SSAB

Appendix 5 RR® and RD® piles

Design and installation manual

RR and RD piles

Preheating and cooling of splice welds

Updated 4/2025

CONTENT

GENERAL

Preheating of base material before welding is very efficient way to avoid hydrogen cracking. Preheating delays the cooling of the weld region and therefore promotes hydrogen effusion in a shorter time to a higher extent after welding than without preheating. Preheating furthermore reduces the state of internal stresses. For multilayer welds it is possible to start without preheating if a sufficiently high interpass temperature can be reached and maintained by a suitable welding sequence. Calculation of required preheat requires knowledge on several parameters of base material, weld consumable and welding process. The pre-calculated tables and graphs in this manual are made to help site personnel to estimate the need of preheating and the required preheat temperature of the base material.

After welding some of the welds need to be tested with non-destructive testing (NDT). NDT cannot be performed too quickly after the welding, the weld needs to cool. Certain hold times apply depending on the properties of the base material and the preheating. Either the weld seam can be too hot for commencing NDT, or if NDT is performed too soon, there might be a risk for hydrogen cracking to appear after NDT. The hold times presented in this manual are taken from EN standards and they are consistent with the preheating methods and temperatures presented.

REQUIRED PREHEAT

Depending on the structure and the installation method, steel piling is executed according to relevant execution standard. Driven RR piles are executed according to EN 12699 (*Execution of special geotechnical works. Displacement piles*), drilled small diameter RD piles are executed according to EN 14199 (*Execution of special geotechnical works. Micropiles*) and RR and RD piles which are part of a pile wall are executed according to EN 12063 (*Execution of special geotechnical work. Sheet pile walls, combined pile walls, high modulus walls*).

Both EN 12699 and EN 14199 refer to EN 1090-2 (Execution of steel structures and aluminium structures. Part 2: Technical requirements for steel structures) on execution and testing requirements of welds, while EN 12063 itself contains the requirements for welds on piles.

Regarding preheating of welds, EN 1090-2 states "*Preheating, when required, shall be carried out in accordance with EN ISO 13916, EN 1011-2 and/or EN 1011-3*". For steels used in steel piles manufactured by SSAB, the standard EN 1011-2 (*Welding. Recommendations for welding of metallic materials. Part 2: Arc welding of ferritic steels*) applies.

Table B.3 in Annex B of EN 12063 gives the required preheating for some steel materials used in piles. The values in the table are general values and clearly conservative for the properties of steels used in SSAB piles. Due to the nature of the general values, EN 12063 states in section B.8.1 "*If chemical composition of steel and welding consumables are known, the preheating temperature can also be calculated according to EN 1011-2*". In general, a more accurate calculation is beneficial.

Annex C of EN 1011-2 gives two alternative preheating methods for preventing hydrogen cracking, method A and method B. It also limits the use of the methods according to chemical composition of the base material. According to the limitations method A is not suitable for all steel materials used in SSAB steel piles. On the other hand, method B can be used for all steel materials used in SSAB steel piles.

The methods A and B are not actual methods for heating the base material. The preheating method refers to calculation procedure to determine the required temperature which the base material must have before the welding begins.

The equations to calculate the required preheat temperature for method B are given in Clause C.3 in EN 1011-2. The preheat temperature is calculated from several factors; chemical composition of the base material (carbon equivalent CET), thickness of the base material, hydrogen content of the weld consumable and heat input during the welding process .

Based on the above mentioned factors, the calculated preheat temperatures for certain steel grades and weld consumables are given in following tables and figures. The calculations are based on following boundary conditions:

- The CET values are calculated from mean values of chemical compositions over long time of manufacturing. Since chemical compositions differ among manufacturers, these graphs are valid only for steel grades presented in this manual

and for steel piles manufactured of them by SSAB.

- Weld consumables used are the recommended weld consumables given in RR® and RD® piles, Design and installation manual. Hydrogen content HD of each weld consumable is according to technical information provided by the manufacturer.

As can be seen from tables and graphs the preheat temperature highly depends on the decisions on site. Weld consumable to be used and also heat input during welding have high impact on the required preheat temperature.

In addition for the calculated preheat temperatures presented in tables and figures also some other things need to be considered in preheat;

- Moist electrodes increase the hydrogen content of the weld. Due to this they must always be dried before use according to instructions given in RR® and RD® piles, Design and installation manual.

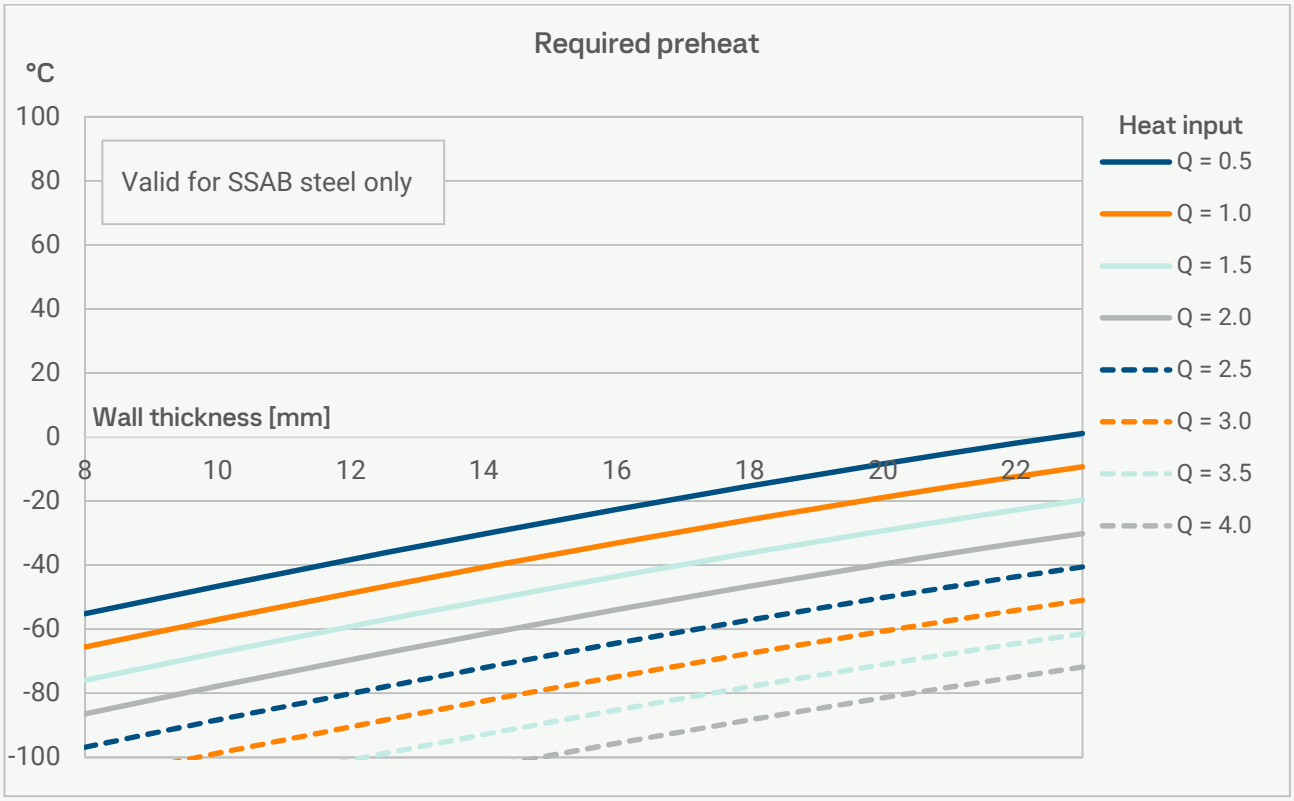
- Moisture in the air condenses to the surface of a cold steel material. Even if the calculated preheat temperature in tables and figures is low, the pile ends need to be preheated to +50 to +100 °C before starting the work if air temperature is below +10 °C.

