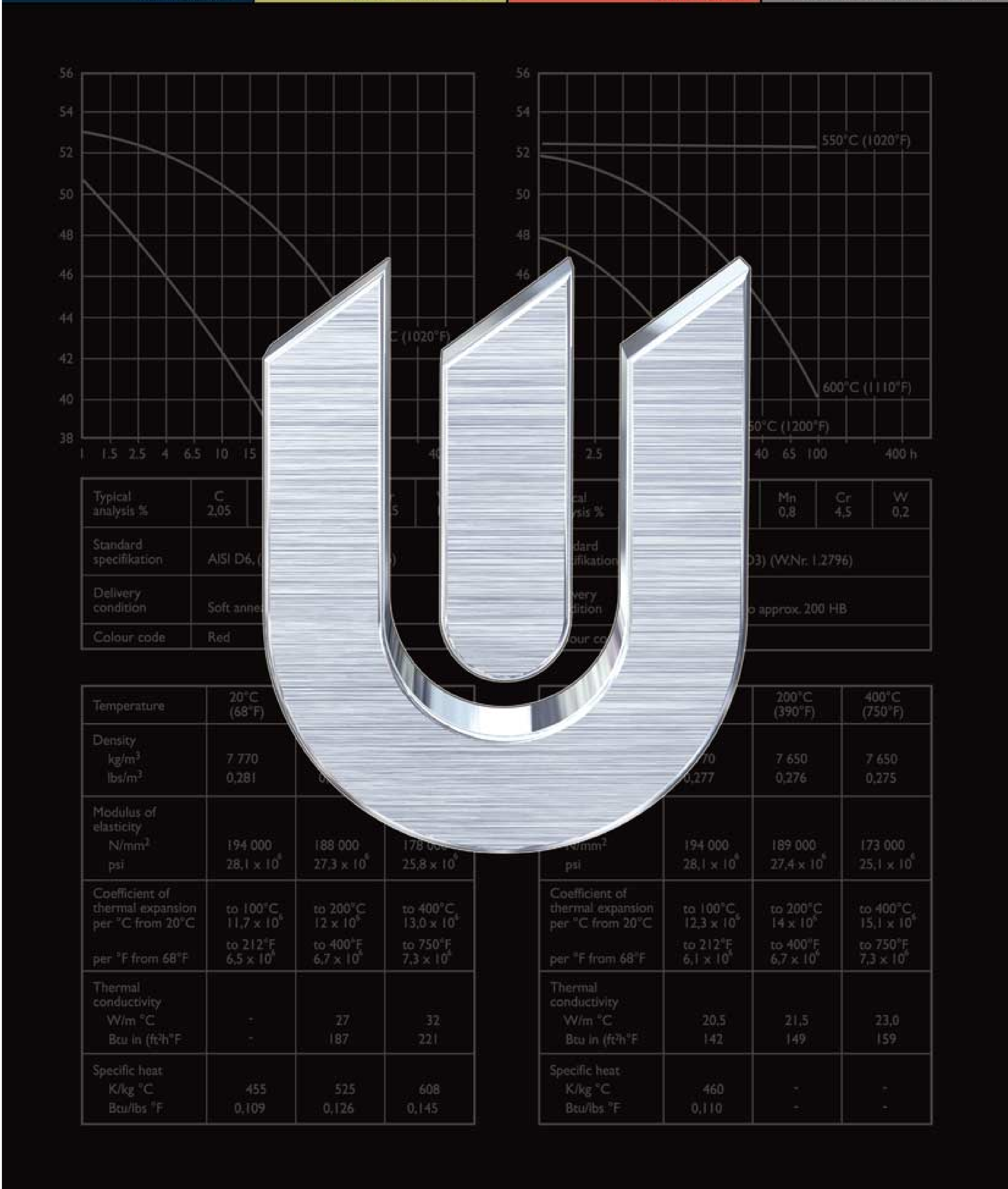
CALMAX

Plastic mould and cold work steel



General

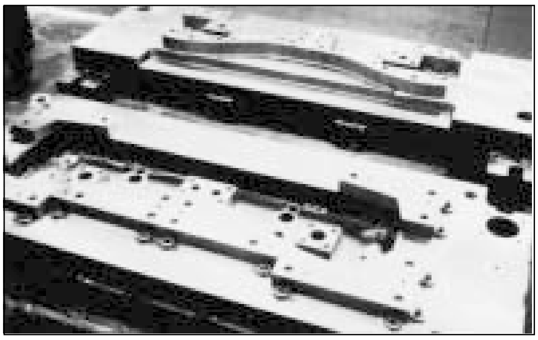
CALMAX is a chromium-molybdenum-vanadium alloyed steel characterized by:

- High toughness
- Good wear resistance
- Good through hardening properties
- Good dimensional stability in hardening
- Good polishability
- Good weldability
- Good flame- and induction hardenability.

