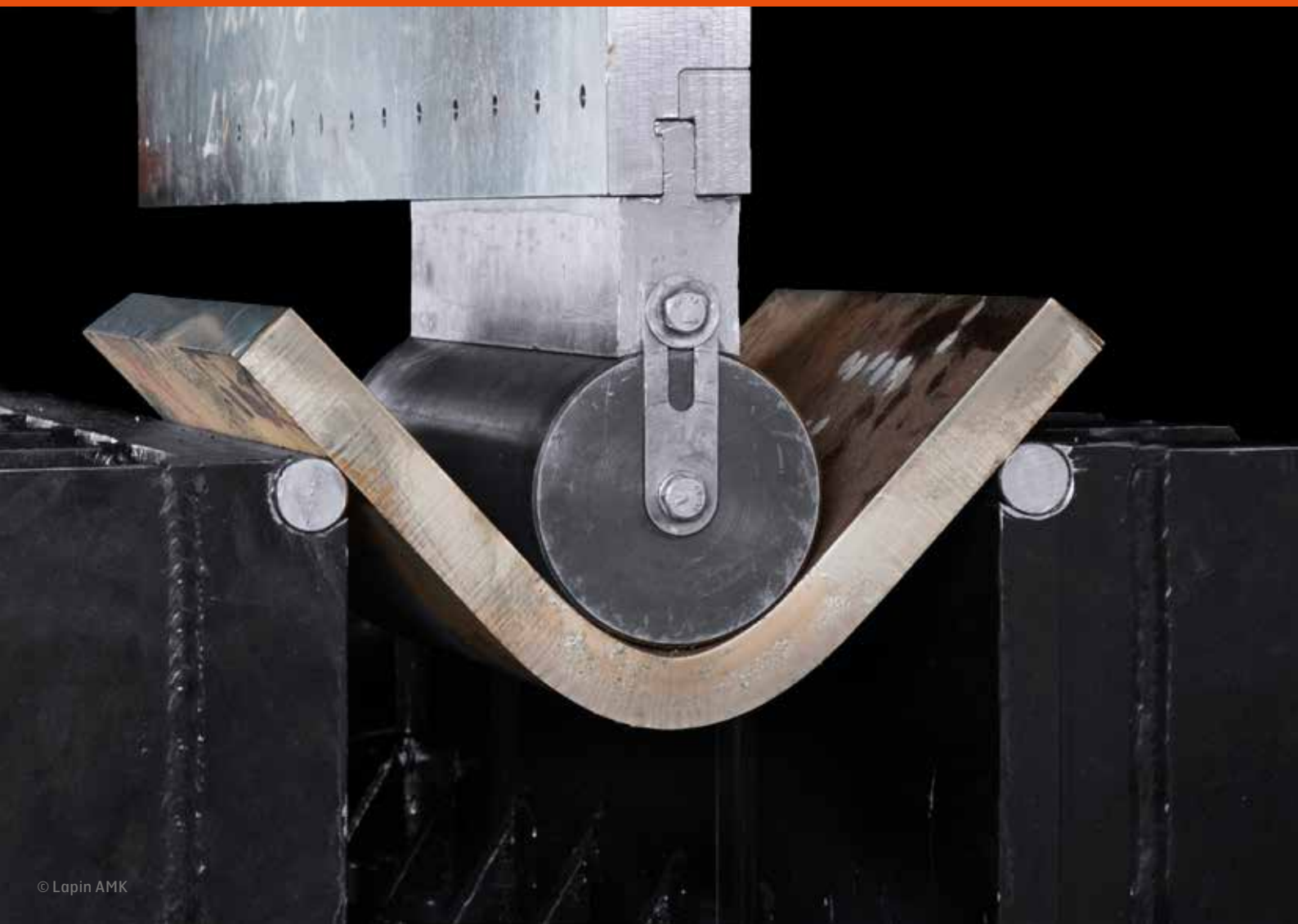


BENDING AND MACHINING



YOUR WEAR DEMANDS COVERED

Raex abrasion resistant steel is designed for steel structures that are exposed to abrasive wear and tear. The wear resistance properties of Raex can significantly prolong the service life of your equipment, saving you time and money.

Raex extends the service life of steel structures by cutting down their weight in comparison to mild steel. Lighter components increase load capacity which saves fuel and reduces emissions by reducing the number of trucks in service.

CONTENTS

INTRODUCTION	3
1 BENDING METHODS	4
2 PREPARATION BEFORE BENDING	5
3 BENDING INSTRUCTIONS	6
3.1 Bending instructions for the workshops	6
3.2 Bending Force	6
3.3 Minimum Bend Radius	7
3.4 Separation of the plate to be bent	8
4 MACHINABILITY	9
4.1 Drilling	9
4.2 Machine Tapping	10
4.3 Sawing	11
4.4 Milling and Turning	12
5 OCCUPATIONAL SAFETY	13

INTRODUCTION

Raex is born from carefully selected raw materials and made in a tightly controlled, integrated steel mill process. The result is reliable quality and dependable performance in hardness, bendability, surface quality and flatness. Raex steels are available as heavy plates and cut-to-length sheets in 300 – 500 HB hardness range. Raex is well appreciated in workshops thanks to its good cutting, welding and bending properties. It helps extend lifetime of machinery and enables new design possibilities to create lightweight products that improve energy efficiency.

The brochure describes the principles of free bending and bottoming and gives practical recommendations for bending of Raex. Generally, the need for bend force and the level of springback increase as the strength of steel increases. To obtain full advantage of good bendability

of Raex, careful workshop practices must be in place. Worn tools, poor lubrication, damaged surface and burrs on cut edges, may all impair bending quality. Plates taken from a cold storage must be allowed to warm up to room temperature before being cold formed.

In addition to bending instructions, this brochure compiles information and recommendations on machining of Raex, including the following methods:

- drilling
- thread cutting
- sawing
- milling and turning.



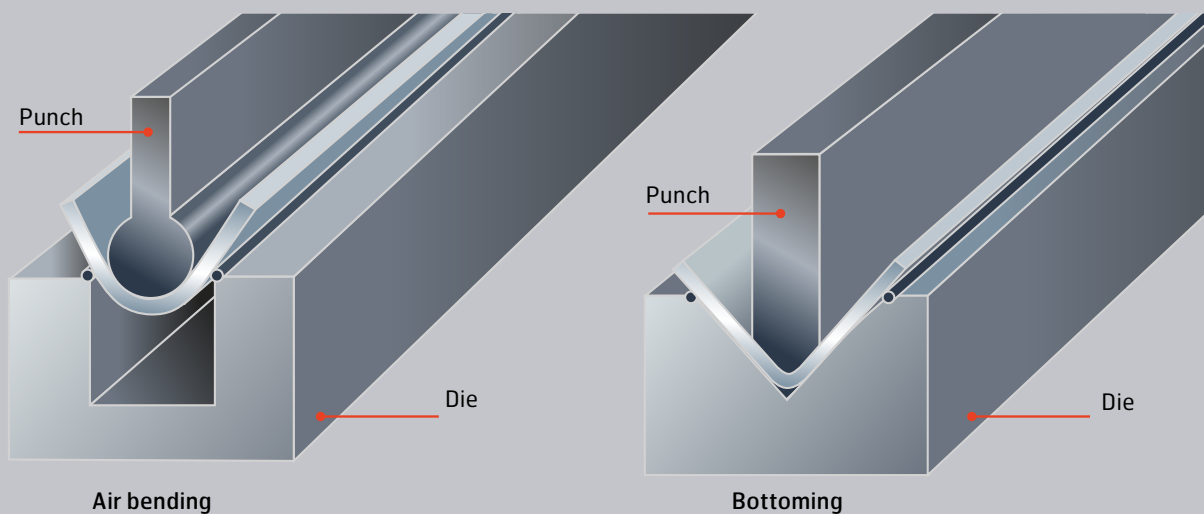
1 BENDING METHODS

The plate is bent to the designed angle or free bending radius in a press break between the punch and the die.

In air bending, the plate rests on the upper edges of the die gap for the entire duration of the pass. The required bending angle is obtained by adjusting the stroke length (Figure 1). The die gap width can be adjusted.

In bottoming, the stroke length is sufficient for the punch to press the plate entirely against the die. A shape matching the punch and die is formed in the plate (Figure 1). The die gap (V-groove) is fixed and its width cannot be adjusted.

FIGURE 1. BENDING METHODS AND TOOLS.



2 PREPARATION BEFORE BENDING

- The temperature of the plate must be a minimum of +20°C.
- It is recommended to bring plates stored in cold places indoors a day prior to bending operations.
- If required, the area to be bent must be heated using a gas flame.
- Preheating to +100 – +200°C reduces the required bending force and improves bendability in general.
- Identify the rolling direction of the plate.
- Possible surface defects must be ground away from the tension side face of the plate.
- Grind away defects on the cut edge of a thermally or mechanically cut plate, at least on the area to be bent.
- Excessive blast cleaning can have a negative effect on bendability. The recommendation for RAEX products are based on tests without a blasted surface.



3 BENDING INSTRUCTIONS

- Safety instructions must be followed in bending.
- The need for bending force, springback effect and the permitted bending radius increase as the strength of the steel increases.
- The bending radius should be as big as possible.
- Bending must be made in a single pass.
- The best possible workshop expertise can be obtained by combining theoretical and empirical data.
- Bending values are defined on the basis of test bending taking the degree of the springback effect into consideration.
- The springback effect in Raex 400 is 8° – 25° and in Raex 500 15° – 35°, depending on bending tool parameters. Wider die-gap results in bigger springback.
- Trial tests are always recommended.

3.1 BENDING INSTRUCTIONS FOR THE WORKSHOP

In practical bending or flanging, the punch diameter is defined on the basis of steel grade, plate thickness and bend radius. Table 1 presents smallest punch diameter (D) for Raex 400, Raex 450 and Raex 500 on the basis of plate thickness (t).

3.2 BENDING FORCE

The bending force (P, in metric tons) needed when bending of steel plates can be estimated using the following formula:

$$P = \frac{b \cdot t^2 \cdot R_m}{(W - R_d - R_p) \cdot 9800}$$

P = Bend force, metric tons

t = Plate thickness, mm

W = Die width, mm (figure 2)

b = Bend length, mm

R_m = Tensile strength, MPa (table 2)

R_d = Die entry radius, mm (figure 2)

R_p = Punch radius, mm

FIGURE 2. BENDING TRANSVERSE TO THE ROLLING DIRECTION IS RECOMMENDED.