TABLES AND GRAPHS TO DEFINE REQUIRED PREHEAT

Steel grade S355J2H, CET = 0.210 %

Weld consumable: ESAB OK 48.00 HD = 4 ml/100 g

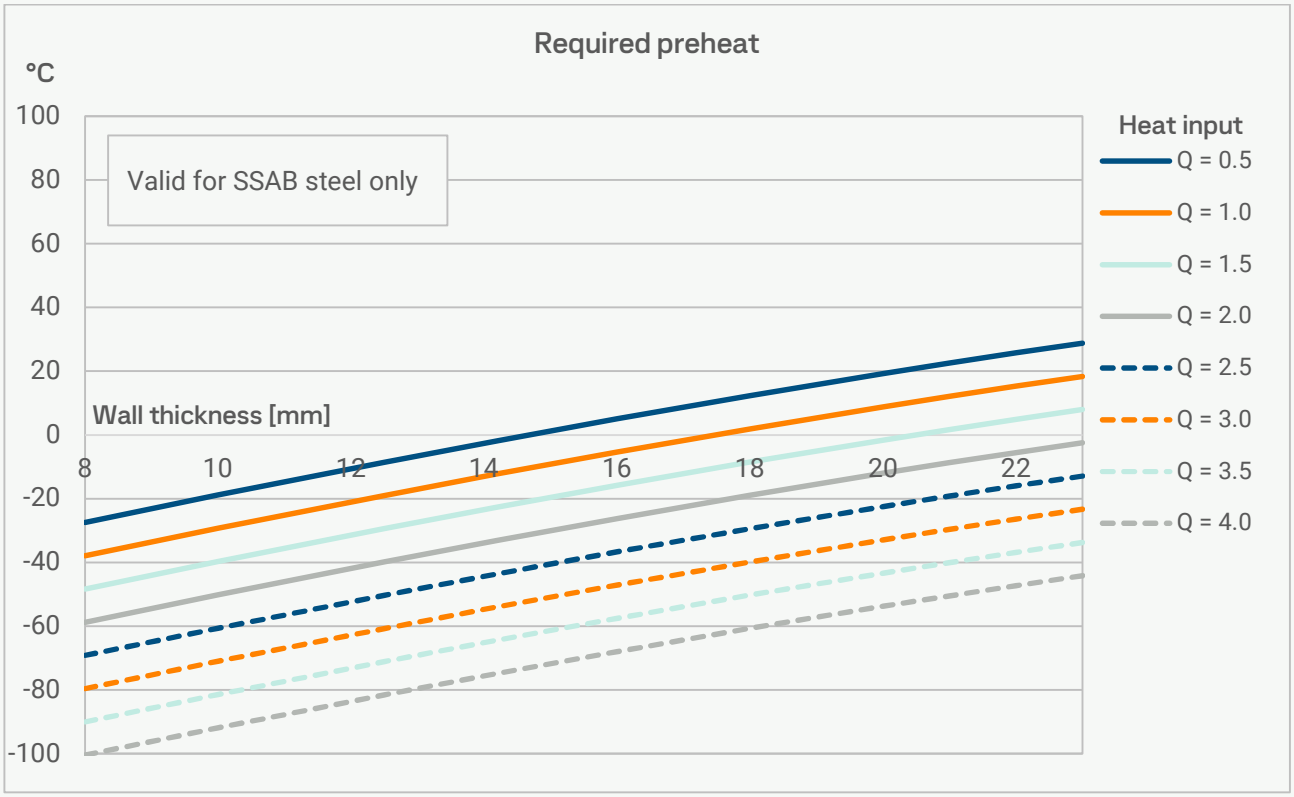
Wall thickness *t* [mm]	Required preheat [°C] Heat input *Q* during welding [kJ/mm]							
	0.5	1.0	1.5	2.0	2.5	3.0	3.5	4.0
8	-55.1	-65.5	-76.0	-86.4	-96.8	-107.2	-117.7	-128.1
10	-46.5	-57.0	-67.4	-77.8	-88.2	-98.7	-109.1	-119.5
12.5	-36.2	-46.6	-57.1	-67.5	-77.9	-88.3	-98.8	-109.2
14.2	-29.5	-39.9	-50.3	-60.8	-71.2	-81.6	-92.0	-102.5
16	-22.6	-33.0	-43.5	-53.9	-64.3	-74.7	-85.2	-95.6
18	-15.3	-25.8	-36.2	-46.6	-57.0	-67.4	-77.9	-88.3
20	-8.4	-18.9	-29.3	-39.7	-50.1	-60.5	-71.0	-81.4
21	-5.1	-15.5	-26.0	-36.4	-46.8	-57.2	-67.7	-78.1
22	-1.9	-12.3	-22.8	-33.2	-43.6	-54.0	-64.5	-74.9



