter. If automatic or robot welding is used, a shielding gas containing 8–10% CO_2 in argon could be used in order to optimize the weld result with regards to the productivity and spatter level. Effects of various shielding gas mixtures can be seen in Figure 1. Recommendations for shielding gas in different welding methods can be found in Table 3. Shielding gas mixtures mentioned in Table 3 are general mixtures that can be used for both short-arc and spray-arc welding.

Figure 1: Shielding gas mixtures and their effect on the welding operation

- Stable arc
- Reduced amount of spatter
- Reduced amount of slag
- Increased productivity

- Good side wall penetration
- Reduced amount of porosity
- Less risk for lack of fusion

Table 3: Examples of shielding gas mixtures and recommendations

Welding method	Arc type	Position	Shielding gas
MAG/ GMAW, solid wire	Short Arc	All positions	18 – 25% CO_2 in Ar
MAG/ MCAW, metal cored wire	Short Arc	All positions	18 – 25% CO_2 in Ar
MAG/ GMAW, solid wire	Spray Arc	Horizontal	15 – 20% CO_2 in Ar
MAG/ GMAW, FCAW	Spray Arc	All positions	15 – 20% CO_2 in Ar
MAG/GMAW, MCAW	Spray Arc	Horizontal	15 – 20% CO_2 in Ar
Robotic and automated MAG/GMAW	Spray Arc	Horizontal	8 – 18 % CO_2 in Ar
TIG/ GTAW		All positions	100% Ar

Note: Gas mixtures including three components, i.e. O_2, CO_2, in Ar are sometimes used in order to optimize the weld properties.

In all welding methods based on shielding gas, the flow of shielding gas depends on the welding situation. As a general guideline, the shielding gas flow in l/min should be set to the same value as the inside diameter of the gas nozzle measured in mm.

Heat input

Heat input (Q) is the amount of energy applied to the base material per length unit. Heat input is calculated according to the formula below:

$$Q = \frac{k \cdot U \cdot I \cdot 60}{v \cdot 1000} \quad \text{kJ/mm}$$

Q = Heat input kJ/mm (kJ/inch)
k = Arc efficiency (dimensionless)
U = Voltage
I = Current
v = Travel speed mm/min (inch/min)

Various welding processes have different thermal efficiency. Table 4 describes approximate values for different welding methods.

Table 4: Thermal efficiency of different welding methods

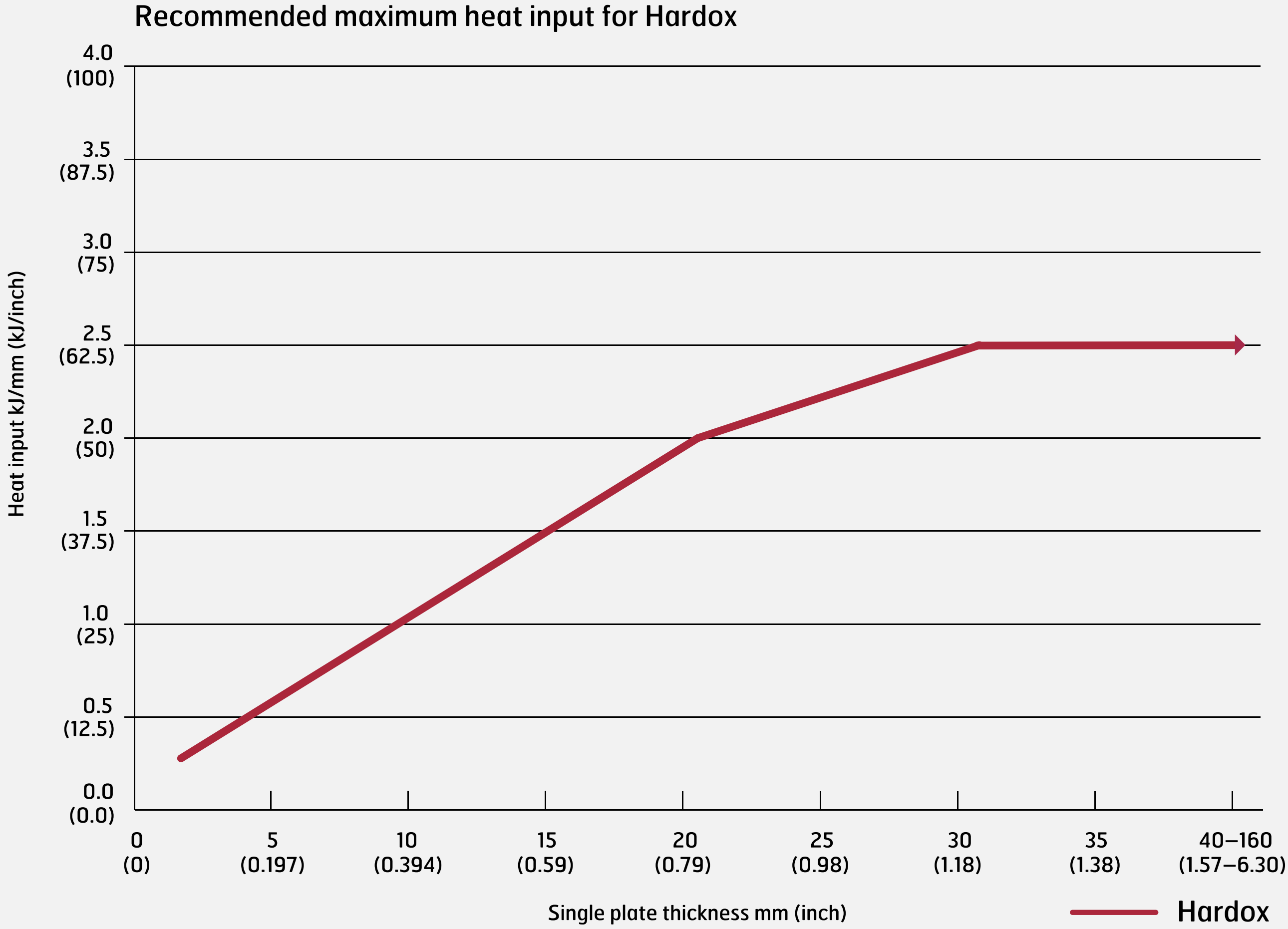
Weld method	Thermal efficiency (k)
MAG/ GMAW	0.8
MMA/ SMAW	0.8
SAW	1.0
TIG/ GTAW	0.6