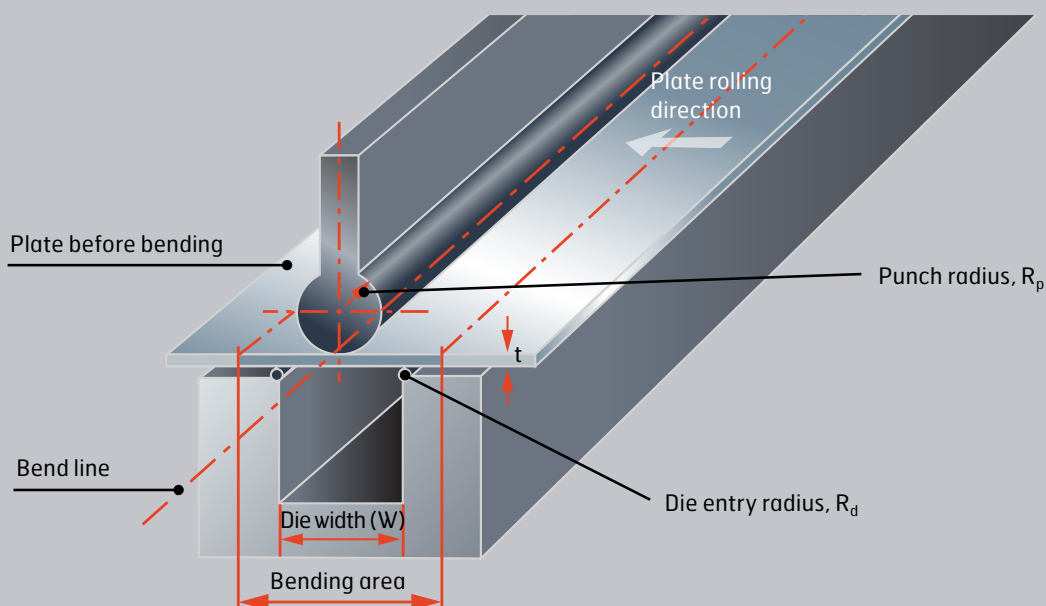


TABLE 1. RAEX ABRASION-RESISTANT STEELS. BENDING INSTRUCTIONS FOR THE WORKSHOP.
Selection of the minimum allowed punch diameter for Raex on the basis of plate thickness

Plate thickness	RAEX 400		RAEX 450				RAEX 500			
	Smallest punch diameter D (mm) to be transversely bent	Smallest punch diameter D (mm) to be longitudinally bent	Smallest punch diameter D (mm) to be transversely bent		Smallest punch diameter D (mm) to be longitudinally bent		Smallest punch diameter D (mm) to be transversely bent		Smallest punch diameter D (mm) to be longitudinally bent	
	Strip/Plate	Strip/Plate	Strip	Plate	Strip	Plate	Strip	Plate	Strip	Plate
2	12	16	12		16					
2.5	15	20	15		20		17.5		20	
3	18	24	18		24		21		24	
4	24	32	24		32		28		32	
5	30	40	30		40		35		40	
6	36	48	36	48	48	60	42	60	48	72
7	42	56	42	56	56	70	49	70	56	84
8	48	64	48	64	64	80		80		96
9	54	72		72		90		90		108
10	60	80		80		100		100		120
11	66	88		88		110		110		132
12	72	96		96		120		120		144
13	78	104		104		130		130		156
14	84	112		112		140		140		168
15	90	120		120		150		150		180
16	96	128		128		160		160		192
17	102	136		136		170		170		204
18	108	144		144		180		180		216
19	114	152		152		190		190		228
20	120	160		160		200		200		240

¹⁾ Bending line vs. plate rolling direction.

When bending in V groove (90°) the recommended die width and plate thickness ratio is W/t ≈ 15.

Typical tensile strength of Raex steels is presented in table 2.

TABLE 2. RAEX ABRASION-RESISTANT STEELS. TYPICAL TENSILE STRENGTH AND HARDNESS VALUES.

Raex grade	Tensile strength R _m (MPa)	Hardness (HBW)
Raex 300	1000	300
Raex 400	1250	400
Raex 450	1450	450
Raex 500	1600	500



3.3 MINIMUM BEND RADIUS

Table 3 shows the minimum bending radii for Raex abrasion-resistant steels. In practical bending or flanging in the engineering works, it is recommendable to use inside bending radii which are greater than the minimum allowed bending radii. In addition to the steel plate, the quality of the bend depends on the bending tools and the performance of the work. Successful bending requires good engineering workshop technology from the steel product processor. Worn-out tools, insufficient lubrication, scratches on the steel surface and burr compromise the quality of the cold forming process.

TABLE 3. RAEX ABRASION-RESISTANT STEELS. MINIMUM BEND RADIUS R, BEND ANGLE $\leq 90^\circ$.

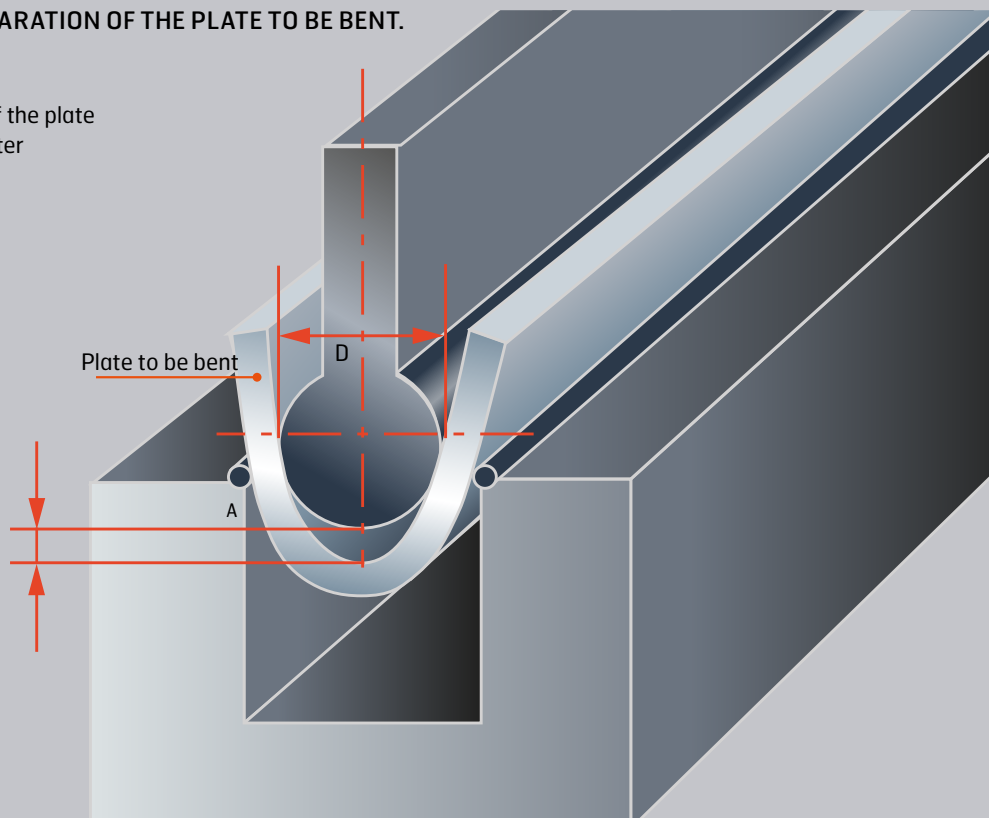
Raex grade	Product form	Thickness (mm)	R/t minimum transverse	R/t minimum longitudinal	Die opening width W/t minimum
Raex 300	Sheet	2 – 8	3	3	12
Raex 400	Sheet	2 – 8	3	4	12
	Plate	6 – 20	3	4	14
Raex 450	Sheet	2 – 8	3	4	12
	Plate	6 – 20	4	5	14
Raex 500	Sheet	2.5 – 7	3.5	4	14
	Plate	6 – 20	5	6	14

3.4 SEPARATION OF THE PLATE TO BE BENT

Figure 3 shows the separation (A) of the plate to be bent from the circle of the punch diameter (D). The separation is well-known for the engineering works that are using high strength steels. Generally, the accuracy of the final bend angle is more important than the radius of the work piece. If the exact bend radius is desired, too, trial bending has to be carried out. As a result of the trial bending, a punch radius is selected that produces a final bend angle matching the target value. In practice, the punch radius is a little bit larger than the final bending radius of the steel.

FIGURE 3. SEPARATION OF THE PLATE TO BE BENT.

A = Separation of the plate
D = Punch diameter





4 MACHINABILITY

GENERAL INSTRUCTIONS FOR MACHINING:

- The machine must be rigid and stable.
- Clamp the workpiece as rigidly and close to the area to be cut as possible.
- Long tool holders and spindle overhangs must be avoided.
- No harmful vibration may occur during any stage of machining.
- Particular caution must be exercised when starting a cutting operation.
- Grind away any rough edges on a thermally cut plate in the area where the first cut is started.
- Sufficient feed and depth of cut must be used.
- Provide a generous flow of cutting fluid.
- Lower the cutting speed in dry cutting.
- When machining abrasion-resistant steels on a regular basis, hard metal tools should be selected using the manufacturers' data sheets.

4.1 DRILLING

Recommended drilling parameters for non-alloyed high-speed steel (HSS) drills and cobalt-alloyed HSS drills are presented in tables 4, 5 and 6. Additionally, recommended drilling parameters for the steel grade Raex 500 using solid cemented carbide drills are included in table 6. Raex 400 and Raex 450 can be drilled with HSS drills. For drilling of Raex 500 hard metal drills are recommended.

GENERAL INSTRUCTIONS FOR DRILLING:

- The drilling machine has to be rigid and stable in order to minimize vibrations.
- Clamp the workpiece securely and close to the area to be machined.
- Short-hole drills are recommended.
- The service life of the drilling tool can be prolonged by decreasing the feed.
- Provide an abundant supply of cutting fluid.

TABLE 4. RAEX 400. RECOMMENDED DRILLING PARAMETERS.

