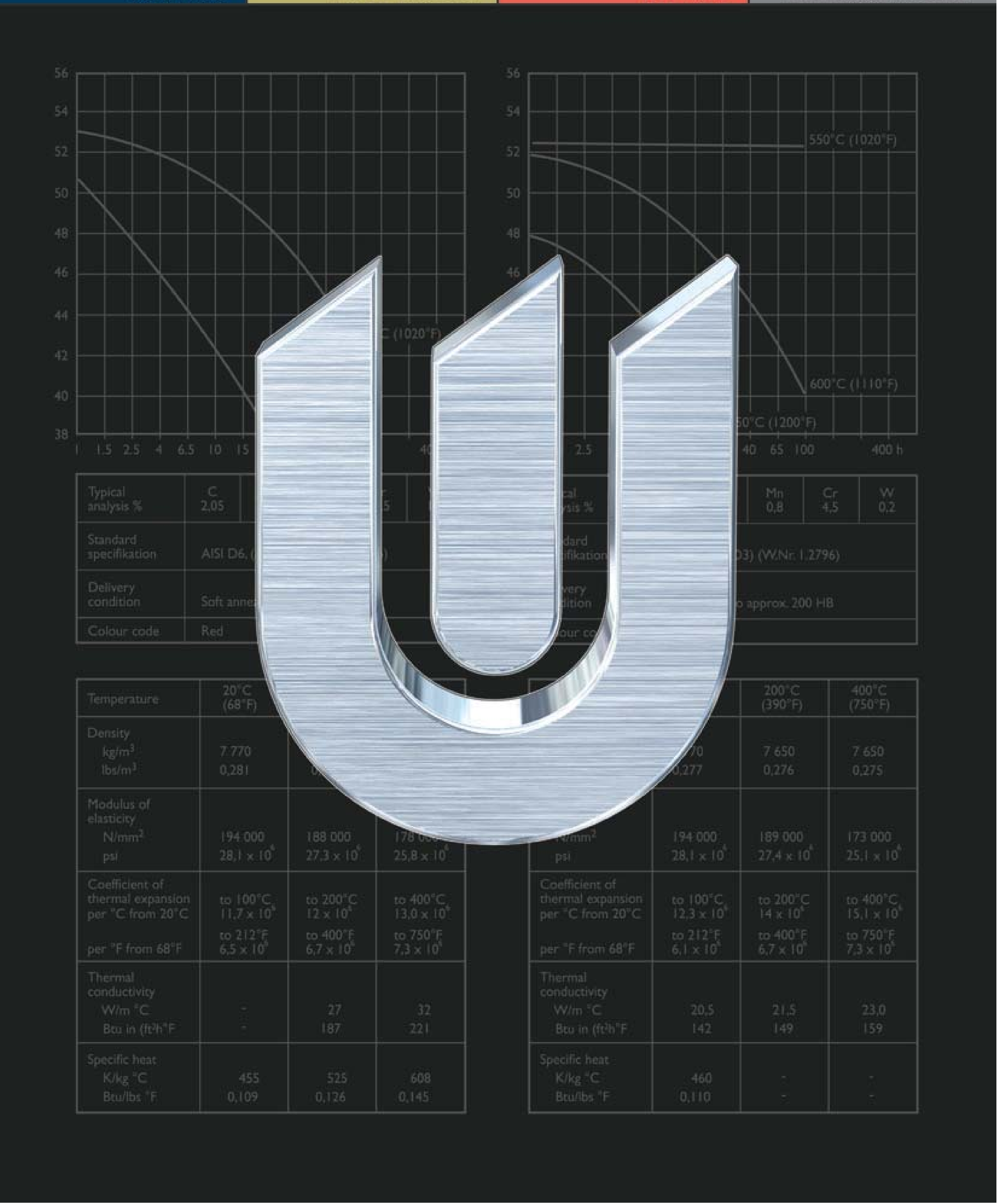
DIEVAR®

Premium hot work tool steel

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



General

Dievar is a high performance chromium-molybdenum-vanadium alloyed hot work tool steel which offers an unparalleled resistance to heat checking, gross cracking, hot wear and plastic deformation. Dievar is characterized by:

- Excellent toughness and ductility in all directions
- Good temper resistance
- Good high temperature strength
- Excellent hardenability
- Good dimensional stability throughout heat treatment and coating operations.

