

**Appendix 5**    **RR® and RD® piles**  
Design and installation manual

**RR and RD piles**  
**Preheating and cooling of splice welds**

6/2019

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## GENERAL

Preheating of base material before welding is often needed 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 in project.

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

The execution of steel structures on site is carried out according to execution standard EN 1090-2:2018 (*Execution of steel structures and aluminium structures. Part 2: Technical requirements for steel structures*). The scope of EN 1090-2:2018 excludes the execution of piles. Even though the execution standards for piles state that the requirements for execution and testing of welds given in EN 1090-2:2018 are used also for steel piles.

On preheating of the welds EN 1090-2:2018 states "Preheating, when required, shall be carried out in accordance with EN ISO 13916, EN 1011-2 and/or EN 1011-3". For steel materials used in steel piles manufactured by SSAB the standard EN 1011-2:2001 (*Welding. Recommendations for welding of metallic materials. Part 2: Arc welding of ferritic steels*) is used.

Annex C of EN 1011-2:2001 gives two alternative preheating methods, 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 pipe piles. On the other hand, method B can be used for all steel materials used in SSAB steel pipe piles.

The equations to calculate the required preheat temperature for method B are given in Clause C.3 in EN 1011-2:2001. 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 pipe 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 figures 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;

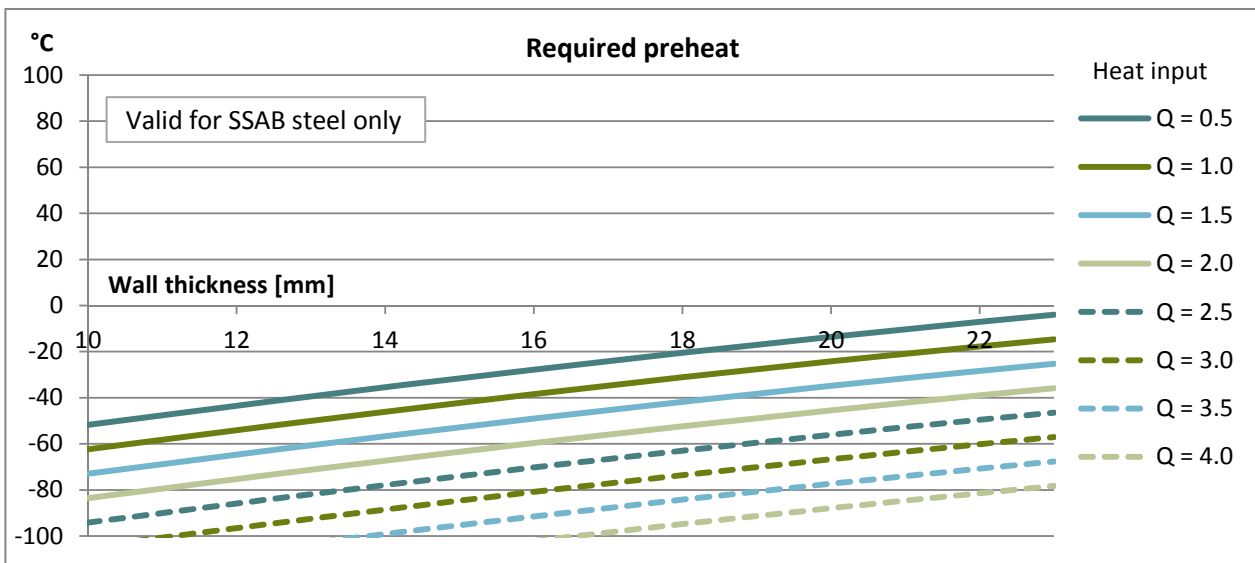
- Moist electrodes increase the hydrogen content of the weld, which means they must always be dried before use.
- Moisture in the air condenses to the surface of a cold steel material. Even if the calculated preheat temperature in tables and figures is low, the pile ends need to be preheated to +50 to +100 °C before starting the work if air temperature is below +10 °C.

## TABLES AND GRAPHS TO DEFINE REQUIRED PREHEAT

Steel grade S355J2H, CET = 0.203 %

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

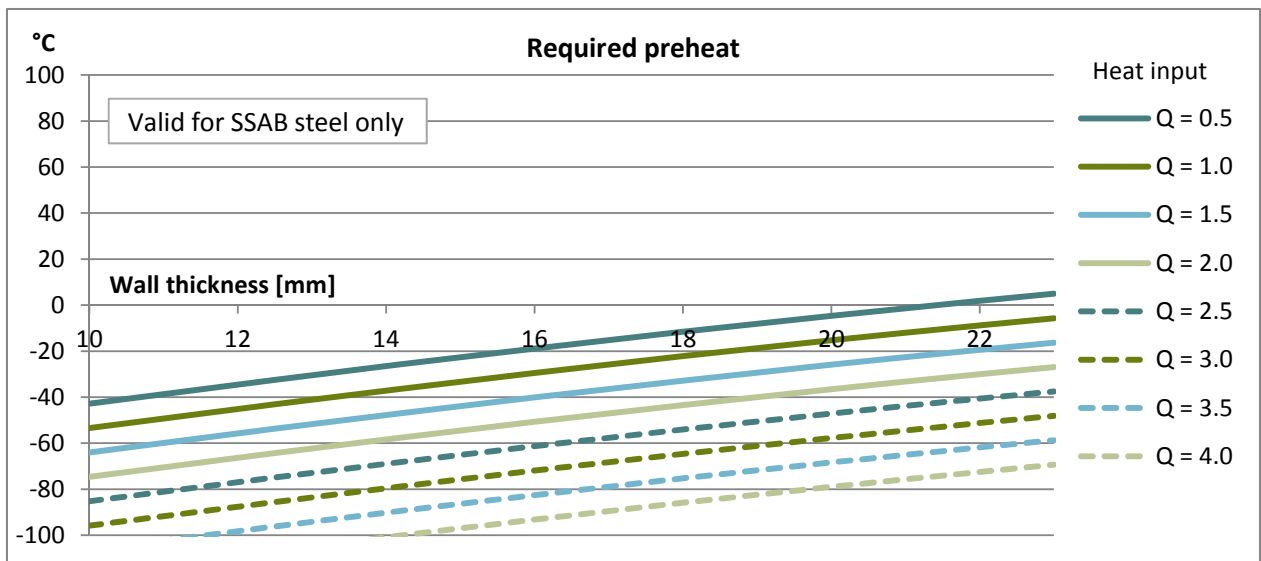
Wall thickness t [mm]	Required preheat [°C]							
	Heat input Q during welding [kJ/mm]							
	0.5	1.0	1.5	2.0	2.5	3.0	3.5	4.0
10	-51.7	-62.4	-73.0	-83.6	-94.2	-104.8	-115.4	-126.0
12.5	-41.4	-52.0	-62.6	-73.3	-83.9	-94.5	-105.1	-115.7
14.2	-34.7	-45.3	-55.9	-66.5	-77.1	-87.7	-98.4	-109.0
16	-27.8	-38.4	-49.0	-59.6	-70.3	-80.9	-91.5	-102.1
18	-20.5	-31.1	-41.7	-52.4	-63.0	-73.6	-84.2	-94.8
20	-13.6	-24.2	-34.8	-45.5	-56.1	-66.7	-77.3	-87.9
21	-10.3	-20.9	-31.5	-42.2	-52.8	-63.4	-74.0	-84.6
22	-7.1	-17.7	-28.3	-39.0	-49.6	-60.2	-70.8	-81.4
23	-4.0	-14.6	-25.2	-35.9	-46.5	-57.1	-67.7	-78.3



