

WEAR-RESISTANT STEELS

Technical terms of delivery for heavy plates
1 March 2019

These general terms apply to all deliveries of durostat® wear-resistant steel supplied as heavy plate by companies in the voestalpine Steel Division. Please use the following link to find a list of the companies affiliated with the Steel Division:

www.voestalpine.com/stahl/en/Companies

The names of companies in the voestalpine Steel Division are referred to simply as **voestalpine** in this document.

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INTRODUCTION

voestalpine operates one of Europe's most modern steelmaking facilities in Linz. Each of the modern lines required for the production of high-quality heavy plates is located next to related facilities and is highly integrated into the works.

Our goal is to innovate and go beyond standard steels, to continually offer high-quality products. The most modern manufacturing technologies, continuous quality control systems as well as intense research and development guarantee optimum product quality.

These technical terms of delivery provide information on the ordering and processing of **wear-resistant heavy plates**. Please direct any of your questions to your responsible sales personnel or technical specialist at voestalpine.

Subject to change pursuant to further development.

The current version is available at www.voestalpine.com/durostat

STEEL GRADES

- » durostat 400
- » durostat 450
- » durostat 500
- » durostat B2

QUALITY MANAGEMENT

voestalpine is a quality leader in a challenging market environment, and it has become the company philosophy to meet the justified expectations and requirements of both the market and the customer with respect to every possible aspect of quality. Comprehensive quality management is a central component of the company strategy. In addition to this comprehensive quality management system, production monitoring using the most modern testing systems is also a necessity. These systems are inspected on a regular basis by external and independent agencies.

COMPREHENSIVE QUALITY MANAGEMENT

The voestalpine companies meet the highest standards of quality management and are certified pursuant to **Lloyd's Register QA Ltd.** in the United Kingdom as well as **ISO 9001** and **IATF 16949**.

This has been confirmed by numerous customer awards presented for best quality performance. Focus has been continually on this pursued path as well as on consistent implementation of all quality standards.

STATE-OF-THE-ART TESTING TECHNIQUES

voestalpine uses the most modern testing techniques and methods, laboratory information and management systems equipped with state-of-the-art technologies. The technical expertise of our testing and inspection laboratories is certified in accordance with international standards, e.g. **ISO/IEC 17025** and **ISO/IEC 17020**, and is accredited by Austrian national standards.

durostat 400, durostat 450, durostat 500

The steel grades durostat 400, durostat 450 and durostat 500 are wear-resistant special steels with hardness of approx. 400 HB, 450 HB resp. 500 HB. These steels provide high levels of resistance to mechanical wear and are specially suitable for components exposed to heavy abrasion, e.g. loading devices, shovels of wheel loaders, bodies of trough tipping wagons, conveyors, excavator components, road machines, screens and crushers.

The technical terms of delivery apply for plate thicknesses from

- » 6 - 120 mm for durostat 400
- » 6 - 70 mm for durostat 450
- » 8 - 50 mm for durostat 500

STEEL GRADE OVERVIEW

Steel grade
durostat 400
durostat 450
durostat 500

Table 1:
Steel grades

PRODUCTION PROCESS

The steel grades durostat 400, durostat 450 and durostat 500 are produced via the LD route. Their high level of hardness is adjusted by means of accelerated cooling after hot rolling (direct hardening) or through conventional chill hardening. Direct hardening is preferred because toughness is improved and scale formation reduced. State-of-the-art alloying technologies with low carbon content guarantee excellent weldability.

CHEMICAL COMPOSITION

HEAT ANALYSIS

GUARANTEED VALUES

Steel grade	Mass [%]									
	C max.	Si max.	Mn max.	P max.	S max.	Al _{tot.} min.	Cr max.	Mo max.	B max.	Ti max.
durostat 400	0.18	0.60	2.10	0.025	0.010	0.020	1.00	0.50	0.005	0.050
durostat 450	0.23	0.60	2.10	0.025	0.010	0.020	1.00	0.50	0.005	0.050
durostat 500	0.30	0.60	2.10	0.025	0.010	0.020	1.00	0.50	0.005	0.050

Table 2:
Chemical
Composition

The steel is fine-grain melted and can contain microalloying elements such as Nb and V.