	Drill diameter (mm)	Feed rate (mm/rev)	Feed rate (mm/minute)	Cutting speed (m/minute)	Speed of rotation (rpm)
Uncoated HSS drill	5	0.10	60–80	9–12	600–800
	15	0.20	40–50	9–12	200–250
	25	0.25	30–40	9–12	110–150
Uncoated HSS-Co drill	5	0.10	70–100	12–15	800–950
	15	0.20	50–70	12–15	250–320
	25	0.20	25–30	9–12	110–150

TABLE 5. RAEX 450. RECOMMENDED DRILLING PARAMETERS.

	Drill diameter (mm)	Feed rate (mm/rev)	Feed rate (mm/minute)	Cutting speed (m/minute)	Speed of rotation (rpm)
Uncoated HSS drill	5	0.08	40–50	8–10	500–650
	15	0.20	35–45	8–10	170–210
	25	0.25	25–35	8–10	100–130
Uncoated HSS-Co drill	5	0.10	60–75	8–10	600–750
	15	0.20	35–45	8–10	170–210
	25	0.20	15–20	6–8	75–100

TABLE 6. RAEX 500. RECOMMENDED DRILLING PARAMETERS.

	Drill diameter (mm)	Feed rate (mm/rev)	Feed rate (mm/minute)	Cutting speed (m/minute)	Speed of rotation (rpm)
Uncoated HSS drill	5	0.10	25	4	250
	15	0.15	15	4	85
	25	0.15	8	4	50
Uncoated HSS-Co drill	5	0.10	25–35	4–6	250–380
	15	0.15	15–20	4–6	80–130
Solid cemented carbide drill	16	0.15	120	40	800



4.2 MACHINE TAPPING

For thread cutting, micro-alloyed HSS-E or cobalt-alloyed HSS-Co taps with four cutting edges are recommended. The best result is obtained by using cutting oil or paste. When the strength of the joint is not critical, thread holes approximately 3–5 percent larger than the standard values are recommended. A larger hole diameter will significantly increase tool life. During the threading pass, unobstructed chip removal must be secured without reversing the tool or alternating the direction of rotation. Shallow holes should be threaded using appropriate taps, see table 7.

TABLE 7. RAEX. MACHINE TAPPING, HSS-E TAP.

	Cutting speed (m/min)	Tap size					
		M10 Spindle speed (rpm)	M16 Spindle speed (rpm)	M20 Spindle speed (rpm)	M24 Spindle speed (rpm)	M30 Spindle speed (rpm)	M42 Spindle speed (rpm)
Raex 400	3.6	115	80	63	53	42	30
Raex 500	1.6	50	40	32	25	21	15

4.3 SAWING

When selecting the sawing machine and blade, the high hardness and strength of the steels should be taken into account. A generous flow of cutting fluid should be provided. In band sawing, the best results are achieved with an asymmetric tooth pitch, see table 8.

GENERAL INSTRUCTION FOR BAND SAWING:

- The blade must be supported and tensioned adequately.
- The burr and hardened layer caused by flame cutting should be ground away from the area where sawing is started.
- Long chip removal distances should be avoided, for example by clamping the workpiece rigidly in a slanting position.
- If the cutting length cannot be reduced, a blade with a coarser tooth pitch can be used.
- The tooth pressures should be reasonably high.
- Blade noise can be eliminated by adjusting the cutting speed.
- Sawing should always be started using manual feed, and the feed should be adjusted to bring the blade into sufficiently stable contact.
- The hardness and strength of the workpiece should be taken into account when adjusting the feed.
- A generous flow of cutting fluid ensures that the blade remains wet throughout the run.
- Tooth damage is in part caused during the exit phase, when the blade wedges, jams, bites and jitters.

TABLE 8. RAEX. CUTTING DATA FOR SAWING.

	Cutting speed m/min Cutting length mm		
	100	200	300
Raex 400	60	50	40
Raex 500	40	35	30

4.4 MILLING AND TURNING

The most common milling operation in the abrasion-resistant steels is roughing. The milling machine must be rigid and of heavy construction. It is necessary to use coated hard metal tools. In terms of cutting data, turning is in principle similar to milling, see table 9.

GENERAL INSTRUCTIONS FOR MILLING:

- A generous flow of cutting fluid should be provided.
- Start milling operations carefully.
- The burr and hardened layer caused by flame cutting should be ground away from the area where the milling is started.
- When rough milling, the first cut should be thick enough to keep the cutting edge from dragging on the scaly, hardened surface of the workpiece.

TABLE 9. RAEX. CUTTING DATA FOR ROUGH MILLING.

Wet rough milling	Indexable insert P40		
	Cutting speed (m/min)	Feed (mm/tooth)	Depth of cut (mm)
Raex 400	75 – 90	0.1 – 0.2	2 – 5
Raex 500	60 – 75	0.1 – 0.15	1 – 4

*Optimal conditions allow using up to 50% higher cutting data.
For dry milling, 20 – 30 % lower values are recommended.*



5 OCCUPATIONAL SAFETY

Special care has to be taken in processing and handling of ultra-high strength steels. If bend radius, for example, is too small and a crack is created in bending point, the plate may fly from the bending tool in the direction of the bend. Those bending the plate must take appropriate precautions to protect themselves and no outsiders are allowed in the area.

The safest location is usually by the bending machine. The handling instructions of the steel supplier and safety instructions of the workshop must be adhered to in detail. New employees must receive appropriate training before they are allowed to process with ultra-high strength steels.

CONTACT

WELDING AND THERMAL CUTTING



YOUR WEAR DEMANDS COVERED

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Raex extends the service life of steel structures by cutting down their weight in comparison to mild steel. Lighter components increase load capacity which saves fuel and reduces emissions by reducing the number of trucks in service.

INTRODUCTION

Raex is an abrasion-resistant steel with good hardness and workshop properties. Modern production technology enables reliable quality and cost effective protection against different type of wear conditions. Raex steels are available as heavy plates and cut to length sheets in 300 – 500 HB hardness range. Raex is well appreciated in workshops thanks to its good cutting, welding and bending properties. It helps extend lifetime of machinery and enables new design possibilities to create lightweight products that improve energy efficiency.

APPLICATIONS FOR RAEX ABRASION RESISTANT STEELS

- Crushers, buckets and lip plates
- Platforms and base structures
- Materials and waste handling machinery, tanks and conveyors
- Silos, hoppers, screens and mixers
- Special containers
- Wearing parts and cutting blades

The wear resistance of Raex steels is based on steel alloying and the hardened delivery condition. High alloying, hardness and strength make the welding and thermal cutting of abrasion resistant steels more demanding than the processing of ordinary structural steel. Welding of

abrasion resistant steels has two main objectives. Firstly, cold cracks need to be prevented in advance. This requirement is emphasised when welding thick plates. Secondly, the mechanical properties of the welded joint need to be optimal. In addition to these two objectives concerning the parent metal, demanding welding operations must satisfy work-specific demands, such as quality level. Things to avoid in thermal cutting include cracks on the cut surface and excessive softening of the cut area.

This technical brochure provides practical welding instructions for the Raex 400, Raex 450 and Raex 500 grades and specifies their special features with regard to thermal cutting. A correct working temperature and heat input, as well as careful preparation, play the key role in welding. The groove surfaces to be welded need to be dry and clean. The content of hydrogen dissolved in the weld metal must be kept especially low, because we are dealing with ultra high strength steel. Low hydrogen content is achieved with correct welding parameters and by using proper welding consumables. The data sheet provides welding consumable recommendations for gas-shielded arc welding, manual metal arc welding, and submerged arc welding. All stages of welding and thermal cutting, from design to finishing, must be performed with care in order to achieve the best possible result.



CONTENTS

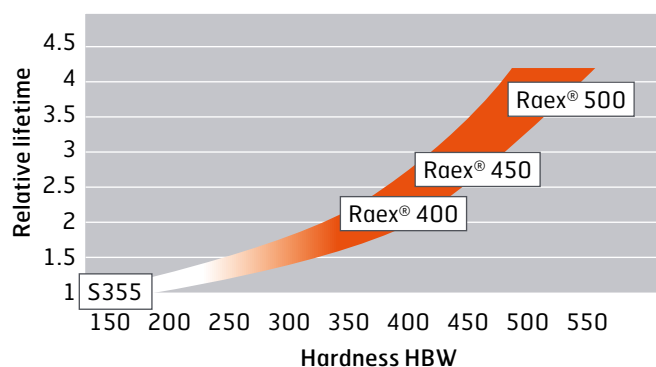
INTRODUCTION	3
1 ABRASION RESISTANT STEEL GRADES	4
2 WELDABILITY OF ABRASION RESISTANT STEELS	5
2.1 Susceptibility to cold cracking	5
2.1.1 Location of cold cracks	5
2.1.2 Factors that cause cold cracking	5
2.1.2.1 Microstructure of a welded joint	5
2.1.2.2 Critical hydrogen content in a welded joint	6
2.1.2.3 Strength and stress level of a welded joint	6
2.1.2.4 Combined effect of three factors	6
2.2 Optimal properties of a welded joint	6
3 WELDING PARAMETERS AND THEIR EFFECT ON THE PROPERTIES OF A WELDED JOINT	7
3.1 The most important welding parameters	7
3.2 Effect of welding parameters on the properties of a welded joint	7
4 WELDING CONSUMABLES	8
4.1 Undermatching i.e. soft ferritic welding consumables	8
4.2 Austenitic stainless welding consumables	8
5 PREVENTION OF COLD CRACKING	10
5.1 Controlling the hardening of the microstructure of a welded joint	10
5.2 Controlling hydrogen content	10
5.3 Relieving residual stresses in a welded joint	10
5.4 Practical tips for welding	10
5.5 Welding at correct working temperature	10
6 ACHIEVING AN OPTIMAL COMBINATION OF PROPERTIES IN WELDED JOINTS	12
6.1 Recommended welding parameters	12
6.2 Soft zone in welded joints	12
7 HEAT TREATMENT	13
8 BEHAVIORS OF STEEL IN THERMAL CUTTING	15
8.1 Thermal cutting procedure	16
8.2 Controlling surface hardness by increasing the working temperature	16
8.3 Prevention of softening in thermal cutting	16
8.4 Practical tips for thermal cutting	16
9 LASER CUTTING PROPERTIES	18

1 ABRASION RESISTANT STEEL GRADES

Raex abrasion resistant steel is designed for steel structures that are exposed to abrasive wear and tear. The wear resistance properties of Raex can significantly prolong the service life of your equipment, saving you time and money. The selection includes steel grades Raex 300, Raex 400, Raex 450 and Raex 500. The average hardness of the steels is 300/400/450/500 HBW, respectively, see figure 1.

