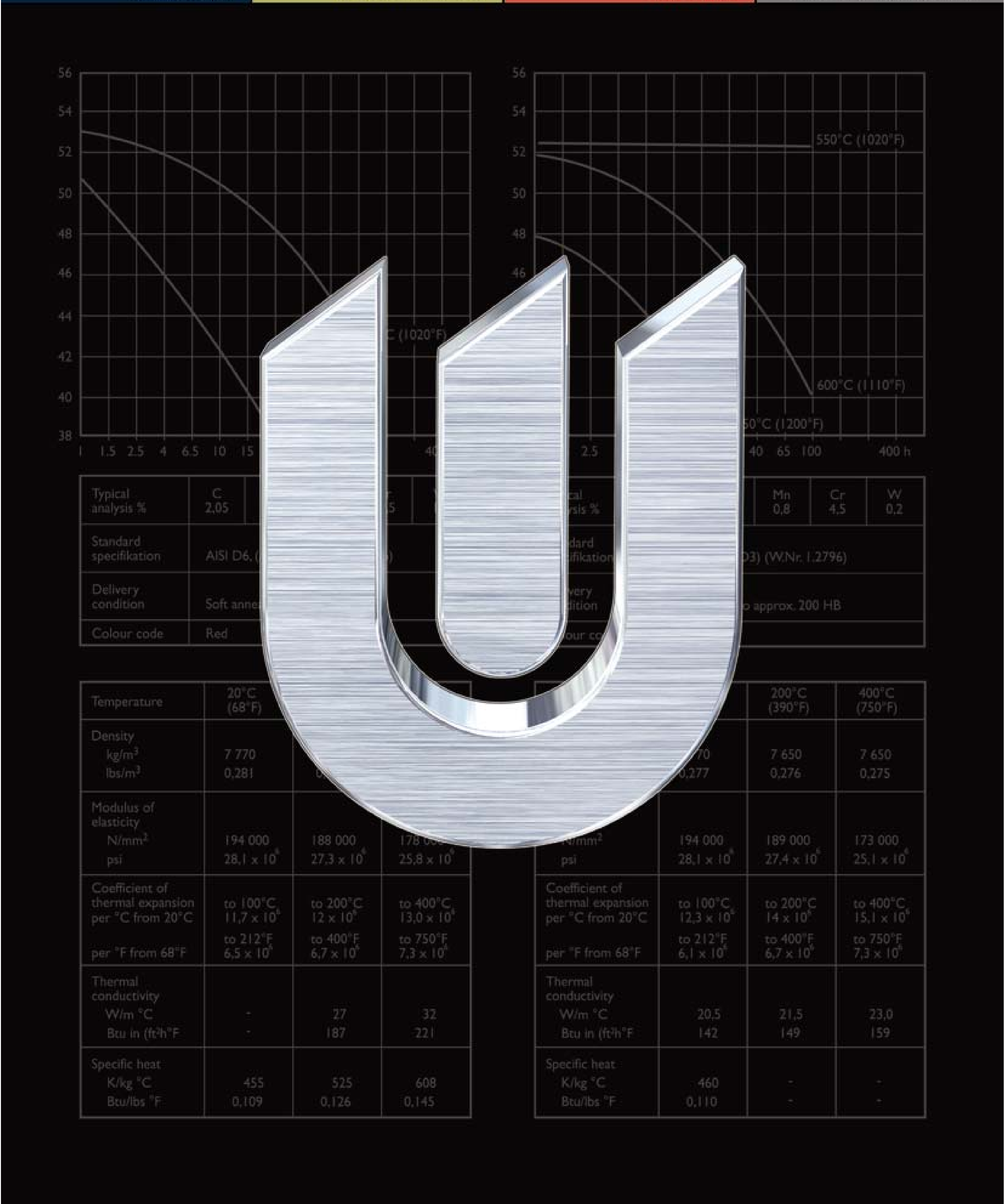
# ORVAR SUPREME

**Hot work tool steel**

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



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.