CARBON EQUIVALENT

Steel grade	Plate thickness [mm]	Mass [%]	
		CEV ¹⁾ max.	CET ²⁾ max.
durostat 400	6 ≤ 35	0.52	0.35
	> 35 - 120	0.57	0.37
durostat 450	6 ≤ 15	0.57	0.37
	> 15 - 70	0.59	0.39
durostat 500	8 ≤ 30	0.59	0.44
	> 30 - 50	0.67	0.47

Table 3:
Carbon
equivalent

¹⁾ CEV = C + Mn/6 + (Cr + Mo + V)/5 + (Ni + Cu)/15, according to IIW

²⁾ CET = C + (Mn + Mo)/10 + (Cr + Cu)/20 + Ni/40, according to SEW 088

AS-DELIVERED CONDITION

The high level of hardness is achieved by direct quenching (accelerated cooling directly after hot rolling) or conventional quenching.

HARDNESS

HARDNESS IN AS-DELIVERED CONDITION

Steel grade	Hardness [HB]
durostat 400	360 - 440
durostat 450	410 - 490
durostat 500	460 - 540

Table 4:
Hardness in
as-delivered
condition

MECHANICAL PROPERTIES

NOTCH IMPACT ENERGY

On request and surcharge we offer following guaranteed values for notch impact energy:

NOTCH IMPACT ENERGY IN AS-DELIVERED CONDITION

Steel grade	Plate thickness [mm]	Notch impact energy ¹⁾ -40 °C, longitudinal min. [J]
Guaranteed values		
durostat 400	6 - 50	27
	> 50 - 120	upon request
durostat 450	6 - 50	20
	> 50 - 70	upon request
durostat 500	8 - 50	upon request
Standard values ²⁾		
durostat 400	-	50
durostat 450	-	30
durostat 500	-	20

¹⁾ Notch impact bending test in accordance with EN ISO 148-1 on Charpy-V longitudinal samples at -40 °C. The mean value from 3 individual samples must reach the specified requirements. No individual value below 70 % of the guaranteed mean value. For thicknesses < 12 mm, subsize-specimen with dimensions of 10 x 7.5 mm or 10 x 5 mm are tested. The guaranteed value is reduced in proportion to the sample cross-section.

²⁾ Typical values of notch impact energy at a plate thickness of 20 mm.

Table 5:
Notch impact
energy

TENSILE STRENGTH

STANDARD VALUES FOR AS-DELIVERED CONDITION (PLATE THICKNESS 20 MM)

Steel grade	Yield strength [MPa]	Tensile strength [MPa]	Fracture elongation $L_0 = 5,65 \sqrt{S_0}$ [%]
durostat 400	1,000	1,250	10
durostat 450	1,100	1,400	9
durostat 500	1,200	1,550	8

Table 6:
Tensile strength

QUALITY TEST

Brinell hardness is measured according to ISO 6505 per heat and for every 40 t. Hardness is measured approx. 1 - 2 mm under the surface. The heat analysis is provided as proof of the chemical composition. Notch impact bending test is done on longitudinal samples at -40 °C and has to be agreed upon ordering.

TOLERANCES AND SURFACE FINISH

Unless otherwise agreed, tolerances according to EN 10029 (thickness tolerance according to class A, flatness tolerance according to class N) and surface finish according to EN 10163-A1 are valid.

MARKING

In general, marking consists of

- » voestalpine symbol
- » Steel grade designation
- » Plate number
- » Heat number

MATERIAL TESTING CERTIFICATE

Type of certificate according to EN 10204 must be agreed upon ordering.