Steel grade S355J2H, CET = 0.210 %

Weld consumable: TRI-MARK TM-770 HD = 8 ml/100 g

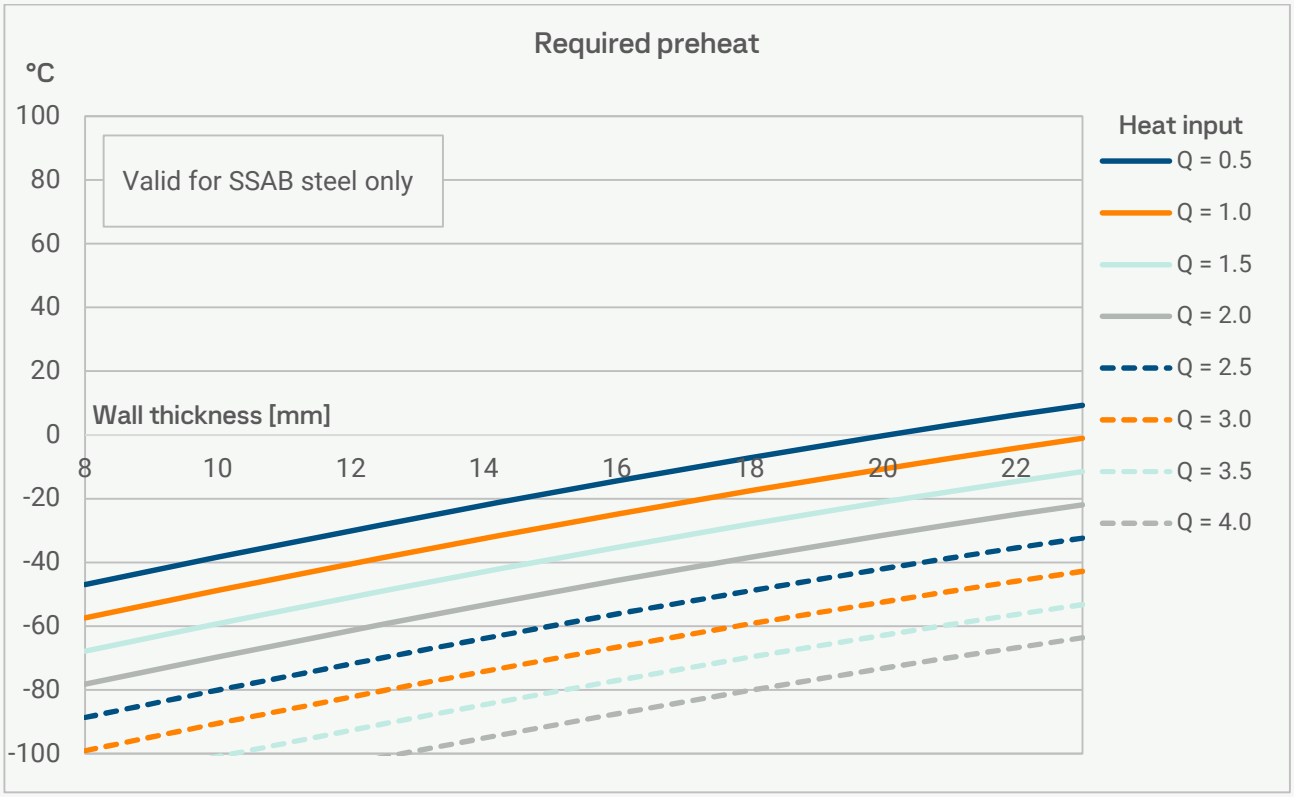
Wall thickness *t* [mm]	Required preheat [°C] Heat input *Q* during welding [kJ/mm]							
	0.5	1.0	1.5	2.0	2.5	3.0	3.5	4.0
8	-27.5	-37.9	-48.3	-58.7	-69.1	-79.6	-90.0	-100.4
10	-18.9	-29.3	-39.7	-50.2	-60.6	-71.0	-81.4	-91.9
12.5	-8.6	-19.0	-29.4	-39.8	-50.3	-60.7	-71.1	-81.5
14.2	-1.8	-12.3	-22.7	-33.1	-43.5	-53.9	-64.4	-74.8
16	5.0	-5.4	-15.8	-26.2	-36.7	-47.1	-57.5	-67.9
18	12.3	1.9	-8.5	-18.9	-29.4	-39.8	-50.2	-60.6
20	19.2	8.8	-1.6	-12.0	-22.5	-32.9	-43.3	-53.7
21	22.5	12.1	1.7	-8.7	-19.2	-29.6	-40.0	-50.4
22	25.7	15.3	4.9	-5.5	-16.0	-26.4	-36.8	-47.2



