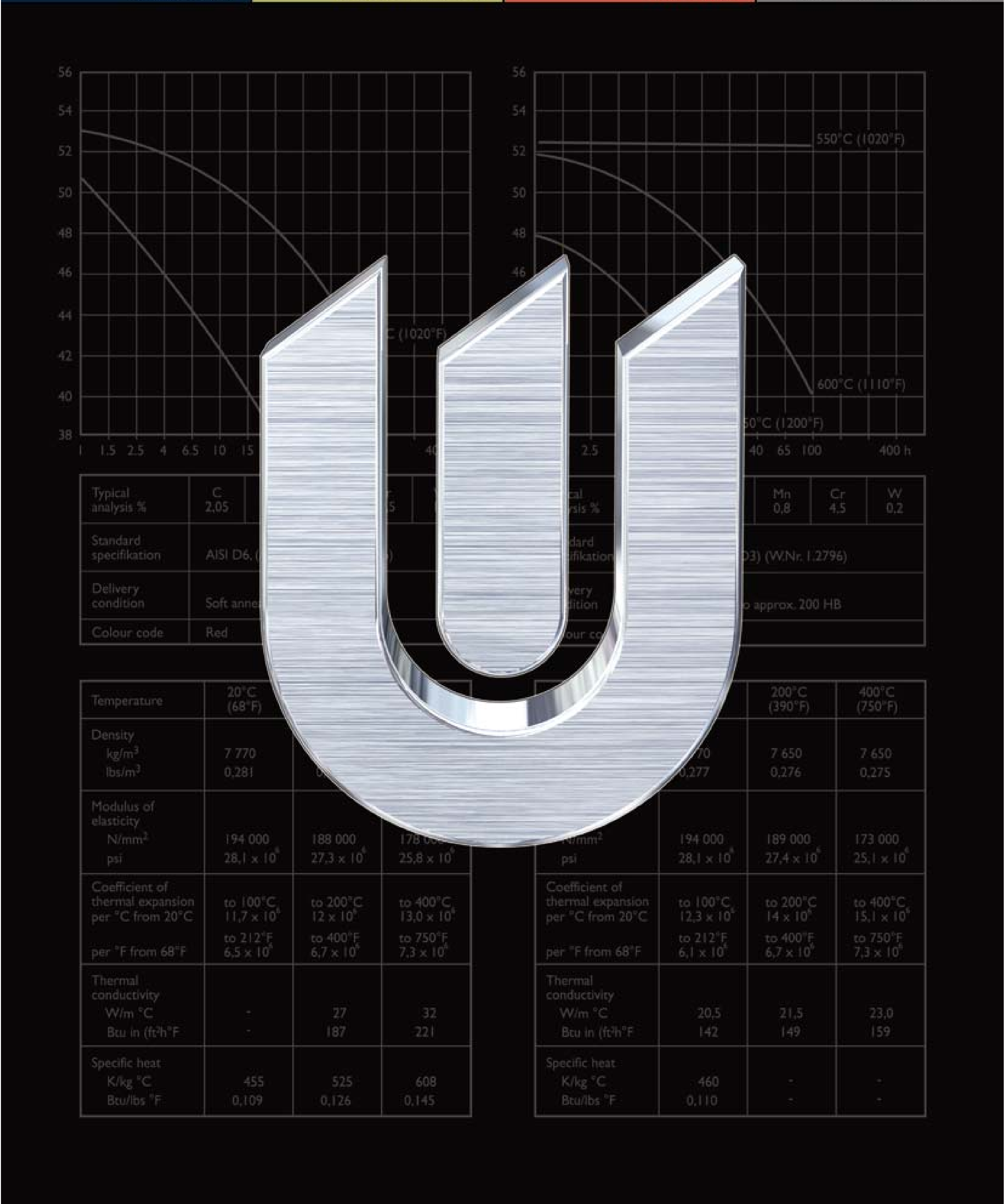
HOTVAR®

Hot work tool steel

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



General

HOTVAR is a high performance molybdenum-vanadium alloyed hot-work tool steel which is characterized by:

- High hot wear resistance
- Very good high temperature properties
- High resistance to thermal fatigue
- Very good temper resistance
- Very good thermal conductivity.