**Steel grade S355J2H, CET = 0.203 %**

Weld consumable TRI-MARK TM-770 HD = 5.1 ml/100 g

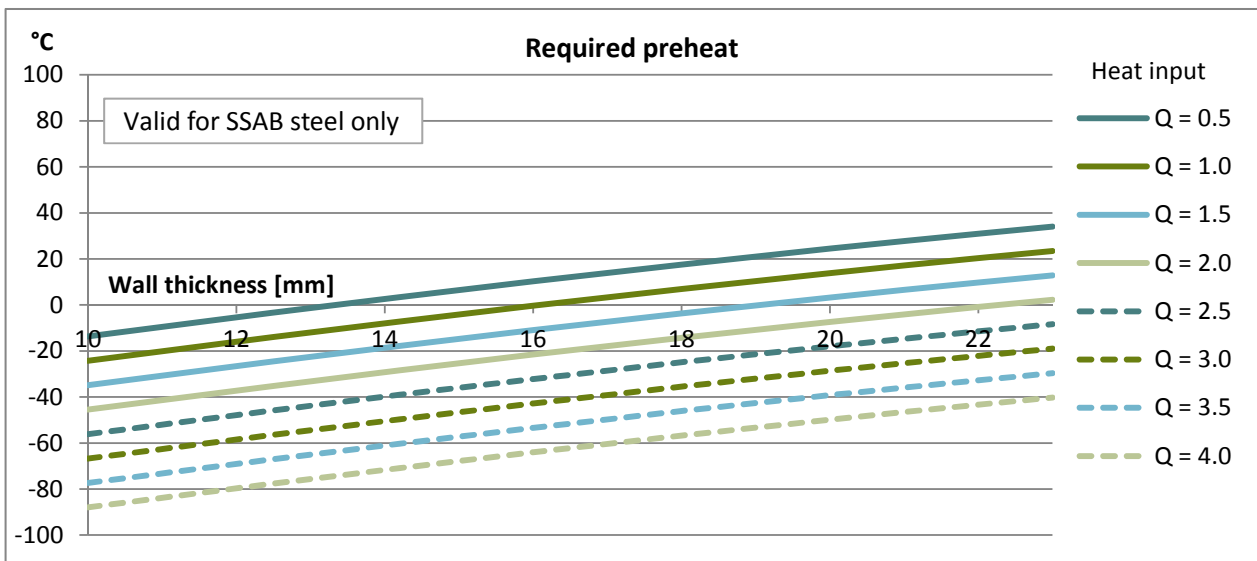
Wall thickness t [mm]	Required preheat [°C]							
	Heat input Q during welding [kJ/mm]							
	0.5	1.0	1.5	2.0	2.5	3.0	3.5	4.0
10	-42.8	-53.4	-64.0	-74.6	-85.3	-95.9	-106.5	-117.1
12.5	-32.5	-43.1	-53.7	-64.3	-74.9	-85.5	-96.2	-106.8
14.2	-25.7	-36.3	-47.0	-57.6	-68.2	-78.8	-89.4	-100.0
16	-18.9	-29.5	-40.1	-50.7	-61.3	-71.9	-82.6	-93.2
18	-11.6	-22.2	-32.8	-43.4	-54.0	-64.7	-75.3	-85.9
20	-4.7	-15.3	-25.9	-36.5	-47.1	-57.8	-68.4	-79.0
21	-1.4	-12.0	-22.6	-33.2	-43.8	-54.5	-65.1	-75.7
22	1.8	-8.8	-19.4	-30.0	-40.6	-51.2	-61.9	-72.5
23	4.9	-5.7	-16.3	-26.9	-37.5	-48.1	-58.8	-69.4



**Steel grade S355J2H, CET = 0.203 %**

Weld consumable ESAB OK Tubrod 15.14 HD = 10 ml/100 g

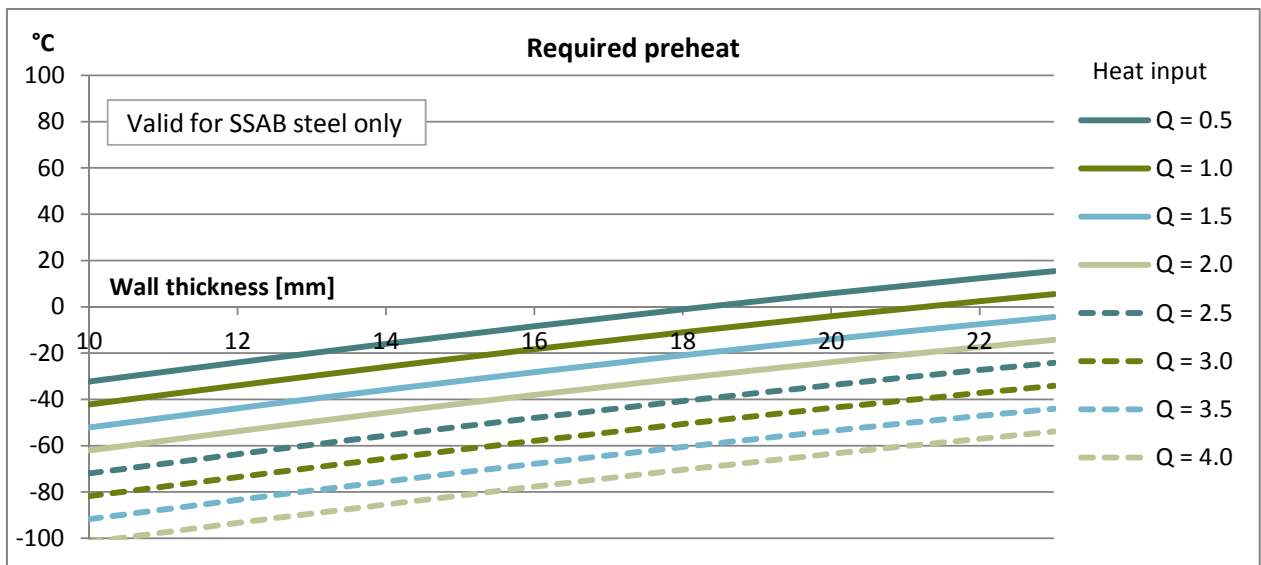
Wall thickness t [mm]	Required preheat [°C]							
	Heat input Q during welding [kJ/mm]							
	0.5	1.0	1.5	2.0	2.5	3.0	3.5	4.0
10	-13.7	-24.3	-34.9	-45.5	-56.1	-66.7	-77.3	-88.0
12.5	-3.3	-13.9	-24.6	-35.2	-45.8	-56.4	-67.0	-77.6
14.2	3.4	-7.2	-17.8	-28.4	-39.0	-49.7	-60.3	-70.9
16	10.3	-0.3	-11.0	-21.6	-32.2	-42.8	-53.4	-64.0
18	17.6	6.9	-3.7	-14.3	-24.9	-35.5	-46.1	-56.7
20	24.5	13.8	3.2	-7.4	-18.0	-28.6	-39.2	-49.8
21	27.8	17.1	6.5	-4.1	-14.7	-25.3	-35.9	-46.5
22	31.0	20.4	9.7	-0.9	-11.5	-22.1	-32.7	-43.3
23	34.1	23.5	12.8	2.2	-8.4	-19.0	-29.6	-40.2



