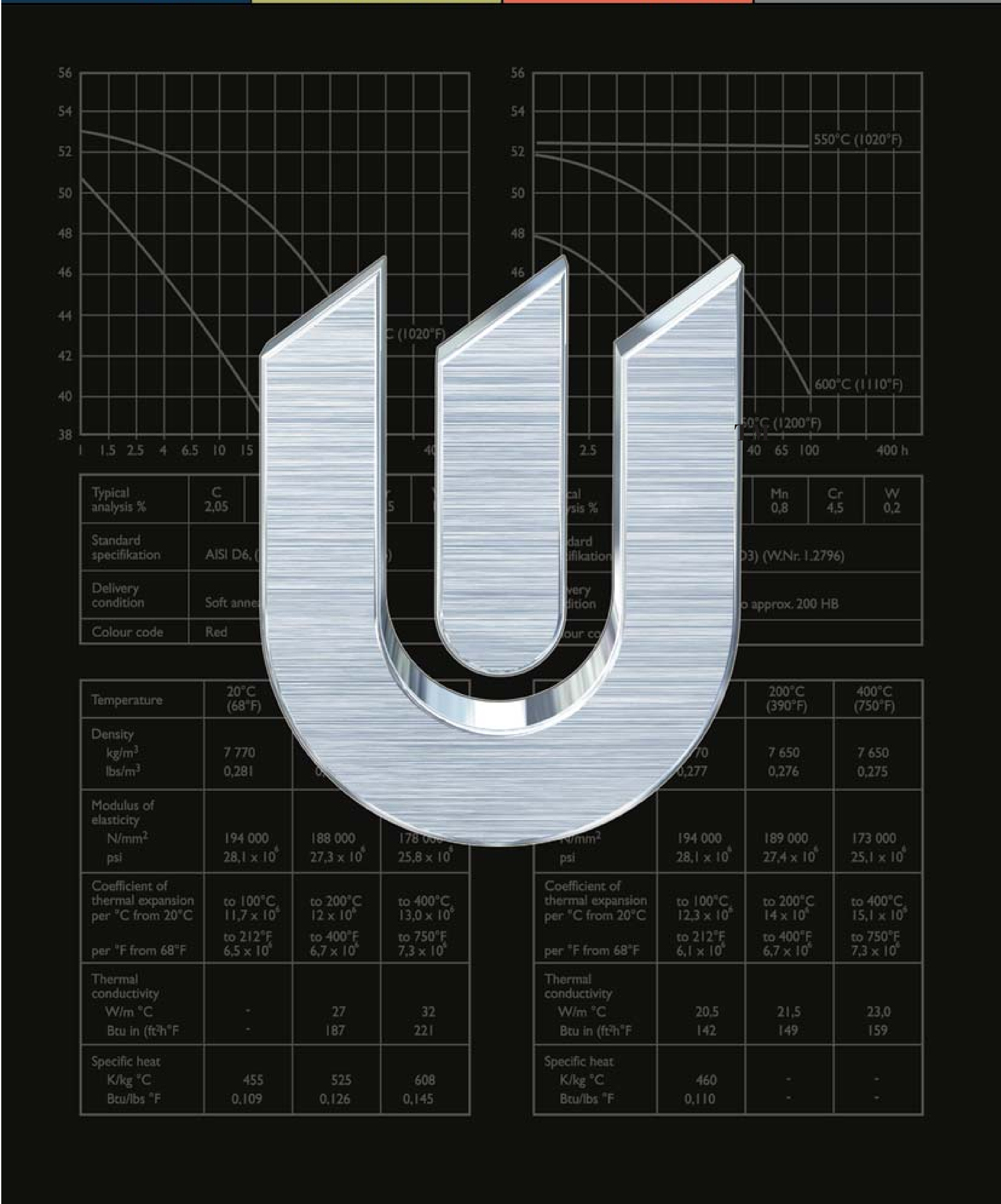
CALDIE™

Tool steel

COLD WORK | PLASTIC MOULDING | HOT WORK | HIGH PERFORMANCE STEEL



General

Caldie is a chromium-molybdenum-vanadium alloyed tool steel which is characterized by:

- Very good chipping and cracking resistance
- Good wear resistance
- High hardness (>60 HRC) after high temperature tempering
- Good dimensional stability in heat treatment and in service
- Excellent through-hardening properties
- Good machinability and grindability
- Excellent polishability
- Good surface treatment properties
- Good resistance to tempering back
- Very good WEDM properties

Typical analysis %	C 0,7	Si 0,2	Mn 0,5	Cr 5,0	Mo 2,3	V 0,5
Standard specification	None					
Delivery condition	Soft annealed to approx. 215 HB					
Colour code	White/grey					

Applications

Caldie is suitable for short to medium run tooling where chipping and/or cracking are the predominant failure mechanisms and where a high compressive strength (hardness of over 60 HRC) is necessary. This makes Caldie an excellent problem solver for severe cold work applications where the combination of a hardness above 60 HRC and a high cracking resistance is of utmost importance e.g. as in the blanking and forming of ultra high strength steel sheets.

Caldie is also very suitable as a substrate steel for applications where surface coatings are desirable or necessary.

Examples

Cold work applications

- Blanking applications where high ductility and toughness are needed to prevent chipping/ cracking
- Cold forging and forming operations where a high compressive strength combined with good resistance to chipping / cracking are necessary
- Machine knives
- Thread rolling dies
- Substrate for surface coatings

HPS applications

- Engineering applications where high ductility and toughness are needed to prevent chipping/ cracking

Properties

The properties below are representative of samples which have been taken from the center of bars with dimensions 203 x 80 and Ø 102 mm. Unless otherwise indicated, all specimens have been hardened at 1025°C (1875°C), gas quenched in a vacuum furnace and tempered twice at 525°C (975°F) for two hours to 60–62 HRC.

PHYSICAL PROPERTIES

Hardened and tempered to 60–62 HRC.

Temperature	20°C (68°F)	200°C (390°F)	400°C (750°F)
Density, kg/m^3 lbs/in^3	 7 820 0,282	–	–
Modulus of elasticity MPa psi	 213 000 $31,2 \times 10^6$	 192 000 $27,8 \times 10^6$	 180 000 $26,1 \times 10^6$
Coefficient of thermal expansion per °C from 20°C per °F from 68°F	 – –	 $11,6 \times 10^{-6}$ $6,4 \times 10^{-6}$	 $12,4 \times 10^{-6}$ $6,9 \times 10^{-6}$
Thermal conductivity W/m °C Btu in/(ft^2h°F)	 – –	 24 174	 28 195
Specific heat J/kg°C Btu/lb°F	 460 0,11	–	–

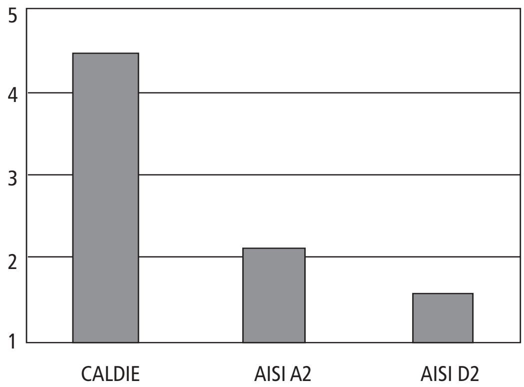
COMPRESSIVE STRENGTH

Approximately compressive strength vs. hardness is shown in the table below.

Hardness HRC	Compressive yield strength, Rc0,2 (MPa)
58	2230
60	2350
61	2430

CHIPPING RESISTANCE

Relative chipping resistance for Caldie, AISI A2 and AISI D2 is shown below.



Heat treatment

SOFT ANNEALING

Protect the steel and heat through to 820°C (1510°F). Then cool in the furnace at 10°C (20°F) per hour to 650°C (1200°F), then freely in air.

STRESS RELIEVING

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

HARDENING

Preheating temperature: 600–650°C (1100–1200°F) and 850–900°C (1560–1650°F) during hardening.

Austenitizing temperature: 1000–1025°C (1830–1875°F), normally 1020°C (1870°F).

Holding time: 30 min.

Protect the part against decarburization and oxidation.