PROCESSING GUIDELINES

COLD FORMING

durostat 400, durostat 450 and durostat 500 can be cold formed if the high hardness is taken into account. The prerequisite for cold forming is the proper preparation of the cut edges. Grinding of the flame- or shear-cut edges in the bending area is recommended. Due to the high level of hardness, bending must take place slowly and steadily.

RECOMMENDED MINIMUM BENDING RADII

Position of the bending edge to the rolling direction	Smallest permitted bending radius		
	durostat 400	durostat 450	durostat 500
Longitudinal	4 x plate thickness	5 x plate thickness	5 x plate thickness
Transverse	3 x plate thickness	4 x plate thickness	4 x plate thickness

Table 7:
Minimum
bending radii

HEAT TREATMENT

In order to maintain its hardness, durostat 400, durostat 450 and durostat 500 may not be heated above 250 °C.

WELDING

GENERAL

Compliance with the generally valid and accepted rules for the welding of low-alloy, high-strength, fine-grain structural steels is mandatory pursuant to EN 1011-2 and the STAHL-EISEN material data sheet SEW 088.

WELD SEAM PREPARATION

Weld preparation can be in the form of machining or thermal cutting. Preheating for thermal cutting is not required for durostat 400 and 450 up to a thickness of 20 mm. Preheating of at least 60 to 80 °C is recommended for greater thicknesses and for durostat 500 throughout the entire thickness range. The fusion faces must be dry and free of impurities before welding begins.

WELDING TECHNIQUES

All conventional welding techniques, both automatic and manual, can be used. Inert-gas-shielded arc welding (MAG, MIG) with solid wire has the advantage of very low hydrogen content in the weld metal and is particularly suitable with regard to resistance against cold cracking.

WELDING CONSUMABLES

Welding consumables are selected according to strength requirements in the welded joint. In an effort to prevent cold cracking, the hydrogen content in the filler metal should be very low ($HD < 5 \text{ ml/100 g SG}$). This is guaranteed by using solid wires in inert gas shielded arc welding. Basic coated electrodes with controlled hydrogen content are recommended for manual metal arc welding processes. Basic electrodes and welding powder must be subjected to secondary drying according to the manufacturer's instructions. durostat plates can be welded by means of "undermatching". The following welding consumables are recommended:

RECOMMENDED WELDING CONSUMABLES FOR durostat 400 / 450 / 500

Welding process, welding filler metals				
Manual electric welding (SMAW) -111	WIG (GTAW) -141	MAG (GMAW) -135	MAG cored wire (FCAW) -136 / -138	UP (SAW) -12
BÖHLER FOX EV 50 (AWS A5.1: E7018-1H4R)	BÖHLER EMK 6 (AWS A5.18: ER70S-6)	BÖHLER EMK 6 (AWS A5.18: ER70S6)	BÖHLER Ti 52 T FD (AWS A5.36: E71T1-M21A4-CS1-H4)	Union S 3 Si + UV421TT (AWS A5.17: F7A8-EH12K)
BÖHLER FOX EV 60 (AWS A5.5: E8018-C3H4R)	BÖHLER Ni 1-IG (AWS A5.28: ER80S-Ni1 mod)	Union K 52 (AWS A5.18: ER70S6)	BÖHLER HL 46 MC (AWS A5.36: E70T15-M21A0-CS1-H4)	BÖHLER SUBARC T55 + UV421TT (AWS A5.17: F7A8-EC1)
Phoenix 120 K (AWS A5.1: E7018-1)	Union I 52 (AWS A5.18: ER70S6)		BÖHLER Kb 52 T-FD (AWS A5.36: E70T5-M21A4-CS1-H4)	

Table 8:
Recommended
welding con-
sumables

If the structure requires that a welded joint provide the same wear resistance as the base material, the coating layers can be created with wear-resistant electrodes, e.g. UTP DUR 600, or the equivalent filler rods for gas-shielded welding, e.g. UTP A DUR 600.

