Quard®

VERSCHLEISSFESTER STAHL

Quend®

HOCHFESTER FEINKORNBAUSTAHL

WELDING

NLMK Europe – Plate

If you want to calculate the optimal parameters for your operations on Quard and Quend, download our **Q Calculator** app!

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1. Introduction

Quard®, abrasion resistant steel, and **Quend®**, high yield strength structural steel, combine their outstanding performance with excellent weldability. Both Quard and Quend are based on a low-alloy steel composition securing carbon equivalents at low levels. Welding of Quard and Quend can be carried out with all weldable steel grades using any of the conventional welding methods, either manually or automatic.

Welding Quard and Quend is as easy as welding commercial steel grades. However, to obtain high-quality welds when welding Quard and Quend, special attention must be paid to the following aspects :

- Need for preheating prior to welding
- Weld heat input applied
- Selection of electrode.

2. Preheating

When welding Q&T steels in thicker gauges, the preheating of the joint area prior to welding becomes necessary in order to prevent weld cracks occurring.

The need for preheating, and at what temperature, depends on several factors : 1) the steel carbon equivalent, 2) the stress conditions in the weld and 3) the type of electrode used.

The carbon equivalent is calculated based on the steel composition specified in the plate certificate. The carbon equivalent is normally given as either CEV or as CET.
The CEV equivalent is the more traditionally and frequently used value for expressing the carbon equivalent of steel.
The CET equivalent, on the other hand, is designed to better adapt to quenched and tempered steel grades.
Both equivalents are given in all technical documentation on the weldability of Quard and Quend.

Irrespective of which carbon equivalent is used, the general rule is the higher the carbon equivalent, the more attention must be paid to preheating.

$$CEV(IIW) = C + Mn/6 + [Mo+Cr+V]/5 + [Ni+Cu]/15 \ (\%)$$

$$CET = C + [Mn+Mo]/10 + [Cr+Cu]/20 + Ni/40 \ (\%)$$

Note :
When comparing carbon equivalents between different steel grades, be sure you compare the same type of equivalent.
When calculating the carbon equivalent of a Quard or Quend plate, always use the ladle composition given in the product certificate, not the maximum analysis given in the data sheet.

3. Hydrogen cracking / Cold cracking

If preheating recommendations are not respected when welding **Quard** or **Quend** in thicker gauges, problems with weld cracking might occur. These types of cracks are referred to as hydrogen cracking or cold cracking, and will appear about 48 hours after welding is completed.

The issue with hydrogen cracking can be totally eliminated by carefully taking into account the preheating requirements of the steel, as well as the recommendations given on consumable selection.

Hydrogen cracks are mainly caused as a result of one or a combination of the factors given below.

- **The carbon equivalent being too high ;**
- **The stress condition in the weld is too high ;**
- **The hydrogen content in the weld metal deposit is too high.**

The primary purpose of preheating is to slow down the cooling rate in the heat-affected zone and weld metal so the hydrogen can slowly diffuse out of the steel. Preheating is most important when welding the root bead as well as when tack welding, since the plate is cold at the start of the welding process.

4. How to avoid hydrogen cracking

By choosing **Quard** and **Quend**, you have automatically selected steel grades produced according to a low-alloy concept, granting very low carbon equivalents regarding their hardness / strength and thus providing excellent weldability.

By obtaining a good fitting of the parts to be welded, and if a balanced welding sequence can be applied, stress built up during welding can be kept to a minimum. By following our instructions, you can select a suitable electrode which suits your requirements perfectly. In doing so, you will avoid unnecessary stresses being built up in the welded joint.

Except for selecting an electrode with the relevant strength, it is essential that the hydrogen content of the welded metal remains low. Always use electrodes that exhibit a weld metal hydrogen content of max. 5 ml / 100 g weld metal. The typical weld metal hydrogen content is always given on the packaging by the supplier.

To obtain a good weld quality when using Quard and Quend, it is recommended that the necessary welding hygiene standards be maintained, keeping the joints clear from rust, oil, grease and moisture.