Excessive heat input increases the width of the heat affected zone (HAZ), which in turn impairs the mechanical properties as well as the wear resistance of the HAZ. Welding with low heat input provides benefits like these:

- Increased wear resistance of the HAZ
- Decreased distortion (single-pass welded joints)
- Increased toughness of the joint
- Increased strength of the joint

A very low heat input might, however, negatively affect the impact toughness ($t_{8/5}$ values below 3 seconds). Figure 2 indicates the recommended maximum heat input (Q) for Hardox.

Figure 2: Recommended maximum heat input for Hardox wear plate



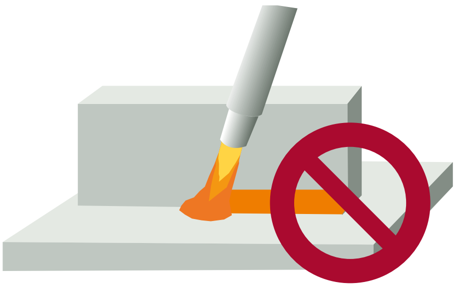
Cooling time $t_{8/5}$

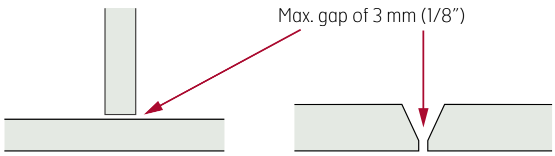
The cooling time ($t_{8/5}$) is the time that it takes for the weld to cool from 800° – 500°C (1472° – 932°F), and it represents the key element of the final microstructure in the weld. Recommended cooling times are often provided for structural steels in order to optimize the weld process for a certain requirement, such as meeting the minimum impact toughness. Recommended maximum cooling times for different Hardox grades are available in SSAB's WeldCalc software. Contact your local SSAB sales representative to find out more about WeldCalc.

Welding sequence and root opening size

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

Figure 3: Avoid start and stops in highly stressed areas like corners. Gap size should not exceed 3 mm (1/8").





Hydrogen cracking

Due to a relatively low carbon equivalent, Hardox resists hydrogen cracking better than other wear-resistant steels.

Minimize the risk of hydrogen cracking by following these recommendations:

- Preheat the weld area to the recommended minimum temperature.
- Measure the preheat temperature according to SSAB recommendations.
- Use processes and consumables that provide a maximum hydrogen content of 5ml/100g weld metal.
- Keep the joint clear from impurities like rust, grease, oil or frost.
- Use only classifications for weld consumables recommended by SSAB.
- Apply a proper welding sequence in order to minimize residual stresses.
- Avoid a root opening size exceeding 3 mm (1/8"); see Figure 3.

Preheat and interpass temperatures

It is essential to follow the recommended minimum preheat temperature as well as the procedure for obtaining and measuring the temperature in and around the joint in order to avoid hydrogen cracking.