Type	Cr-Mo-V Hot Work Steel
Standard specification	None
Delivery condition	Soft annealed to approx.160 HB
Color code	Grey/yellow

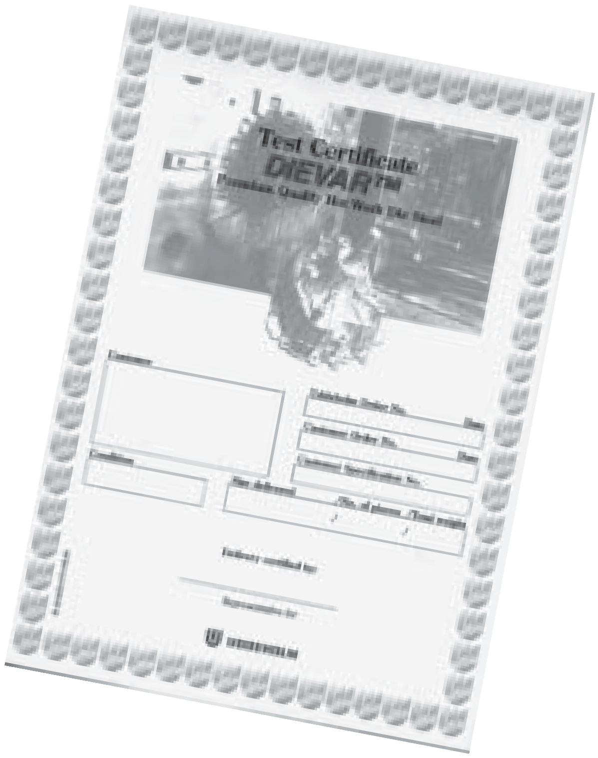
IMPROVED TOOLING PERFORMANCE

Dievar is a proprietary, premium hot work tool steel developed by Uddeholm. It is manufactured utilizing the very latest in production and refining techniques. The Dievar technology has yielded a die steel with the ultimate resistance to heat checking, gross cracking, hot wear and plastic deformation. The unique properties profile for Dievar makes it the best choice for die casting, forging and extrusion tooling.

ESR plant

Hot work applications

Dievar is certified to a minimum, average Charpy V-notch impact toughness of 14 ft-lbs (19 J) and a minimum unnotched impact toughness of 220 ft-lbs (300 J) per testing procedure defined by NADCA #207–97 and #207–2003. These high levels of toughness and ductility yield the optimum resistance to gross cracking and heat checking respectively.



In practical terms, heat checking is the most common failure mechanism for the majority of hot work tooling. Dievar's superior ductility (i.e. approximatively two times that of premium H13) yields the highest possible level of heat checking resistance. Furthermore, Dievar's outstanding toughness and hardenability can be used to achieve further gains in heat checking resistance, if gross cracking is not a factor with competitive die steels, by allowing a higher working hardness to be used (+2 HRC) without risking gross cracking failure. Higher working hardnesses are known to impede the initiation of thermal fatigue cracks.

Regardless of the dominant failure mechanism; be it heat checking, gross cracking, hot wear or plastic deformation, Dievar offers the potential for significant improvements in tooling economy.

Dievar is the material of choice for high demand die casting, forging and extrusion tooling.

- Tools which are large and/or complex
- Tools which will be subjected to high service temperature and pressures
- Tools which will undergo severe thermal cycling in service

Dievar should also be considered in cold work applications where high toughness is a requirement.

Properties

The reported properties are representative of samples which have been taken from the center of an 8" x 24" (203 x 610 mm) bar. Unless otherwise indicated all specimens have been hardened at 1875°F (1025°C), quenched in oil and tempered twice at 1160°F (625°C) for two hours; yielding a working hardness of 44–46 HRC.