You will find further information and alternative welding consumables at www.boehler-welding.com. Our experienced welding experts will be happy to consult you.

HEAT CONTROL DURING WELDING

Table 9 contains recommendations for heat control during the welding of durostat® plate grades. Welding parameters should be set to achieve $t_{8/5}$ times of 5 to 20 seconds in an effort to ensure high strength and toughness properties.

RECOMMENDED HEAT CONTROL DURING THE ELECTRIC ARC WELDING OF durostat 400 / 450 / 500

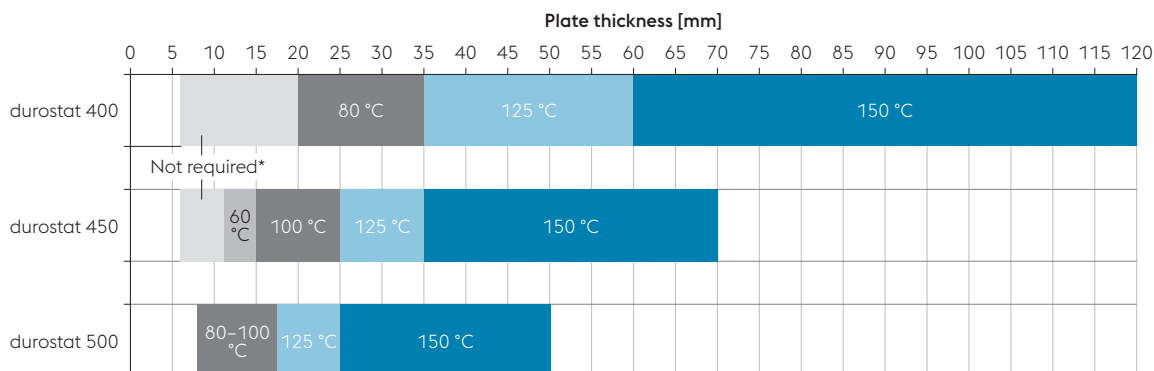
Base material	Recommended preheating [°C]	Interpass temperature [°C]	$t_{8/5}$ range [s]
durostat 400	Ambient temperature (> 5) - 150	≤ 150	5 - 20
durostat 450			
durostat 500	80 - 150		

Table 9:
Recommended
heat control
during electric
arc welding

Preheating within the ranges presented in Table 9 is also recommended. Because the required preheating temperature is dependent on the carbon equivalent, hydrogen content of the weld metal and heat input, we recommend that each case be separately determined pursuant to EN 1011 1011 and SEW 088. Figure 1 shows the recommended preheating temperatures in the example of MAG welds with a heat input of 1 kJ/mm and a hydrogen content of 3 ml/100 grams of weld metal, depending on the range of available plate thicknesses.

RECOMMENDED PREHEATING TEMPERATURES DURING WELDING

in the example of MAG WELDS with $E_s = 1$ kJ/mm ($k = 0.85$) and $HD = 3$ ml/100 g SG



* for component temperatures > 5 °C and dry, clean faces

Figure 1:
Recommended
preheating
temperatures
for welding

Figure 2 also shows the plate thickness ranges for durostat 400 and 450 with regard to heat input. Preheating of the base material is not required for butt welds (to the left of the corresponding blue limit line). In order to limit the width of the heat affected zone and not to exceed the recommended $t_{8/5}$ time, it is recommended that heat input be adapted to the plate thickness (dark blue limit lines). This results in optimum heat input without preheating in the green and yellow areas for durostat 400 and exclusively in the yellow area for durostat 450. Preheating is always recommended for durostat 500.