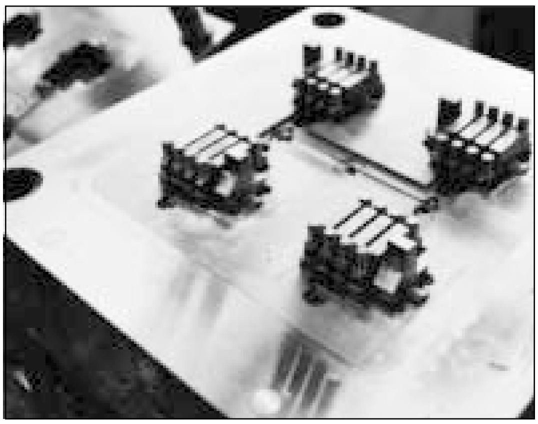
Typical analysis %	C 0,6	Si 0,35	Mn 0,8	Cr 4,5	Mo 0,5	V 0,2
Delivery condition	Soft annealed to approx. 200 HB					
Colour code	White/violet					

Applications

CALMAX is a steel suitable for both cold work and plastic applications. For further information see page 6 and 7.



Typical blanking die where CALMAX could be used because of the high demands on toughness.



Mould for the production of electrical components. CALMAX would be a good choice here because of the high demands on wear resistance.

Properties

PHYSICAL DATA

Temperature	20°C (68°F)	200°C (400°F)	400°C (750°F)
Density kg/m³ lbs/in³	 7 770 0,281	 7 720 0,279	 7 650 0,276
Modulus of elasticity N/mm² psi	 194 000 28,1 x 10^6	 188 000 27,3 x 10^6	 178 000 25,8 x 10^6
Coefficient of thermal expansion per °C from 20°C	to 100°C 11,7 x 10^{-6}	to 200°C 12,0 x 10^{-6}	to 400°C 13,0 x 10^{-6}
per °F from 68°F	to 212°F 6,5 x 10^{-6}	to 400°F 6,7 x 10^{-6}	to 750°C 7,3 x 10^{-6}
Thermal conductivity W/m °C Btu in (ft²h°F)	 – –	 27 187	 32 221
Specific heat J/kg°C Btu/lbs°F	 455 0,109	 525 0,126	 608 0,145

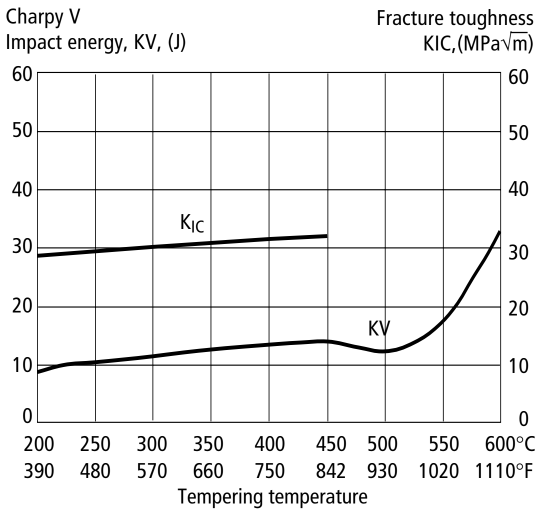
COMPRESSIVE STRENGTH

Approximate values at room temperature.

Hardness HRC	Rcm N/mm²	Rc0,2 N/mm²
56	2300	1900
58	2500	2000
60	2700	2100

IMPACT STRENGTH

Approximate values at room temperature for different tempering temperatures. Hardened at 960°C (1760°F). Quenched in air. Tempered twice.



Cover photos:
Cold work and plastic products where CALMAX would be a good choice for the die/mould.

Heat treatment

SOFT ANNEALING

Protect the steel and heat through to 860°C (1580°F), holding time 2h. Cool in furnace 20°C/h to 770°C (35°F/h to 1420°F), then 10°C/h to 650°C (18°F/h to 1200°F) and subsequently freely in air.