**Steel grade S440J2H, CET = 0.230 %**

Weld consumable ESAB OK 55.00      HD = 4 ml/100 g

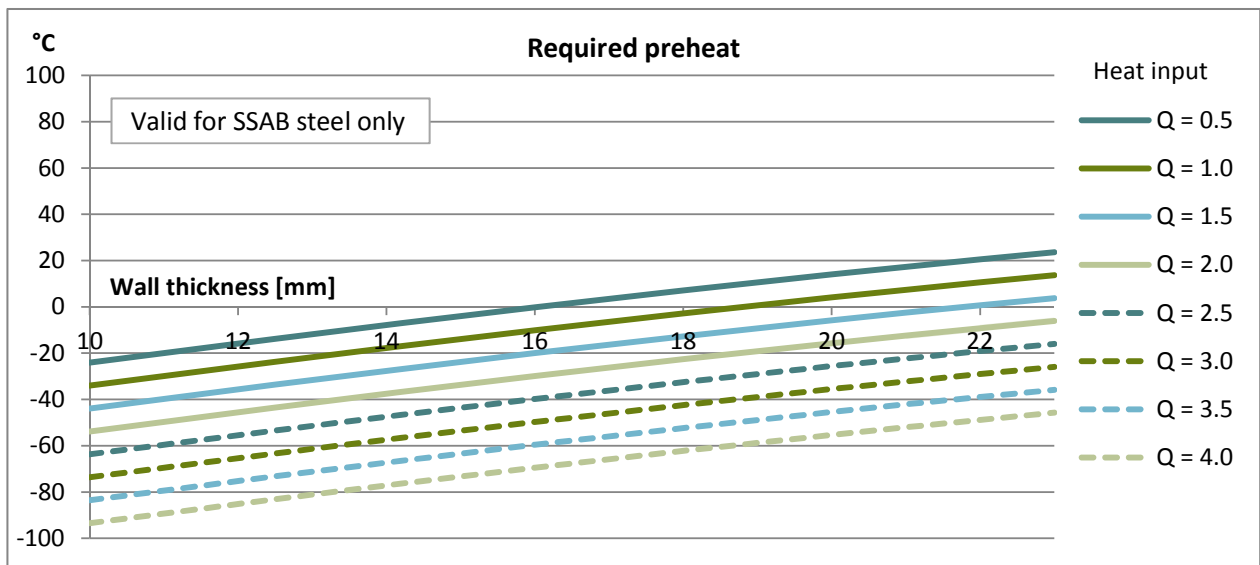
Wall thickness t [mm]	Required preheat [°C]							
	Heat input Q during welding [kJ/mm]							
	0.5	1.0	1.5	2.0	2.5	3.0	3.5	4.0
10	-32.3	-42.2	-52.1	-62.0	-71.9	-81.8	-91.7	-101.6
12.5	-22.0	-31.9	-41.8	-51.7	-61.6	-71.5	-81.4	-91.3
14.2	-15.2	-25.2	-35.1	-45.0	-54.9	-64.8	-74.7	-84.6
16	-8.4	-18.3	-28.2	-38.1	-48.0	-57.9	-67.8	-77.7
18	-1.1	-11.0	-20.9	-30.8	-40.7	-50.6	-60.5	-70.4
20	5.8	-4.1	-14.0	-23.9	-33.8	-43.7	-53.6	-63.5
21	9.1	-0.8	-10.7	-20.6	-30.5	-40.4	-50.3	-60.2
22	12.3	2.4	-7.5	-17.4	-27.3	-37.2	-47.1	-57.0
23	15.4	5.5	-4.4	-14.3	-24.2	-34.1	-44.0	-53.9