PHYSICAL PROPERTIES

Data at room and elevated temperatures.

Temperature	68°F (20°C)	750°F (400°C)	1110°F (600°C)
Density, lbs/in³ kg/m³	0.281 7 800	0.277 7 700	0.274 7 600
Modulus of elasticity psi MPa	30.5×10^6 210 000	26.1×10^6 180 000	21.0×10^6 145 000
Coefficient of thermal expansion per °F from 68°F per °C from 20°C	– –	7.0×10^{-6} 12.7×10^{-6}	7.3×10^{-6} 13.3×10^{-6}
Thermal conductivity Btu in/(ft²h°F) W/m °C	– –	216 31	223 32

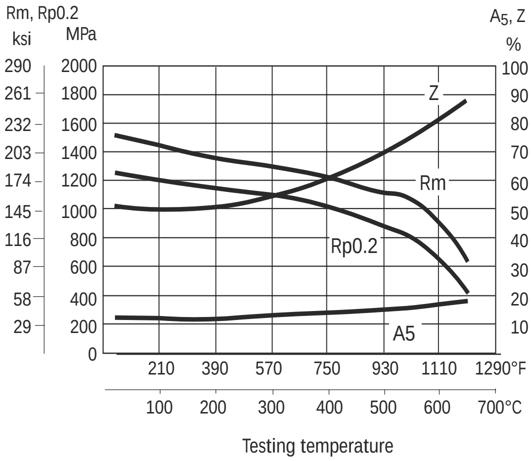
MECHANICAL PROPERTIES

Tensile properties at room temperature, short transverse direction.

Hardness	44 HRC	48 HRC	52 HRC
Tensile strength, R_m	1480 MPa 214 000 psi	1640 MPa 237 000 psi	1900 MPa 275 000 psi
Yield strength, $R_{p0.2}$	1210 MPa 175 000 psi	1380 MPa 200 000 psi	1560 MPa 226 000 psi
Elongation, A_5	13 %	13 %	12.5 %
Reduction of area, Z	55 %	55 %	52 %

Tensile properties at elevated temperature.

Longitudinal direction.

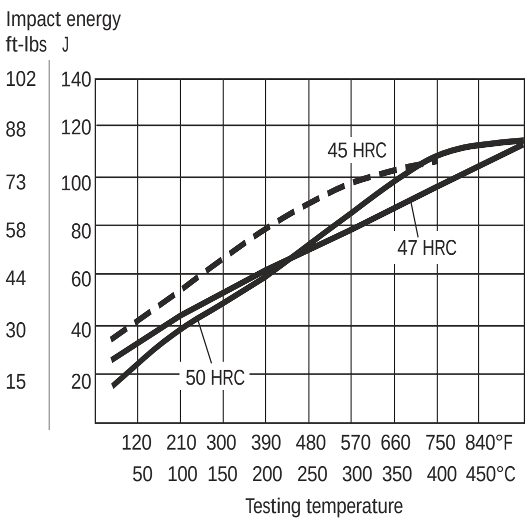


Minimum average impact properties for Dievar (in accordance with testing procedures outlined by NADCA #207–97 and #207–2003).

Testing technique	Minimum average
Charpy V Notch Room temperature	14 ft-lbs (19 J)
Charpy V Notch 500°F (260°C)	50 ft-lbs (70 J)
Unnotched	220 ft-lbs (300 J)

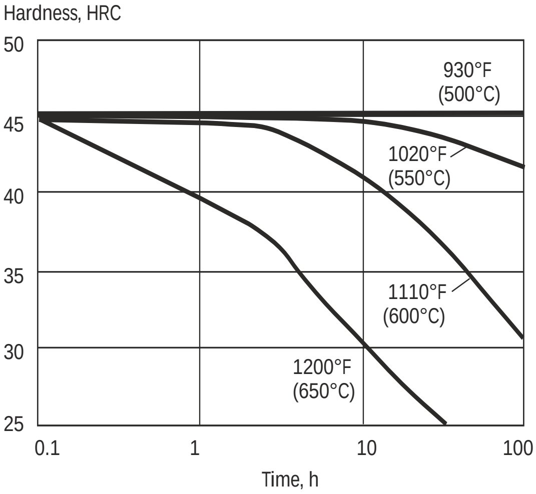
Charpy V-notch impact toughness at elevated temperature, typical values.