The resistance of steel against general abrasive wear and tear improves as the hardness increases. Figure 1 shows the relative service life of Raex 400, Raex 450 and Raex 500 steels in an abrasion test. However, it must be remembered that the material wear is always case-specific and depends on several different factors.

FIGURE 1. RAEX 400, RAEX 450 AND RAEX 500. ABRASION TEST.



The relative lengthening of service life as the steel hardness increases. The service life of an ordinary S355 structural steel has been modified into the reference value of 1.

2 WELDABILITY OF ABRASION RESISTANT STEELS

The high strength and hardness of abrasion resistant steels is achieved by alloying and quenching. A correct hardenability is achieved with suitable alloying. Due to high alloying, the welding of abrasion resistant steels is more demanding than that of ordinary structural steel. In the welding of abrasion resistant steels, special attention must be paid to two objectives:

- Prevention of cold cracks in welded joints.
- Achieving optimal properties in welded joints.

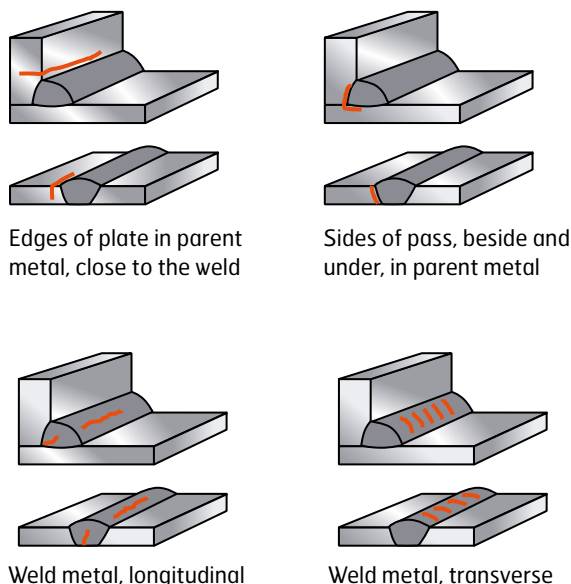
2.1 SUSCEPTIBILITY TO COLD CRACKING

The most common factor impeding the weldability of abrasion resistant steels is cold cracking. Cold cracks are usually formed when the weld cools down to about +150°C or below, hence the term "cold crack". Alternatively, cold cracking is known as hydrogen cracking or delayed cracking. The detrimental effect of hydrogen may manifest itself as cracking only after several days from welding. When planning NDT testing of the welded structure, the delay in the emergence of cold cracks must be taken into account.

2.1.1 Location of cold cracks

Figure 2 shows the critical areas where cold cracks appear in the weld metal, fusion line and heat affected zone.

FIGURE 2. PLACES SUSCEPTIBLE TO COLD CRACKS IN WELDED JOINTS OF HIGH-STRENGTH ABRASION RESISTANT STEELS.



2.1.2 Factors that cause cold cracking

Cold cracking is the detrimental combined effect of three simultaneous factors. These factors are, as shown in figure 3, 1) the microstructure of the welded joint, 2) the hydrogen content of the welded joint, and 3) the stress level in the welded joint.

2.1.2.1 Microstructure of a welded joint

Good wear resistance is based on a martensitic microstructure in the parent metal and the weld metal, as well as in the heat-affected zone of a welded joint. If the joint cools too quickly, the martensite may become too hard and low in toughness. Such a microstructure is susceptible to cracking. The hardening capacity of steel and weld metal is represented with carbon equivalent formulae that are based on alloying. The formulae "CEV" and "CET" shown here are widely used for abrasion resistant steels. The abbreviation "CE" is also used for CEV.

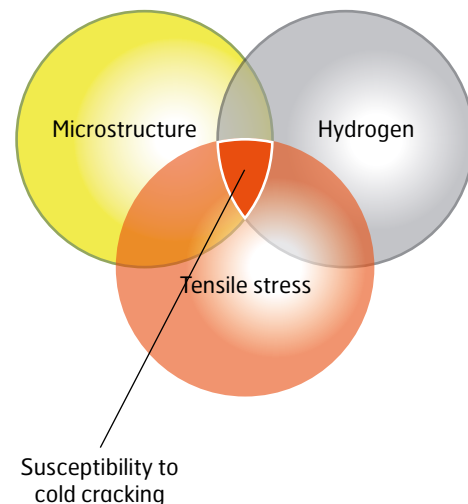
Carbon equivalent formulae used to represent the hardening capacity of steel and weld metal.

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

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

An increase in carbon equivalent, or hardening capacity, leads to a harder microstructure.

FIGURE 3. THE SUSCEPTIBILITY TO COLD CRACKING OF A WELDED JOINT IS THE DETRIMENTAL COMBINED EFFECT OF THREE FACTORS.



2.1.2.2 Critical hydrogen content in a welded joint

Hydrogen is a very lightweight gas that dissolves in steel as atoms and molecules. When a steel plate is manufactured, it already contains small amounts of hydrogen. The manufacturing process of Raex steels is such that the natural hydrogen content of the steel plates remains safely small. Therefore, in welding, hydrogen that predisposes steel to cold cracking tries to penetrate the joint from outside the steel plate.

Critical hydrogen content is not a specific constant, but its value is affected especially by the microstructure of steel. Martensite, ferrite and austenite phases are present in the microstructure of wear-resistant steel, depending on the temperature and treatment state. Only very small amounts of hydrogen dissolves in a martensitic and ferritic microstructure, unlike an austenitic microstructure that can hold considerably more.

During welding, most hydrogen gas is dissolved in steel at high temperatures in which the microstructure of steel is austenitic. When the welded joint cools, the microstructure of steel becomes ferritic or martensitic. In these microstructures only a small amount of hydrogen is dissolved, and the safe space required for the physical placement of hydrogen atoms is restricted. Therefore hydrogen atoms that get trapped in the microstructure of the welded joint may cause local internal tension and crack formation, known as cold cracking.

2.1.2.3 Strength and tensile stress level of a welded joint

Welding as well as other plate processing produce stresses in the joint. The strength and residual stress of a welded joint is determined mainly by the strength of the weld metal. Residual stress depends on the strength of the filler metal and on the rigidity of the structure and the thickness of the steel sheet. At the highest, the stress in the welded joint equals the yield point of the steel. High stress increases susceptibility to cold cracking.

2.1.2.4 Combined effect of three factors

The microstructure, hydrogen content and tensile stress in a welded joint are interdependent in the emergence of cold cracks. For example, if the tensile stress level of a joint increases with the same welding procedure, even lower hydrogen content leads to cold cracking. Similarly, a higher strength and more fragile microstructure are prone to cracking at lower hydrogen contents. In fighting cold cracking, the combined effect of these three factors needs to be predicted, and welding needs to be planned accordingly.

2.2 OPTIMAL PROPERTIES OF A WELDED JOINT

The properties required of abrasion resistant steels are not as extensive as those set for structural steels. The same goes for welded joints and structures made of abrasion resistant steels. Despite this fact, when planning the welding of abrasion resistant steels, the joint should be assessed in relation to the properties in table 1.

When designing wear-resistant structures, welds should be positioned, as far as possible, in places that are not subjected to the heaviest loading. If especially good wear resistance is required of a welded joint, high strength welding consumables with suitable alloying must be used. In structures where numerical values of impact toughness are required of welded joints, values that match those of the parent metal can be achieved with tough welding consumables and correct welding parameters.

The properties in table 1 are interdependent. Increasing hardness and strength, for example, has a decreasing effect on impact toughness. Optimal properties in the weld area are ensured with the correct welding parameters and the recommended working temperature. No numerical values are usually given for the properties of welded joints of abrasion resistant steels, apart from hardness, and possibly strength. Neither of these properties are usually tested.

TABLE 1. OPTIMAL COMBINATION OF PROPERTIES IN WELDED JOINTS OF ABRASION RESISTANT STEELS.

Combination of properties
Hardness
Wear resistance
Strength
Impact toughness

3 WELDING PARAMETERS AND THEIR EFFECT ON THE PROPERTIES OF A WELDED JOINT

During welding, steel undergoes a strong thermal effect. The temperature of the joint rises quickly from the working temperature to the temperature of liquid steel, above +1500°C. The heat input of welding and the cooling rate of the joint are the main variables with which the welding procedure is controlled.

3.1 THE MOST IMPORTANT WELDING PARAMETERS

The heat energy used in welding is indicated with the concepts heat input (Q) and arc energy (E). The relationship between heat input and welding energy is represented by the welding procedure specific coefficient of thermal efficiency "k". At its highest, k=1, in which case the thermal efficiency is 100 percent and all the arc energy is used for heat input. The most important welding parameters and variables are given in figure 4. The typical thermal efficiency of methods used in welding abrasion resistant steels is given in table 2.

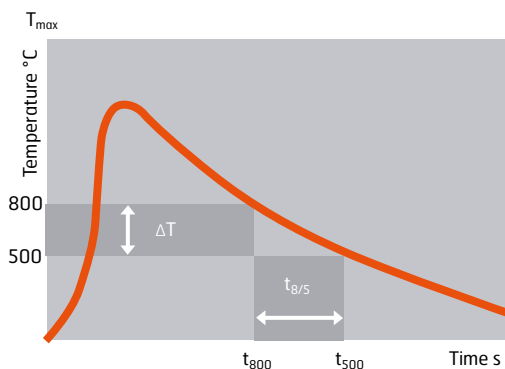
3.2 EFFECT OF WELDING PARAMETERS ON THE PROPERTIES OF A WELDED JOINT

Heat input and the cooling rate of a joint are directly related. With high heat input the joint cools slowly, and with low heat input, it cools quickly. For the microstructure of the heat-affected zone (HAZ) of a welded joint, the most crucial thing is the cooling time from +800°C to +500°C, i.e. $t_{8/5}$, figure 5. The factors that affect the cooling rate of a welded joint are given in table 3.

The effects of higher and lower heat input on the welding of abrasion resistant steels are shown in figure 6. High heat input indicates a long $t_{8/5}$ time, while low heat input indicates a short $t_{8/5}$ time.

In arc welding the higher heat input requirement is based on the improvement of welding efficiency. Higher heat input in the welding of thin abrasion resistant plates is restricted by its negative effect on steel hardness.