**Steel grade S440J2H, CET = 0.230 %**

Weld consumable ESAB OK 48.08      HD = 5 ml/100 g

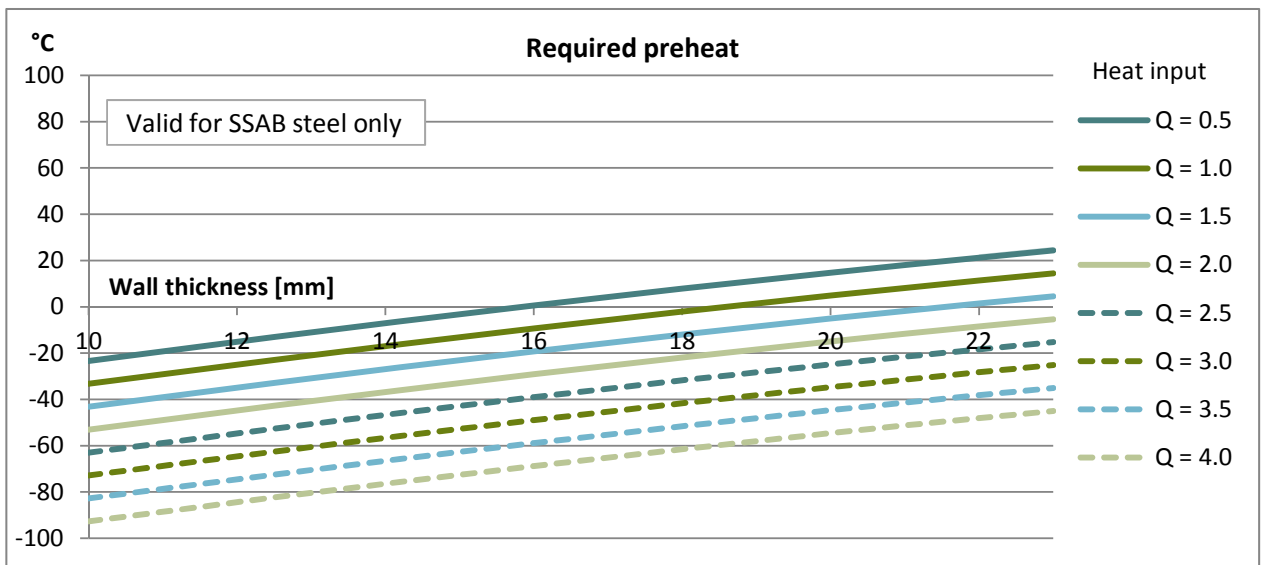
Wall thickness t [mm]	Required preheat [°C]							
	Heat input Q during welding [kJ/mm]							
	0.5	1.0	1.5	2.0	2.5	3.0	3.5	4.0
<b>10</b>	-24.1	-34.0	-43.9	-53.8	-63.7	-73.6	-83.5	-93.5
<b>12.5</b>	-13.8	-23.7	-33.6	-43.5	-53.4	-63.3	-73.2	-83.1
<b>14.2</b>	-7.1	-17.0	-26.9	-36.8	-46.7	-56.6	-66.5	-76.4
<b>16</b>	-0.2	-10.1	-20.0	-29.9	-39.8	-49.7	-59.6	-69.5
<b>18</b>	7.1	-2.8	-12.7	-22.6	-32.5	-42.4	-52.3	-62.2
<b>20</b>	14.0	4.1	-5.8	-15.7	-25.6	-35.5	-45.4	-55.3
<b>21</b>	17.3	7.4	-2.5	-12.4	-22.3	-32.2	-42.1	-52.0
<b>22</b>	20.5	10.6	0.7	-9.2	-19.1	-29.0	-38.9	-48.8
<b>23</b>	23.6	13.7	3.8	-6.1	-16.0	-25.9	-35.8	-45.7



**Steel grade S440J2H, CET = 0.230 %**

Weld consumable TRI-MARK TM-770 HD = 5.1 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
10	-23.4	-33.3	-43.2	-53.1	-63.0	-72.9	-82.8	-92.7
12.5	-13.1	-23.0	-32.9	-42.8	-52.7	-62.6	-72.5	-82.4
14.2	-6.3	-16.2	-26.1	-36.0	-45.9	-55.8	-65.7	-75.6
16	0.6	-9.3	-19.2	-29.1	-39.1	-49.0	-58.9	-68.8
18	7.8	-2.1	-12.0	-21.9	-31.8	-41.7	-51.6	-61.5
20	14.7	4.8	-5.1	-15.0	-24.9	-34.8	-44.7	-54.6
21	18.0	8.1	-1.8	-11.7	-21.6	-31.5	-41.4	-51.3
22	21.2	11.3	1.4	-8.5	-18.4	-28.3	-38.2	-48.1
23	24.4	14.4	4.5	-5.4	-15.3	-25.2	-35.1	-45.0