STRESS RELIEVING

After rough machining the tool should be heated through to 650°C (1200°F), holding time 2h.
Cool slowly to 500°C (930°F), then freely in air.

HARDENING

Preheating: 600–750°C (1110–1380°F).
Austenitizing temperature: 950–970°C (1740–1780°F), normally 960°C (1760°F).

Temperature °C	Temperature °F	Holding* time minutes	Hardness before tempering (HRC)
950	1740	30	62
960	1760	30	63
970	1780	30	64

* *Holding time = time at austenitizing temperature after the tool is fully heated through.*

Protect the part against decarburization and oxidation during hardening.

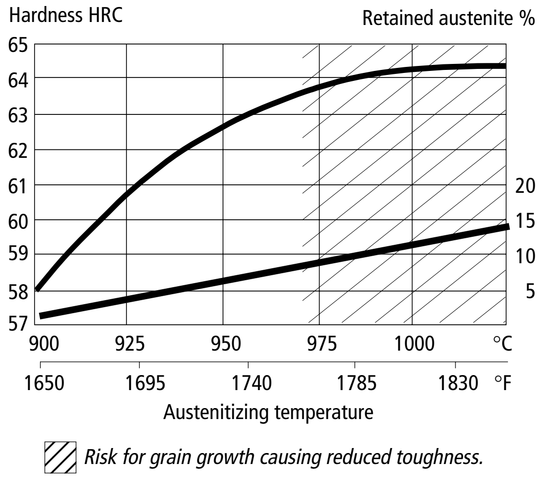
QUENCHING MEDIA

- Forced air/gas
- Vacuum furnace with sufficient overpressure
- Martempering bath or fluidized bed at 200–550°C (320–1020°F) followed by forced air cooling
- Oil.

Note 1: Quenching in oil gives an increased risk for dimensional changes and cracks.

Note 2: Temper the tool as soon as its temperature reaches 50–70°C (120–160°F).

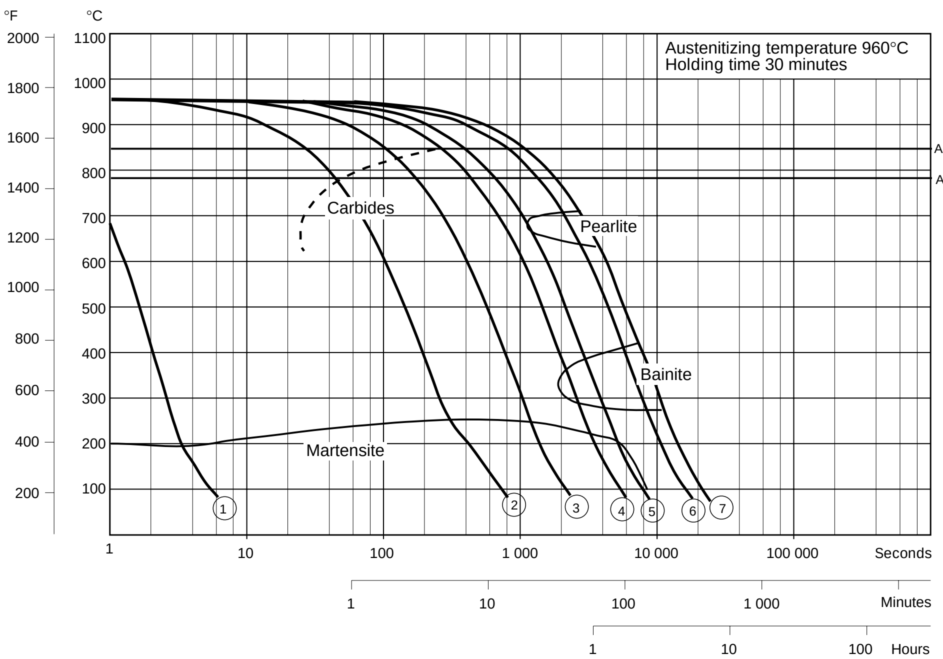
Hardness and retained austenite as a function of austenitizing temperature



Risk for grain growth causing reduced toughness.

CCT-graph

Austenitizing temperature 960°C. Holding time 30 minutes.