Typical analysis %	C 0.55	Si 1.0	Mn 0.75	Cr 2.6	Mo 2.25	V 0.85
Standard specification	None					
Delivery condition	Soft annealed to approx. 210 HB					
Color code	Red/brown					

IMPROVED TOOLING PERFORMANCE

HOTVAR is a premium hot work steel developed by Uddeholm to provide a very good performance in tooling up to 1200°F (650°C). The alloy elements in *HOTVAR* are balanced to give high hot wear resistance and good high temperature properties. *HOTVAR* is manufactured by special techniques.

Applications

HOTVAR is a hot-work tool steel suitable for applications where hot wear and/or plastic deformation are the dominating failure mechanisms.

Applications and tools of special interest:

- Warm forging, dies and punches
- Roll forging, rolling segments
- Rock orbital forging, punches and dies
- Upset forging, clamping tools
- Progressive forging, dies
- Axial closed die rolling, top and bottom dies
- Cross forming, segments
- Hot bending, tools
- Hot calibration, tools
- Zinc die casting, dies
- Al-tube extrusion.

Recommended hardness level is 54–58 HRC.
For improving the wear resistance the tools can be plasma nitrided or nitrocarburized.

Properties

All specimens are taken from the centre of a bar 4.5" (115 mm Ø). Unless otherwise indicated all specimens were hardened at 1920°F (1050°C), quenched in air and tempered 2 + 2 h at 1070°F (575°C) to a hardness corresponding to 56 HRC.

PHYSICAL DATA

Data at room and elevated temperatures.

Temperature	70°F (20°C)	750°F (400°C)	1110°F (600°C)
Density lbs/in³	0.281	0.277	0.274
kg/m³	7,800	7,700	7,600
Modulus of elasticity psi	30.5 x 10^6	26.1 x 10^6	20.3 x 10^6
MPa	210,000	180,000	140,000
Coefficient of thermal expansion per °F from 68°F	–	7.0 x 10^{-6}	7.3 x 10^{-6}
°C from 20°C	–	12.6 x 10^{-6}	13.2 x 10^{-6}
Thermal conductivity Btu in (ft²h °F)	215	230	230
W/m °C	31	33	33

MECHANICAL PROPERTIES

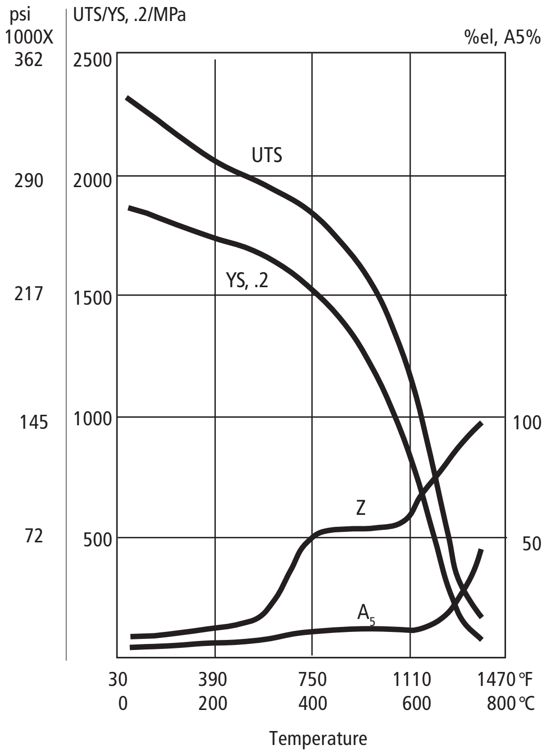
Approximate tensile strength at room temperature.

Hardness	54 HRC	56 HRC	58 HRC
Tensile strength UTS psi	305,000	320,000	335,000
MPa	2,100	2,200	2,300
Yield strength YS, .2% psi	260,000	265,000	270,000
MPa	1,800	1,820	1,850

Dies for axial closed die rolling.