Influence of alloying elements on the selections of preheat and interpass temperatures

A unique combination of alloying elements optimizes the mechanical properties of Hardox. This combination governs preheat and interpass temperatures of Hardox steel during welding, and can be used to calculate the carbon equivalent. Carbon equivalent is usually expressed as CEV or CET according to the formulas below.

$$CEV = C + \frac{Mn}{6} + \frac{(Mo+Cr+V)}{5} + \frac{(Ni+Cu)}{15} \quad (\%)$$

$$CET = C + \frac{(Mn+Mo)}{10} + \frac{(Cr+Cu)}{20} + \frac{Ni}{40} \quad (\%)$$

The alloying elements are specified in the mill certificate of the plate and are stated in weight percentages in these two formulas. A higher carbon equivalent usually requires a higher preheat and interpass temperature. The typical carbon equivalent for Hardox is stated in in SSAB's product data sheets at www.ssab.com under Products>Brands>Hardox.

Preheat and interpass temperatures for Hardox

Minimum recommended preheat and maximum interpass temperatures during welding are given in Tables 5a, 5b and 6. Unless otherwise stated, these values are applicable for welding with unalloyed and low-alloyed welding consumables.

- When plates of different thicknesses but of the same steel grade are welded together, the thicker plate determines the required preheat and interpass temperatures; see Figure 4.
- When different steel types are welded together, the plate requiring the highest preheat temperature determines the required preheat and interpass temperatures.
- Table 5 is applicable for heat inputs of 1.7 kJ/mm (43.2 kJ/inch) or higher. If heat inputs of 1.0 – 1.69 kJ/mm (25.4 – 42.9 kJ/inch) are used, we recommend that you increase the temperature by 25°C (77°F) above the recommended preheat temperature.
- If a lower heat input than 1.0 kJ/mm (25.4 kJ/inch) is applied, we recommend that you use SSAB's WeldCalc software to calculate the recommended minimum preheating temperature.
- If the ambient humidity is high or the temperature is below 5°C (41°F), the lowest recommended preheat temperatures given in Table 5a and 5b should be increased by 25°C (77°F).
- For double V-butt welds in thicknesses above 30 mm (1.181"), we recommend that the root pass is shifted approximately 5 mm (0.197") away from the centerline of the plate.

Table 5a: Recommended preheating temperatures. The single plate thickness in millimeters is shown on the x-axis.

Minimum recommended preheat and interpass temperatures for different single plate thicknesses (mm)

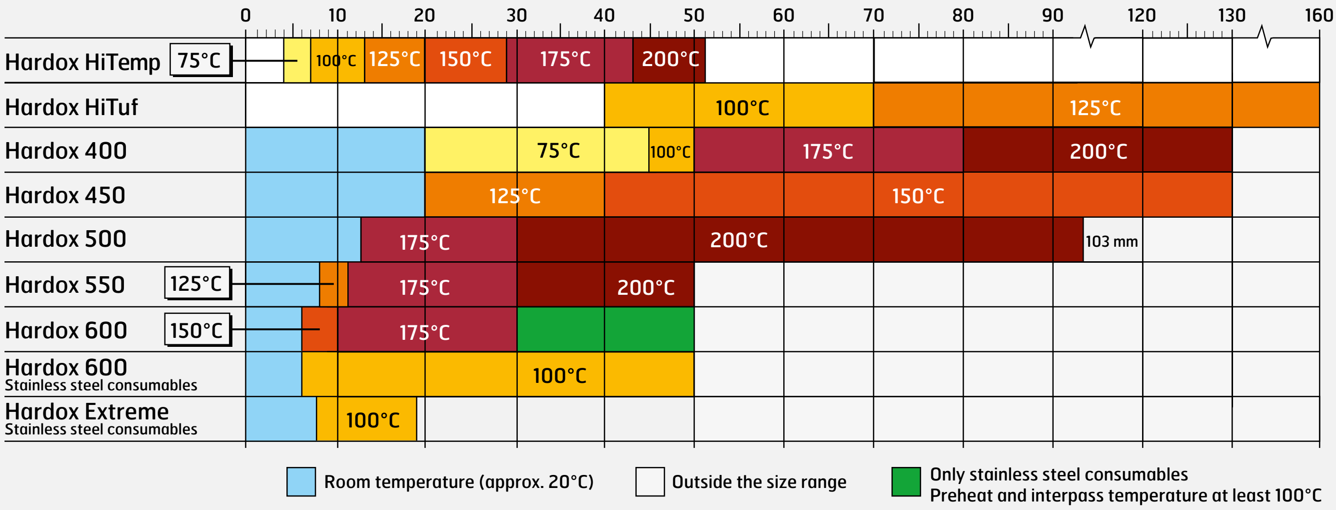


Table 5b: Recommended preheating temperatures. The single plate thickness in inches is shown on the x-axis.