FIGURE 5. TEMPERATURE OF A WELDING PROCEDURE VS. TIME AS A DIAGRAM.



$$\Delta T = 800^{\circ}\text{C} - 500^{\circ}\text{C}$$

$t_{8/5}$ = cooling time from +800°C to +500°C

TABLE 2. TYPICAL THERMAL EFFICIENCY FOR DIFFERENT WELDING METHOD.

Welding method	Thermal efficiency, k
Gas-shielded arc welding, MAG methods	0.8
Manual metal arc welding	0.8
Submerged arc welding	1.0
Plasma arc welding and TIG welding	0.6

TABLE 3. FACTORS THAT AFFECT THE COOLING RATE OF A WELDED JOINT.

Welding energy
Plate thickness / thicknesses
Joint form
Type of joint preparation
Working temperature
Welding sequence

FIGURE 4. HEAT INPUT IN WELDING AND WELDING ENERGY AND OTHER WELDING VARIABLES.

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

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

$$Q = k \times E$$

Q = Heat input, i.e. quantity of heat transferred during welding to the weld per unit of length (kJ/mm)

E = Arc energy, i.e. energy conveyed by the welding procedure per unit of length (kJ/mm)

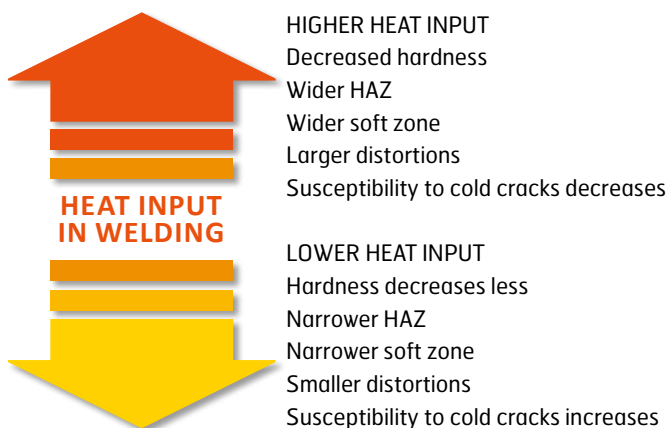
k = Thermal efficiency, i.e. relationship between heat input (Q) and arc energy (E)

U = Voltage (V)

I = Current (A)

v = Welding speed (mm/min)

FIGURE 6. BRASION RESISTANT STEELS. THE EFFECTS OF HEAT INPUT ON WELDABILITY.



4 WELDING CONSUMABLES

Undermatching ferritic welding consumables are used for welding of ordinary S355 structural steel. They are by far the most widely used consumables for abrasion resistant steels, and they are recommended for all hardness classes.

Undermatching austenitic consumables are originally intended for welding of austenitic stainless steels. They are a safe choice especially for the hardest abrasion resistant steels and thick plates as well as for repair welding.

4.1 UNDERMATCHING I.E. SOFT FERRITIC WELDING CONSUMABLES

In welding of abrasion resistant steels, the hydrogen content of ferritic consumables has a strong impact on the susceptibility to cold cracking. Therefore, ferritic consumables must be low in hydrogen – that is hydrogen content $HD \leq 5 \text{ ml/100 g}$ (hydrogen content class H5).

A welding consumable is defined as undermatching, if the pure weld metal produced by it is essentially softer than the steel. The yield strength of pure weld metal produced by undermatching filler metal is about 500 MPa and its toughness is good. Undermatching, low hydrogen filler metal is recommended for welding of abrasion resistant steels because of its many advantages, table 4.

TABLE 4. THE ADVANTAGES OF UNDERMATCHING WELDING CONSUMABLES COMPARED TO HIGH STRENGTH CONSUMABLES.

Advantages
Good welding properties
Extensive selection and good availability
Cost-effective both at purchase as well as during use
Lower stress level in the weld
A tough and ductile welding consumable tolerates stress well
Lower carbon equivalent and, respectively, lower hardenability
Lower susceptibility to cold cracking
Tolerates hydrogen better than a higher-strength welding consumable
Less need to increase working temperature than with higher-strength welding consumables

The recommended ferritic undermatching consumables for the common welding processes are given in tables 5a and 5b.

TABLE 5a. RAEX 400/450/500. UNDERMATCHING FERRITIC WELDING CONSUMABLES. EN CLASSIFICATION. Corresponding, or nearly corresponding brands (Esab). Yield strength of pure weld metal max. about 500 MPa. The “X” in the standard can mean one or more specification markings.

MAG solid wire welding (weld metal)	MAG flux-cored welding: Metal-cored wire	MAG flux-cored welding: Rutile flux-cored wire	Submerged arc welding: Wire+ flux	Manual metal arc welding
EN ISO 14341: G 46 X OK Autrod 12.64 (G 46 3 M G4Si1, G 42 2 C G4Si1)) OK AristoRod 12.63 (G 46 4 M G4Si1, G 42 2 C G4Si1))	EN ISO 17632: T 46 X PZ6102 (T 46 4 M M 2 H5)	EN ISO 17632: T 46 X OK Tubrod 15.14 (T 46 2 P M 2 H5, T 46 2 P C 2 H5)	EN ISO 14171 S 46X OK Autrod 12.32+ OK Flux 10.71 (S 46 4 AB S3Si)	EN ISO 2560: E 46 X OK 55.00 (E 46 5 B 32 H5)
EN ISO 14341: G 42 X OK Autrod 12.51 (G 42 3 M G3Si1, G 38 2 C G3Si1)	EN ISO 16834: T 42 X OK Tubrod 14.12 (T 42 2 M M 1 H10, T 42 2 M C 1 H10)		EN 756 S 38 X OK Autrod 12.22+ OK Flux 10.71 (S 38 4 AB S2Si)	EN ISO 2560: E 42 X OK 48.00 (E 42 4 B 42 H5)

TABLE 5b. RAEX 400/450/500. UNDERMATCHING FERRITIC WELDING CONSUMABLES. AWS CLASSIFICATION. Corresponding, or nearly corresponding brands (Esab). Yield strength of pure weld metal max. about 500 MPa. The “X” in the standard can mean one or more specification markings.

MAG solid wire welding	MAG flux-cored welding: Metal-cored wire	MAG flux-cored welding: Rutile flux-cored wire	Submerged arc welding: Wire+ flux	Manual metal arc welding
AWS A5.18 ER70S-X OK Autrod 12.51 (ER70S-6) OK AristoRod 12.63 (ER70S-6)	AWS A5.18 E70C-X OK Tubrod 14.12 (E70C-6M, E70C-6C) PZ6102 (E70C-6M H4)	AWS A5.20 E71T-X OK Tubrod 15.14 (E71T-1, E71T-1M)	AWS A5.17 F7X OK Autrod 12.22+ OK Flux 10.71 (F7A5-EM12K)	AWS A5.1 E7018X OK 48.00 (E7018) OK 55.00 (E7018-1)

The contents of this brochure represent general suggestions. SSAB AB accepts no responsibility for their suitability in individual cases. The user is therefore responsible to make the necessary adaptations to the conditions in each individual case.

TABLE 6. THE ADVANTAGES AND CHARACTERISTICS OF AUSTENITIC STAINLESS CONSUMABLES IN WELDING OF ABRASION RESISTANT STEELS.

Good welding properties
Good selection and availability
High purchase price
The stress level of the weld is low
Very tough and ductile welding consumable
Austenitic microstructure dissolves hydrogen without susceptibility to cold cracking
Usually no need to increase working temperature
Withstands welding stresses

TABLE 7a. RAEX 400/450/500. UNDERMATCHING AUSTENITIC WELDING CONSUMABLES, EXAMPLES. EN CLASSIFICATION.

Corresponding, or nearly corresponding brands (Esab). Strength class of pure weld metal max. about 500 MPa. The “X” in the standard can mean one or more specification markings.

MIG solid wire welding	MIG flux-cored welding: Metal-cored wire	MAG flux-cored welding: Rutile flux-cored wire	Submerged arc welding: Wire+ flux	Manual metal arc welding
EN 12072: G 18 8 Mn	EN 12073: T 18 8 Mn X	EN 12073: T 18 8 Mn X EN 14700: T Fe 10	EN 12072: S 18 8 Mn	EN 1600: E 18 8 MnX
OK Autrod 16.95 (G 18 8 Mn)	OK Tubrod 15.34 (T 18 8 Mn M M 2)	OK Tubrodur 14.71 (T Fe 10)	OK Autrod 16.97 (S18 8 Mn) + OK Flux 10.93	OK 67.45 (E 18 8 Mn B 4 2)

TABLE 7b. RAEX 400/450/500. UNDERMATCHING AUSTENITIC WELDING CONSUMABLES, EXAMPLES. AWS CLASSIFICATION.

Corresponding, or nearly corresponding brands (Esab). Strength class of pure weld metal max. about 500 MPa. The “X” in the standard can mean one or more specification markings.

MIG solid wire welding	MAG flux-cored welding, Metal-cored wire	MAG flux-cored welding, Rutile flux-cored wire	Submerged arc welding Wire+ flux	Manual metal arc welding
AWS 5.9 ER307	AWS 5.9 EC307	AWS 5.22 EC307T-x	AWS 5.9 ER307	AWS 5.4 E307-X
OK Autrod 16.95 (ER307)	OK Tubrod 15.34	OK Tubrodur 14.71	OK Autrod 16.97+ OK Flux 10.93	OK 67.45

5 PREVENTION OF COLD CRACKING

Keeping the level of hydrogen penetrating into the welded joint low is crucial in preventing cold cracking. In order to stay below critical hydrogen content, it is necessary to use welding methods and consumables with a low hydrogen content. In addition, welding instructions of Raex have to be complied with. A correct working temperature and heat input in order to achieve a suitable cooling rate play a key role in welding. A sufficiently high interpass temperature must be used in multi-run welding. The need to prevent cold cracking is emphasised when the hardness of the steel and the plate thickness increase. A plate that was stored cold must warm up thoroughly, at least to room temperature (+20°C), before welding or other plate processing.

5.1 CONTROLLING THE HARDENING OF THE MICROSTRUCTURE OF A WELDED JOINT

A martensitic microstructure implies good resistance to wear. If the joint cools too quickly after welding, martensite can become detrimentally hard and low in ductility in the weld metal and/or heat affected zone of the weld. Cold cracking is prevented by restricting the hardening of the microstructure with correct welding parameters. The hardenability of steel and welding consumables appears from their carbon equivalent value.