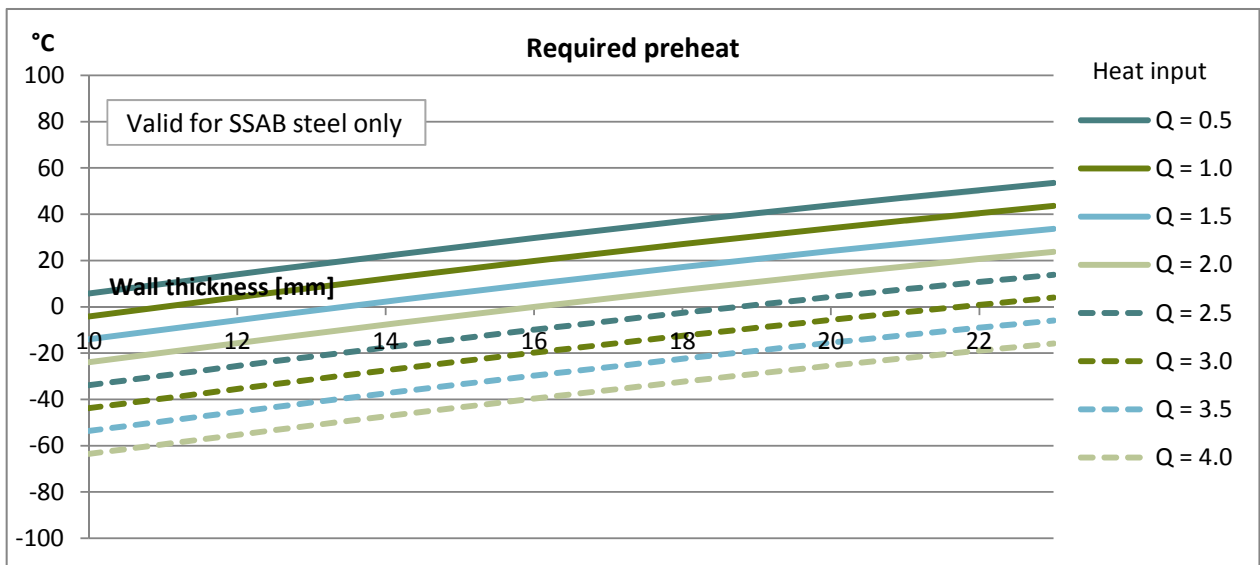




**Steel grade S440J2H, CET = 0.230 %**

Weld consumable ESAB OK Tubrod 15.14 HD = 10 ml/100 g

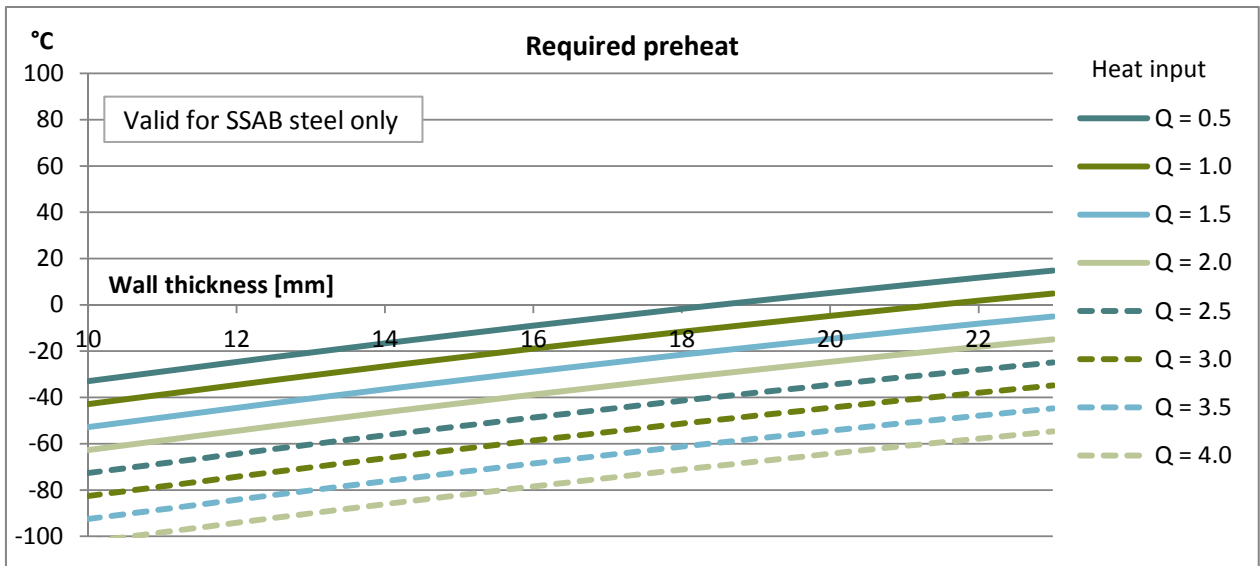
Wall thickness t [mm]	Required preheat [°C]							
	Heat input Q during welding [kJ/mm]							
	0.5	1.0	1.5	2.0	2.5	3.0	3.5	4.0
10	5.8	-4.1	-14.0	-23.9	-33.8	-43.7	-53.6	-63.6
12.5	16.1	6.2	-3.7	-13.6	-23.5	-33.4	-43.3	-53.2
14.2	22.8	12.9	3.0	-6.9	-16.8	-26.7	-36.6	-46.5
16	29.7	19.8	9.9	0.0	-9.9	-19.8	-29.7	-39.6
18	37.0	27.1	17.2	7.3	-2.6	-12.5	-22.4	-32.3
20	43.9	34.0	24.1	14.2	4.3	-5.6	-15.5	-25.4
21	47.2	37.3	27.4	17.5	7.6	-2.3	-12.2	-22.1
22	50.4	40.5	30.6	20.7	10.8	0.9	-9.0	-18.9
23	53.5	43.6	33.7	23.8	13.9	4.0	-5.9	-15.8



**Steel grade S460MH, CET = 0.229 %**

Weld consumable ESAB OK 55.00      HD = 4 ml/100 g

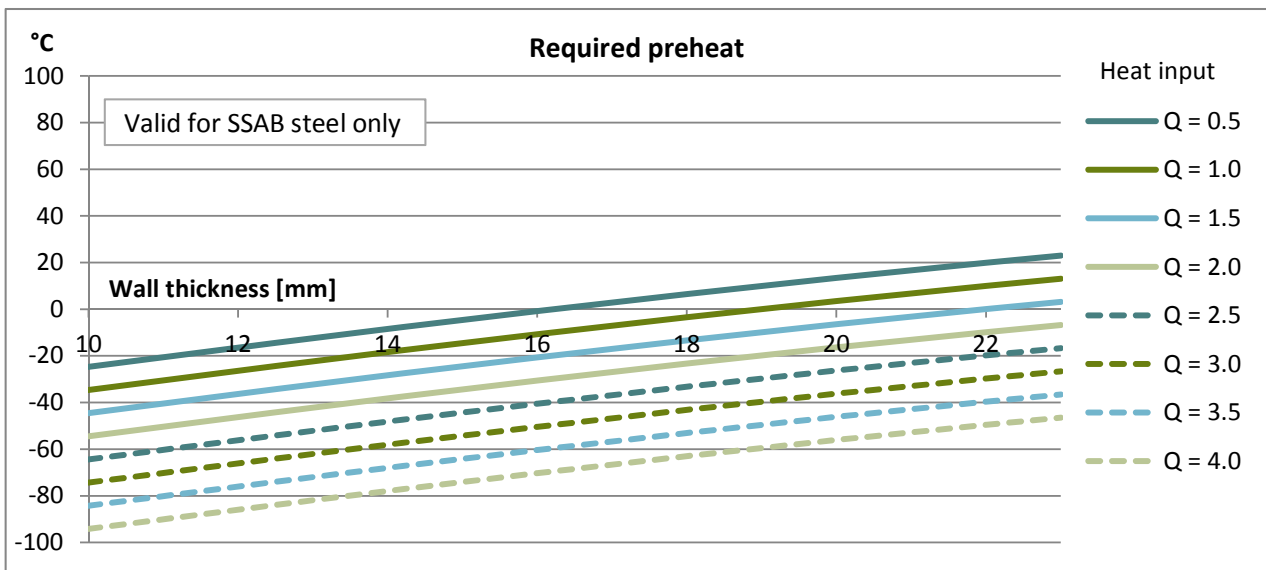
Wall thickness t [mm]	Required preheat [°C]							
	Heat input Q during welding [kJ/mm]							
	0.5	1.0	1.5	2.0	2.5	3.0	3.5	4.0
10	-32.9	-42.8	-52.8	-62.7	-72.6	-82.5	-92.5	-102.4
12.5	-22.6	-32.5	-42.5	-52.4	-62.3	-72.2	-82.2	-92.1
14.2	-15.9	-25.8	-35.7	-45.6	-55.6	-65.5	-75.4	-85.3
16	-9.0	-18.9	-28.8	-38.8	-48.7	-58.6	-68.5	-78.5
18	-1.7	-11.6	-21.6	-31.5	-41.4	-51.3	-61.3	-71.2
20	5.2	-4.7	-14.7	-24.6	-34.5	-44.4	-54.4	-64.3
21	8.5	-1.4	-11.4	-21.3	-31.2	-41.1	-51.1	-61.0
22	11.7	1.8	-8.2	-18.1	-28.0	-37.9	-47.9	-57.8
23	14.8	4.9	-5.0	-15.0	-24.9	-34.8	-44.7	-54.7