Short transverse direction.



Temper resistance

The specimens have been hardened and tempered to 45 HRC and then held at different temperatures from 1 to 100 hours.



Oil pan cover

Die casting die for aluminum oil pan cover

Heat treatment—general recommendations

SOFT ANNEALING

Protect the steel and heat through to 1560°F (850°C). Then cool in 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 930°F (500°C), then freely in air.

HARDENING

Preheating temperature: 1110–1650°F (600–900°C). Normally a minimum of two preheats, the first in the 1110–1200°F (600–650°C) range, and the second in the 1510–1560°F (820–850°C) range.

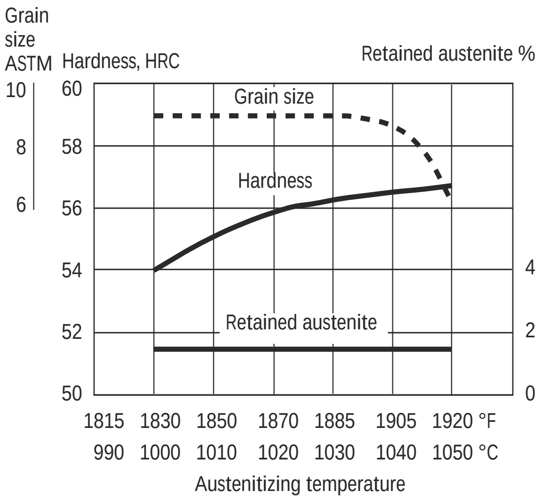
Austenitizing temperature: 1830–1885°F (1000–1030°C), normally 1875°F (1025°C). For large cross sections, 1850°F (1010°C) is recommended.

Temperature °C	Temperature °F	Soaking time minutes	Hardness **before** tempering
1000	1830	30	52 ±2 HRC
1025	1875	30	55 ±2 HRC

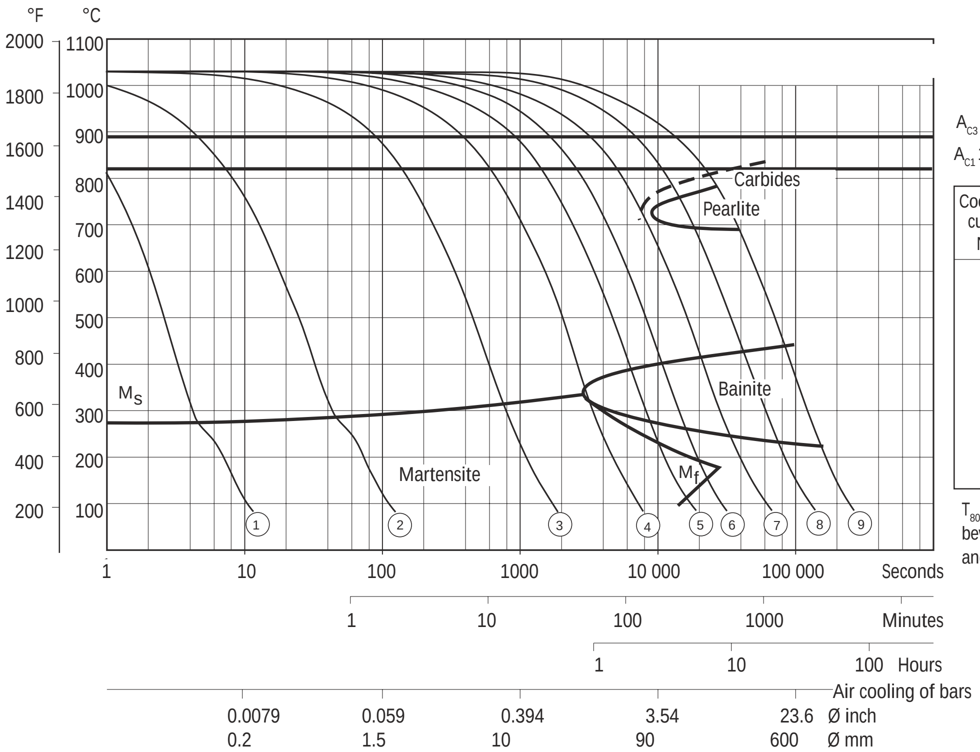
Soaking time = time at hardening temperature after the tool is fully heated through.