5.2 CONTROLLING HYDROGEN CONTENT

Keeping the hydrogen level low in the consumable and the heat affected zone is crucial in preventing cold cracking. It is recommended to use a low-hydrogen welding method and low-hydrogen consumables to achieve a hydrogen content of max. 5 ml/100 g. A low hydrogen level can be achieved with the correct consumables, for example, gas-shielded arc welding (MAG) with solid wire and flux-cored wire, submerged arc welding, and manual metal arc welding basic-coated rods. The manufacturers' instructions must be complied with when selecting, using and storing consumables.

The entry of hydrogen into the welded joint is increased by moisture on the surface of the groove, as well as dirt and contaminants such as grease or paint. To minimise cold cracking, the top of the groove must be kept completely dry and metallic clean before and during welding.

5.3 RELIEVING RESIDUAL STRESS IN A WELDED JOINT

Cold cracking can be efficiently prevented by relieving residual stress. The easiest way to relieve residual stress in the welded joints of Raex steels is to use undermatching ferritic or austenitic consumables. The stress can also be relieved with certain welding techniques. Especially when welding thin plates, the size of the weld needs to be optimised, and unnecessarily large welds are to be avoided. The temperature must be kept uniform in the different parts of the structure at all stages of welding. If needed, the structure to be welded should be supported or secured during tack welding or welding.

5.4 PRACTICAL TIPS FOR WELDING

Ways to relieve residual stress and improve the strength of the welded structure are presented in table 8.

5.5 WELDING AT CORRECT WORKING TEMPERATURE

Suitably high working temperature and sufficient heat input slow down the cooling of a welded joint to the correct rate. Thanks to these measures there will be no cold cracking.

The correct working temperature is determined on the basis of the following factors:

- Steel grade and its carbon equivalent value.
- Combined plate thickness.
- Heat input.
- Hydrogen content of welding consumable.
- Carbon equivalent value of welding consumables.
- Strength level of welding consumables.
- Type of welding consumable (ferritic / austenitic).

The need to raise the working temperature increases with the carbon equivalent, hardness and plate thickness of the steel grade. The typical carbon equivalent values of Raex steels for each plate thickness are given in their respective data sheets. Plate-specific carbon equivalent values which can be used in the preparing of a detailed welding plan are given in material certificates.

The recommended working temperatures for Raex 400, Raex 450 and Raex 500 are shown in figure 7. The recommendations are based on standard EN 1011-2. The working temperatures apply to undermatching ferritic consumables with hydrogen content 5 ml/100 g or below.

The working temperature is usually raised by preheating. In multi-run welding the energy brought to the joint by the previous run may be sufficient to maintain the correct working temperature before the welding of the next run, so external heating is not required during welding. In multi-run welding, the working temperature recommendations apply as the minimum interpass temperature. The interpass temperature may not be lower than the working temperature recommendation and not higher than +220°C. The smaller the hydrogen content generated by the welding method, the less need there is to raise the working temperature. If consumables HD>5 ml/100 g need to be used, the working temperature must be raised above the values in the table. The need to raise the working temperature decreases as the heat input is increased.

Raising the working temperature is especially important in tack welding and repair welding, because a small and local weld cools quickly and hardens at a rapid rate. Starting and stopping the welding run at the corners of a structure should be avoided. Experience in the welding of hardened steels speaks for the clear advantages of preheating. Even moderate preheating to temperatures under +100°C affects weldability favourably, also for plate thicknesses that do not require preheating according to the instructions. In welding large-sized and complicated structures, as well as in especially difficult conditions, a working temperature above the tabular values but below +220°C must be used. Working temperatures or interpass temperatures higher than that should not be used, because they decrease the hardness of the weld.

TABLE 8. PRACTICAL WAYS TO RELIEVE RESIDUAL STRESS.

Relieve residual stress already during the planning stage.
Minimise rigidity differences in various parts of the structure.
Optimise the size of the weld.
Predict and control distortions.
Use prestressing in the welding of large structures.
Favour small gaps in constructions to be welded.
Make good use of two-side full penetration grooves, when welding of thick plates.
Grind smooth the edges and corners of a welded steel structure.
Finish the welding of a fatigue critical structure by grinding smooth the connections between welds and parent metal.

FIGURE 7. UPDATED PREHEATING TABLE FOR WELDING

Steel grade	Plate thickness, mm									
	<div><div></div><div>1020304050607080</div></div>									
Raex 400	+20		+75	+100	+125	+150	+175			
Raex 450	+20	+75	+100	+125	+150	+175			+200	
Raex 500	+20	+100	+125	+150	+175		+200			

6 ACHIEVING AN OPTIMAL COMBINATION OF PROPERTIES IN WELDED JOINTS

Strength, hardness and resistance to wear are the things required of welded joints of abrasion resistant steel. Depending on the use and the usage conditions, other requirements include impact strength and case-specific properties. Despite hardness, there are no other general numeral requirements. Optimal properties in the weld area are ensured with the correct welding parameters and the recommended working temperature.

6.1 RECOMMENDED WELDING PARAMETERS

The recommended welding parameters are determined with the variable $t_{8/5}$. Achieving optimal properties in a welded joint requires that the selected heat input corresponds to a cooling time $t_{8/5} = 10\text{--}20$ seconds. In practical welding work the cooling time of 10 seconds corresponds to the minimum value of heat input, and the cooling time of 20 seconds to the maximum value of heat input. A too small $t_{8/5}$ (quick cooling) increases the hardening of the HAZ and susceptibility to cold cracking. A too large $t_{8/5}$ (slow cooling) decreases the hardness, strength and impact toughness of the joint.

In figures 8 a to f the recommended minum and maximum values of heat input for RAEX steels are presented. The working temperatures in figure 7 have been taken into account when determining heat input limits. The minimum heat input values in the figure 8 can be decreased by raising the working temperature. This may be necessary e.g. in tack welding and the welding of back welds or root passes.

6.2 SOFT ZONE IN WELDED JOINTS

The high strength and hardness of abrasion resistant steel is achieved by alloying and hardening. In fusion welding the temperature of the joint reaches $+1500^{\circ}\text{C}$ or more. Consequently, soft zones are formed in the joint when welding abrasion resistant steels. There is always softening in the HAZ. In addition, the weld metal usually remains softer than

the hard base metal. A typical hardness profile of welded joints in Raex steels is shown in figure 9.

Comments on hardness profile:

- The hardness of the HAZ in welded joints of Raex steels is typically lower than that of the base metal.
- The hardness profile of thermally cut Raex steel from the cut edge towards the base metal follows the hardness profile of the HAZ with two exceptions: the maximum hardness of the cut edge is somewhat greater, and the soft zone of the cut plate narrower than in a welded joint.
- The hardness of the HAZ in ordinary S355 steel is typically greater than the hardness of the base metal; the same applies to thermally cut edges.

The hardness profile of welded joints in Raex steels:

- The hardness of the weld metal depends on heat input and the alloying of the welding consumables.
- In the HAZ, close to the fusion line, the hardness equals that of the base metal.
- The softening of the HAZ is emphasised when heat input is increased, i.e. when the cooling time ($t_{8/5}$) becomes longer.

The softening tendency caused by welding must be taken into account especially with harder grades and small thicknesses. To avoid softening, thin plates should be welded at room temperature of $+20^{\circ}\text{C}$ and pre-heating is not allowed. Softening is prevented by limiting heat input and by observing the maximum work temperature/interpass temperature.

In abrasion resistant steel applications a soft zone does not usually shorten the useful life of the equipment or structure. However, in applications where structural strength is required, the soft zone should be taken into account in the design. In such structures welded joints should not be placed in the most stressed locations.

FIGURE 8a. MAXIMUM AND MINIMUM HEAT INPUT FOR RAEX 400 (BUTT WELD)

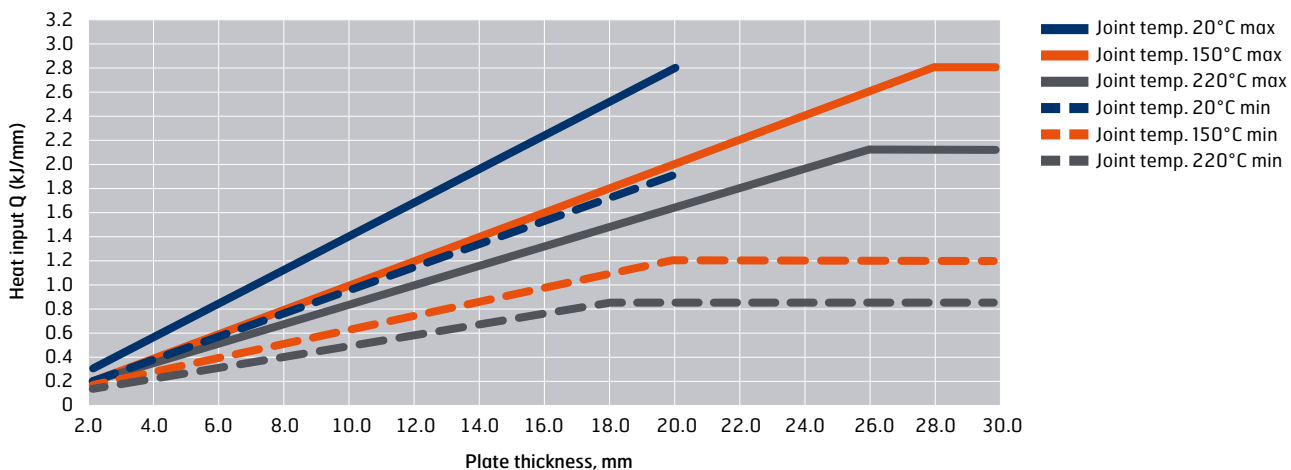


FIGURE 8b. MAXIMUM AND MINIMUM HEAT INPUT FOR RAEX 450 (BUTT WELD)