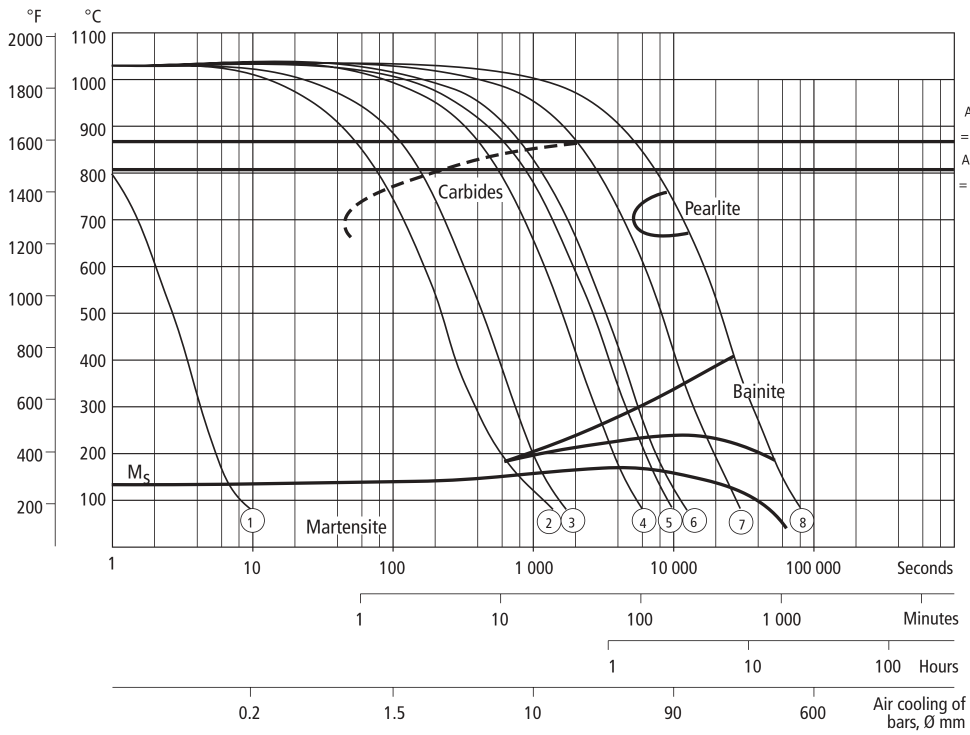
QUENCHING MEDIA

- High speed gas/circulating atmosphere
- Vacuum furnace (high speed gas with sufficient overpressure)
- Martempering bath at 500–550°C (930–1020°F)
- Martempering bath at approx. 200–350°C (390–660°F)

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

CCT-graph

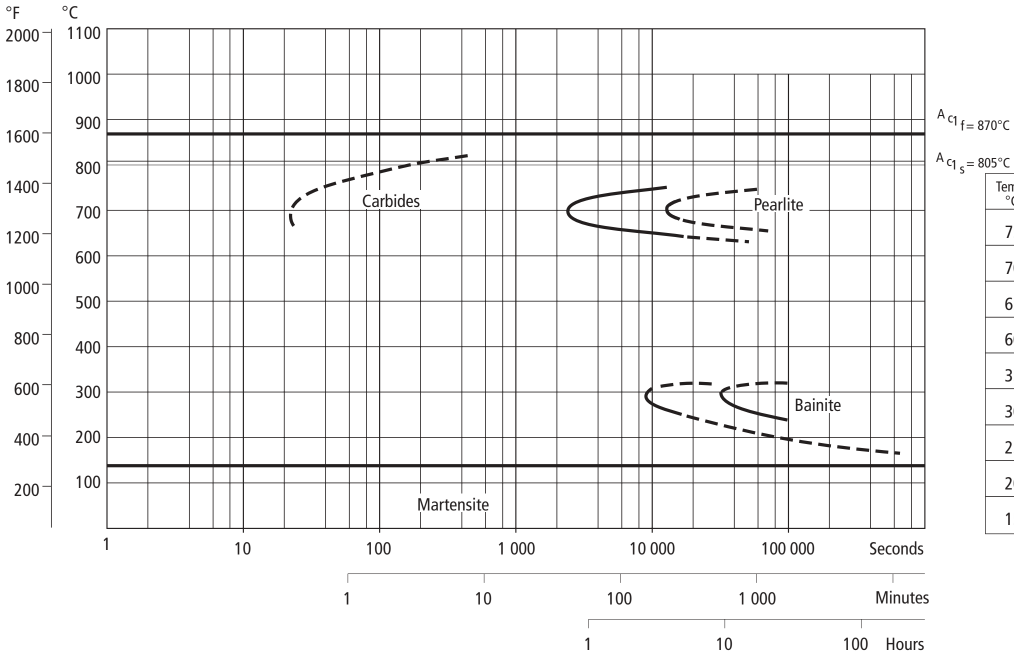
Austenitizing temperature 1020°C (1870°F). Holding time 30 minutes



