

DILLIMAX 965

High strength fine grained structural steel

Quenched and tempered

Material data sheet, edition April 2016¹

DILLIMAX 965 is a high strength quenched and tempered, fine grained structural steel with a minimum yield strength of 960 MPa (140 ksi)² in its delivery condition (referring to the lowest thickness range).

DILLIMAX 965 is preferentially used for welded steel structures within mechanical constructions, plant constructions and structural steel works, such as machines for structural engineering, conveying plants, hoists and cranes.

Product description

Designation and range of application

DILLIMAX 965 can be delivered in three qualities as follows:

- **Basic (B)** with minimum impact values at -20 °C (-4 °F)²: **DILLIMAX 965 B**
Material No. 1.8941 – S960Q according to EN 10025-6
- **Tough (T)** with minimum impact values at -40 °C (-40 °F)²: **DILLIMAX 965 T**
Material No. 1.8933 – S960QL according to EN 10025-6
- **Extra tough (E)** with minimum impact values at -60 °C (-76 °F)²: **DILLIMAX 965 E**
Material No. 1.8934 – S960QL1

DILLIMAX 965 can be delivered in thicknesses from 6 to 120 mm ($\frac{1}{4}$ to 4.7 in.)² according to the dimensional program.

DILLIMAX 965 fulfils all requirements of EN 10025-6. If a CE marking according to EN 10025-1 is needed, an additional attestation for the corresponding quality according to EN 10025-6 has to be ordered.

¹ The current version of this material data sheet can be also found on <http://www.dillinger.de>.

² The approximately converted values in brackets are for information only.

Chemical composition

For the ladle analysis, the following limiting values in % are applicable:

DILLIMAX 965	C	Si	Mn	P	S	Cr	Ni	Mo	V+Nb	B
B, T, E	≤ 0.20	≤ 0.50	≤ 1.40	≤ 0.018	≤ 0.005	≤ 0.90	≤ 2.0	≤ 0.70	≤ 0.10	≤ 0.004

The steel is fine grained through sufficient aluminium content.

The limiting CEV^a values are lower than the values given in EN 10025-6:

Plate thickness t [mm]	DILLIMAX 965 max. CEV ^a (CET ^b) [%]	See EN 10025-6 max. CEV ^a [%]
t ≤ 50	0.70 (0.43)	0.82
50 < t ≤ 120		-

^a CEV = C + Mn/6 + (Cr+Mo+V)/5 + (Cu+Ni)/15

^b CET = C + (Mn+Mo)/10 + (Cr+Cu)/20 + Ni/40

Even lower carbon equivalent values may be agreed on request.

Delivery condition

Water quenched and tempered according to EN 10025-6.

Mechanical properties in the delivery condition

Tensile test at ambient temperature – transverse test pieces –

Plate thickness t [mm] (in.) ^a	Tensile strength	Minimum yield strength	Minimum elongation	
	R _m [MPa] (ksi) ^a	R _{eH} ^b [MPa] (ksi) ^a	A ₅ [%]	A _{2in.} ^c [%]
t ≤ 50 (2)	980 – 1 150 (142 – 167)	960 (140)	12	13
50 (2) < t ≤ 60 (2.4)	950 – 1 100 (138 – 160)	930 (135)		
60 (2.4) < t ≤ 100 (4)	900 – 1 100 (130 – 160)	850 (123)		
100 (4) < t ≤ 120 (4.7)	850 – 1 050 (123 – 152)	800 (116)		

^a The approximately converted values in brackets are for information only.

^b If not apparent, the yield strength R_{p0.2} is measured instead.

^c These values apply if tested according to ASTM A370.

Impact test on Charpy-V-specimens

DILLIMAX 965	Specimen direction	Impact energy KV ₂ [J] (ft.-lb.) ^a at test temperature
Basic (B)	longitudinal/transverse	30/27 (22/20) at -20 °C (-4 °F) according to EN 10025-6
Tough (T)	longitudinal/transverse	30/27 (22/20) at -40 °C (-40 °F) according to EN 10025-6
Extra tough (E)	longitudinal/transverse	30/27 at -60 °C (-76 °F)

^a The approximately converted values in brackets are for information only.

The specified minimum value is the average of 3 tests. One individual value may be below the minimum average value specified, provided that it is not less than 70 % of that value. For plate thicknesses below 12 mm, the test can be carried out on Charpy-V test pieces with reduced width; the minimum width must be 5 mm. The minimum impact value will be decreased proportionally.

Testing

Tensile and impact tests will be performed according to EN 10025-6 once per heat and 40 t.

Tests on every heat treatment unit may be possible on request. The test pieces are taken and prepared according to part 1 and 6 of EN 10025.

The tensile test is carried out on specimens of gauge length $L_0 = 5.65 \cdot \sqrt{S_0}$ respectively $L_0 = 5 \cdot d_0$, in accordance with EN ISO 6892- 1. Tensile tests according to ASTM A370 may be agreed. The impact test will be carried out on transverse Charpy-V-specimens in accordance with EN ISO 148-1 using a 2 mm striker.