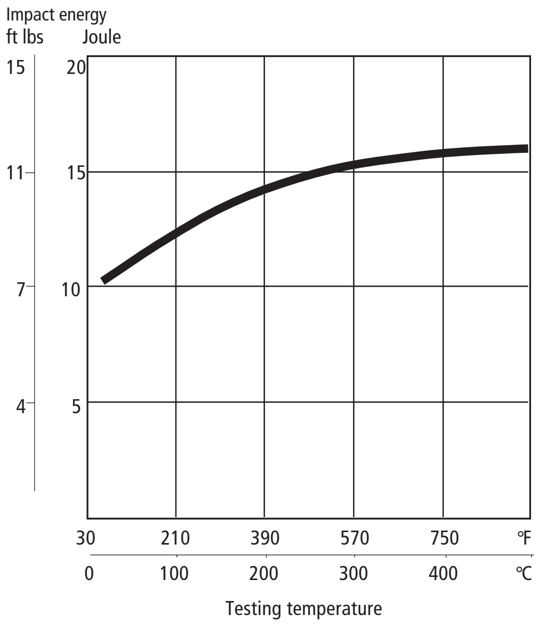
Hot strength

Hot strength in longitudinal direction.



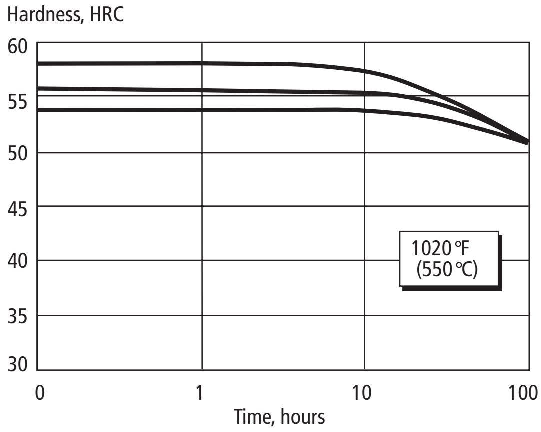
Effect of testing temperature on impact energy

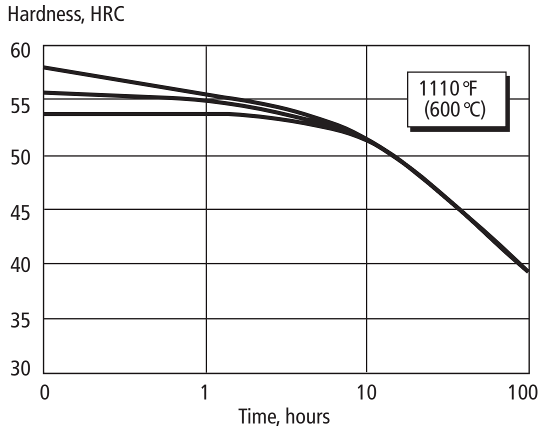
Charpy -V specimens, transverse direction.

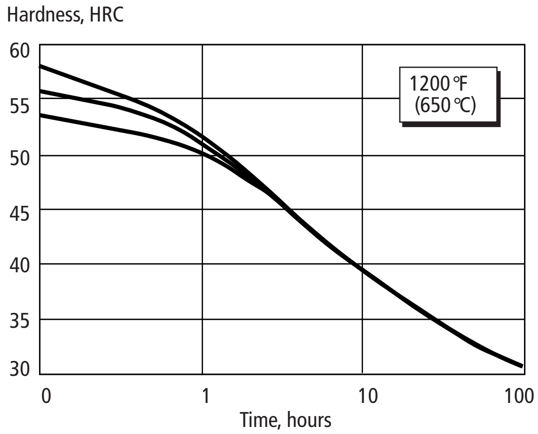


Effect of time at high temperature on hardness

The softening at high temperatures and different holding times are shown below. The specimens have first been hardened and tempered to 54, 56 and 58 HRC.







Heat treatment—general recommendations

SOFT ANNEALING

Protect the steel and heat through to 1500 °F (820 °C). Then cool in the furnace at 20 °F (10 °C) per hour to 1110 °F (600 °C), then freely in air.

STRESS RELIEVING

After rough machining the tool should be heated through to 1200 °F (650 °C), holding time 2 hours. Cool slowly to 660 °F (350 °C), then freely in air.