Protect the tool against decarburization and oxidation during austenitizing.

Hardness, grain size and retained austenite as functions of austenitizing temperature



CCT graph—Austenitizing temperature 1875°F (1025°C). Holding time 30 minutes.



Cooling curve No.	Hard-ness HV 10	$T_{800-500}$ (sec)
1	681	1.5
2	627	15
3	620	280
4	592	1 248
5	566	3 205
6	488	5 200
7	468	10 400
8	464	20 800
9	405	41 600

$T_{800-500}$ = cooling time beween 1472°F (800°C) and 932°F (500°C).

QUENCHING

As a general rule, quench rates should be as rapid as possible. Accelerated quench rates are required to optimize tool properties specifically with regards to toughness and resistance to gross cracking. If higher working hardness are to be investigated, with the goal of improved heat checking resistance, it is imperative that the minimum recommended quench rates are allowed. However, risk of excessive distortion and cracking must be considered.

Quenching media

The quenching media should be capable of creating a fully hardened microstructure (i.e. martensite) throughout the die, whenever possible. As a rule, transformation products such as carbides, pearlite and bainite should be avoided. Minimum quench rates for Dievar are defined by the CCT diagram. The severity of the quenching media will depend upon die size and geometry. Possible quenching media include but are not limited to:

- High speed gas/circulating atmosphere.
- Vacuum (high speed gas with sufficient positive pressure). An interrupted quench at 610–840°F (320–450°C) is recommended where distortion control and quench cracking are a concern.
- Martempering bath or fluidized bed at 840–1020°F (450–550°C).
- Martempering bath or fluidized bed at 360–390°F (180–200°C).
- Warm oil, approx. 180°F (80°C).

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

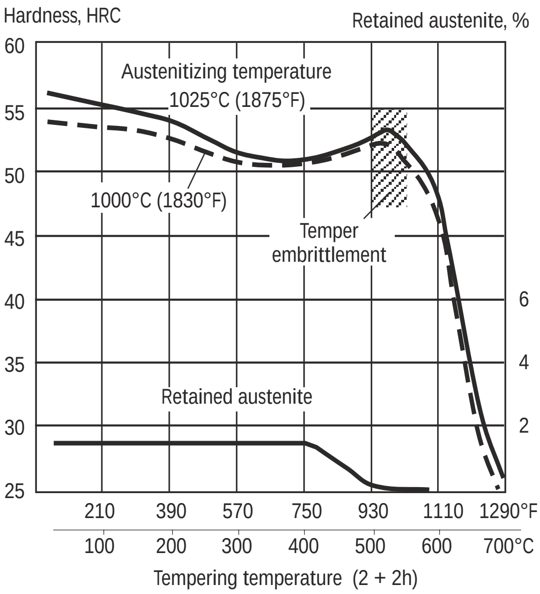
TEMPERING

The optimal working hardness and tempering temperature for a die are very dependent upon the specific application. As a general rule, if heat checking is the primary concern and there is no history of gross cracking for a given premium H13 die, then an increase in working hardness of approximately 2 HRC is recommended for the Dievar tool. If gross cracking is a concern for the given project then a comparable working hardness should be used.