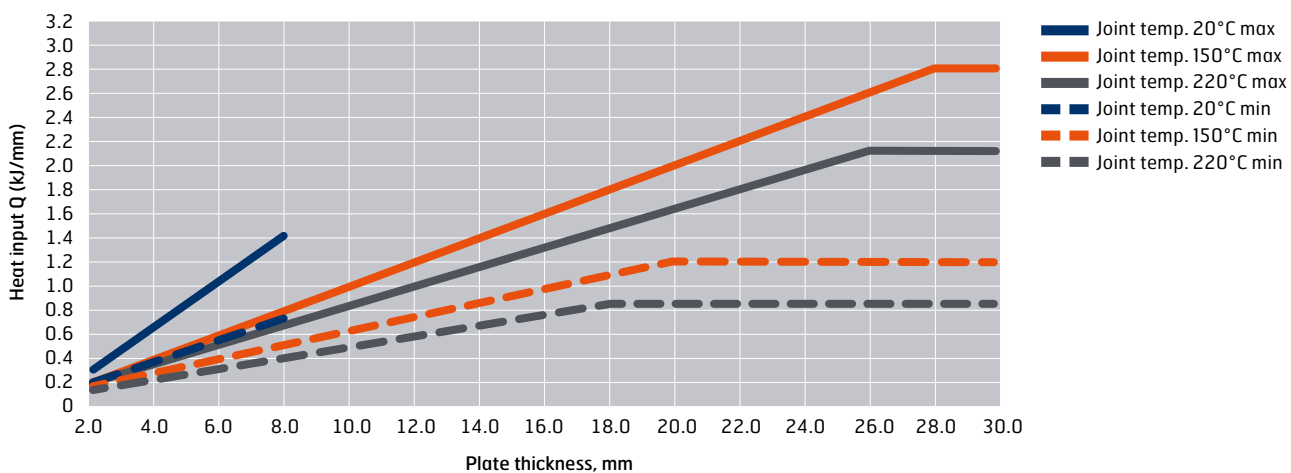


FIGURE 8c. MAXIMUM AND MINIMUM HEAT INPUT FOR RAEX 500 (BUTT WELD)

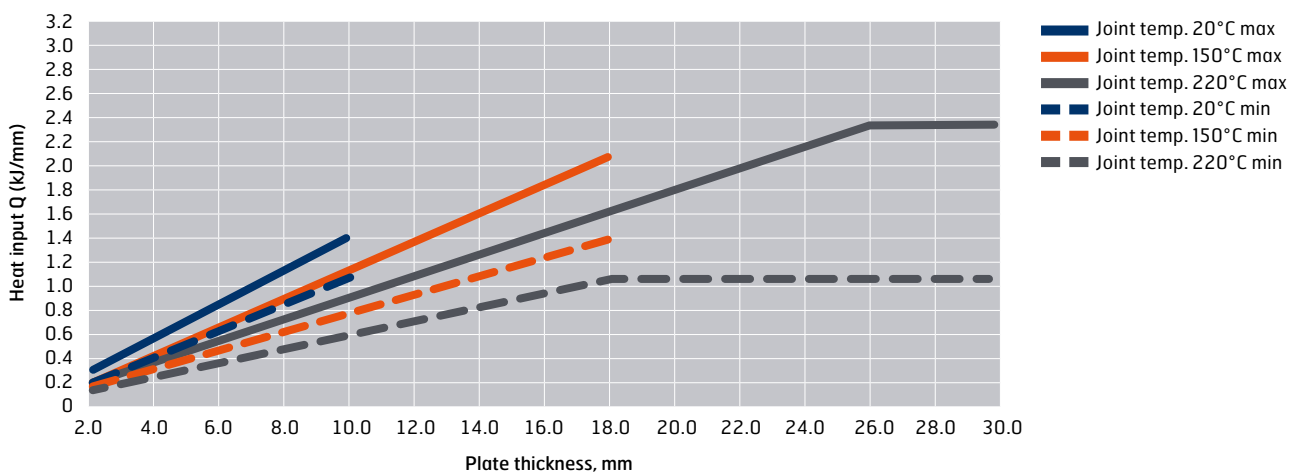


FIGURE 8d. MAXIMUM AND MINIMUM HEAT INPUT FOR RAEX 400 (FILLET WELD)

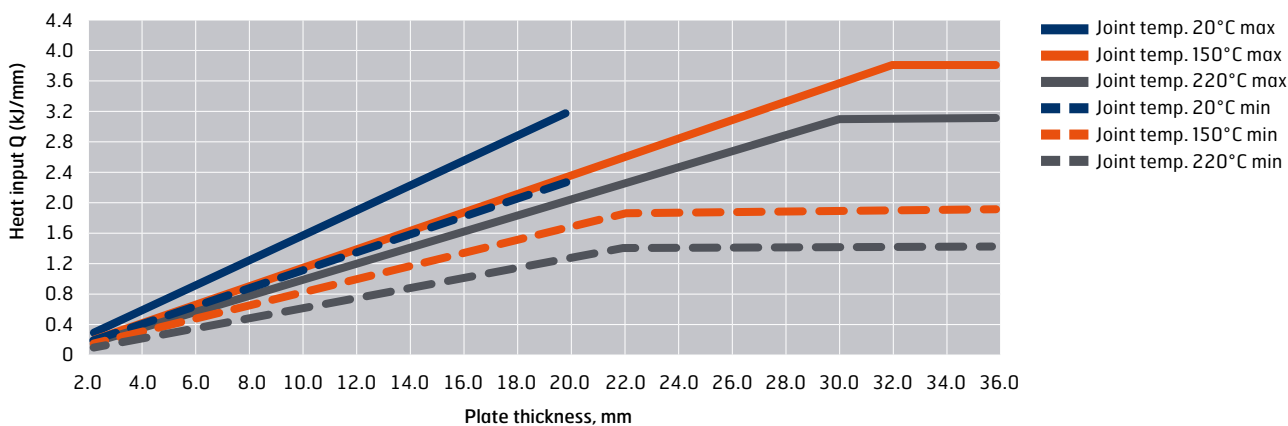


FIGURE 8e. MAXIMUM AND MINIMUM HEAT INPUT FOR RAEX 450 (FILLET WELD)

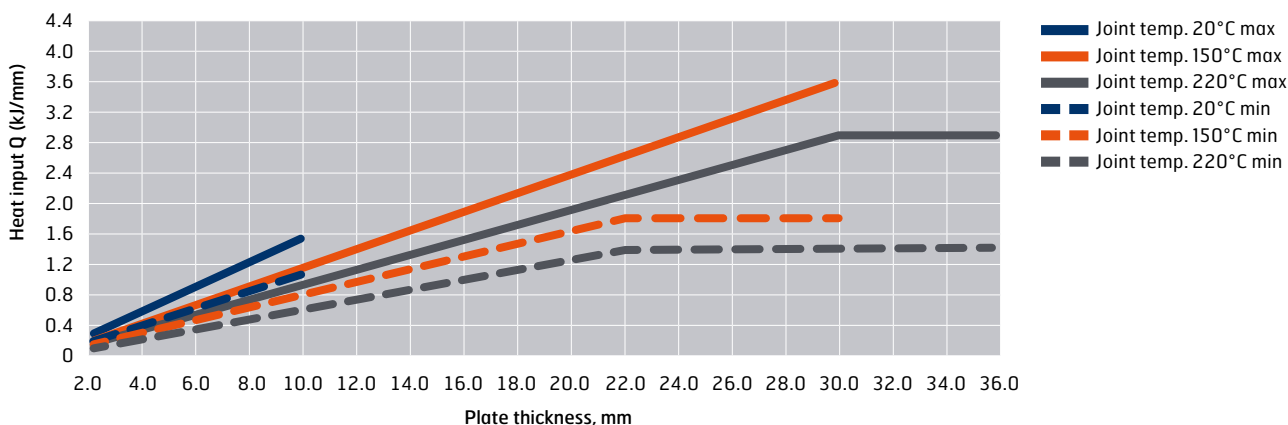


FIGURE 8f. MAXIMUM AND MINIMUM HEAT INPUT FOR RAEX 500 (FILLET WELD)

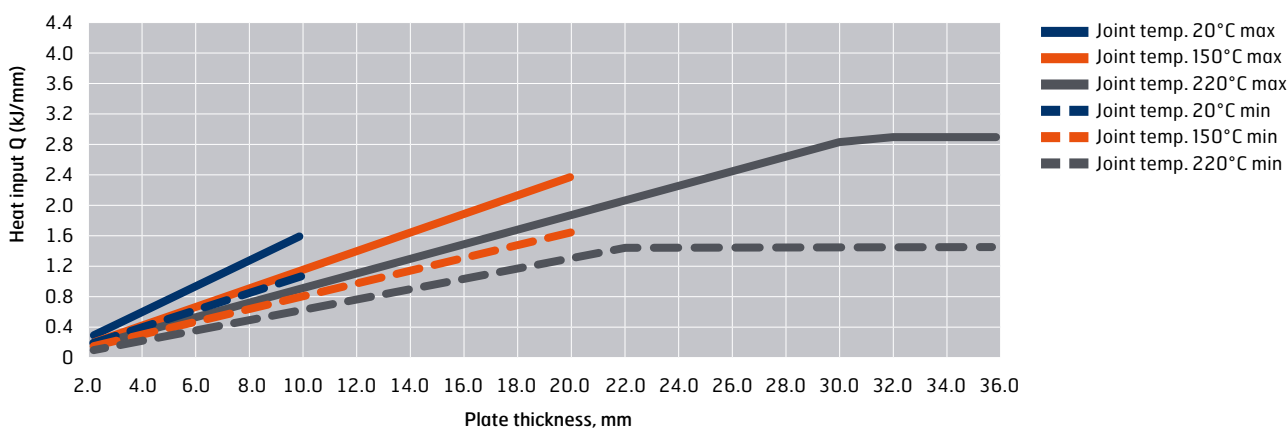
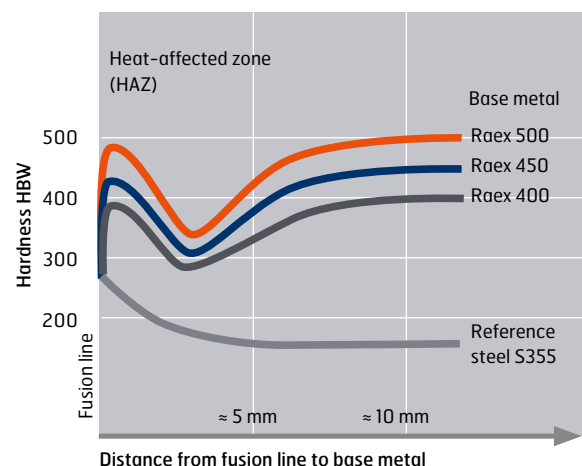


FIGURE 9. A TYPICAL HARDNESS PROFILE OF THE HAZ OF A WELDED JOINT WHEN USING THE RECOMMENDED $T_{8/5}$ COOLING TIMES.