HARDENING

Pre-heating temperature: first step at 895–1110 °F (480–600 °C), second step at 1560 °F (850 °C).
Austenitizing temperature: 1920–1960 °F (1050–1070 °C), normally 1920 °F (1050 °C) but when maximum hardness is required the normally temperature is 1960 °F (1070 °C).

QUENCHING MEDIA

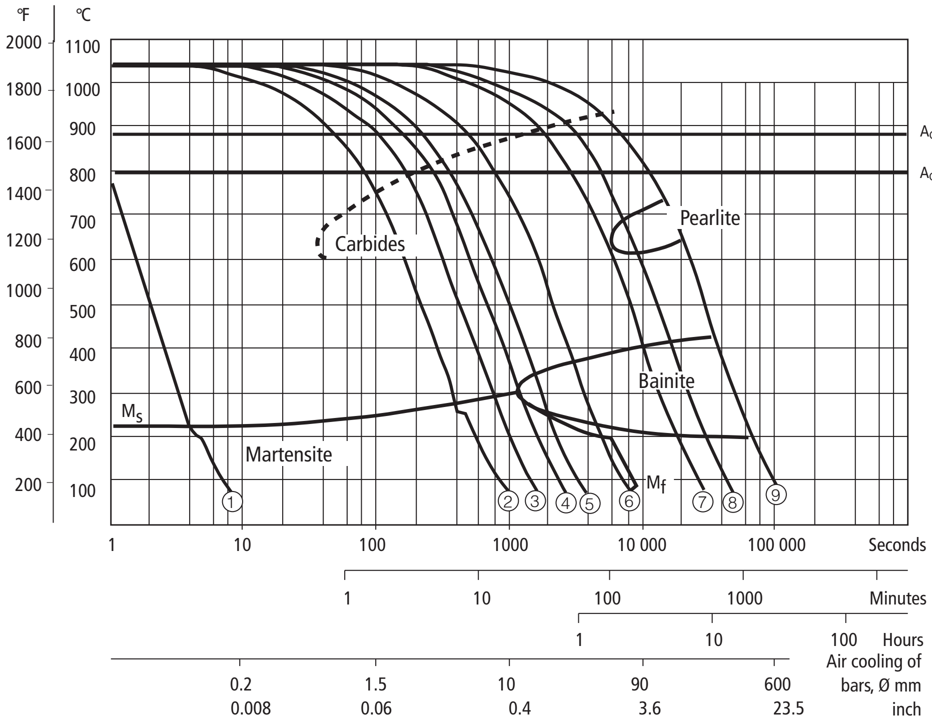
- High speed gas/circulating atmosphere
- Vacuum (high speed gas with sufficient positive pressure)
- Martempering bath or fluidized bed at 840–1020 °F (450–550 °C)
- Martempering bath or fluidized bed at approx. 360–430 °F (180–220 °C)
- Warm oil, about 175 °F (80 °C).

Note. 1: Temper the tool as soon as its temperature reaches 120–160 °F (50–70 °C).

Note. 2: In order to obtain the optimum properties for the tool, the cooling rate should be fast but not at a level that gives excessive distortion or cracks.

CCT -graph

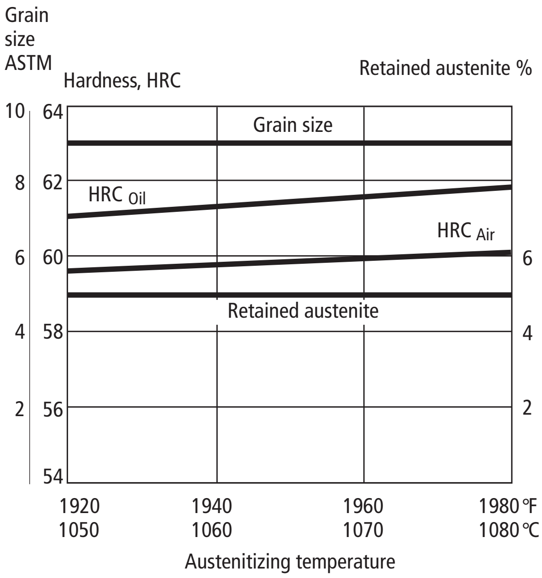
Austenitizing temperature 1920 °F (1050 °C). Holding time 30 minutes.