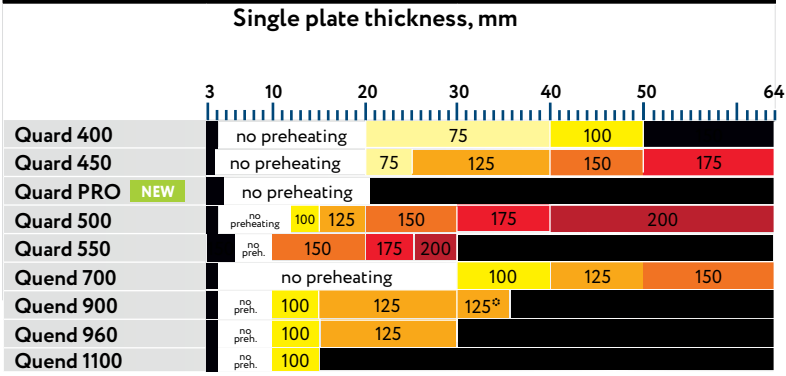
5. Recommended preheating temperatures

The preheating requirement increases with :

- **Increasing carbon equivalent ;**
- **Increasing plate thickness ;**
- **Increasing hydrogen content in the as deposit weld metal ;**
- **Decreasing heat input.**

The recommended minimum preheating requirement is given in relation to single plate thickness. The test method on which the preheating recommendations are based is the Tekken test.

Table 1. Welding with a heat input of ⩾ 1.7 kJ / mm. As deposit weld metal hydrogen content : ⩽ 5 ml / 100 g weld metal.



*Preliminary calculated preheat temperatures. Products under development.

IMPORTANT NOTE !!!

- **If preheating is to be applied, preheating must also be performed during the initial tack welding and fitting / clamping of plates.**
- **When performing tack welding, the length of the welds should be at least 50 mm.**
- **If the carbon equivalent of the consumable is higher than the carbon equivalent of the plate, a preheating temperature approximately 25°C higher than the temperature given in Tables 1 and 2 must be applied.**
- **If preheating is to be applied, the temperature in the weld must not fall below the preheating temperature specified during the entire welding sequence.**
- **If the ambient temperature or the temperature of the plate when welding remains below +5°C, the recommended preheating temperature should be increased by 25°C.**

6. Recommended interpass temperature

In multiple bead welds and short sequence weld lengths, the heat generated from the beads will be accumulated and increase the temperature in the welded area. As a result, the temperature in the weld before applying the next bead may become very high. In order to avoid a too high interpass temperature, which could affect the mechanical properties in the heat-affected zone, the recommended maximum interpass temperatures, given in Table 2, must be respected.

Table 2. Recommended maximum interpass temperature.

Grade	Interpass temp.
Quard 400/450	225°C
Quard 500/550	200°C
Quend 700/900/960	325°C
Quend 1100	200°C

7. Recommended heat input

The heat input expresses the energy (heat) that is put into the weld during the welding of one weld bead.

The higher the heat input, the more heat needs to be transferred from the weld into the steel.

Calculation of welding heat input.

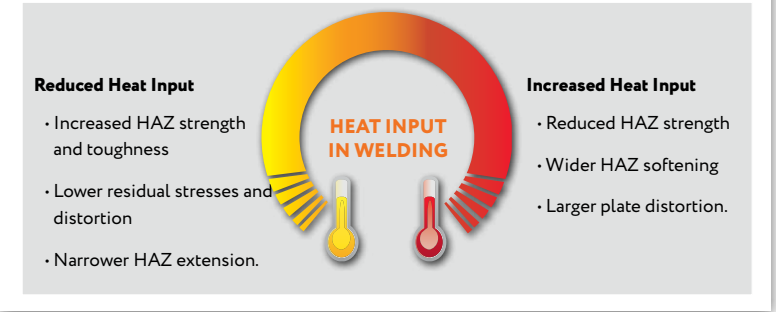
$$Q = \frac{k \times U \times I \times 60}{v \times 1000}$$

Q = Heat input (KJ/mm)
U = Voltage (V)
I = Current (A)
v = Welding speed (mm/min.)
k = Thermal efficiency

Thermal efficiency	k
MMA	0,8
MAG, all types	0,8
SAW	1,0
TIG	0,6

Quard and Quend receive their mechanical properties by quenching and, when necessary, by subsequent tempering. If the heat-affected zone (HAZ) is being exposed to very high temperatures, the mechanical properties upon delivery might be affected.

Effect on heat input on the weld mechanical properties.



A high heat input promotes high productivity. However, if it is too high, it will have a negative impact on the weld strength, impact toughness, weld distortion and extension of the heat-affected zone.