Minimum recommended preheat and interpass temperatures for different single plate thicknesses (inch)

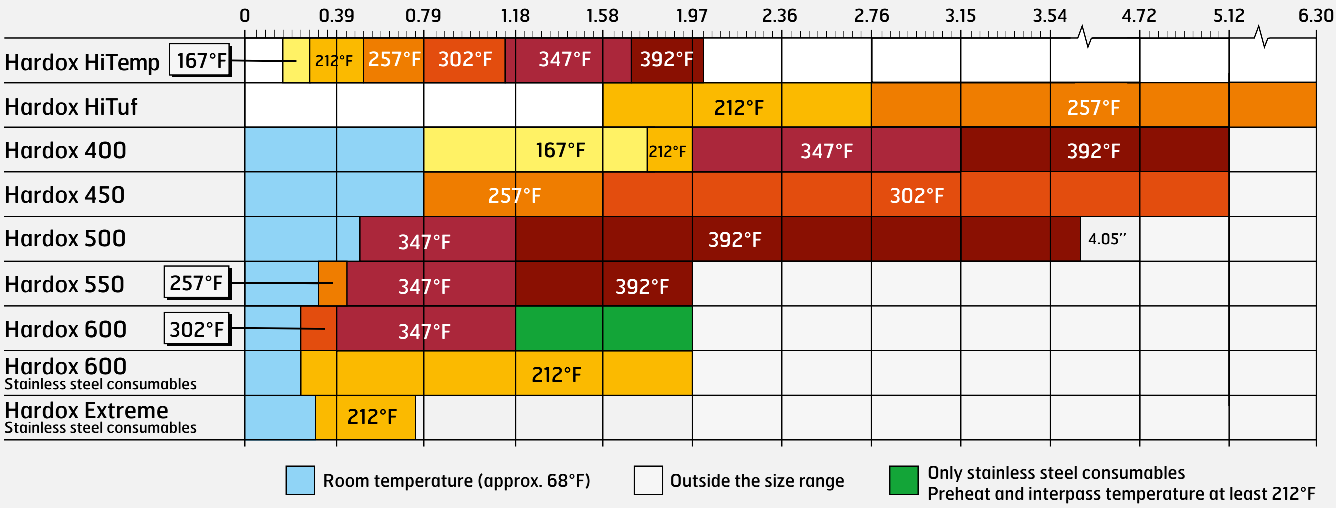
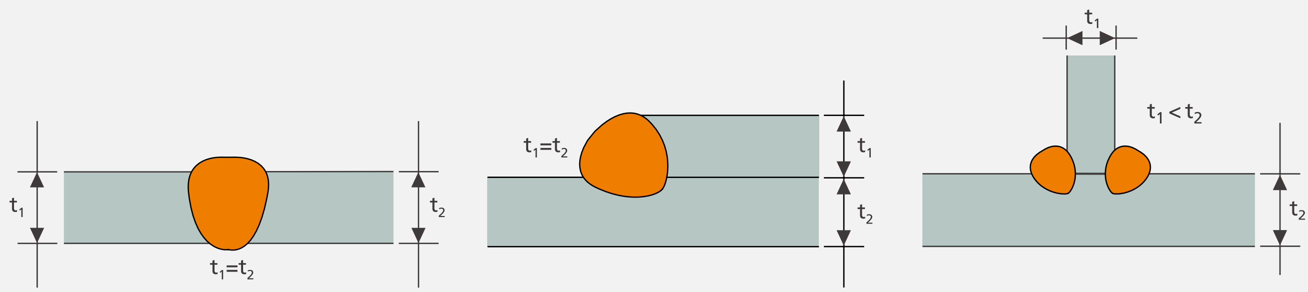


Figure 4: Schematic drawing showing "single plate thickness"



$t_1=t_2$ The single plate thickness is t_1 or t_2, provided that the same steel type is used.

$t_1=t_2$ The single plate thickness is t_1 or t_2, provided that the same steel type is used.

$t_1<t_2$ In this case, the single plate thickness is t_2, provided that the same steel type is used.

The interpass temperature shown in Table 6 is the maximum recommended temperature in the joint (on top of the weld metal) or immediately adjacent to the joint (start position), just before start of next weld pass.

Table 6: Maximum recommended interpass temperature/preheating temperature.

Hardox HiTemp	300°C (572°F)
Hardox HiTuf**	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 of up to approx. 400°C (752°F) can be used in certain cases for Hardox HiTuf. In such cases, use WeldCalc.

The minimum recommended preheat and maximum interpass temperatures shown in Tables 5 and 6 are not affected at heat inputs higher than 1.7 kJ/mm (43.2 kJ/inch). The information is based on the assumption that the welded joint is allowed to air cool to ambient temperature. Note that these recommendations also apply to tack welds and root runs. In general, each of the tack welds should be at least 50 mm (2”) long. For joints with plate thicknesses of up to 8 mm (0.31”), shorter tack lengths may be used. The distance between tack welds can be varied as required.

Attaining and measuring the preheat temperature

The required preheat temperature can be achieved in several ways. Electric preheater elements (Figure 5) around the prepared joint are often best, since uniform heating of the area can be obtained. The temperature should be monitored by using, for example, a contact thermometer.

We suggest that you measure the recommended preheating temperature on the opposite side of the heating operation; see Figure 6.