# General

*ORVAR SUPREME* is a chromium-molybdenum-vanadium-alloyed steel which is characterized by:

- High level of resistance to thermal shock and thermal fatigue
- Good high-temperature strength
- Excellent toughness and ductility **in all directions**
- Good machinability and polishability
- Excellent through-hardening properties
- Good dimensional stability during hardening.

| Typical analysis % | C | Si | Mn | Cr | Mo | V |
|---|---|---|---|---|---|---|
| | 0,39 | 1,0 | 0,4 | 5,2 | 1,4 | 0,9 |
| Standard specification | Premium AISI H13, W.-Nr. 1.2344 | | | | | |
| Delivery condition | Soft annealed to approx. 180 HB | | | | | |
| Colour code | Orange | | | | | |

### IMPROVED TOOLING PERFORMANCE

The name "SUPREME" implies that by special processing techniques and close control, the steel attains high purity and a very fine structure. Further, *ORVAR SUPREME* shows significant improvements in isotropic properties compared to conventionally produced AISI H 13 grades.

These improved isotropic properties are particularly valuable for tooling subjected to high mechanical and thermal fatigue stresses, e.g. die casting dies, forging tools and extrusion tooling. In practical terms, tools may be used at somewhat higher working hardnesses (+1 to 2 HRC) without loss of toughness. Since increased hardness slows down the formation of heatchecking cracks, improved tool performance can be expected.

*ORVAR SUPREME* meets the North American Die Casting Association (NADCA) #207-97 for **premium** high quality H-13 die steel.

# Applications

### TOOLS FOR DIE CASTING

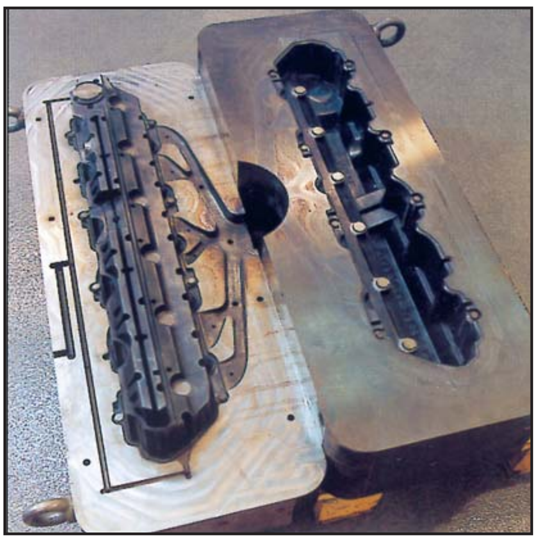
| Part | Tin, lead zinc alloys HRC | Aluminium, magnesium alloys, HRC | Copper alloys HRC |
|---|---|---|---|
| Dies | 46–50 | 42–48 | (QRO 90 S) |
| Fixed inserts cores | 46–52 | 44–48 | (QRO 90 S) |
| Sprue parts | 48–52 | 46–48 | (QRO 90 S) |
| Nozzles | 35–42 | 42–48 | (QRO 90 S) |
| Ejector pins (nitrided) | 46–50 | 46–50 | 46–50 |
| Plunger, shot-sleeve (normally nitrided) | 42–46 | 42–48 | (QRO 90 S) |
| Austenitizing temperature | 1020–1030°C (1870–1885°F) | | 1040–1050°C (1900–1920°F) |

### TOOLS FOR EXTRUSION

| Part | Aluminium, magnesium alloys, HRC | Copper alloys HRC | Stainless steel HRC |
|---|---|---|---|
| Dies | 44–50 | 43–47 | 45–50 |
| Backers, die-holders, liners, dummy blocks, stems | 41–50 | 40–48 | 40–48 |
| Austenitizing temperature (approx.) | 1020–1030°C (1870–1885°F) | 1040–1050°C (1900–1920°F) | |

### TOOLS FOR HOT PRESSING

| Material | Aust. temp. (approx.) | HRC |
|---|---|---|
| Aluminium, magnesium | 1020–1030°C (1870–1885°F) | 44–52 |
| Copper alloys | 1040–1050°C (1900–1920°F) | 44–52 |
| Steel | 1040–1050°C (1900–1920°F) | 40–50 |



### MOULDS FOR PLASTICS

| Part | Austenitizing temp. | HRC |
|---|---|---|
| Injection moulds<br>Compression/<br>transfer moulds | 1020–1030°C (1870–1885°F)<br><br>Tempering 250°C (480°F) | 50–52 |