Cooling Curve No.	Hardness HV 10	$T_{800-500}$ (sec)
1	824	2
2	813	140
3	803	280
4	803	1030
5	792	1596
6	690	2325
7	525	5215
8	464	13850

TTT-graph

Austenitizing temperature 1020°C (1870°F). Holding time 30 minutes.

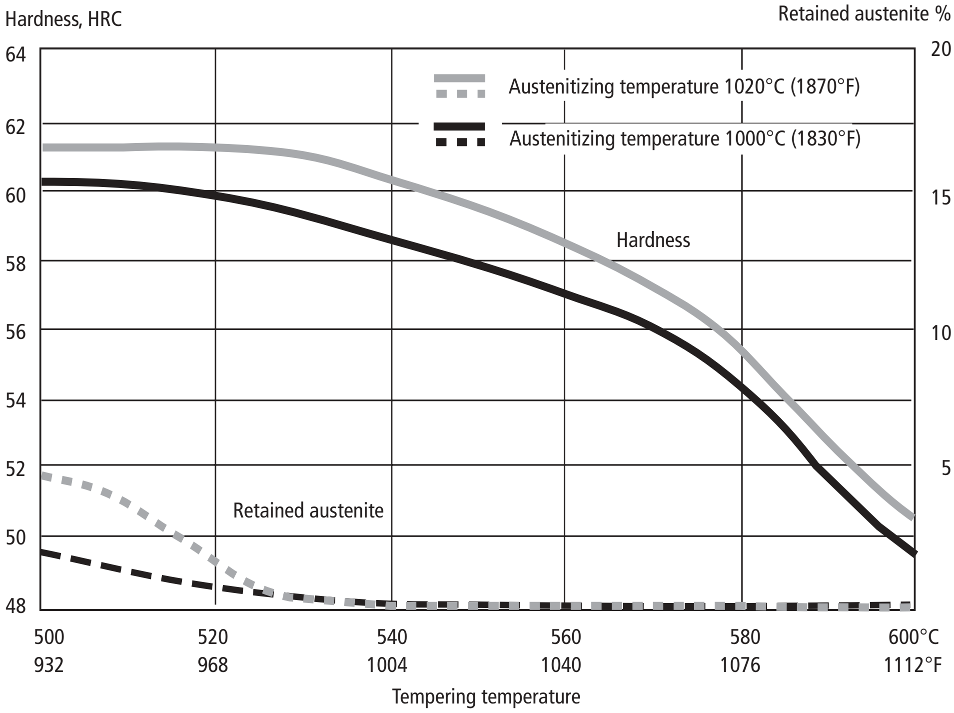


Temp. °C	Time hours	Hardn. HV 10
750	8,2	243
700	3,9	333
650	23,1	390
600	14,3	824
350	14,6	835
300	8,2	542
250	23,2	606
200	8,1	835
150	23,5	824