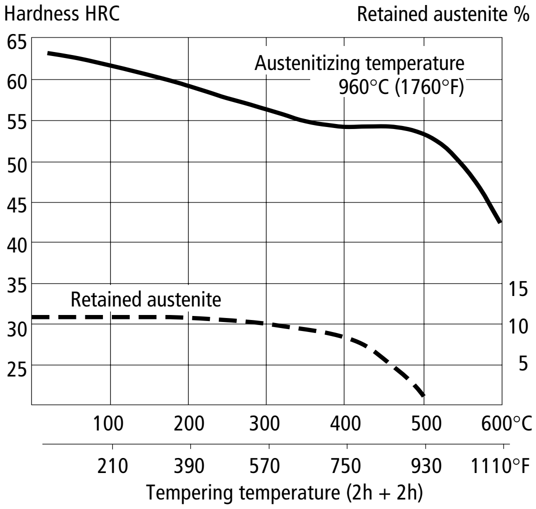


Cooling Curve No.	Hard-ness HV10	$T_{800–500}$ sec.
1	820	1
2	762	107
3	743	423
4	734	1071
5	657	1596
6	455	3228
7	413	4292

TEMPERING

Choose the tempering temperature according to the hardness required by reference to the tempering graph. Temper twice with intermediate cooling to room temperature. Lowest tempering temperature 180°C (360°F). Holding time at temperature minimum 2h.

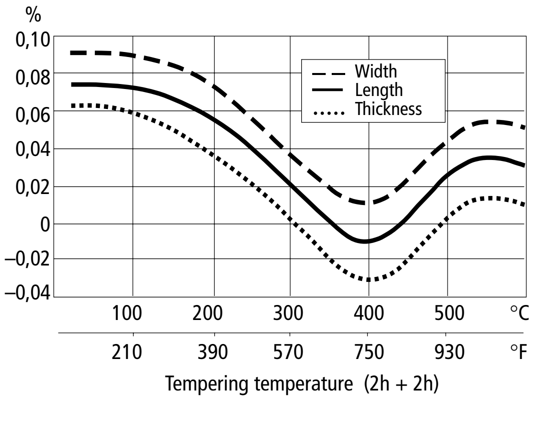
Tempering graph



DIMENSIONAL CHANGES

The dimensional changes during hardening and tempering vary depending on temperature, type of equipment and cooling media used during heat treatment.
The size and geometric shape of the tool are also of essential importance. Thus the tool should always be manufactured with enough working allowance to compensate for distortion. Use 0,20% as a guideline for *CALMAX*.
An example of dimensional changes for a plate 100 x 100 x 10 mm, hardened and tempered under ideal conditions, is shown in the figure below.

Hardening: 960°C (1760°F)/30 min./air.



SURFACE TREATMENT

Some tools are given a surface treatment in order to reduce friction and increase tool wear resistance. The most commonly used treatments are nitriding and surface coating with wear resistant layers of titanium carbide and titanium nitride (CVD, PVD).

Two commonly used nitriding processes are ion nitriding and gas nitriding. Ion nitriding is normally performed at a lower temperature than gas nitriding and is, therefore, the preferred method for *CALMAX* when a substrate hardness of ≥54 HRC is required.

Nitriding process	Temp. °C (°F)	Time (h)	Case depth mm	Substrate hardness HRC	Case hardness HV
Ion	465* (870*)	18	200	54	1075
Gas	510* (950*)	12	200	52	1075

** The nitriding temperature used should be 15–25°C (59–77°F) lower than the previously used tempering temperature.*

A thick case depth considerably reduces the toughness of the tool. The case depth, which can be controlled by the nitriding time, should be selected to suit the application in question.

CALMAX can also be CVD coated but the deposition temperature should not exceed 960°C (1760°F). The tool should be re-hardened after being coated.

PVD coatings can be deposited at temperatures between 200°C (390°F) and 500°C (930°F). If 200°C (390°F) is used, the *CALMAX* substrate hardness will be higher than that obtained at a deposition temperature of 500°C (930°F). However, the adhesion of the coating on the steel is better if a deposition temperature of 500°C (930°F) is used. The PVD deposition temperature should be approx. 20°C (68°F) lower than the previously used tempering temperature.

Machining recommendations

The cutting data below are to be considered as guiding values which must be adapted to existing local condition.