### OTHER APPLICATIONS

| Application | Austenitizing temp. | HRC |
|---|---|---|
| Severe cold punching, scrap shears | 1020–1030°C (1870–1885°F)<br>Tempering 250°C (480°F) | 50–52 |
| Hot shearing | 1020–1030°C (1870–1885°F)<br>Tempering<br>1. 250°C (480°F) or<br>2. 575–600°C (1070–1110°F) | 50–52<br>45–50 |
| Shrink rings (e.g. for cemented carbide dies) | 1020–1030°C (1870–1885°F)<br>Tempering 575–600°C (1070–1110°F) | 45–50 |
| Wear-resisting parts | 1020–1030°C (1870–1885°F)<br>Tempering 575°C (1070°F)<br>Nitriding | Core<br>50–52<br>Surface<br>~1000$HV_1$ |

# Properties

All specimens are taken from the centre of a 407 x 127 mm (16" x 5") bar. Unless otherwise is indicated all specimens were hardened 30 minutes at 1025°C (1875°F), quenched in air and tempered 2 + 2 h at 610°C (1130°F). The hardness were 45 ± 1 HRC.

### PHYSICAL DATA

Data at room and elevated temperatures.

| Temperature | 20°C (68°F) | 400°C (750°F) | 600°C (1110°F) |
|---|---|---|---|
| Density<br>kg/m³<br>lbs/in³ | <br>7800<br>0,281 | <br>7700<br>0,277 | <br>7600<br>0,274 |
| Modulus of elasticity<br>MPa<br>psi | <br>210 000<br>30,5 x $10^6$ | <br>180 000<br>26,1 x $10^6$ | <br>140 000<br>20,3 x $10^6$ |
| Coefficient of thermal expansion per<br>°C from 20°C<br>°F from 68°F | <br>–<br>– | <br>12,6 x $10^{-6}$<br>7,0 x $10^{-6}$ | <br>13,2 x $10^{-6}$<br>7,3 x $10^{-6}$ |
| Thermal conductivity<br>W/m °C<br>Btu in/(ft²h°F) | <br>25<br>176 | <br>29<br>204 | <br>30<br>211 |

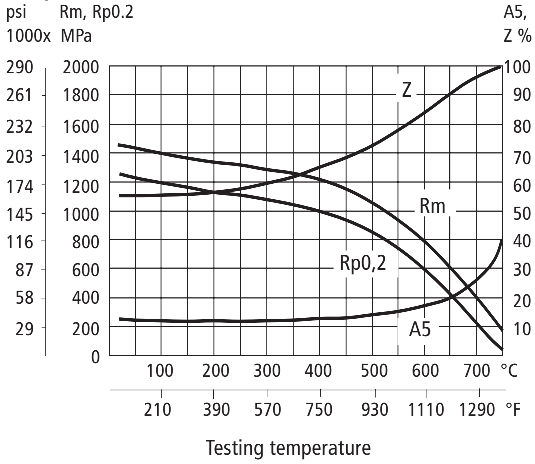
### MECHANICAL PROPERTIES

Approximate tensile strength at room temperature.

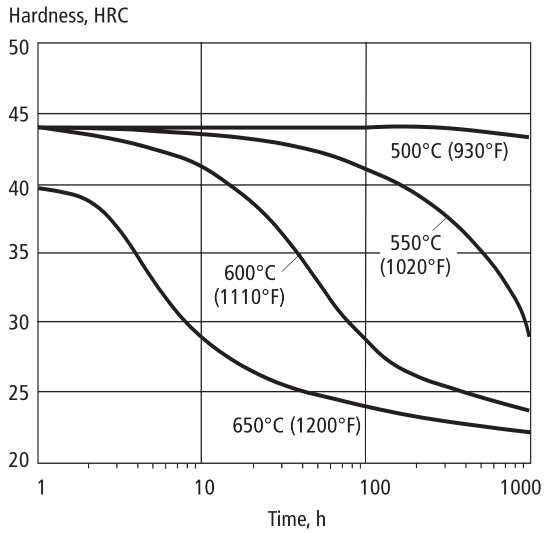
| Hardness | 52 HRC | 45 HRC |
|---|---|---|
| Tensile strength<br>$R_m$ | 1820 MPa<br>185 kp/mm²<br>117 tsi<br>263 000 psi | 1420 MPa<br>145 kp/mm²<br>92 tsi<br>206 000 psi |
| Yield strength<br>$R_{p0,2}$ | 1520 MPa<br>155 kp/mm²<br>98 tsi<br>220 000 psi | 1280 MPa<br>130 kp/mm²<br>83 tsi<br>185 000 psi |

*Approximate strength at elevated temperatures*

Longitudinal direction.