The total heat exposure of the HAZ is controlled by the combination of heat input and the preheating/interpass temperature. Restrictions regarding the maximum heat input have been suggested (Figures 1 and 2) in order to avoid jeopardising the properties of the heat-affected zone.

Figure 1. Recommended max./min. heat input when welding Quard 400/450.
(Minimum value refers to conventional welding methods).

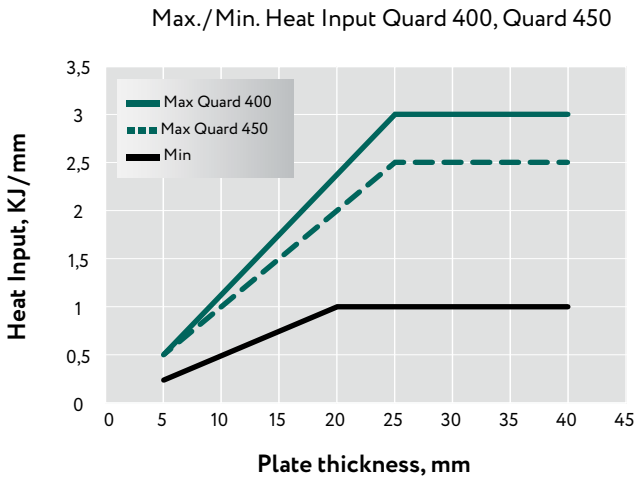
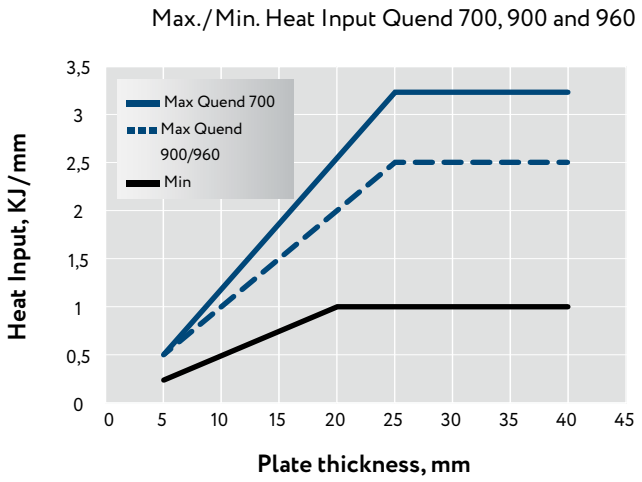


Figure 2. Recommended max./min. heat input when welding Quend 700/900/960.
(Minimum value refers to conventional welding methods).



Recommended Δt8/5	
Steel grade	**Cooling time, 800°C to 500°C**
Quend 700	5-25 s.
Quend 900/960/1100	5-15 s.

8. Selection of electrodes

The electrodes recommended to be used when welding **Quard** and **Quend** are referred to the group of unalloyed or low-alloyed ferritic consumables. Depending on the welding method to be used, the electrode may be of solid wire type (GMAW) or in combination with a flux (as for MMA, SAW or FCAW welding). If using a flux system, it is recommended using a basic flux. This is because a basic flux generally produces a cleaner weld deposit and higher weld metal impact toughness, as well as being less susceptible to hydrogen pick up.

To minimise the risk of developing hydrogen cracks, welding should always be performed using low hydrogen electrodes, having an as deposit weld metal hydrogen content of max. 5 ml/100 g weld metal.

When welding Quard abrasion resistant steels, electrodes having a yield strength of maximum 500 MPa should be used. Using higher strength electrodes increases the stress level in the weld and, in turn, the sensitivity to form cold cracks. By using an electrode of limited strength, the weld metal is allowed to relax stresses if exposed to high weld restrained conditions.

When welding Quend structural steels, the requirements of the applicable construction standard must be met regarding the transverse weld strength. In this case, consumables of matching or slightly overmatching yield strength must be selected. This means the weld metal strength should be the same or slightly higher than the strength of the parent metal. To find such electrodes is easy for Quend 700, yet for Quend 960-1100, only a few electrode manufacturers are able to supply these high-strength consumables.

In Tables 3-5, electrodes recommended to be used for welding Quard and Quend have been listed according to the weld method chosen. The AWS Class and EN Class designations have also been provided in the tables, representing the strength level, toughness and composition of recommended consumables.