Steel grade S355J2H, CET = 0.210 %

Weld consumable: ESAB OK Tubrod 15.14 HD = 5 ml/100 g

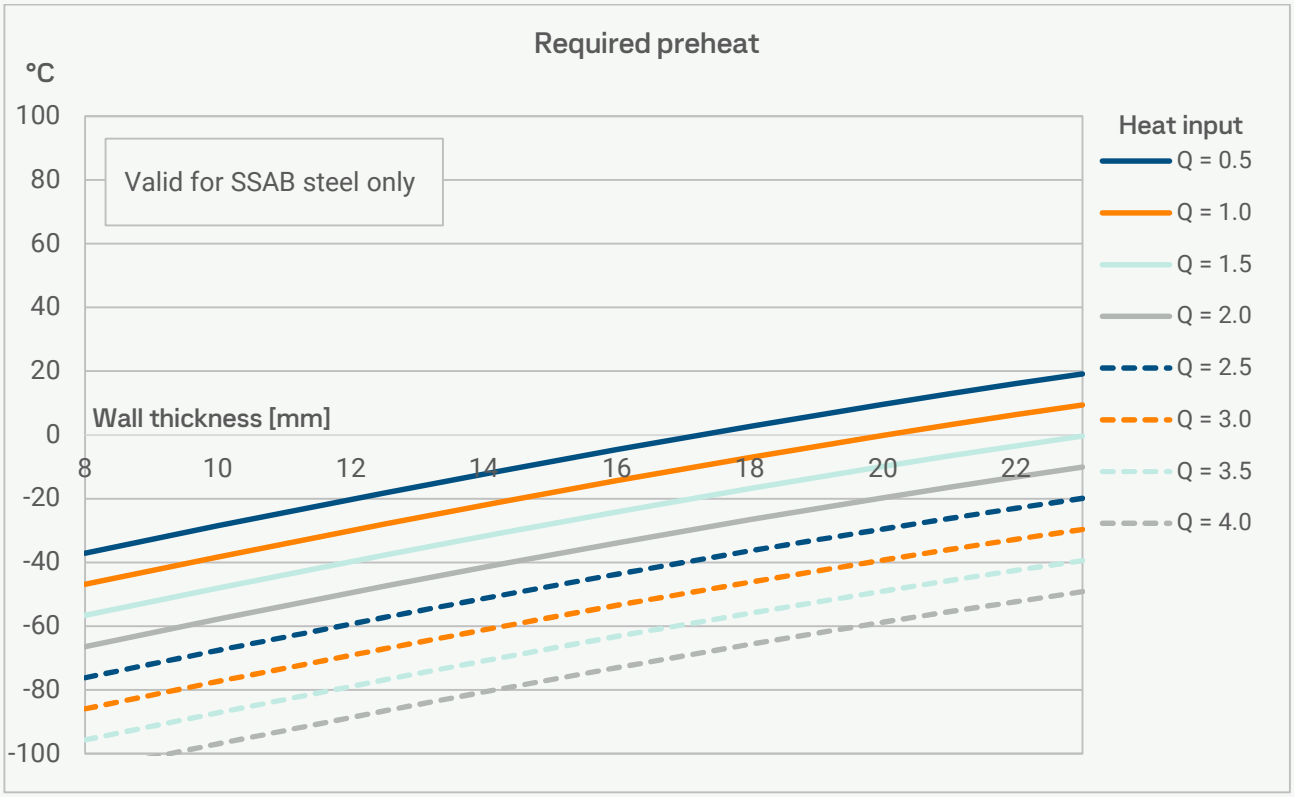
Wall thickness *t* [mm]	Required preheat [°C] Heat input *Q* during welding [kJ/mm]							
	0.5	1.0	1.5	2.0	2.5	3.0	3.5	4.0
8	-46.9	-57.3	-67.8	-78.2	-88.6	-99.0	-109.5	-119.9
10	-38.4	-48.8	-59.2	-69.6	-80.1	-90.5	-100.9	-111.3
12.5	-28.0	-38.5	-48.9	-59.3	-69.7	-80.2	-90.6	-101.0
14.2	-21.3	-31.7	-42.1	-52.6	-63.0	-73.4	-83.8	-94.3
16	-14.4	-24.9	-35.3	-45.7	-56.1	-66.6	-77.0	-87.4
18	-7.1	-17.6	-28.0	-38.4	-48.8	-59.3	-69.7	-80.1
20	-0.2	-10.7	-21.1	-31.5	-41.9	-52.4	-62.8	-73.2
21	3.1	-7.4	-17.8	-28.2	-38.6	-49.1	-59.5	-69.9
22	6.3	-4.2	-14.6	-25.0	-35.4	-45.9	-56.3	-66.7



Steel grades S440J2H and S460MH, CET = 0.235 %

Weld consumables: ESAB OK 55.00 HD = 4 ml/100 g
ESAB OK 48.08 HD = 4 ml/100 g

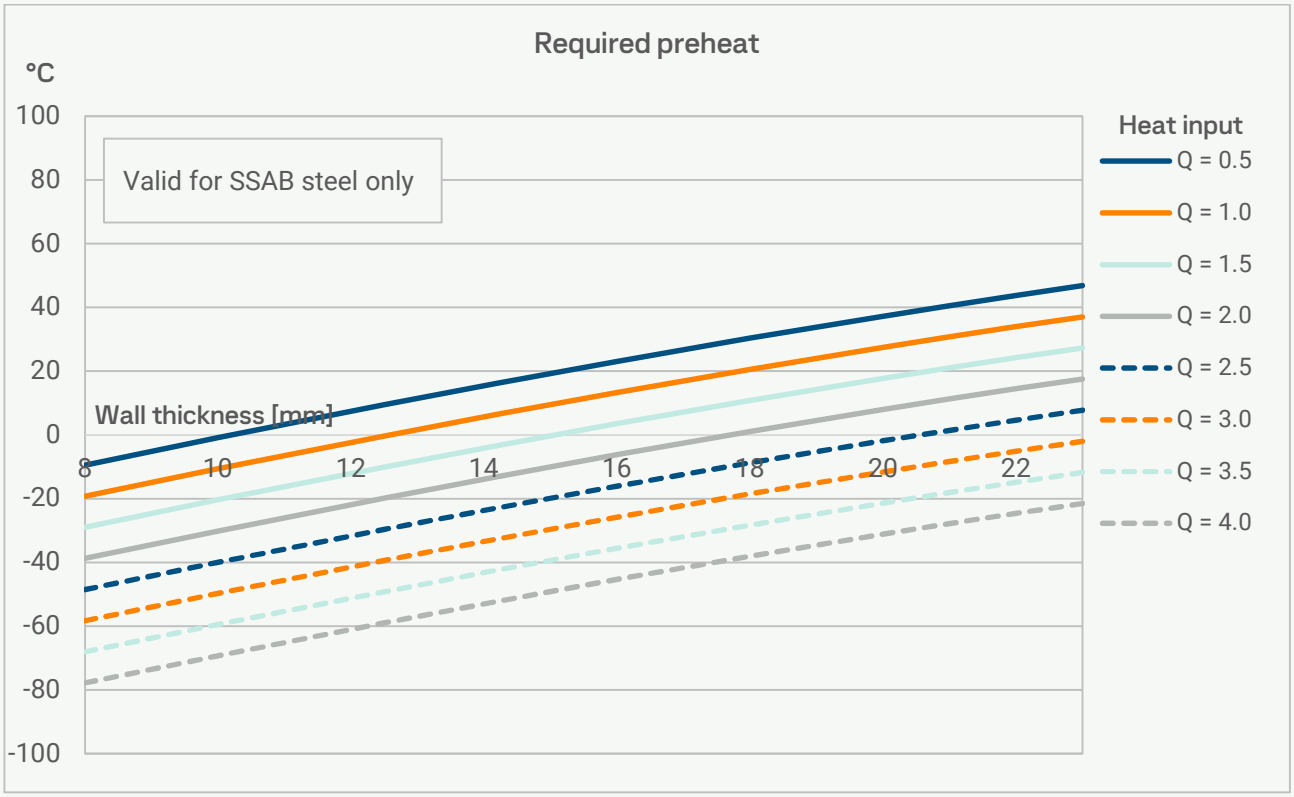
Wall thickness *t* [mm]	Required preheat [°C] Heat input *Q* during welding [kJ/mm]							
	0.5	1.0	1.5	2.0	2.5	3.0	3.5	4.0
8	-37.1	-46.8	-56.6	-66.4	-76.1	-85.9	-95.7	-105.4
10	-28.5	-38.3	-48.1	-57.8	-67.6	-77.3	-87.1	-96.9
12.5	-18.2	-28.0	-37.7	-47.5	-57.3	-67.0	-76.8	-86.6
14.2	-11.5	-21.2	-31.0	-40.8	-50.5	-60.3	-70.0	-79.8
16	-4.6	-14.4	-24.1	-33.9	-43.6	-53.4	-63.2	-72.9
18	2.7	-7.1	-16.8	-26.6	-36.4	-46.1	-55.9	-65.7
20	9.6	-0.2	-9.9	-19.7	-29.5	-39.2	-49.0	-58.8
21	12.9	3.1	-6.6	-16.4	-26.2	-35.9	-45.7	-55.5
22	16.1	6.3	-3.4	-13.2	-23.0	-32.7	-42.5	-52.3