WELDING WITHOUT PREHEATING OF durostat 400 / 450

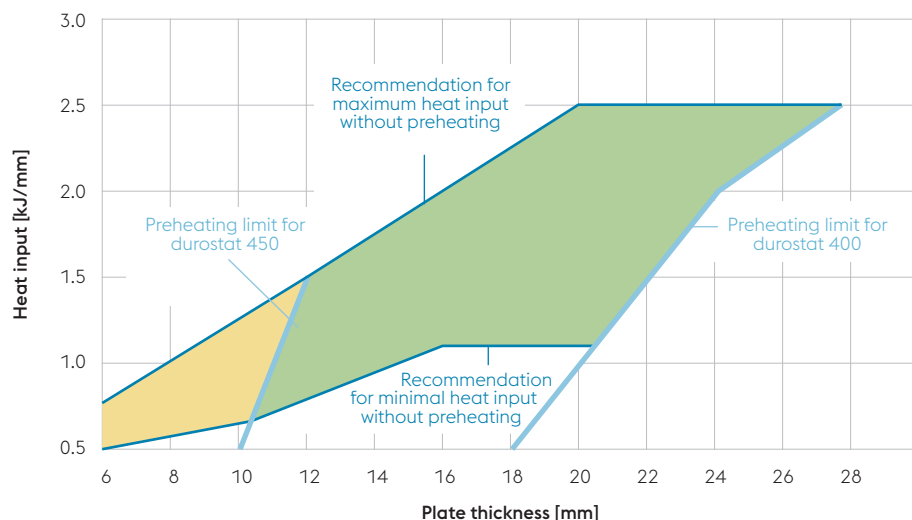


Figure 2:
Welding without
preheating

The preheating temperatures recommended here apply to butt welds. For single fillet welds, lower preheating temperatures can be assumed because of the lower residual stress under normal circumstances and assuming sufficient experience of the welder.

Where special strength and toughness is required of the weld metal, an interpass temperature of 150 °C should not be exceeded.

WELDING CALCULATOR APP

With the Welding Calculator App from voestalpine (available for Android and iOS), you can now easily calculate cooling times $t_{8/5}$ and preheating temperatures pursuant to EN 1011-2 and based on your individual specifications. You can also optimize your welding activities with retroactive calculations. Based on climatic conditions, the app also recommends parameters for edge drying and features a module for calculating the required volume of welding consumables.



You will find more detailed information about the Welding Calculator App at
www.voestalpine.com/alform/en/Service/Welding-Calculator

DELIVERABLE DIMENSIONS durostat 400

Thickness mm																		
120																		
100																		
90																		
80																		
70																		
65																		
60																		
55																		
50																		
45																		
40																		
35																		
30																		
25																		
20																		
15																		
14																		
13																		
12																		
11																		
10																		
9																		
8																		
7																		
6																		
Width mm		1,500	1,600	1,700	1,800	1,900	2,000	2,100	2,200	2,300	2,400	2,500	2,600	2,700	2,800	2,900	3,000	

Maximum length: 12,000 mm

Maximum length: 10,000 mm at a thickness of 6 mm and a width of equal to or greater than 2,000 mm.

Different dimensions on request.

DELIVERABLE DIMENSIONS durostat 450

Thickness mm																	
70																	
65																	
60																	
55																	
50																	
45																	
40																	
35																	
30																	
25																	
20																	
15																	
14																	
13																	
12																	
11																	
10																	
9																	
8																	
7																	
6																	
Width mm		1,500	1,600	1,700	1,800	1,900	2,000	2,100	2,200	2,300	2,400	2,500	2,600	2,700	2,800	2,900	3,000

Maximum length: 12,000 mm

Maximum length: 10,000 mm at a thickness of 6 mm and a width of equal to or greater than 2,000 mm.

Different dimensions on request.

DELIVERABLE DIMENSIONS durostat 500

Thickness mm													
50													
45													
40													
35													
30													
25													
20													
15													
10													
8													
Width mm		1,500	1,600	1,700	1,800	1,900	2,000	2,100	2,200	2,300	2,400	2,500	

Maximum length: 12,000 mm

Different dimensions on request.

durostat B2

durostat B steels are heat-treatable steels delivered in as-rolled condition for components in agricultural machines (e.g. ploughs and harrows), cutting edges for front-end loaders or brick-molding boxes.