The tempering temperature for a given working hardness should be selected by referencing the below tempering graph. Temper minimum of two times with intermediate cooling to room temperature after each tempering operation. Holding time at temperature minimum 2 hours. Check working hardness between tempers and adjust temperature accordingly to maintain the specified working hardness. A stress temper is recommended.

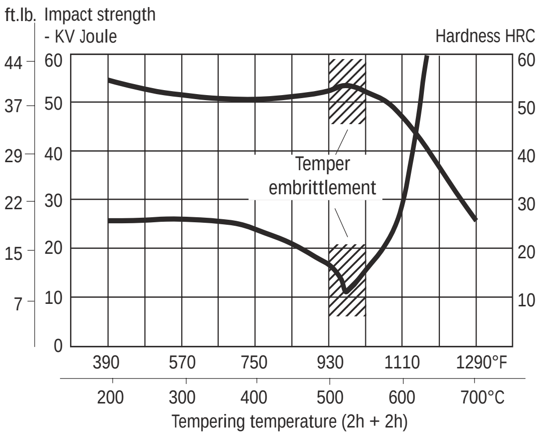
Do not temper in the range of 930–1020°F (500–550°C) to avoid temper embrittlement.

Tempering graph



Effect of tempering temperature on room temperature Charpy V notch impact energy

Short transverse direction.



DIMENSIONAL CHANGES DURING HARDENING AND TEMPERING

During hardening and tempering the tool is exposed to both thermal and transformation stresses. These stresses will result in dimensional changes and distortion. Insufficient levels of machine stock may result in slower than recommended quench rates during heat treatment. In order to predict maximum levels of distortion with a proper quench, a stress relief is always recommended between rough and semi-finish machining, prior to hardening.

For a stress relieved Dievar tool a minimum machine stock of 0.3% of the largest tool dimension is recommended to account for acceptable levels of distortion during a heat treatment with a rapid quench.

NITRIDING AND NITROCARBURIZING

Nitriding and nitrocarburizing result in a hard surface layer which has the potential to improve resistance to wear and soldering, as well as resistance to premature heat checking. Dievar can be nitrided and nitrocarburized via a plasma, gas, fluidized bed, or salt process. The temperature for the deposition process should be 50–90°F (25–50°C) below the highest previous tempering temperature, depending upon the process time and temperature. Otherwise a permanent loss of core hardness, strength, and/or dimensional tolerances may be experienced.

During nitriding and nitrocarburizing, a brittle compound layer, known as the white layer, may be generated. The white layer is very brittle and may result in cracking or spalling when exposed to heavy mechanical or thermal loads. As a general rule the white layer formation should be avoided for a majority of hot work tooling applications.

The following guidelines can be used to minimize the risk of overnitrided conditions:

- Nitride layers in excess of 0.005" (0.125 mm) should be avoided in most hot work applications
- Ion processes are preferred
- Nitrocarburizing will reduce the tendency towards white layer formation and the white layer will be more ductile in comparison to a conventional nitride process.

Nitriding/Nitrocarburizing process parameter guidelines

Process	Time	Depth	Hardness $HV_{0.2}$
Gas nitriding at 950°F (510°C)	10 h 30 h	0.0063 inch 0.16 mm 0.0087 inch 0.22 mm	1000
Plasma nitriding at 895°F (480°C)	10 h	0.0059 inch 0.15 mm	1000
Nitrocarburizing – in gas at 1075°F (580°C) – in salt bath at 1075°F (580°C)	 2 h 1 h	 0.0051 inch 0.13 mm 0.0031 inch 0.08 mm	900

* *Depth of case = distance from surface where hardness is 50 $HV_{0.2}$ over base hardness.*

Cutting data recommendations

The cutting data below should to be considered as guidelines only. These guidelines must be adapted to local machining conditions.