Steel grades S440J2H and S460MH, CET = 0.235 %

Weld consumable: TRI-MARK TM-770 HD = 8 ml/100 g

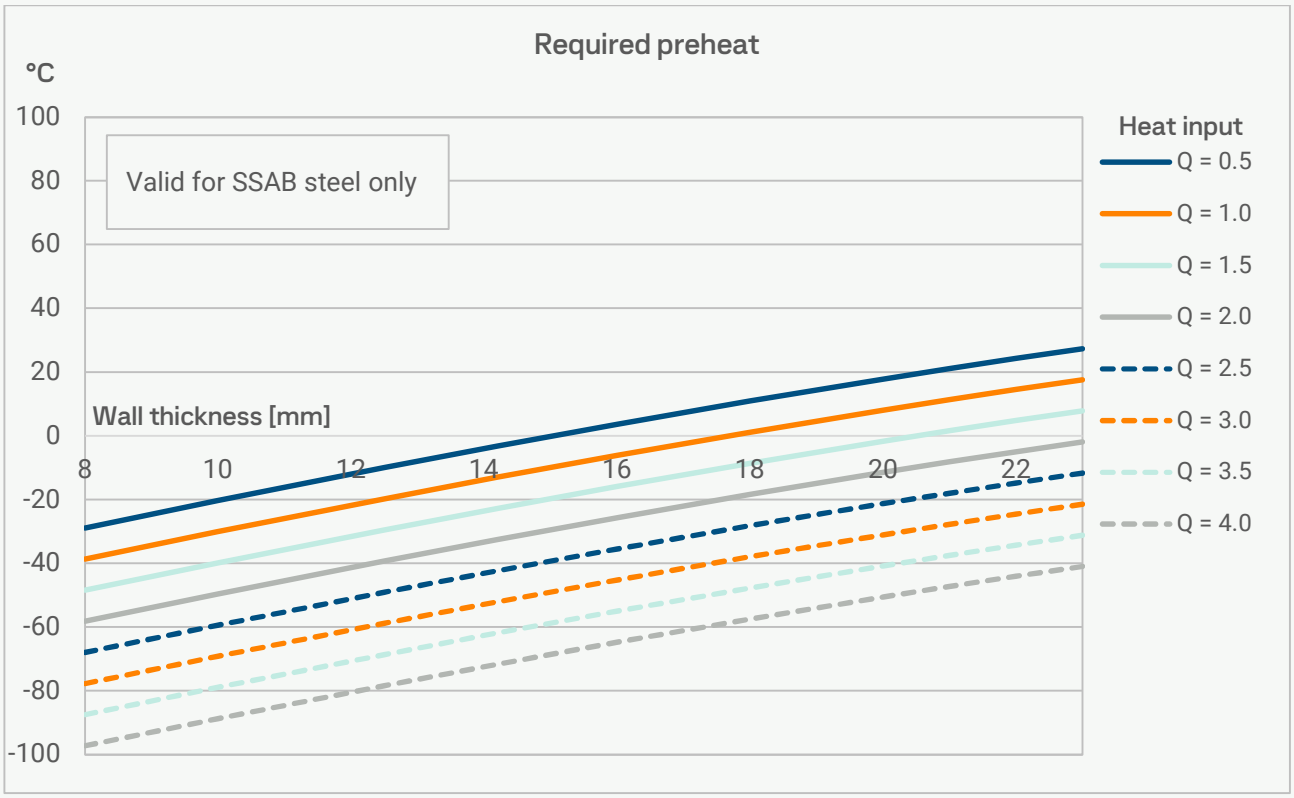
Wall thickness *t* [mm]	Required preheat [°C] Heat input *Q* during welding [kJ/mm]							
	0.5	1.0	1.5	2.0	2.5	3.0	3.5	4.0
8	-9.4	-19.2	-29.0	-38.7	-48.5	-58.3	-68.0	-77.8
10	-0.9	-10.6	-20.4	-30.2	-39.9	-49.7	-59.5	-69.2
12.5	9.5	-0.3	-10.1	-19.8	-29.6	-39.4	-49.1	-58.9
14.2	16.2	6.4	-3.3	-13.1	-22.9	-32.6	-42.4	-52.2
16	23.1	13.3	3.5	-6.2	-16.0	-25.8	-35.5	-45.3
18	30.3	20.6	10.8	1.1	-8.7	-18.5	-28.2	-38.0
20	37.2	27.5	17.7	8.0	-1.8	-11.6	-21.3	-31.1
21	40.5	30.8	21.0	11.3	1.5	-8.3	-18.0	-27.8
22	43.8	34.0	24.2	14.5	4.7	-5.1	-14.8	-24.6