The technical terms of delivery apply for plate thicknesses from

» 8 - 50 mm.

STEEL GRADE OVERVIEW

Steel grade
durostat B2

Table 10:
Steel grades

PRODUCTION PROCESS

durostat B2 steels are produced via the LD route.

CHEMICAL COMPOSITION

HEAT ANALYSIS

GUARANTEED VALUES

Steel grade	Mass [%]									
	C max.	Si max.	Mn max.	P max.	S max.	Al _{tot.} min.	Cr max.	Mo max.	B max.	Ti max.
durostat B2	0.30	0.60	2.10	0.025	0.010	0.020	1.00	0.50	0.005	0.050

Table 11:
Chemical
Composition

The steel is fine-grain melted and can contain microalloying elements such as Nb and V.

AS-DELIVERED CONDITION

The plates are delivered in as-rolled condition (hot-rolled, untreated), since usually heat treatment such as quenching or tempering is carried out on the finished parts.

MECHANICAL PROPERTIES

STANDARD VALUES FOR AS-ROLLED CONDITION (PLATE THICKNESS 20 MM)

Steel grade	Yield strength [MPa]	Tensile strength [MPa]	Fracture elongation $L_0 = 5.65 \sqrt{S_0}$ [%]	Hardness [HB]
durostat B2	400	650	20	200

Table 12:
Mechanical
Properties

ACHIEVABLE HARDNESS (FOLLOWING QUENCHING IN WATER)

Steel grade	Hardness [HB]
durostat B2	approx. 500

Table 13:
Achievable
Hardness

QUALITY TEST

The heat analysis is provided as proof of the chemical composition.

TOLERANCES AND SURFACE FINISH

Unless otherwise agreed, tolerances according to EN 10029 (thickness tolerance according to class A, flatness tolerance according to class N) and surface finish according to EN 10163-A1 are valid.

MARKING

In general, marking consists of:

- » voestalpine symbol
- » Steel grade designation
- » Plate number
- » Heat number

MATERIAL TESTING CERTIFICATE

Type of certificate according to EN 10204 must be agreed upon ordering.

PROCESSING GUIDELINES

HOT FORMING AND HEAT TREATMENT

durostat B steel plates can be hot formed and machined in untreated condition. Cold forming in as-rolled condition is only possible to a limited extent.

HOT FORMING AND HEAT TREATMENT TEMPERATURES

Steel grade	Hot forming [°C]	Quenching and tempering in	
		Water [°C]	Oil [°C]
durostat B2	1,100 - 800	870 - 900	900 - 930

Table 14:
Heat
Treatment

WELDING

GENERAL

The durostat B2 grade in as-rolled condition requires increased care during welding as a result of its good hardenability and high strength. Compliance with the generally valid and accepted rules for the welding of low-alloy, high-strength, fine-grain structural steels is mandatory pursuant to EN 1011-2 and the STAHL-EISEN material data sheet SEW 088. If the material is to be welded after hardening, the recommendations for welding consumables and the technical conditions of durostat 500 can be applied.

WELD SEAM PREPARATION

Weld preparation can be in the form of machining or thermal cutting. A preheating temperature of at least 60 to 80 °C is recommended for thermal cutting. The fusion faces must be dry and free of impurities before welding begins.

WELDING TECHNIQUES

All conventional welding techniques, both automatic and manual, can be used. Inert-gas-shielded arc welding (MAG, MIG) with solid wire has the advantage of very low hydrogen content in the weld metal and is particularly suitable with regard to resistance against cold cracking.

WELDING CONSUMABLES

The choice of welding consumables depends on the strength requirements of the welded joint. durostat sheets can be welded using the technique of undermatching. The welding consumables listed in Table 15 are recommended.