Figure 5: Example of electrical heating mats

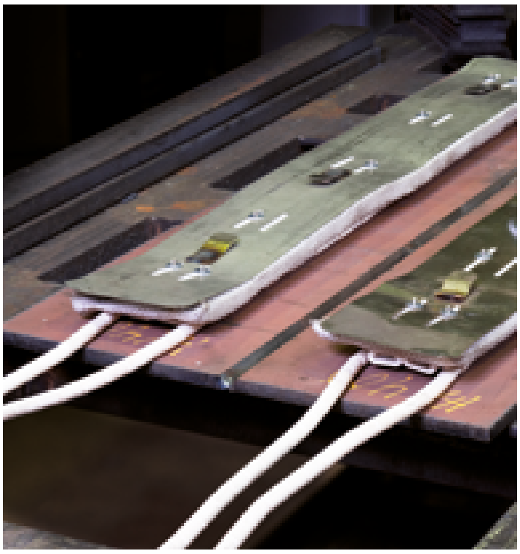
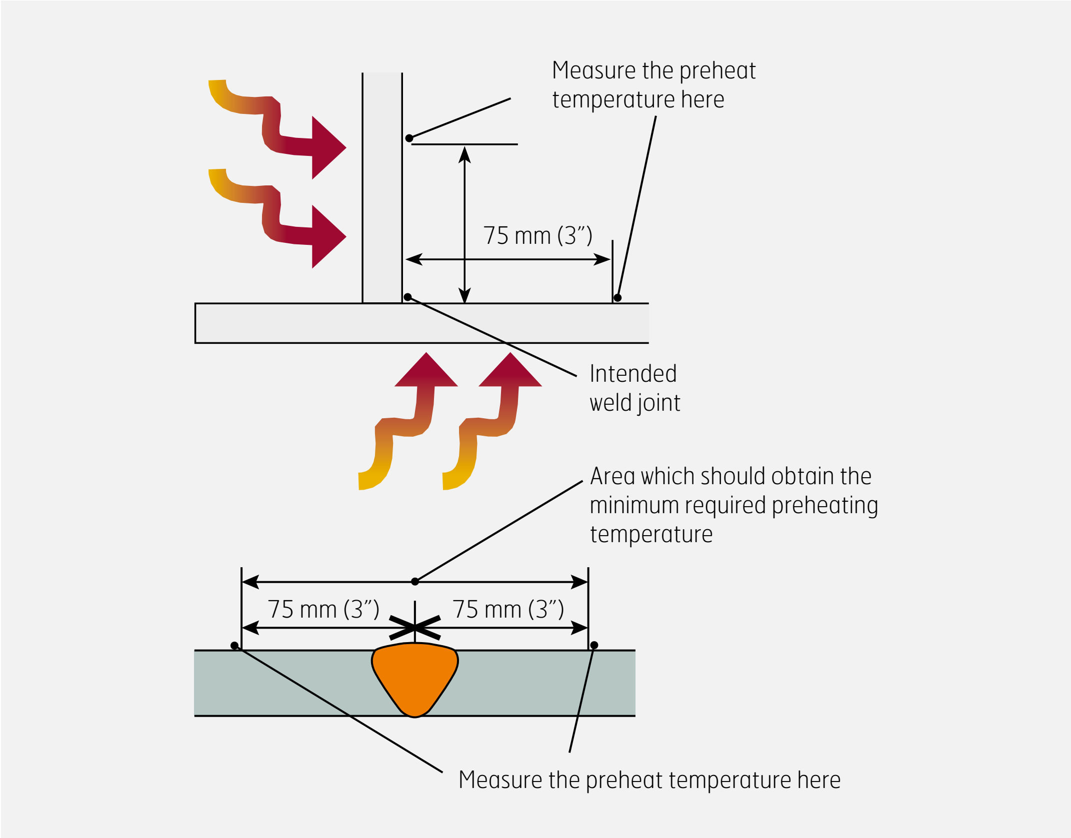


Figure 6: Recommended preheating operation



A minimum waiting time of 2 min/25 mm (2 min/ 1 inch) thickness should be conducted before measuring the preheating temperature. The minimum preheating temperature should be obtained in an area of 75 + 75 mm (3"+ 3") around the intended weld joint; see Figure 6.

Hard facing

If the weld joint is located in an area with the expectation of high wear, you can employ hardfacing with special consumables to increase the wear resistance of the weld metal. Both the instructions for joining and hardfacing for Hardox should be followed. Some consumables for hardfacing require a very high preheat temperature that may exceed the maximum recommended interpass temperature for Hardox steel. It is worth noting that using a preheat temperature above the maximum recommended interpass temperature for Hardox steel may reduce the hardness of the base plate and result in deterioration of wear resistance of the preheated area.

Minimum and maximum preheat temperatures are the same as for conventional types of welding; see Tables 5a and 5b. See Figure 7 for the definition of single plate thickness for hard facing situations.