Steel grades S440J2H and S460MH, CET = 0.235 %

Weld consumable: ESAB OK Tubrod 15.14 HD = 5 ml/100 g

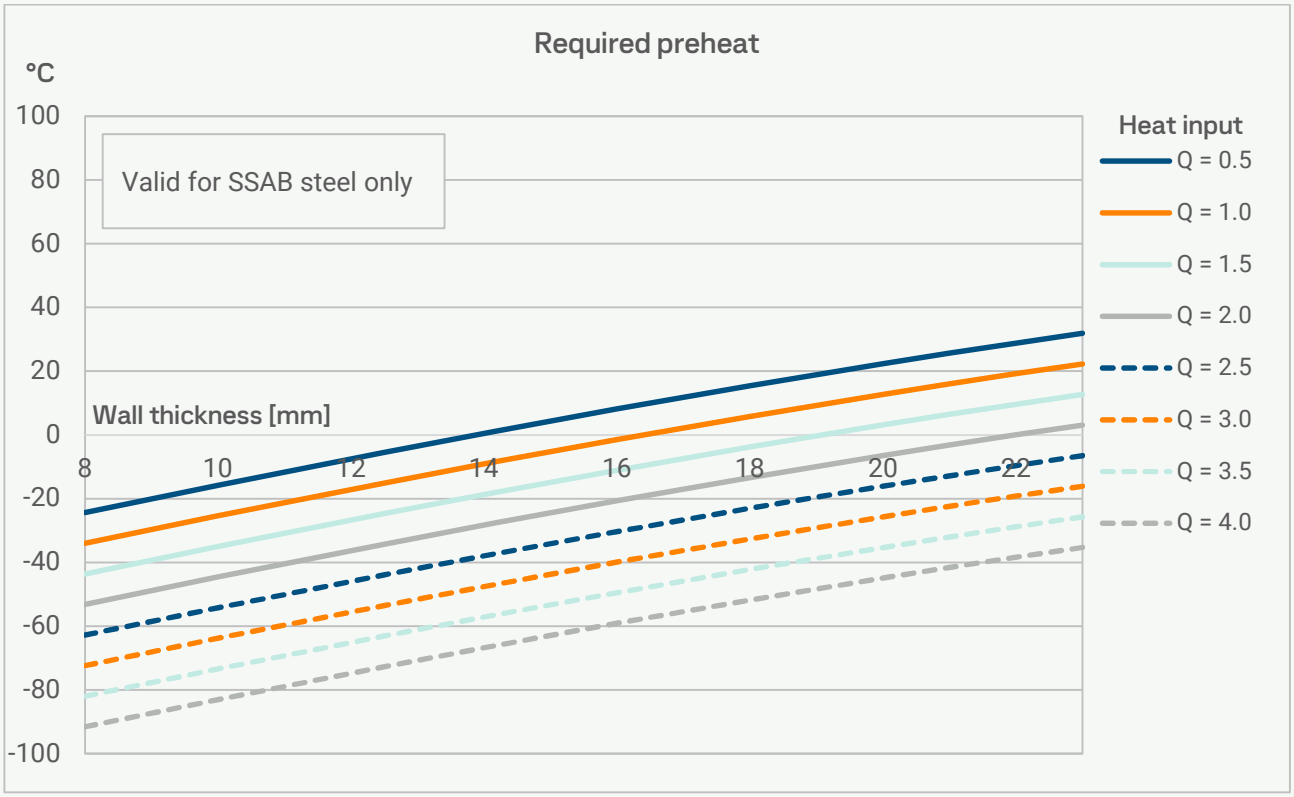
Wall thickness *t* [mm]	Required preheat [°C] Heat input *Q* during welding [kJ/mm]							
	0.5	1.0	1.5	2.0	2.5	3.0	3.5	4.0
8	-28.9	-38.7	-48.4	-58.2	-68.0	-77.7	-87.5	-97.3
10	-20.3	-30.1	-39.9	-49.6	-59.4	-69.2	-78.9	-88.7
12.5	-10.0	-19.8	-29.5	-39.3	-49.1	-58.8	-68.6	-78.4
14.2	-3.3	-13.0	-22.8	-32.6	-42.3	-52.1	-61.9	-71.6
16	3.6	-6.2	-15.9	-25.7	-35.5	-45.2	-55.0	-64.8
18	10.9	1.1	-8.7	-18.4	-28.2	-37.9	-47.7	-57.5
20	17.8	8.0	-1.8	-11.5	-21.3	-31.0	-40.8	-50.6
21	21.1	11.3	1.5	-8.2	-18.0	-27.7	-37.5	-47.3
22	24.3	14.5	4.8	-5.0	-14.8	-24.5	-34.3	-44.1



Steel grade S550J2H, CET = 0.242 %

Weld consumables: ESAB OK 74.78 HD = 5 ml/100 g
ESAB Dual Shield 55 HD = 5 ml/100 g