**Steel grade S460MH, CET = 0.229 %**

Weld consumable ESAB OK 48.08      HD = 5 ml/100 g

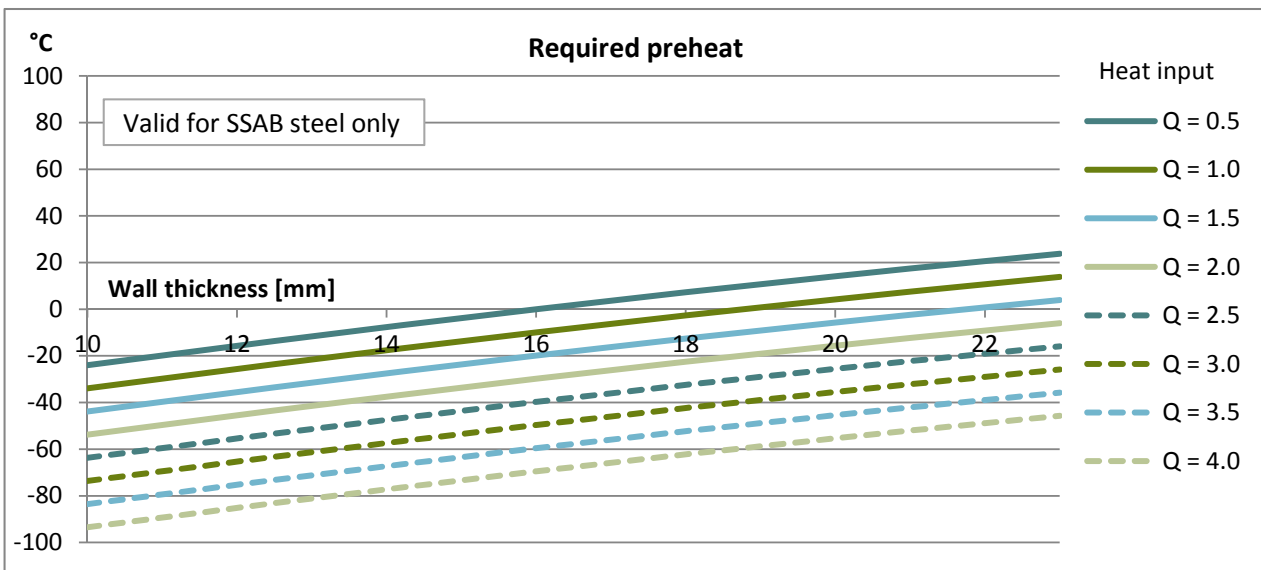
Wall thickness t [mm]	Required preheat [°C]							
	Heat input Q during welding [kJ/mm]							
	0.5	1.0	1.5	2.0	2.5	3.0	3.5	4.0
10	-24.7	-34.7	-44.6	-54.5	-64.4	-74.4	-84.3	-94.2
12.5	-14.4	-24.3	-34.3	-44.2	-54.1	-64.0	-74.0	-83.9
14.2	-7.7	-17.6	-27.5	-37.5	-47.4	-57.3	-67.2	-77.2
16	-0.8	-10.7	-20.7	-30.6	-40.5	-50.4	-60.4	-70.3
18	6.5	-3.5	-13.4	-23.3	-33.2	-43.2	-53.1	-63.0
20	13.4	3.5	-6.5	-16.4	-26.3	-36.3	-46.2	-56.1
21	16.7	6.8	-3.2	-13.1	-23.0	-32.9	-42.9	-52.8
22	19.9	10.0	0.0	-9.9	-19.8	-29.7	-39.7	-49.6
23	23.0	13.1	3.1	-6.8	-16.7	-26.6	-36.6	-46.5



**Steel grade S460MH, CET = 0.229 %**

Weld consumable TRI-MARK TM-770 HD = 5.1 ml/100 g

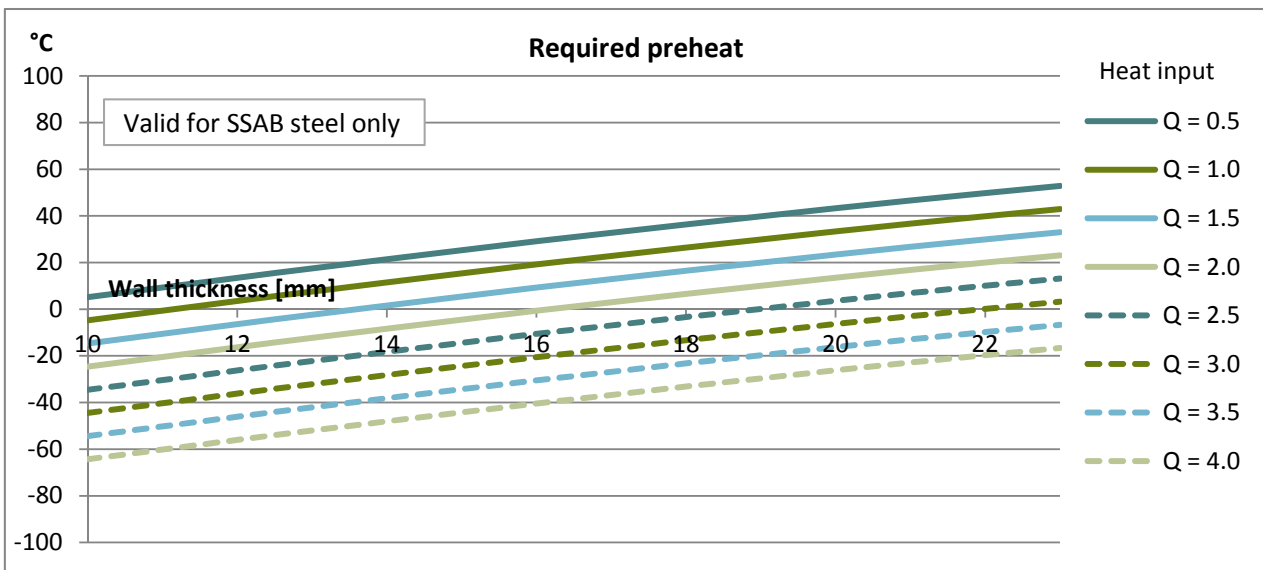
Wall thickness t [mm]	Required preheat [°C]							
	Heat input Q during welding [kJ/mm]							
	0.5	1.0	1.5	2.0	2.5	3.0	3.5	4.0
10	-24.0	-33.9	-43.8	-53.8	-63.7	-73.6	-83.5	-93.5
12.5	-13.7	-23.6	-33.5	-43.4	-53.4	-63.3	-73.2	-83.1
14.2	-6.9	-16.8	-26.8	-36.7	-46.6	-56.5	-66.5	-76.4
16	-0.1	-10.0	-19.9	-29.8	-39.8	-49.7	-59.6	-69.5
18	7.2	-2.7	-12.6	-22.5	-32.5	-42.4	-52.3	-62.2
20	14.1	4.2	-5.7	-15.6	-25.6	-35.5	-45.4	-55.3
21	17.4	7.5	-2.4	-12.3	-22.3	-32.2	-42.1	-52.0
22	20.6	10.7	0.8	-9.1	-19.1	-29.0	-38.9	-48.8
23	23.7	13.8	3.9	-6.0	-16.0	-25.9	-35.8	-45.7