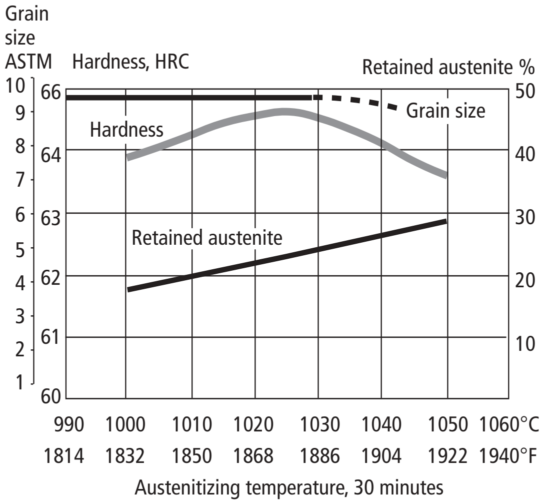
TEMPERING

Choose the tempering temperature according to the hardness required by reference to the tempering graph below. Temper at least twice with intermediate cooling to room temperature. The lowest tempering temperature which should be used is 525°C (980°F). The minimum holding time at temperature is 2 hours.

Tempering graph



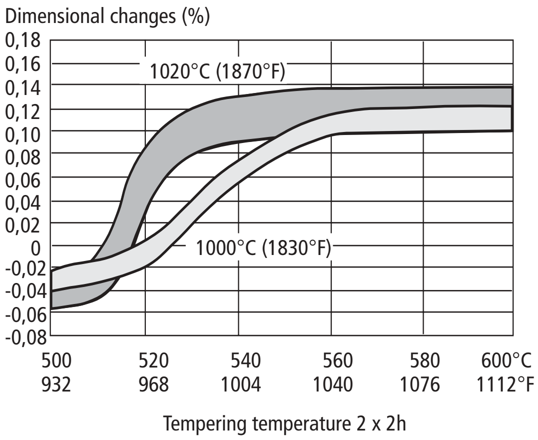
Hardness, grain size and retained austenite as a function of austenitizing temperature



DIMENSIONAL CHANGES

The dimensional changes have been measured after austenitizing at 1000°C (1830°F)/30 minutes and 1020°C (1870°F)/30 minutes followed by gas quenching in N_2 at a cooling rate of 1,1°C/s between 800–500°C (1470–930°F) in a cold chamber vacuum furnace.
Specimen size: 100 x 100 x 100 mm (3,9"x 3,9"x 3,9")

Values for all directions are within the marked areas.



Surface treatments

Tool steels may be given a surface treatment in order to reduce friction and increase wear resistance. The most commonly used treatments are nitriding and surface coating with wear resistant layers produced via PVD or CVD.

The high hardness and toughness together with a good dimensional stability makes Caldie suitable as a substrate steel for various surface coatings.

NITRIDING AND NITROCARBURIZING

Nitriding and nitrocarburizing result in a hard surface layer which is very resistant to wear and galling.
The surface hardness after nitriding is approximately 1000–1200 $HV_{0,2kg}$. The thickness of the layer should be chosen to suit the application in question.

PVD

Physical vapour deposition, PVD, is a method of applying a wear-resistant coating at temperatures between 200–500°C (390–930°F).

CVD

Chemical vapour deposition, CVD, is used for applying wear-resistant surface coatings at a temperature of around 1000°C (1830°F).

Cutting data recommendations

The cutting data below are to be considered as guiding values, which must be adapted to existing local conditions. More information can be found in the Uddeholm publication “ Cutting data recommendation”.

Condition: soft annealed to approximate 220 HB

TURNING

Cutting data parameters	Turning with carbide		Turning with high speed steel
	Rough turning	Fine turning	Fine turning
Cutting speed (v_c) m/min f.p.m.	140–190 460–620	190–240 620–785	15–20 50–65
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 0,002–0,012
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	– –

MILLING

Face- and square shoulder milling

Cutting data parameters	Milling with carbide	
	Rough milling	Fine milling
Cutting speed (v_c) m/min f.p.m.	130–160 430–525	160–200 525–656
Feed (f_z) mm/tooth inch/tooth	0,2–0,4 0,008–0,016	0,1–0,2 0,004–0,008
Depth of cut (a_p) mm inch	2–4 0,08–0,16	0,5–2 0,02–0,08
Carbide designation ISO US	P20–P40 C6–C5 Coated carbide	P10–20 C7–C6 Coated carbide or cermet

End milling

Cutting data parameters	Type of milling		
	Solid carbide	Carbide indexable insert	High speed steel
Cutting speed (v_c) m/min f.p.m.	110–140 360–460	100–140 330–460	18–23[1)] 60–75[1)]
Feed (f_z) mm/tooth inch/tooth	0,01–0,20[2)] 0,0003–0,008[2)]	0,06–0,20[2)] 0,002–0,008[2)]	0,01–0,30[2)] 0,0003–0,012[2)]
Carbide designation ISO US	–	P20–P30 C6–C5	– –

1) For coated HSS end mill v_c = 32–38 m/min. (105–125 f.p.m.).
2) Depending on radial depth of cut and cutter diameter.