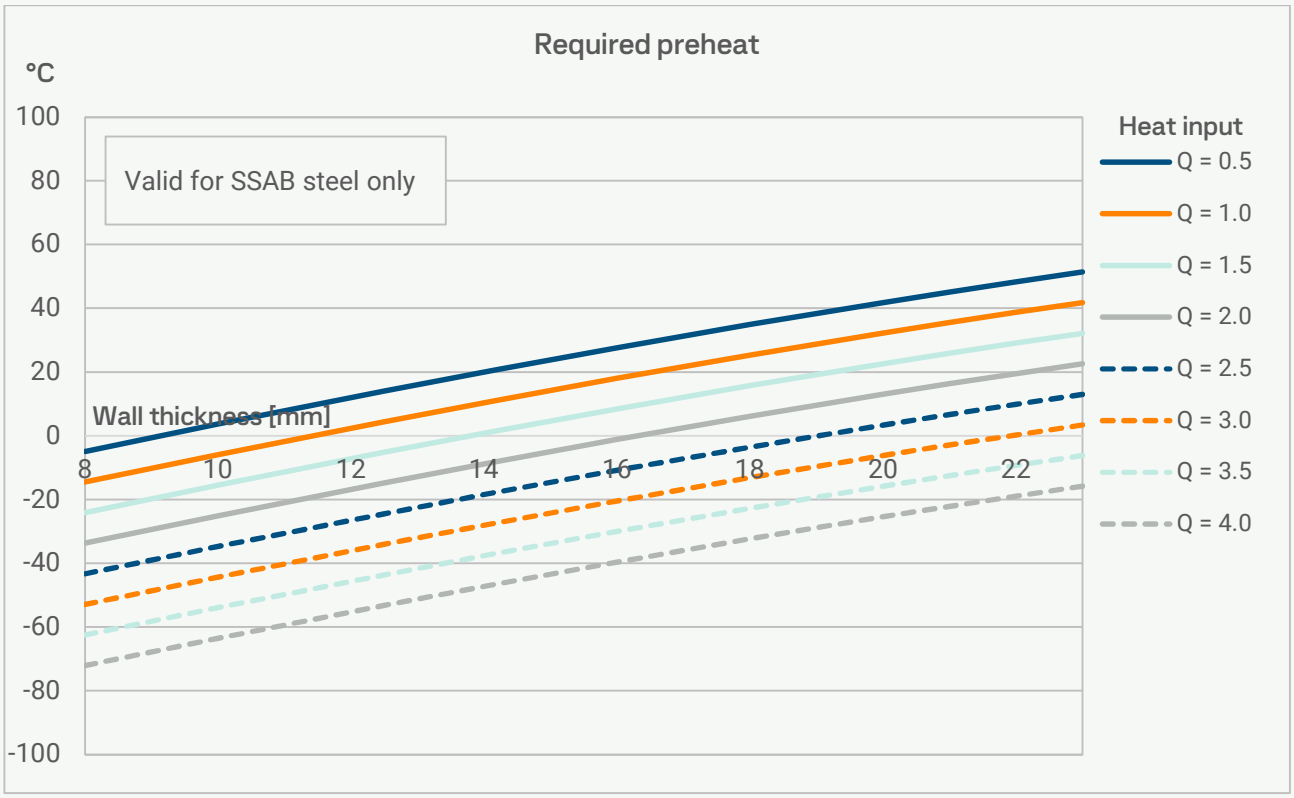
Wall thickness *t* [mm]	Required preheat [°C] Heat input *Q* during welding [kJ/mm]							
	0.5	1.0	1.5	2.0	2.5	3.0	3.5	4.0
8	-24.4	-34.0	-43.6	-53.2	-62.8	-72.4	-81.9	-91.5
10	-15.8	-25.4	-35.0	-44.6	-54.2	-63.8	-73.4	-83.0
12.5	-5.5	-15.1	-24.7	-34.3	-43.9	-53.5	-63.1	-72.7
14.2	1.3	-8.3	-17.9	-27.5	-37.1	-46.7	-56.3	-65.9
16	8.1	-1.5	-11.1	-20.7	-30.3	-39.9	-49.5	-59.1
18	15.4	5.8	-3.8	-13.4	-23.0	-32.6	-42.2	-51.8
20	22.3	12.7	3.1	-6.5	-16.1	-25.7	-35.3	-44.9
21	25.6	16.0	6.4	-3.2	-12.8	-22.4	-32.0	-41.6
22	28.8	19.2	9.6	0.0	-9.6	-19.2	-28.8	-38.4



Steel grade S550J2H, CET = 0.242 %

Weld consumable: TRI-MARK TM-881K2 HD = 8 ml/100 g

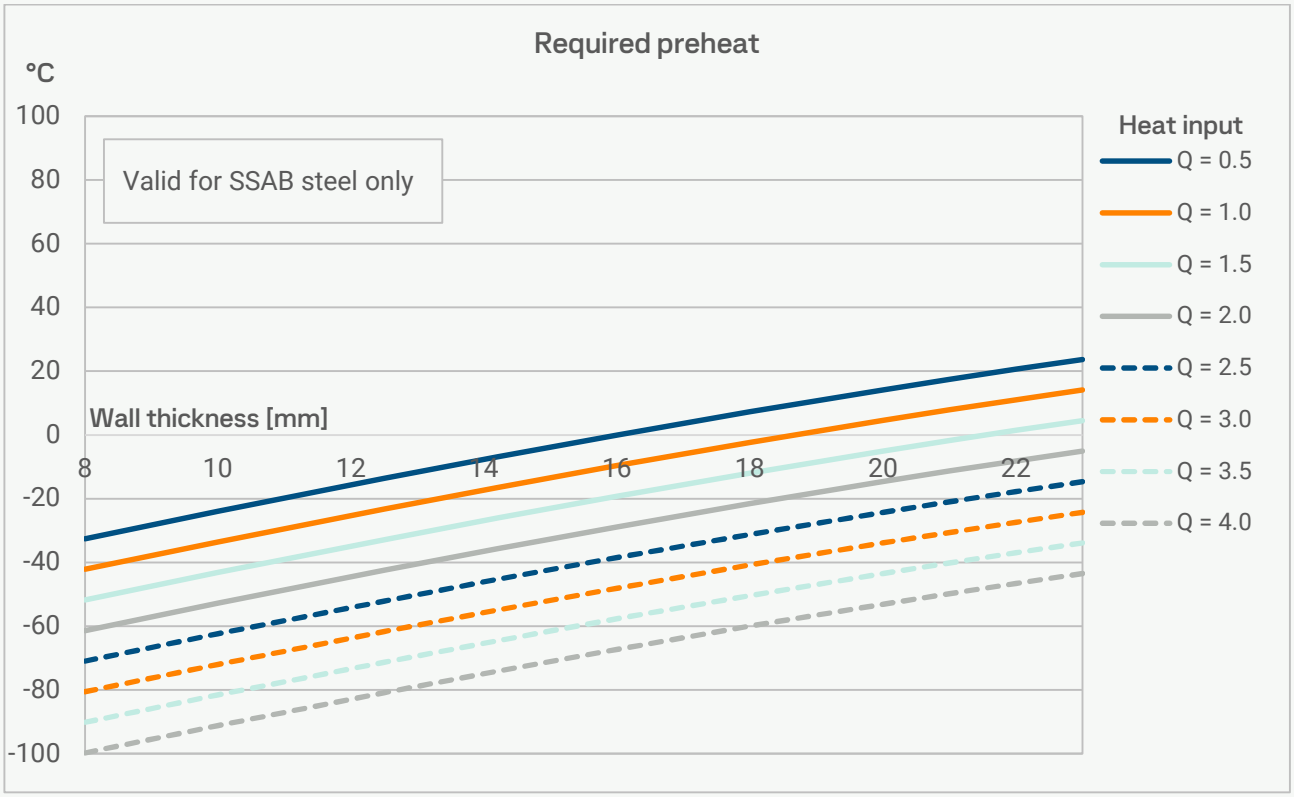
Wall thickness *t* [mm]	Required preheat [°C] Heat input *Q* during welding [kJ/mm]							
	0.5	1.0	1.5	2.0	2.5	3.0	3.5	4.0
8	-4.9	-14.5	-24.1	-33.7	-43.3	-52.9	-62.5	-72.1
10	3.7	-5.9	-15.5	-25.1	-34.7	-44.3	-53.9	-63.5
12.5	14.0	4.4	-5.2	-14.8	-24.4	-34.0	-43.6	-53.2
14.2	20.7	11.1	1.5	-8.1	-17.7	-27.3	-36.9	-46.4
16	27.6	18.0	8.4	-1.2	-10.8	-20.4	-30.0	-39.6
18	34.9	25.3	15.7	6.1	-3.5	-13.1	-22.7	-32.3
20	41.8	32.2	22.6	13.0	3.4	-6.2	-15.8	-25.4
21	45.1	35.5	25.9	16.3	6.7	-2.9	-12.5	-22.1
22	48.3	38.7	29.1	19.5	9.9	0.3	-9.3	-18.9