RECOMMENDED WELDING CONSUMABLES FOR durostat B2

Welding process, welding filler metals				
Manual electric welding (SMAW) -111	WIG (GTAW) -141	MAG (GMAW) -135	MAG cored wire (FCAW) -136 / -138	SP (PA) -12
BÖHLER FOX EV 50 (AWS A5.1: E7018-1H4R)	BÖHLER EMK 6 (AWS A5.18: ER70S-6)	BÖHLER EMK 6 (AWS A5.18: ER70S6)	BÖHLER Ti 52 T FD (AWS A5.36: E71T1-M21A4-CS1-H4)	Union S 3 Si + UV421TT (AWS A5.17: F7A8-EH12K)
BÖHLER FOX EV 60 (AWS A5.5: E8018-C3H4R)	BÖHLER Ni 1-IG (AWS A5.28: ER80S-Ni1 mod)	Union K 52 (AWS A5.18: ER70S6)	BÖHLER HL 46 MC (AWS A5.36: E70T15-M21A0-CS1-H4)	BÖHLER SUBARC T55 + UV421TT (AWS A5.17: F7A8-EC1)
Phoenix 120 K (AWS A5.1: E7018-1)	Union I 52 (AWS A5.18: ER70S6)		BÖHLER Kb 52 T-FD (AWS A5.36: E70T5-M21A4-CS1-H4)	

Table 15:
Recommended
welding
consumables

The filler metals for recommended above are also recommended for welding after hardening. If materials are to be welded prior to hardening, please consult one of our experienced welding experts. You will find further information and alternative welding consumables at www.boehler-welding.com.

If the structure requires that a welded joint provide the same wear resistance as the base material, the coating layers can be created with wear-resistant electrodes, e.g. UTP DUR 600, or the equivalent filler rods for gas-shielded welding, e.g. UTP A DUR 600.

In an effort to prevent cold cracking, the hydrogen content in the filler metal should be very low ($HD < 5 \text{ ml}/100 \text{ g SG}$). This is guaranteed by using solid wires in inert gas shielded arc welding. Basic coated electrodes with controlled hydrogen content are recommended for manual metal arc welding processes. Basic electrodes and welding powder must be subjected to secondary drying according to the manufacturer's instructions.

HEAT CONTROL DURING WELDING

Table 16 contains recommendations for heat control during the welding of durostat B2 grades. Welding parameters that lead to $t_{8/5}$ times of 5 to 20 seconds result in optimum mechanical properties in the welded joint. In an effort to avoid excessive hardening in the heat-affected zone (in non-hardened condition), preheating is recommended within the range indicated in Table 16. Because the required preheating temperature is dependent on the carbon equivalent, hydrogen content of the weld metal and heat input, we recommend that each case be separately determined pursuant to EN 1011 1011 and SEW 088.

RECOMMENDED HEAT CONTROL DURING THE ELECTRIC ARC WELDING OF durostat B2

Base material	Recommended preheating [°C]	Interpass temperature [°C]	$t_{8/5}$ range [s]
durostat B2	80 - 150	≤ 150	5 - 20

Table 16:
Recommended
heat control
during electric
arc welding

WELDING CALCULATOR APP

With the Welding Calculator App from voestalpine (available for Android and iOS), you can now easily calculate cooling times $t_{8/5}$ and preheating temperatures pursuant to EN 1011-2 and based on your individual specifications. You can also optimize your welding activities with retroactive calculations. Based on climatic conditions, the app also recommends parameters for edge drying and features a module for calculating the required volume of welding consumables.



You will find more detailed information about the Welding Calculator App at
www.voestalpine.com/alform/en/Service/Welding-Calculator

DELIVERABLE DIMENSIONS durostat B2

Thickness mm													
50													
45													
40													
35													
30													
25													
20													
15													
10													
8													
Width mm		1,500	1,600	1,700	1,800	1,900	2,000	2,100	2,200	2,300	2,400	2,500	

Maximum length: 18,700 mm

Different dimensions on request.

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