Condition: Soft annealed to approx. 200 HB

TURNING

Cutting data parameters	Rough turning carbide	Fine turning carbide	Fine turning High speed steel
Cutting speed (v_C) m/min f.p.m	 150–200 492–656	 200–250 656–820	 20–25 66–82
Feed (f) mm/r i.p.r	 0,2–0,4 0,008–0,016	 0,05–0,2 0,002–0,008	 0,05–0,3 0,002–0,01
Depth of cut (a_P) mm inch	 2–4 0,08–0,16	 0,5–2 0,02–0,08	 0,5–3 0,02–0,12
Carbide designation ISO US	P20–P30 C6–C5 Coated carbide	P10 C7 Coated carbide or cermet	– –

DRILLING

High speed steel twist drill

Drill diameter mm	Drill diameter inch	Cutting speed (v_c) mm	Cutting speed (v_c) inch	Feed (f) mm/r	Feed (f) i.p.r.
–5	–3/16	13–15*	43–49*	0,05–0,10	0,002–0,004
5–10	3/16–3/8	13–15*	43–49*	0,10–0,20	0,004–0,008
10–15	3/8–5/8	13–15*	43–49*	0,20–0,25	0,008–0,010
15–20	5/8–3/4	13–15*	43–49*	0,25–0,30	0,010–0,012

* *For coated HSS drill v_c =23–25 m/min. (75–82 f.p.m.).*

Carbide drill

Cutting data parameters	Type of drill		
	Solid carbide	Indexable insert	Brazed carbide[1]
Cutting speed (v_c) m/min f.p.m	120–150 394–492	210–230 689–755	70–100 230–328
Feed (f) mm/r i.p.r	 0,10–0,35[2] 0,004–0,014[2]	 0,03–0,12[2] 0,001–0,005[2]	 0,15–0,40[2] 0,006–0,016[2]

[1] Drills with internal cooling channels and a brazed tip.
[2] Depending on drill diameter.

MILLING

Face and side milling

Cutting data parameters	Rough milling carbide	Fine milling carbide
Cutting speed (v_c) m/min f.p.m	 160–240 525–787	 240–280 722–919
Feed (f_z) mm/tooth in/tooth	 0,2–0,4 0,008–0,016	 0,1–0,2 0,004–0,008
Depth of cut (a_p) mm inch	 2–5 0,08–0,20	 –2 0,08
Carbide designation ISO US	P20–P40 C6–C5 Coated carbide	P10–P20 C6–C7 Coated carbide or cermet

End milling

Cutting data parameters	Type of end mill		
	Solid carbide	Carbide indexable insert	High speed steel
Cutting speed (v_c) m/min f.p.m	 120–150 394–492	 150–200 492–656	 40–45[1] 131–148[1]
Feed (f_z) mm/tooth in/tooth	 0,006–0,20[2] 0,0002–0,008[2]	 0,06–0,20[2] 0,002–0,008[2]	 0,01–0,35[2] 0,0004–0,014[2]
Carbide designation ISO US	 – –	 P15–P40 C6–C5	 – –

[1] For coated HSS end mill v_c =55–60 m/min. (180–197 f.p.m.).
[2] Depending on radial depth of cut and cutter diameter.

GRINDING

A general grinding wheel recommendation is given below. More information can be found in the Uddeholm brochure "Grinding of Tool Steel".

Wheel grinding

Type of grinding	Soft annealed condition	Hardened condition
Face grinding straight wheel	A 46 HV	A 46 HV
Face grinding segments	A 24 GV	A 36 GV
Cylindrical grinding	A 46 LV	A 60 KV
Internal grinding	A 46 JV	A 60 JV
Profile grinding	A 100 LV	A 120 JV

Welding

Good results when welding *CALMAX* can be achieved if proper precautions are taken.

1. Always keep the arc length as short as possible. The electrode should be angled at 90° to the joint sides to minimize under cut. In addition, the electrode should be held at an angle of 75–80° to the direction of forward travel.
2. For large repairs, weld the initial layers with a soft weld metal. Make the two first layers with the same electrode diameter and current.
3. Large repair welds should be made at elevated temperature.
4. The joints should be prepared properly.