Condition: Soft annealed to ~160 HB

TURNING

Cutting data parameters	Turning with carbide: Rough turning	Turning with carbide: Fine turning	Turning with high speed steel: Fine turning
Cutting speed (v_c) ft/min m/min	 490–655 150–200	 655–820 200–250	 50–65 15–20
Feed (f) in/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_p) inch mm	 0.08–0.16 2–4	 0.02–0.08 0.5–2	 0.02–0.08 0.5–2
Carbide designation US ISO	 C6–C5 P20–P30 Coated carbide	 C7 P10 Coated carbide or cermet	 – –

MILLING

Face- and square shoulder milling

Cutting data parameters	Milling with carbide: Rough milling	Milling with carbide: Fine milling
Cutting speed (v_c) ft/min m/min	 430–590 130–180	 590–720 180–220
Feed (f_z) in/tooth mm/tooth	 0.008–0.016 0.2–0.4	 0.004–0.008 0.1–0.2
Depth of cut (a_p) inch mm	 0.08–0.16 2–4	 –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	Type of milling: Carbide indexable insert	Type of milling: High speed steel
Cutting speed (v_c) ft/min m/min	 425–560 130–170	 390–520 120–160	 80–100[1] 25–30[1]
Feed (f_z) in/tooth mm/tooth	 0.001–0.008[2] 0.03–0.20[2]	 0.003–0.008[2] 0.08–0.20[2]	 0.002–0.014[2] 0.05–0.35[2]
Carbide designation US ISO	 – –	 C6–C5 P20–P30	 – –

[1] For coated HSS end mill v_c 150–160 ft/min (40–50 m/min).
[2] Depending on radial depth of cut and cutter diameter.

DRILLING

High speed steel twist drill

Drill diameter inch	Drill diameter mm	Cutting speed (v_c) ft/min	Cutting speed (v_c) m/min	Feed (f) in/r	Feed (f) mm/r
–3/16	– 5	49–66*	15–20*	0.002–0.006	0.05–0.15
3/16–3/8	5–10	49–66*	15–20*	0.006–0.008	0.15–0.20
3/8–5/8	10–15	49–66*	15–20*	0.008–0.010	0.20–0.25
5/8–3/4	15–20	49–66*	15–20*	0.010–0.014	0.25–0.35

** For coated HSS drill v_c ~110–130 ft/min (35–40 m/min).*

Carbide drill

Cutting data parameters	Type of drill: Indexable insert	Type of drill: Solid carbide	Type of drill: Brazed carbide[1]
Cutting speed (v_c) ft/min m/min	 590–720 180–220	 390–490 120–150	 195–295 60–90
Feed (f) in/r mm/r	 0.002–0.01[2] 0.05–0.25[2]	 0.004–0.01[2] 0.10–0.25[2]	 0.006–0.01[2] 0.15–0.25[2]

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

Cutting data recommendations

The cutting data below should to be considered as guidelines only. These guidelines must be adapted to local machining conditions.

Condition: Hardened and tempered to 44–46 HRC

TURNING

Cutting data parameters	Turning with carbide: Rough turning	Turning with carbide: Fine turning
Cutting speed (v_c) ft/min m/min	 130–195 40–60	 230–295 70–90
Feed (f) in/r mm/r	 0.008–0.016 0.2–0.4	 0.002–0.008 0.05–0.2
Depth of cut (a_p) inch mm	 0.04–0.08 1–2	 0.02–0.04 0.5–1
Carbide designation US ISO	 C6–C5 P20–P30 Coated carbide	 C7 P10 Coated carbide or mixed ceramic

MILLING

Face- and square shoulder milling

Cutting data parameters	Milling with carbide: Rough milling	Milling with carbide: Fine milling
Cutting speed (v_c) ft/min m/min	 160–295 50–90	 295–425 90–130
Feed (f_z) in/tooth mm/tooth	 0.008–0.016 0.2–0.4	 0.004–0.008 0.1–0.2
Depth of cut (a_p) inch mm	 0.08–0.16 2–4	 –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	Type of milling: Carbide indexable insert	Type of milling: High speed steel TiCN coated
Cutting speed (v_c) ft/min m/min	 195–260 60–80	 230–295 70–90	 16–33 5–10
Feed (f_z) in/tooth mm/tooth	 0.001–0.008[1)] 0.03–0.20[1)]	 0.003–0.008[1)] 0.08–0.20[1)]	 0.002–0.014[1)] 0.05–0.35[1)]
Carbide designation US ISO	 – –	 C6–C5 P10–P20	 – –

[1)] Depending on radial depth of cut and cutter diameter.