Figure 7: Definition of single plate thickness

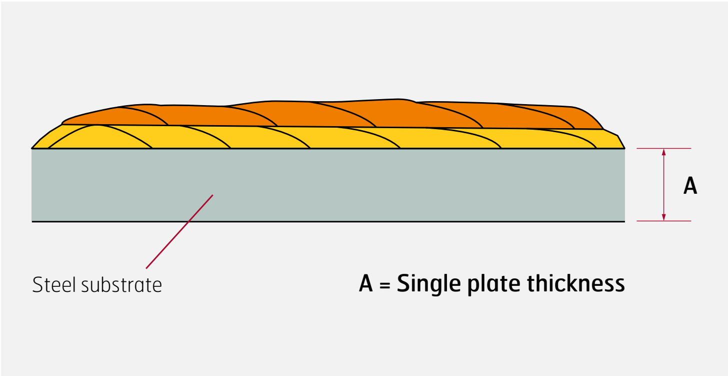
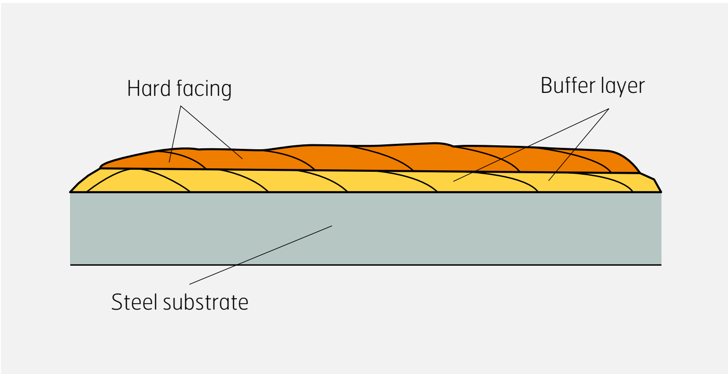


Figure 8: Example of welding sequence using consumables for buffer layer and hard facing



It is beneficial to weld a buffer layer with extra high toughness between the ordinary welded joint or plate and the hard facing. The choice of consumables for the buffer layer should follow the welding recommendations for Hardox wear plate. Stainless steel consumables in accordance with AWS 307 and AWS 309 should preferably be used for the buffer layer; see Figure 8.

Recommendations for minimizing distortion

The amount of distortion during and after welding is related to the base plate thickness and welding procedure. Distortion becomes more obvious in thinner gauges, while heavy deformation or even burn-through can cause problems and can compromise the whole structure.

Minimize the amount of distortion during welding by following these recommendations:

- Weld with a heat input as low as possible (single pass welded joints).
- Minimize the cross sectional area; see Figure 9.
- Prebend, clamp or angle the parts before welding in order to compensate for the deformation; see Figure 10.
- Avoid an irregular root opening.
- Use symmetrical welds; see Figure 9.
- Minimize reinforcements and optimize the throat thickness of the fillet welds.
- Weld from rigid areas to loose ends.
- Decrease spacing between the tack welds.
- Use a back-step welding technique; see Figures 11-12.