Cooling curve No.	Hardness HV_{10}	$T_{800–500}$ (sec)
1	772	1
2	734	140
3	715	280
4	707	450
5	690	630
6	548	1390
7	473	5215
8	464	8360
9	351	19400

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

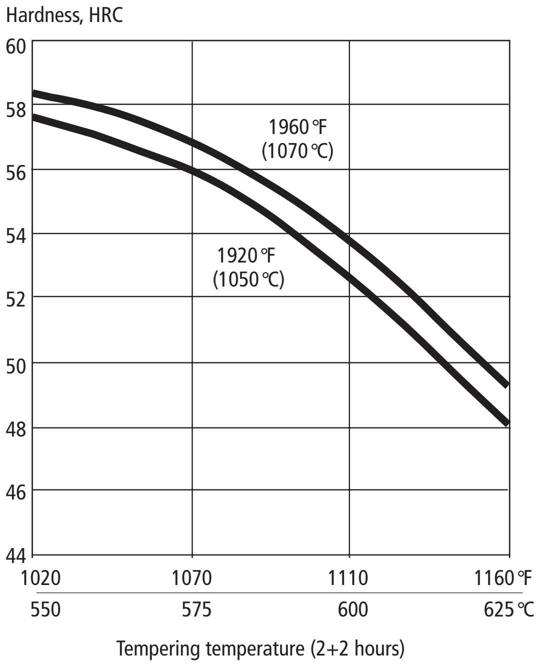
Samples Ø 1 inch (25 mm).



TEMPERING

Choose the tempering temperature according to the hardness required by reference to tempering graph. Temper minimum twice with intermediate cooling to room temperature. Holding time at temperature minimum 2 hours.

Tempering graph



DIMENSIONAL CHANGES DURING HARDENING AND TEMPERING

During hardening and tempering the tool is exposed to thermal as well as transformation stresses. This will inevitably result in dimensional changes and in the worse case distortion. It is therefore recommended to always leave enough machining allowance after machining before the die is hardened and tempered. Normally the size in the largest direction will shrink and the size in the smallest direction might increase, but this is also a matter of the tool size, the tool design as well as the cooling rate after hardening.

For *HOTVAR* it is recommend to leave a machining allowance of 0.005"/inch/maximum dimension on all dimensions, if the tool has been stress relieved after rough machining.

NITRIDING AND NITROCARBURIZING

Nitriding and nitrocarburizing result in a hard surface layer which is very resistant to wear and erosion. The nitrided layer is, however, brittle and may crack or spall when exposed to mechanical or thermal shock, the risk increases with layer thickness. Before nitriding, the tool should be hardened and tempered at a temperature at least 90 °F (50 °C) above the nitriding temperature.

In general, plasma nitriding is the preferred method because of better control over nitrogen potential. Plasma nitriding at 895 °F (480 °C) in a 75% hydrogen/25% nitrogen mixture result in a surface hardness of about 1000 $HV_{0,2}$.

HOTVAR can also be nitrocarburized in either gas or salt bath. The surface hardness after nitrocarburizing is about 900 $HV_{0,2}$.

DEPTH OF NITRIDING

Process	Time	Depth inch	Depth mm
Plasma nitriding at 895 °F (480 °C)	10 30	0.0070 0.0106	0.18 0.27
Nitrocarburizing			
–in gas at 1075 °F (580 °C)	2.5	0.0080	0.20
–in salt bath at 1075 °F (580 °C)	1	0.0050	0.13

It should be noted that *HOTVAR* exhibits better nitridability than AISI H13. For this reason, the nitriding times for *HOTVAR* should be shortened in relation to H13, otherwise there is a considerable risk that the case depth will be too great.

Machining recommendations

The cutting data below, valid for *HOTVAR* in soft annealed condition, are to be considered as guiding values which must be adapted to existing local conditions. More detailed information can be found in Uddeholm "Cutting Data Recommendations".