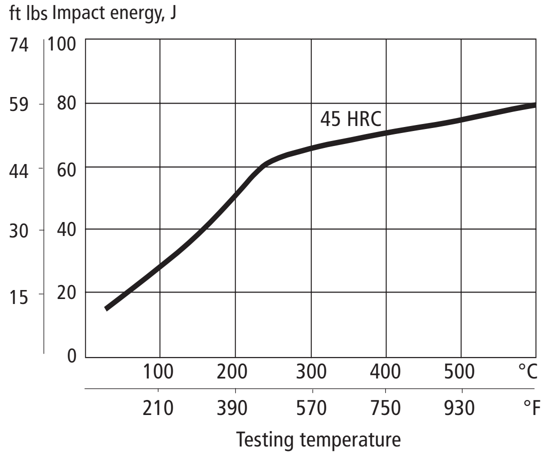



*Effect of time at high temperatures on hardness*



*Effect of testing temperature on impact energy*

Charpy V specimens, short transverse direction.




### 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

*Pre-heating temperature:* 600–850°C (1110–1560°F), normally in two pre-heating steps.

*Austenitizing temperature:* 1020–1050°C (1870–1920°F), normally 1020–1030°C (1870–1885°F).

| Temperature °C | Temperature °F | Soaking* time minutes | Hardness before tempering |
|---|---|---|---|
| 1025 | 1875 | 30 | 53±2 HRC |
| 1050 | 1920 | 15 | 54±2 HRC |

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

*Protect the part against decarburization and oxidation during hardening.*

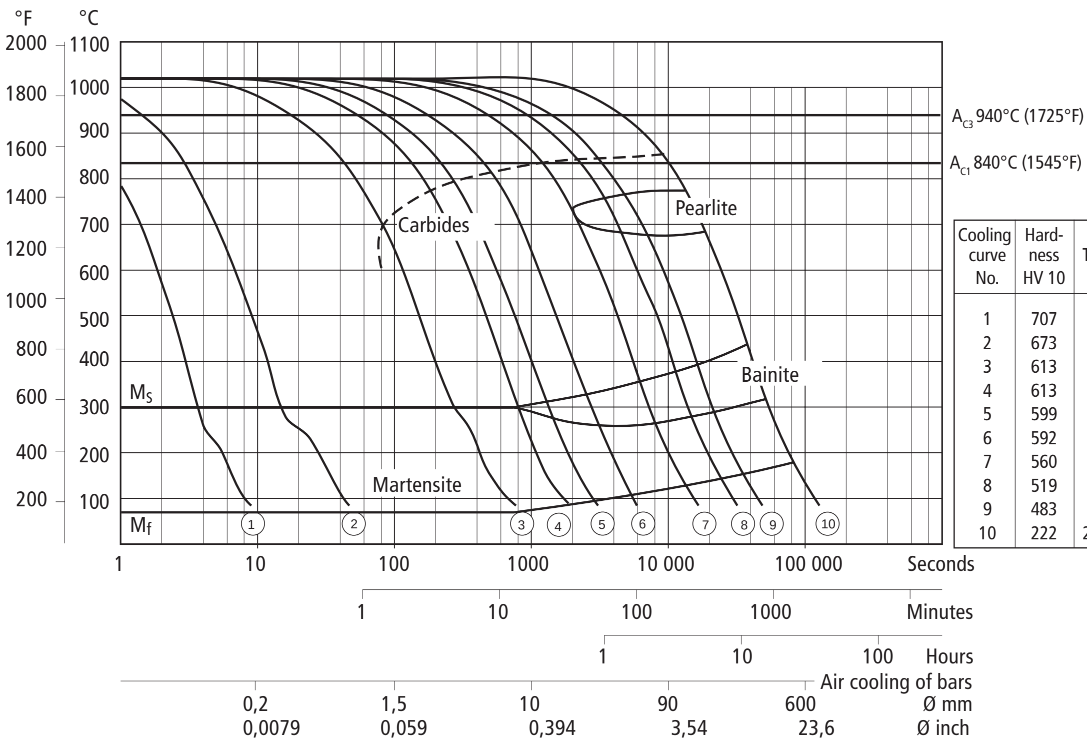
# Heat treatment– general recommendations

### SOFT ANNEALING

Protect the steel and heat through to 850°C (1560°F). Then cool in the furnace at 10°C (20°F) per hour to 650°C (1200°F), then freely in air.