DRILLING

High speed steel twist drill

Drill diameter mm	Drill diameter inch	Cutting speed (v_c) m/min	Cutting speed (v_c) f.p.m.	Feed (f) mm/r	Feed (f) i.p.r.
– 5	–3/16	15–20*	49–66*	0,05–0,10	0,002–0,004
5–10	3/16–3/8	15–20*	49–66*	0,10–0,20	0,004–0,008
10–15	3/8–5/8	15–20*	49–66*	0,20–0,30	0,008–0,012
15–20	5/8–3/4	15–20*	49–66*	0,30–0,35	0,012–0,014

1) For coated HSS drill v_c = 35–40 m/min. (110–130 f.p.m.).

Carbide drill

Cutting data parameters	Type of drill		
	Indexable insert	Solid carbide	Brazed carbide[1)]
Cutting speed (v_c) m/min f.p.m.	160–200 525–655	110–140 360–460	60–90 19–295
Feed (f) mm/r i.p.r.	0,05–0,15[2)] 0,002–0,006[2)]	0,10–0,25[2)] 0,004–0,01[2)]	0,15–0,25[2)] 0,006–0,01[2)]

1) Drill with internal cooling channels and brazed carbide tip.
2) Depending on drill diameter.

GRINDING

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

Wheel recommendation

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 60 KV	A 60 KV
Internal grinding	A 46 JV	A 60 IV
Profile grinding	A 100 KV	A 120 JV

Electrical Discharge Machining

If EDM is performed in the hardened and tempered condition, finish with "fine-sparking", i.e. low current, high frequency.
For optimal performance the EDM'd surface should the be ground/polished and the tool re-tempered at approx. 25°C (50°F) lower than the original tempering temperature.

Further information is given in the Uddeholm brochure "EDM of Tool Steel".

Flame hardening

Use oxy-acetylene equipment with a capacity of 800–1250 l/h. Oxygen pressure 2,5 bar, acetylene pressure 1,5 bar. Adjust to give neutral flame. Temperature: 980–1020°C (1795–1870°F). Cool freely in air. The hardness at the surface will be 58–62 HRC and 41 HRC (400 HB) at a depth of 3–3,5 mm (0,12"–0,14").

Further information

Please contact your local Uddeholm office for further information on the selection, heat treatment, application and availability of Uddeholm tool steels.

Welding

Welding of die components can be performed, with acceptable results, as long as the proper precautions are taken during the preparation of the joint, the filler material selection, the preheating of the tool, the controlled cooling of the tool and the post weld heat treatment processes. The following guidelines summarize the most important welding process parameters.

For more detailed information refer to Uddeholm's "Welding of Tool Steel" brochure.

Welding method	**TIG**	**MMA**
Preheating temperature	200–250°C (390–485°F)	200–250°C (390–485°F)
Filler material	UTP A696 UTP ADUR600 UTPA 73G2	UTP 69 UTP 67S UTP 73G2
Maximum interpass temperature	350°C (660°F)	350°C (660°F)
Post weld cooling	20–40°C/h (40–80°F/h) for the first 2 hours and then freely in air.	
Hardness after welding	54–62 HRC	55–62 HRC
Post weld heat treatment		
Hardened condition	Temper at 510°C (950°F) for 2 hours	
Soft annealed condition	Soft-anneal according to the "Heat treatment recommendations"	

Minor repairs can be made at room temperature with the TIG-method.

Relative comparison of Uddeholm cold work tool steel

MATERIAL PROPERTIES AND RESISTANCE TO FAILURE MECHANISMS