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

Q = Heat input (kJ/mm)
 k = Thermal efficiency
 k = 0.8 for MAG, FCAW and MMA
 k = 1.0 for SAW
 U = Voltage (V), I = Current (A)
 v = Welding speed (mm/min)

Comparison with a corresponding hardness profile of a standard S355 structural steel.

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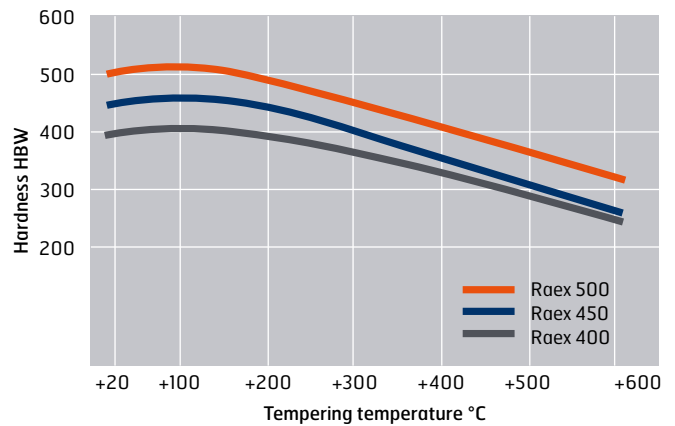
7 HEAT TREATMENT

Abrasion resistant steels are not intended to be heat treated. Heat treatment at elevated temperatures decreases their hardness, strength and wear resistance properties. Figure 10 shows the change in the hardness of Raex steels after tempering at various temperatures. As shown in the figure, some of the hardness generated by the hardening process has disappeared in tempering.

Heat treating in a temperature of more than about +250°C reduces the hardness. So, Raex steels cannot be stress relieved without reducing their hardness. Post weld heat treatment (PWHT) is not recommended, respectively.

In some applications, hardened steel is tempered or stress relieved by choice after welding or other machine shop operations. In this case, the mechanical properties entailed by such a heat treatment are accepted. The toughness of hardened steel can be improved by tempering – this may be the argument behind the decision of deliberate heat treatment. Stress relieving may reduce the stress formed in a steel plate during work shop fabrication.

FIGURE 10. THE EFFECT OF TEMPERING TEMPERATURE ON HARDNESS.



The hardness values have been measured at room temperature after tempering at elevated temperatures. The holding time was 2 hours, after which the steels cooled in air to room temperature.

8 BEHAVIORS OF STEEL IN THERMAL CUTTING

Thick plates and large objects are generally cut using thermal methods. During thermal cutting the steel surface undergoes local heat treatment to a depth of a few millimetres from the cut edge, including changes in the microstructure. Due to these changes both a hard and a soft layer are formed on the cut edge.

8.1 THERMAL CUTTING PROCEDURE

The surface of thermally cut steel experiences a short-term heating almost to the melting point of steel. After cutting, the cut cools down quickly, unless the cooling rate is controlled. In thermal cutting, steel surface undergoes microstructural changes similar to the HAZ. The outermost surface of the cut piece hardens. The hardened surface is susceptible to cold cracking. Under the hardened surface, a soft zone has been formed, figure 11. The soft zone has undergone annealing. The width of both zones depends on the cutting method and cutting parameters.

8.2 CONTROLLING SURFACE HARDNESS BY INCREASING THE WORKING TEMPERATURE

In thermal cutting it is recommended that the hardness of the heat-treated surface is controlled so as to ensure that the surface remains undamaged. A sufficiently low maximum hardness prevents cracks from forming on the cut edge. Preheating is often used to control the hardening. The recommended working temperatures for thermal cutting are shown in figure 12.

Preheating above the room temperature can be avoided when the cutting speed is adjusted to be suitably slow and when cutting nozzles and other equipment are chosen accordingly. In order to find the best cutting method, it is advisable to contact our Technical Customer Service or the cutting equipment manufacturer.

8.3 PREVENTION OF SOFTENING IN THERMAL CUTTING

The cutting energy of large steel sections is freely transmitted to the surrounding plate, which accelerates the cooling of the cutting area and restricts the width of the soft zone. However, in the flame cutting of plates 30 mm or less in thickness, the distance between cutting lines must be at least 200 mm in order to avoid the softening of the entire plate. The cutting order can be conveniently used to control softening.

Reduced section size and plate thickness increase softening. With small sections the thermal energy generated by the cutting method and the possible preheating

accumulates in the cut section, which slows the cooling process. Of all thermal cutting methods the ones that cause the least softening are laser cutting and plasma cutting of suitable thicknesses. The soft zone of laser or plasma cut steel is narrower than that of flame cut steel (figure 13). Submerged plasma cutting and flame cutting efficiently control the softening of the cut section and are therefore suitable for the cutting of sections of all sizes. To control softening, it is recommended that cold cutting methods are used, for example non-thermal waterjet cutting or abrasive waterjet cutting.

8.4 PRACTICAL TIPS FOR THERMAL CUTTING

The effect of minus degree on the plate processing properties should be taken into account in the workshop. Plates that have been stored in a cold environment should be brought in well in advance before flame cutting and welding. Figure 13 shows the time needed for warming up, when a steel plate is brought inside from a subzero temperature. The measurements were performed for plates of three different thicknesses, in February in Northern Finland.

The test in figure 13 gave the following warming results from -20°C to +17°C:

- about 8 hours for a 12 mm plate
- about 12 hours for a 21 mm plate
- about 17 hours for a 40 mm plate.

The surface and the centre of the plate warm up at equal rate. Larger, thicker plates stacked one on the other will warm up more slowly. As a basic rule, a cold plate (width 2 m, length 6 m) that has been stored outside in a subzero temperature warms to room temperature in about 24 hours.

Practical tips:

- Before cutting, cold plates must be allowed to thoroughly warm-up to room temperature (+20°C).
- Plates from cold storage have to be moved to machine shop on the preceding day.
- Cold plates have to be stored on wooden bearers.
- A cold 40 mm plate (-20°C) warms to room temperature (+20°C) in about 24 hours.
- When cutting thick plates, an elevated working temperature should be used according to figure 12.
- For chip removal of a thermally cut section, the hardened surface and sharp edges must be removed by grinding.

FIGURE 11. ABRASION RESISTANT STEEL PLATE, 6 mm. TYPICAL HARDNESS PROFILE OF A THERMALLY CUT SURFACE ILLUSTRATED FROM THE CUT EDGE TOWARDS THE BASE STEEL.

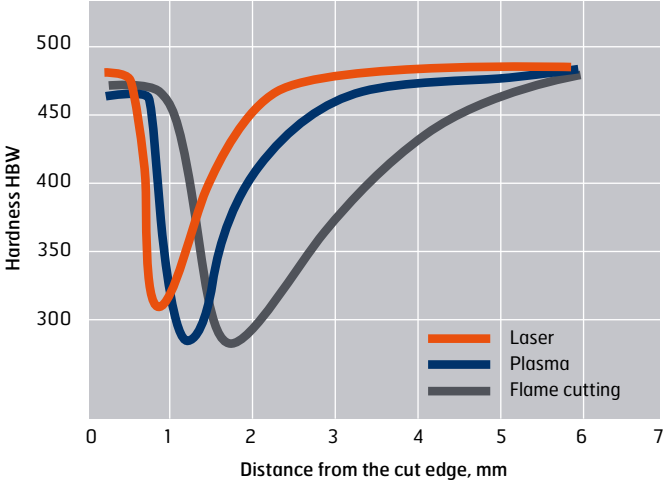


FIGURE 12. RECOMMENDED WORKING TEMPERATURE (°C) FOR FLAME CUTTING

Steel grade	Plate thickness, mm							
	<div><div></div><div>1020304050607080</div></div>							
Raex 400	+20			+100	+125		+150	
Raex 450	+20			+125		+150		
Raex 500	+20		+125	+150	+175			

FIGURE 13. THE WARM-UP TIME OF COLD (–20°C) STEEL PLATES IN A HALL WITH A TEMPERATURE BETWEEN +20°C AND +22°C.

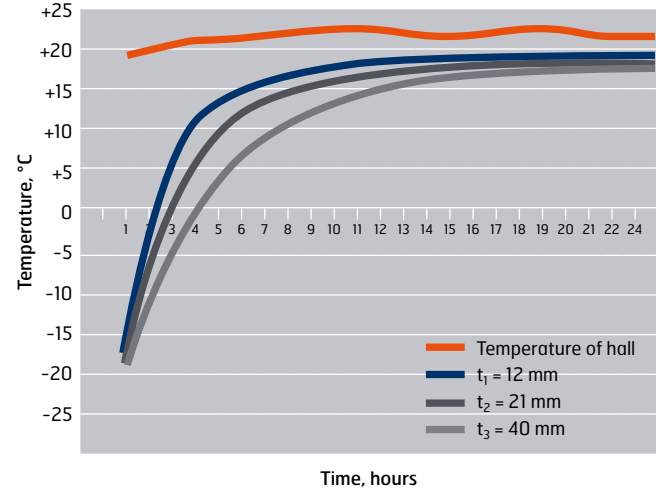


Plate sizes 12 x 1000 x 2000, 21 x 1000 x 1600 and 40 x 1000 x 2000 mm.










9 LASER CUTTING PROPERTIES

Laser cutting properties are dependent on the machine condition, power but also the chemical composition and surface quality of steel plate. For RAEX steels it is recommended to laser cut with the mill scale in order to achieve the best cut edge quality.

Laser cutting properties are very good up to 20 mm thicknesses in different delivery conditions. Mill scale and shot blasted surfaces can be laser cut with fiber -and CO₂

-laser by using the laser cutting machine suppliers default cutting parameters and speeds. For primer coated cutting speed needs to be reduced or primer coating needs to be evaporated before cutting the plate. It is recommended to evaporate primer coating before cutting in order to gain same cut edge quality as it is on mill scale or shot blasted surfaces. Different cut edge qualities can be seen from below with different delivery conditions cut with CO₂ -laser.

FIGURE 14. CUT EDGE QUALITY WITH DIFFERENT DELIVERY CONDITIONS.

Surface condition	10 mm	15 mm	20 mm
Mill scale			
Shot blasted			
Primer painted			

CONTACT