**Steel grade S460MH, CET = 0.229 %**

Weld consumable ESAB OK Tubrod 15.14 HD = 10 ml/100 g

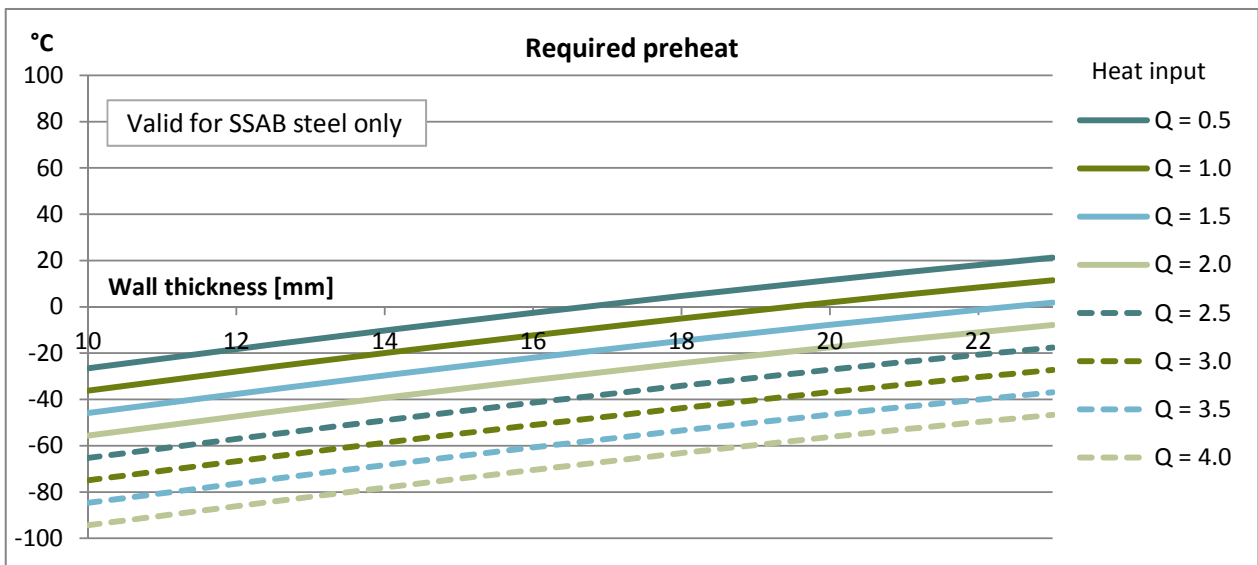
Wall thickness t [mm]	Required preheat [°C]							
	Heat input Q during welding [kJ/mm]							
	0.5	1.0	1.5	2.0	2.5	3.0	3.5	4.0
10	5.2	-4.8	-14.7	-24.6	-34.5	-44.5	-54.4	-64.3
12.5	15.5	5.6	-4.4	-14.3	-24.2	-34.1	-44.1	-54.0
14.2	22.2	12.3	2.4	-7.6	-17.5	-27.4	-37.3	-47.3
16	29.1	19.2	9.2	-0.7	-10.6	-20.5	-30.5	-40.4
18	36.4	26.4	16.5	6.6	-3.3	-13.3	-23.2	-33.1
20	43.3	33.4	23.4	13.5	3.6	-6.4	-16.3	-26.2
21	46.6	36.7	26.7	16.8	6.9	-3.0	-13.0	-22.9
22	49.8	39.9	29.9	20.0	10.1	0.2	-9.8	-19.7
23	52.9	43.0	33.0	23.1	13.2	3.3	-6.7	-16.6



**Steel grade S550J2H, CET = 0.238 %**

Weld consumable TRI-MARK TM-881 K2 HD = 4 ml/100 g

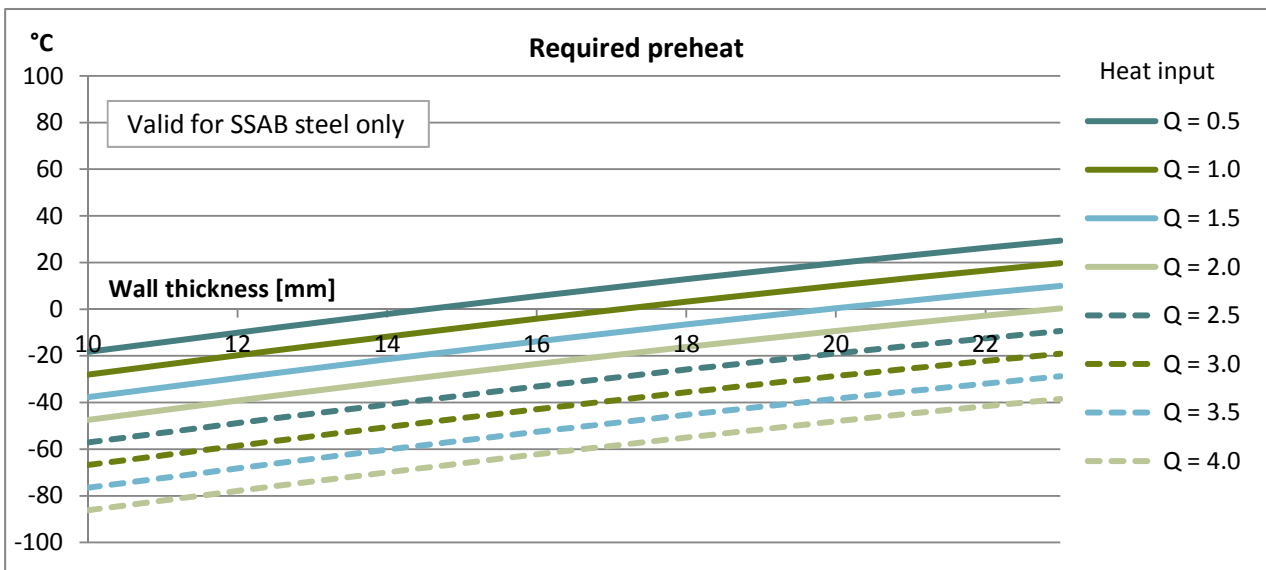
Wall thickness t [mm]	Required preheat [°C]							
	Heat input Q during welding [kJ/mm]							
	0.5	1.0	1.5	2.0	2.5	3.0	3.5	4.0
10	-26.5	-36.2	-45.9	-55.6	-65.3	-75.0	-84.7	-94.4
12.5	-16.2	-25.9	-35.6	-45.3	-55.0	-64.7	-74.4	-84.0
14.2	-9.5	-19.2	-28.8	-38.5	-48.2	-57.9	-67.6	-77.3
16	-2.6	-12.3	-22.0	-31.7	-41.4	-51.1	-60.7	-70.4
18	4.7	-5.0	-14.7	-24.4	-34.1	-43.8	-53.5	-63.2
20	11.6	1.9	-7.8	-17.5	-27.2	-36.9	-46.6	-56.3
21	14.9	5.2	-4.5	-14.2	-23.9	-33.6	-43.3	-52.9
22	18.1	8.4	-1.3	-11.0	-20.7	-30.4	-40.1	-49.7
23	21.2	11.5	1.8	-7.9	-17.6	-27.3	-37.0	-46.6