Unless otherwise agreed, the test results are documented in an inspection certificate 3.1 in accordance with EN 10204.

Identification of plates

Unless otherwise agreed, the marking is carried out via steel stamps with at least the following information:

- steel grade (e.g. DILLIMAX 965 B, T or E)
- heat number
- number of mother plate and individual plate
- the manufacturer's symbol
- inspection representative's sign

Processing

The entire processing and application techniques are of fundamental importance to the reliability of products made from this steel. The user should ensure that his design, construction and processing methods are aligned with the material, correspond to the state-of-the-art that the fabricator has to comply with and are suitable for the intended use. The customer is responsible for the selection of the material. The recommendations of the EN 1011 (welding) and CEN/TR 10347 (forming) as well as recommendations regarding job safety in accordance with national rules should be observed.

Cold forming

Cold forming means forming below 500 °C (932 °F). DILLIMAX 965 can be cold formed with regard to its high yield strength. Flame cut or sheared edges in the bending area should be ground before cold forming. Cold forming is related to a hardening of the steel and to a decrease in toughness. Some codes may limit the maximum permissible strain during cold forming. Depending on the relevant code this can result in the need of larger bending radiuses than indicated in the chart. For larger cold forming amounts we recommend you to consult the steel producer prior to ordering.

During the processing, the necessary safety measures have to be taken, so that nobody will be exposed to a danger by a possible fracture of the work piece during the forming process.

The following geometries can usually be achieved by cold forming without the formation of surface defects (t is the plate thickness):

	Minimum bending radius	Minimum die width
Transverse direction	3 t	9 t
Longitudinal direction	4 t	12 t

Hot forming

If the temperature of about 500 °C (932 °F) is exceeded, the initial tempering can be altered so that the mechanical properties are affected. To regain the initial properties new quenching and tempering become necessary. In this respect we recommend you to contact the steel producer prior to ordering, in all cases where hot forming at higher temperatures is required.

Finally, it is the fabricator's responsibility to obtain the required values of the steel through an appropriate heat treatment.

Flame cutting and welding

Due to its high yield strength, DILLIMAX 965 requires special care during plate processing.

For flame cutting, the following minimum preheating temperatures are recommended: 50 °C (122 °F) for plate thickness up to 20 mm, 100 °C (212 °F) for plate thickness up to 50 mm and 150 °C (302 °F) for thicker plates. For general welding instructions, please consult the EN 1011. In order to ensure that the tensile strength of the weld metal fulfils the requirements of the base metal, the heat input and interpass temperature must be limited

during welding. Experience has shown that the welding conditions should be chosen so that the cooling time $t_{8/5}$ does not exceed 8 seconds. This is applicable when using suitable filler materials of a corresponding yield strength class.

The high yield strength of the base material must be taken into account when choosing the filler materials. It should be considered that increased heat input leads to lower tensile properties in the weld metal. If a stress relieving heat treatment is planned during or after plate processing, this must also be considered when selecting the filler materials. To avoid hydrogen-induced cold cracking, only filler materials, which add very little hydrogen to the base metal, may be used. Therefore, shielded arc welding should be preferred. For manual arc welding, electrodes with basic coating (type HD < 5 ml/100 g in accordance with ISO 3690) and dried according to the manufacturer's instructions should be used. With increasing plate thickness, increasing hydrogen charge and restraint of the weld, a soaking for hydrogen effusion immediately after welding is recommended.

Heat treatment

A stress relief heat treatment can be performed at a maximum temperature of 560 °C (1 040 °F) and maximum holding time of 60 minutes without significant impairment of the properties. After a stress relief heat treatment using the specified parameters, the requirements for mechanical and technological properties are met. It has to be specified prior to ordering if higher stress relieving temperatures or longer holding times have to be applied. The verification of appropriate stress relieving parameters for a delivered plate may be possible on request. Detailed instructions for flame cutting, welding, machining and about the structural properties of the DILLIMAX are provided in the technical information "*MAKE SAVINGS WITH HIGH STRENGTH STEELS – DILLIMAX*".

General technical delivery requirements

Unless otherwise agreed, the general technical delivery requirements in accordance with EN 10021 apply.

Tolerances

Unless otherwise agreed, the tolerances will be in accordance with EN 10029, with class A for thickness and table 4, steel group H, for the maximum flatness deviation. Smaller flatness deviations may be possible on request prior to order.

Surface quality

Unless otherwise agreed, the specifications will be in accordance with EN 10163-2, class A2.

Ultrasonic testing

If not agreed otherwise, DILLIMAX 965 fulfils the requirements of class S₁E₁ in accordance with EN 10160.

General note

If special requirements, which are not covered in this material data sheet, are to be met by the steel due to its intended use or processing, these requirements are to be agreed before placing the order.

The information in this data sheet is a product description. This data sheet is updated at irregular intervals. The current version is relevant. The latest version is available from the mill or as download at www.dillinger.de.

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