TIG Welding recommendations

Consumables	Hardness as welded	Hardness after rehardening	Preheat temper
UTPA 73G2	53–56 HRC	51 HRC	
UTPA 67S	55–58 HRC	52 HRC	
CastoTig 5*	60–64 HRC		200–250°C (390–480°F)
CALMAX/CARMO TIG WELD	58–61 HRC	58–61 HRC	

**CastoTig 5 should not be used for more than 4 layers because of the increased risk of cracking.*

MMA (SMAW) Welding recommendations

Consumables	Hardness as welded	Hardness after rehardening	Preheat temper
ESAB OK 84.52	53–54 HRC	49 HRC	
UTP 67S	55–58 HRC	52 HRC	
CITODUR 600B	57–60 HRC	53–54 HRC	
Fontargen E 711	57–60 HRC	53–54 HRC	200–250°C (390–480°F)
CALMAX/CARMO WELD	58–61 HRC	58–61 HRC	

HEAT TREATMENT AFTER WELDING

Hardened condition

Temper at 10–20°C (50–70°F) below the original tempering temperature.

Soft annealed condition

Heat through to 860°C (1580°F) in protected atmosphere. Cool in furnace at 10°C/h to 650°C (18°F/h to 1200°F), then freely in air.

Further information on welding of tool steel is given in the Uddeholm brochure "Welding of Tool Steel".

EDM

If spark erosion is performed in the hardened and tempered condition, the tool should be given an additional temper at about 25°C (35°F) lower than previous tempering temperature

Cold work applications

TYPICAL APPLICATION AREAS

- General blanking and forming
- Heavy duty blanking and forming
- Deep drawing
- Coining
- Cold extrusion dies with complicated geometry
- Rolls
- Shear blades
- Prototype tooling.

TRADITIONAL PRESSWORK STEELS

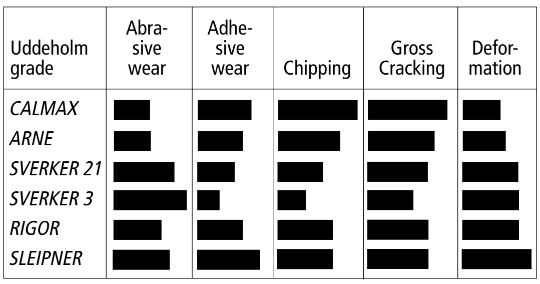
The majority of presswork tools used today are manufactured using traditional tool steels such as O1, A2, D2, D3 or D6.
These steels offer an apparent adequate wear resistance and their hardness range is suitable for most applications. However, the poor toughness, flame- and induction hardenability and weldability of these grades often results in low productivity and high maintenance costs due to unexpected tool failure. For this reason, the new general presswork tool steel *CALMAX* has been developed. The aim of *CALMAX* is to secure an optimal tooling economy, i.e. the lowest tooling costs per part produced.

TODAYS DEMANDS

The pressworking industry has gone through some considerable changes in the last decades. Stainless steel and surface coated strip have been commercialized and high speed presses have been developed. To these technological advances just in time (JIT) manufacture and the moves toward increased productivity and tool life guarantees must be added. The traditional presswork tool steels are still routinely specified and selected but often result in poor tool performance and productivity.

The well balanced properties profile of *CALMAX* is much better matched to modern work materials and manufacturing methods. *CALMAX* offers the high degree of safety which is essential for optimal tooling performance and maximum productivity.

RESISTANCE TO FAILURE MECHANISMS



Plastic moulding applications

TYPICAL APPLICATION AREAS

- Long run moulds
- Moulds for reinforced plastics
- Moulds for compression moulding.

The excellent combination of toughness and wear resistance makes *CALMAX* suitable for different moulding applications.

Moulds made in *CALMAX* will have good resistance to abrasion and give a safe and long production life.

WELDING

For best results after polishing and etching use consumables with the same composition as the mould steel, i.e. use *CALMAX/CARMO* consumables.

PHOTO-ETCHING AND POLISHING

CALMAX has a very homogeneous structure. This coupled with its low content of non metallic inclusions (due to vacuum degassing during manufacturing) ensures accurate and consistent pattern reproduction after the photo-etching process and very good surface finish after polishing. Etching should be done in a media used for steel with high chrom-content.

Further information is given in the Uddeholm brochure "Photo-etching of Tool Steel" and "Polishing Mould Steel".

PROPERTY COMPARISON CHART

Uddeholm steel grade	Wear resistance	Toughness	Polishability
CALMAX			
GRANE			
ORVAR SUPREME			
RIGOR			

Further information

Please contact your local office for further information on the selection, heat treatment, application and availability of Uddeholm tool steels, including the publications "Steels for Moulds" and "Steels for Presswork Tooling".

This information is based on our present state of knowledge and is intended to provide general notes on our products and their uses. It should not therefore be construed as a warranty of specific properties of the products described or a warranty for fitness for a particular purpose.