TURNING

Cutting data speed steel parameters	Turning with carbide		Turning with high
	Rough turning	Fine turning	Fine turning
Cutting speed (v_c) f.p.m. m/min.	490–560 150–170	560–625 170–190	65–80 20–25
Feed (f) i.p.r. mm/r	0.008–0.016 0.2–0.4	0.002–0.008 0.05–0.2	0.002–0.012 0.05–0.3
Depth of cut (a) inch mm	0.08–0.16 2–4	0.02–0.08 0.5–2	0.02–0.12 0.5–3
Carbide designation US ISO	C6–C5 P20–P30 Coated carbide	C7 P10 Coated carbide or cermet	– –

DRILLING

High speed steel twist drill

Drill diameter Ø inch	Drill diameter Ø mm	Cutting speed (v_c) f.p.m.	Cutting speed (v_c) m/min.	Feed (f) i.p.r.	Feed (f) mm/r
–3/16	–5	46–52*	14–16*	0.002–0.006	0.05–0.15
3/16–3/8	5–10	46–52*	14–16*	0.006–0.008	0.15–0.20
3/8–5/8	10–15	46–52*	14–16*	0.008–0.010	0.20–0.25
5/8–3/4	15–20	46–52*	14–16*	0.010–0.014	0.25–0.35

** For coated HSS drill v_c 60–72 f.p.m. (18–22 m/min.).*

Carbide drill

Cutting data parameters	Type of drill		
	Indexable insert	Solid carbide	Brazed carbide[1]
Cutting speed (v_c) f.p.m. m/min.	520–650 160–200	425–525 130–160	180–195 55–60
Feed (f) i.p.r. mm/r	0.002–0.010[2] 0.05–0.25[2]	0.004–0.010[2] 0.10–0.25[2]	0.006–0.010[2] 0.15–0.25[2]

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

MILLING

Face and square shoulder milling

Cutting data parameters	Milling with carbide	
	Rough milling	Fine milling
Cutting speed, (v_c) f.p.m. m/min.	455–655 140–200	655–785 200–240
Feed (f_z) inch/tooth mm/tooth	0.008–0.016 0.2–0.4	0.003–0.007 0.1–0.2
Depth of cut (a_p) inch mm	0.08–0.2 2–5	–0.08 –2
Carbide designation US ISO	C6–C5 P20–P40 Coated carbide	C7 P10 Coated carbide or cermet

End milling

Cutting data parameters	Type of milling		
	Solid carbide	Carbide indexable insert	High speed steel
Cutting speed (v_c) f.p.m. m/min.	360–490 110–150	390–520 120–160	65–80[1] 20–25[1]
Feed (f_z) inch/tooth mm/tooth	0.001–0.008[2] 0.03–0.2[2]	0.003–0.008[2] 0.08–0.2[2]	0.002–0.014[2] 0.05–0.35[2]
Carbide designation US ISO	C3–C5 K10, P40	C6–C5 P20–P30	– –

[1] For coated HSS end mill v_c 115–130 f.p.m. (35–40 m/min.).
[2] Depending on radial depth of cut and cutter diameter.

GRINDING

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

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

Electrical-discharge machining, EDM

If spark-erosion, EDM, is performed in the hardened and tempered condition, the white re-cast layer should be removed mechanically e.g. by grinding or stoning. The tool should then be given an additional temper at approx. 50°F (25°C) below the previous tempering temperature.
More detailed information can be found in the Uddeholm publication "EDM of Tool Steel".

Welding

Good results when welding tool steel can be achieved if proper precautions are taken during welding (elevated working temperature, joint preparation, choice of consumables and welding procedure).

Welding method	TIG	MMA
Working temperature	620–700°F 325–375°C	620–700°F 325–375°C
Filler metals	QRO 90 TIG-WELD	QRO 90 WELD
Hardness after welding	50–55 HRC	50–55 HRC
Heat treatment after welding		
Hardened condition	Temper at 40°F (20°C) below the original tempering temperature.	
Soft annealed condition	Soft anneal the material at 1500°F (820°C) in protected atmosphere. Then cool in the furnace at 20°F (10°C) per hour to 1200°F (650°C) then freely in air.	

More detailed information can be found in the Uddeholm brochure "Welding of Tool Steel".

Further information

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