Steel grade S550J2H, CET = 0.242 %

Weld consumable: ESAB Coreweld 55 LT H4 HD = 4 ml/100 g

Wall thickness *t* [mm]	Required preheat [°C] Heat input *Q* during welding [kJ/mm]							
	0.5	1.0	1.5	2.0	2.5	3.0	3.5	4.0
8	-32.5	-42.1	-51.7	-61.3	-70.9	-80.5	-90.1	-99.7
10	-24.0	-33.6	-43.2	-52.8	-62.4	-72.0	-81.6	-91.2
12.5	-13.7	-23.3	-32.9	-42.5	-52.1	-61.6	-71.2	-80.8
14.2	-6.9	-16.5	-26.1	-35.7	-45.3	-54.9	-64.5	-74.1
16	0.0	-9.6	-19.2	-28.8	-38.4	-48.0	-57.6	-67.2
18	7.2	-2.4	-12.0	-21.6	-31.2	-40.8	-50.4	-60.0
20	14.1	4.5	-5.1	-14.7	-24.3	-33.9	-43.5	-53.1
21	17.4	7.8	-1.8	-11.4	-21.0	-30.6	-40.1	-49.7
22	20.6	11.0	1.4	-8.2	-17.8	-27.3	-36.9	-46.5



COOLING OF WELDS

EN 1090-2 gives regulations on minimum hold time of the welds before NDT can be performed. The minimum hold times are given in table below, originally Table 23 in EN 1090-2.

		Hold time (hours) [a]	
If preheat is applied in accordance with method A of EN 1011-2, Annex C			
Weld size [mm] [b]	**Heat input *Q* [kJ/mm]**	**S275 – S460**	**Above S460**
a or *s* ≤ 6	All	Cooling period only	24
6 < *a* or *s* ≤ 12	≤ 3	8	24
	> 3	16	40
a or *s* > 12	≤ 3	16	40
	> 3	24	48
If preheat is applied in accordance with method B of EN 1011-2, Annex C			
Weld size [mm] [b]		**S275 – S690**	**Above S690**
a or *s* ≤ 20		Cooling period only	24
a or *s* > 20		24	48

[a] The time between weld completion and commencement of NDT shall be stated in the NDT report. In the case of “Cooling period only” this will last until the weld is cool enough for NDT to commence.

[b] Size applies to the nominal throat a of fillet weld or the nominal material thickness *s* of a full penetration weld. For individual partial penetration butt welds the governing criterion is the nominal weld depth *a*, but for pairs partial penetration butt welds welded simultaneously it is the sum of the nominal weld throats *a*.

According to EN 1090-2, the hold times presented in above table can be reduced, if welds require preheat and if they are also post-heated. Naturally for welds with hold time “Cooling period only” this reduction cannot be done.

As stated before in the preheating chapter, all the steel materials used in SSAB steel pipe piles fill the requirements for the use of method B according to EN 1011-2.

All steel grades used in SSAB steel piles have yield strength above 275 MPa and below 690 MPa. Therefore they all belong to column “S275 - S690”.

The wall thickness, and also the weld size, is normally maximum 20 mm. For some large diameter piles the wall thickness can be over 20 mm. In steel piles the splice welds are most often full penetration welds, so the size is most often same as the wall thickness. Due to this the wall thickness of base material can be used when determining the hold time.

Based on the above, the hold times for SSAB steel piles are:

Wall thickness ≤ 20 mm **Cooling period only**
Wall thickness > 20 mm **24 hours**

NOTES

NOTES

SSAB is a Nordic and US-based steel company that builds a stronger, lighter and more sustainable world through value added steel products and services. Working with our partners, SSAB has developed SSAB Fossil-free™ steel and plans to reinvent the value chain from the mine to the end customer, largely eliminating carbon dioxide emissions from our own operations. SSAB Zero™, a largely carbon emission-free steel based on recycled steel, further strengthens SSAB's leadership position and our comprehensive, sustainable offering independent of the raw material. SSAB has employees in over 50 countries and production facilities in Sweden, Finland and the US. SSAB is listed on Nasdaq Stockholm and has a secondary listing on Nasdaq Helsinki. Join us on our journey! **www.ssab.com**, **Facebook**, **Instagram**, **LinkedIn**, **X** ja **YouTube**.

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