Figure 9: Cross section of the weld and how it influences the angle deviation

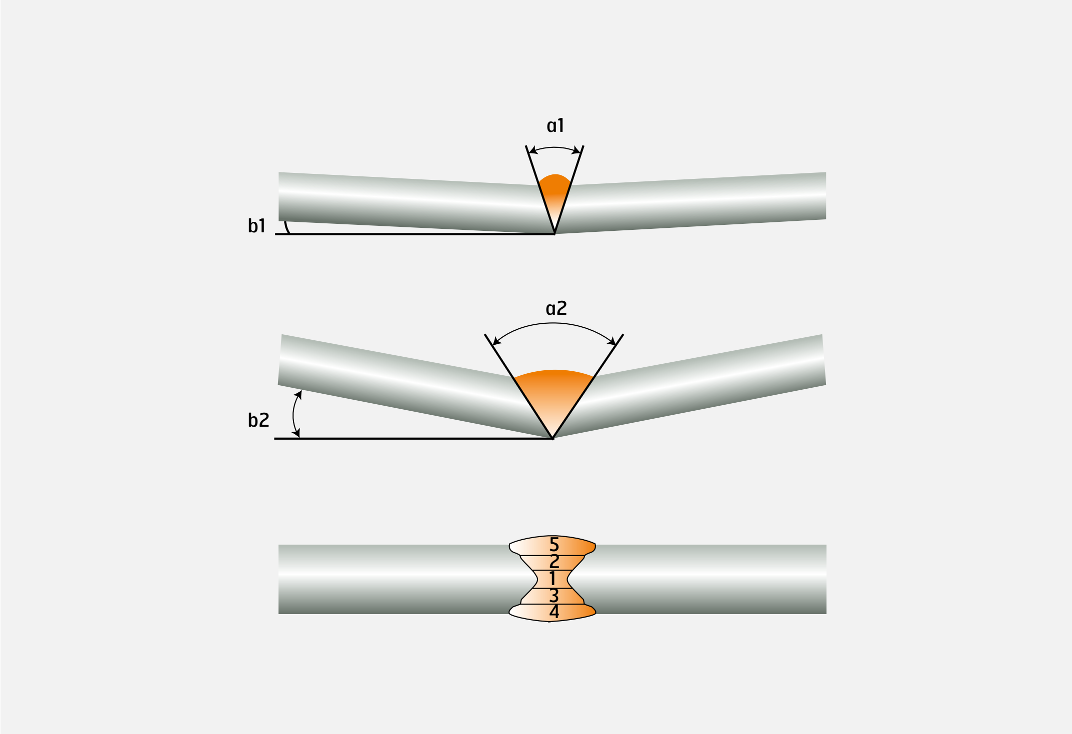


Figure 10: Presetting of a fillet joint and a single-V butt joint.