DRILLING

High speed steel twist drill (TiCN coated)

Drill diameter inch	Drill diameter mm	Cutting speed (v_c) ft/min	Cutting speed (v_c) m/min	Feed (f) in/r	Feed (f) mm/r
–3/16	– 5	13–20	4–6	0.002–0.004	0.05–0.10
3/16–3/8	5–10	13–20	4–6	0.004–0.006	0.10–0.15
3/8–5/8	10–15	13–20	4–6	0.006–0.008	0.15–0.20
5/8–3/4	15–20	13–20	4–6	0.008–0.012	0.20–0.30

Carbide drill

Cutting data parameters	Type of drill: Indexable insert	Type of drill: Solid carbide	Type of drill: Brazed carbide[1)]
Cutting speed (v_c) ft/min m/min	 195–260 60–80	 195–260 60–80	 130–160 40–50
Feed (f) in/r mm/r	 0.002–0.01[2)] 0.05–0.25[2)]	 0.004–0.01[2)] 0.10–0.25[2)]	 0.006–0.01[2)] 0.15–0.25[2)]

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

GRINDING

General grinding wheel recommendations are provided below. More information can be found in the Uddeholm brochure "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 46 LV	A 60 KV
Internal grinding	A 46 JV	A 60 IV
Profile grinding	A 100 LV	A 120 JV

Electrical Discharge Machining

Following the EDM process, the applicable die surfaces are covered with a resolidified layer (white layer) and a rehardened and untempered layer, both of which are very brittle and hence detrimental to die performance, especially with regards to heat checking and gross cracking.

If EDM is used during the rough machining or semi-finish machining phases (i.e. prior to hardening) the white layer must be completely removed by mechanical means (i.e. grinding, stoning) prior to heat treatment. Remnants of an EDM recast layer significantly increase the risk of quench cracking during the hardening operation.

If EDM is utilized during finish machining the following precautions must be taken to restore die surface properties, prior to going into service.

1. Finish the EDM process with a fine cut (i.e. low current, high frequency). This fine cut must remove enough material to diminish all effects of the rough EDM process.
2. Stone all cavity surfaces to remove the hard, resolidified (white) layer.
3. Stress temper the die at 50°F (25°C) below the highest previous tempering temperature. Hold the tool for a minimum of 2 hours once the temperature is equalized throughout the tool and then cool in air.
4. For die casting tools, this post EDM stress temper shall be performed as the last step in the die making procedure. The oxidized surface from this operation shall be left intact as a good reservoir for lubricant and to act as an oxide barrier against washout.

Die for hydraulic top slide

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 die, the controlled cooling of the die and the post weld heat treatment processes.
When welding a coated die component the coating must be stripped away from the immediate vicinity of the weld zone to prevent cracking.
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*	620–710°F (325–375°C)	620–710°F (325–375°C)
Filler metals	DIEVAR TIG-WELD QRO 90 TIG-WELD	QRO 90 WELD
Maximum interpass temperature	885°F (475°C)	885°F (475°C)
Post welding cooling	20–40°F/h (10–20°C/h) for the first 2–3 hours and then freely in air.	
Hardness after welding	50–55 HRC	50–55 HRC
Heat treatment after welding		
Hardened condition	Temper at 50°F (25°C) below the highest previous tempering temperature.	
Soft annealed condition	Soft-anneal the material at 1560°F (850°C) in protected atmosphere. Then cool in the furnace at 20°F (10°C) per hour to 1110°F (600°C) then freely in air.	

**Preheating temperature must be established throughout the die and must be maintained for the entirety of the welding process, to prevent weld cracking.*

Further information

Please, contact Bohler-Uddeholm North America for further information on the selection, heat treatment, application and availability of Uddeholm tool steels.