**Steel grade S550J2H, CET = 0.238 %**

Weld consumable ESAB OK 74.78      HD = 5 ml/100 g

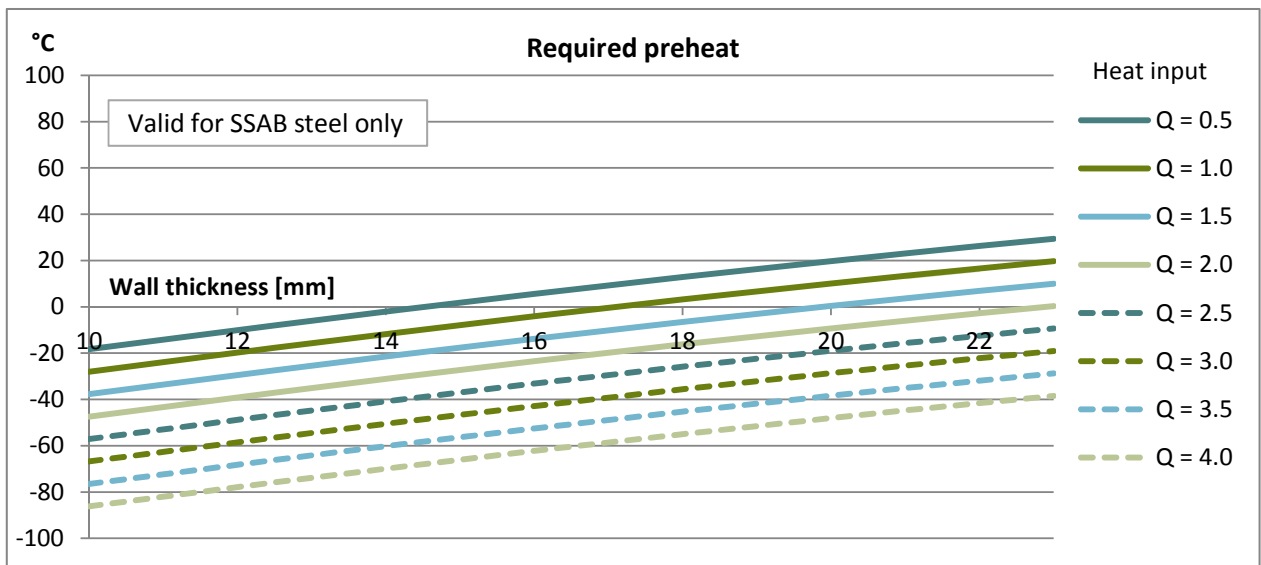
Wall thickness t [mm]	Required preheat [°C]							
	Heat input Q during welding [kJ/mm]							
	0.5	1.0	1.5	2.0	2.5	3.0	3.5	4.0
10	-18.3	-28.0	-37.7	-47.4	-57.1	-66.8	-76.5	-86.2
12.5	-8.0	-17.7	-27.4	-37.1	-46.8	-56.5	-66.2	-75.9
14.2	-1.3	-11.0	-20.7	-30.4	-40.0	-49.7	-59.4	-69.1
16	5.6	-4.1	-13.8	-23.5	-33.2	-42.9	-52.6	-62.3
18	12.9	3.2	-6.5	-16.2	-25.9	-35.6	-45.3	-55.0
20	19.8	10.1	0.4	-9.3	-19.0	-28.7	-38.4	-48.1
21	23.1	13.4	3.7	-6.0	-15.7	-25.4	-35.1	-44.8
22	26.3	16.6	6.9	-2.8	-12.5	-22.2	-31.9	-41.6
23	29.4	19.7	10.0	0.3	-9.4	-19.1	-28.8	-38.5



**Steel grade S550J2H, CET = 0.238 %**

Weld consumable 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
10	-18.3	-28.0	-37.7	-47.4	-57.1	-66.8	-76.5	-86.2
12.5	-8.0	-17.7	-27.4	-37.1	-46.8	-56.5	-66.2	-75.9
14.2	-1.3	-11.0	-20.7	-30.4	-40.0	-49.7	-59.4	-69.1
16	5.6	-4.1	-13.8	-23.5	-33.2	-42.9	-52.6	-62.3
18	12.9	3.2	-6.5	-16.2	-25.9	-35.6	-45.3	-55.0
20	19.8	10.1	0.4	-9.3	-19.0	-28.7	-38.4	-48.1
21	23.1	13.4	3.7	-6.0	-15.7	-25.4	-35.1	-44.8
22	26.3	16.6	6.9	-2.8	-12.5	-22.2	-31.9	-41.6
23	29.4	19.7	10.0	0.3	-9.4	-19.1	-28.8	-38.5





## COOLING OF WELDS

EN 1090-2:2018 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 1090-2:2018.

		Hold time (hours) <sup>a</sup>	
If preheat is applied in accordance with Method A of EN 1011-2:2001, Annex C			
Weld size [mm] <sup>b</sup>	Heat input $Q$ [kJ/mm]	S275 – S460	Above S460
$a$ or $s \leq 6$	All	Cooling period only	24
$6 < a$ or $s \leq 12$	$\leq 3$	8	24
	$> 3$	16	40
$a$ or $s > 12$	$\leq 3$	16	40
	$> 3$	24	48
If preheat is applied in accordance with Method B of EN 1011-2:2001, Annex C			
Weld size [mm] <sup>b</sup>		S275 – S690	Above S690
$a$ or $s \leq 20$		Cooling period only	24
$a$ or $s > 20$		24	48

<sup>a</sup> 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.

<sup>b</sup> 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 1090-2:2018, 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 standard EN 1011-2:2001.

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 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  $\leq 20$  mm**      **Cooling period only**  
**Wall thickness  $> 20$  mm**      **24 hours**

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The SSAB logo consists of the letters 'SSAB' in a bold, blue, sans-serif font. The 'S' and 'A' are connected, and the 'B' has a distinctive shape with a vertical bar on its right side.