Designation of weld methods :	
MMA	Manual Metal Arc welding
MAG/GMAW	Metal Active Gas welding – Gas Metal Arc Welding
MIG	Metal Inert Gas welding
FCAW	Flux Cord Arc welding
SAW	Submerge Arc Welding

Table 3. Ferritic consumables suitable for welding of Quard 400/450/500/ 550.

	MMA Manual metal arc	**GMAW** Gas metal arc	**FCAW** Flux corded arc	**SAW** Submerged arc
EN Class	EN ISO 2560 E4X	EN ISO 14341 G4X	EN 17632 T4X	EN 14171 S4X
AWS Class	A5.5 E70	A5.28 ER70S	A5.29 E7XT	A5.23 F7
ESAB	OK 48.04	OK Autrod 12.51	OK Tubrod 14.11	12.22 + 10.71
Oerlikon	Tenacito 70	Carbofil 1 (a)	Fluxofil 31/41	L-70 / OP121TT
Bohler	FOX EV50	EMK& , NiCu-1G	Kb 52-FD	EMS2 / BB22

Table 4. Ferritic consumables suitable for welding of Quend 700.

	MMA Manual metal arc	**GMAW** Gas metal arc	**FCAW** Flux corded arc	**SAW** Submerged arc
EN Class	EN 18275 E69	EN 16834 G69	EN ISO 18276 T69	EN 26304 S69
AWS Class	A5.5 E110	A5.28 ER110-S	A5.29 E11XT	A5.23 F11
ESAB	OK 75.75	OK Autrod 13.29	OK Tubrod 14.03	13.43 + 10.62
Oerlikon	Tenacito 100	Carbofil NiMoCr	Fluxofil 42	--
Bohler	FOX EV85	X70 GI	Union MV NiMoCr	--

Table 5. Ferritic consumables suitable for welding of Quend 900/960.

	MMA Manual metal arc	**GMAW** Gas metal arc	**FCAW** Flux corded arc	**SAW** Submerged arc
EN Class	EN 18275 E89	EN 16834 G89	EN ISO 18276 T89	EN 26304 S89
AWS Class	N/A	N/A	N/A	N/A
ESAB	OK 75.78	--	Coreweld 89	--
Bohler	FOX EV100	X90 GI	--	--

When selecting electrodes for welding Quend 900 and Quend 960, please consult Technical Support at NLMK Clabecq.

9. Austenitic consumables

Austenitic (stainless steel) consumables may be used for welding both Quard and Quend. The major benefit of using austenitic electrodes is that you can weld Quard and Quend of thicker gauges, where preheating is normally required, without preheating. The austenitic electrodes are far more expensive when compared to ferritic electrodes ; however, if preheating is not possible, austenitic consumables become an option. The austenitic electrodes recommended for welding Quard should comply with the AWS 307 (or 309) classification, given in Table 6 below.

Table 6. Austenitic consumables suitable for welding of Quard 400/450/500.

	MMA Manual metal arc	**GMAW** Gas metal arc	**FCAW** Flux corded arc	**SAW** Submerged arc
EN Class	EN ISO 3581 E18 8	EN 14343 G18 8	EN I7633 T18 8	EN 14343 S18 8
AWS Class	A5.4 E307	A5.9 ER307	A5.9 EC307	A5.9 ER307
ESAB	OK 16.45	OK Autrod 16.95	OK Tubrod 14.71	16.97 + 10.93

10. Improved wear resistance in welds

When welding Quard abrasion resistant plates, the weld should be positioned in low stressed areas and areas exposed to low wear from sliding or impacting abrasives. If the weld is located in areas exposed to high wear, the abrasion resistance of the weld can be improved by using hard-facing consumables when producing the top/cap beads of the weld. The hard-facing electrodes are usually very rich in chromium (3-13% Cr); this is why the carbon equivalent of the weld metal always exceeds the equivalent of the parent material. It is therefore important that the recommendations given by the hard-facing electrode supplier are followed, using the correct preheat and welding parameters.

11. Laser welding of Quard and Quend

Laser welding can be used when welding Quard and Quend, with or without adding consumables. To secure the strength and toughness in the weld it is recommended to use laser welding together with a consumable. A proven welding process to obtain excellent weld mechanical properties is that of laser hybrid welding. For more information regarding laser welding of Quard and Quend, please contact our weld specialists at NLMK Clabecq Technical Support.

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