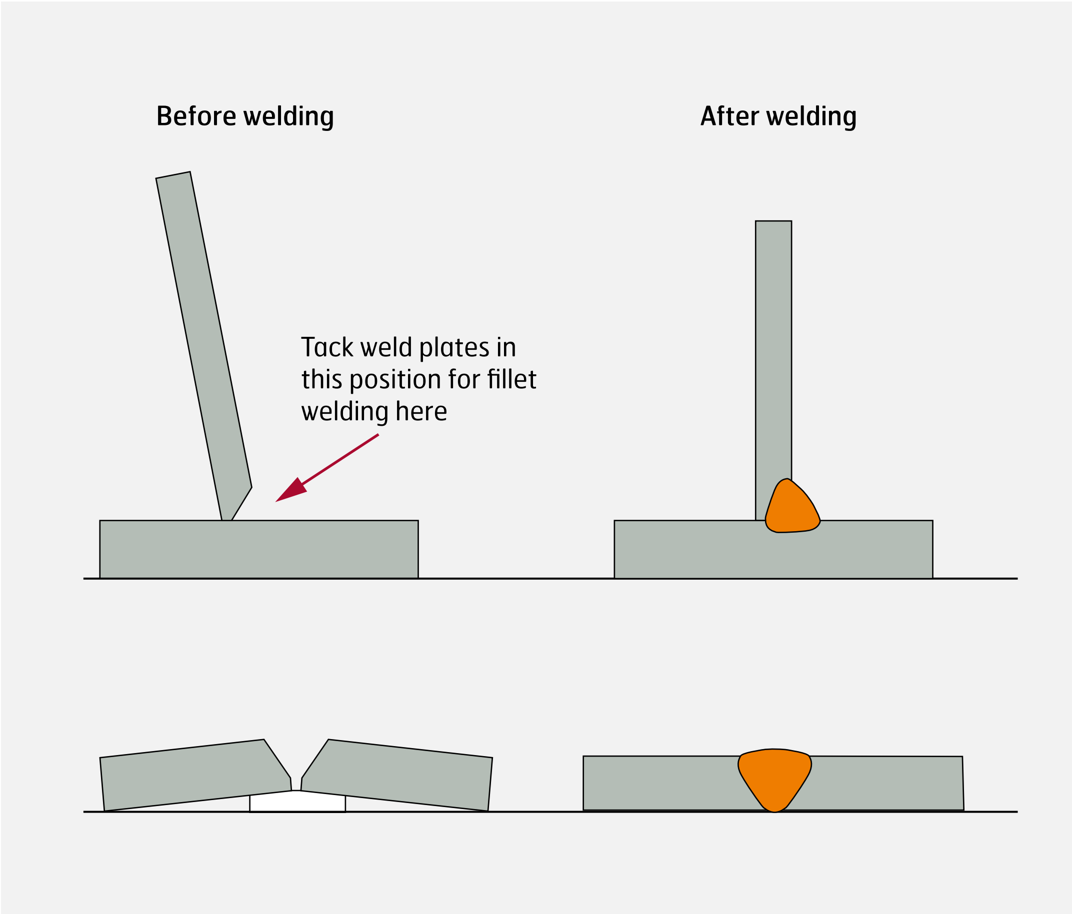


Figure 11: Use a symmetrical weld sequence

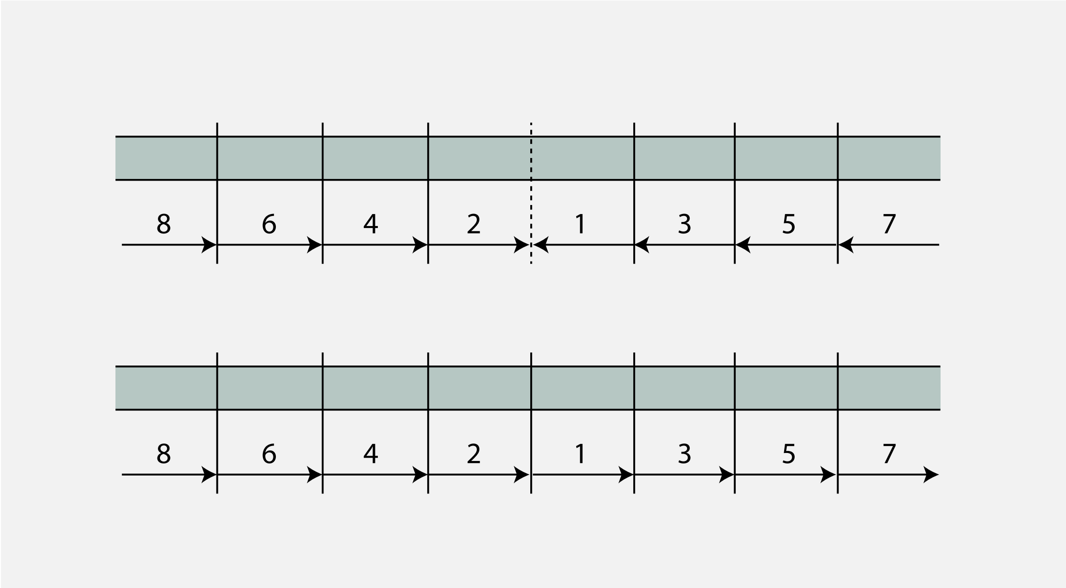
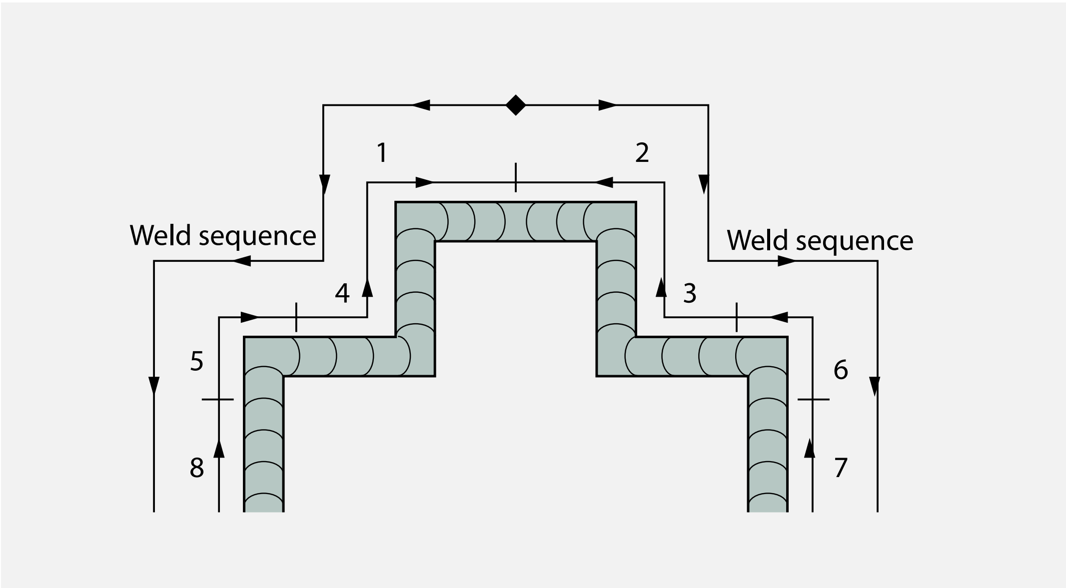


Figure 12: Example of back step welding technique



Welding on Hardox primer

You can weld directly on Hardox primer thanks to its low zinc content. The primer can be easily brushed or ground away in the area around the joint; see Figure 13. Removing primer prior to welding can be beneficial, since it can minimize the porosity in the weld and can facilitate out-of-position welding. If primer remains on the weld surface, then the sub-surface and surface porosity of the weld may be slightly higher. FCAW with basic flux offers the lowest porosity. It is important to maintain good ventilation in all welding processes to avoid the harmful effect the primer could have on the welder and surroundings.

Figure 13: The primer is easy to brush away if necessary

Post-weld heat treatment

Hardox HiTuf can be stress relieved by post-weld heat treatment, although this is seldom necessary. Other Hardox steels should not use this method for stress relieving, since this may impair the mechanical properties. For more information, consult the Welding Handbook from SSAB. You can order it at www.ssab.com.

HARDOX®
WEAR PLATE

SSAB is a Nordic and US-based steel company. SSAB offers value added products and services developed in close cooperation with its customers to create a stronger, lighter and more sustainable world. SSAB has employees in over 50 countries. SSAB has production facilities in Sweden, Finland and the US. SSAB is listed on the Nasdaq OMX Nordic Exchange in Stockholm and has a secondary listing on the Nasdaq OMX in Helsinki.

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