*CCT graph*

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




| Cooling curve No. | Hardness HV 10 | $T_{800-500}$ (sec) |
|---|---|---|
| 1 | 707 | 1 |
| 2 | 673 | 6 |
| 3 | 613 | 105 |
| 4 | 613 | 316 |
| 5 | 599 | 527 |
| 6 | 592 | 1054 |
| 7 | 560 | 2772 |
| 8 | 519 | 5271 |
| 9 | 483 | 7944 |
| 10 | 222 | 20768 |

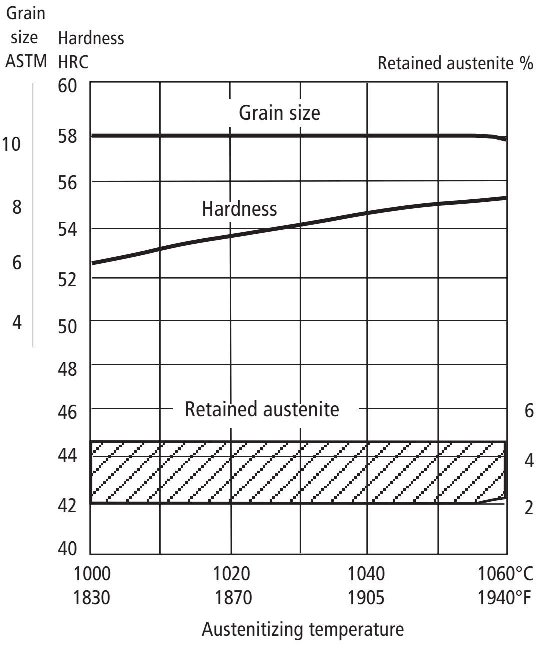
## QUENCHING MEDIA

- High speed gas/circulating atmosphere
- Vacuum (high speed gas with sufficient positive pressure). An interrupted quench is recommended where distortion control and quench cracking are a concern
- Martempering bath or fluidized bed at 450–550°C (840–1020°F), then cool in air
- Martempering bath or fluidized bed at approx. 180–220°C (360–430°F) then cool in air
- Warm oil.

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

*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.

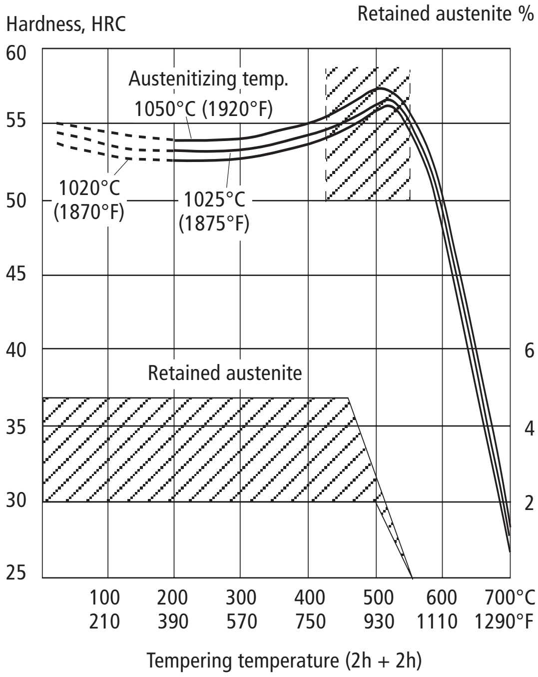
*Hardness, grain size and retained austenite as functions of austenitizing temperature*

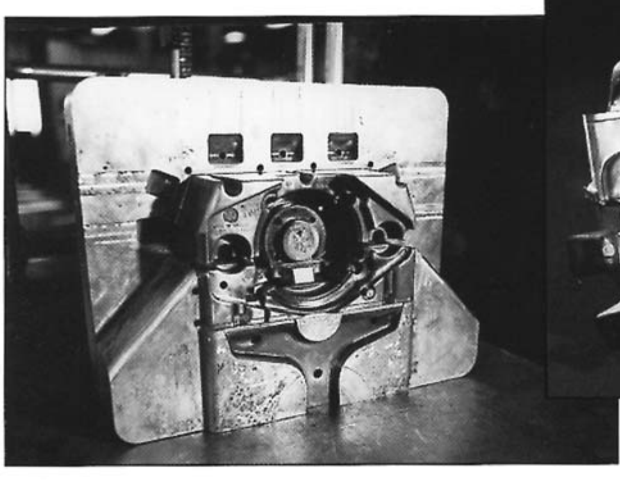


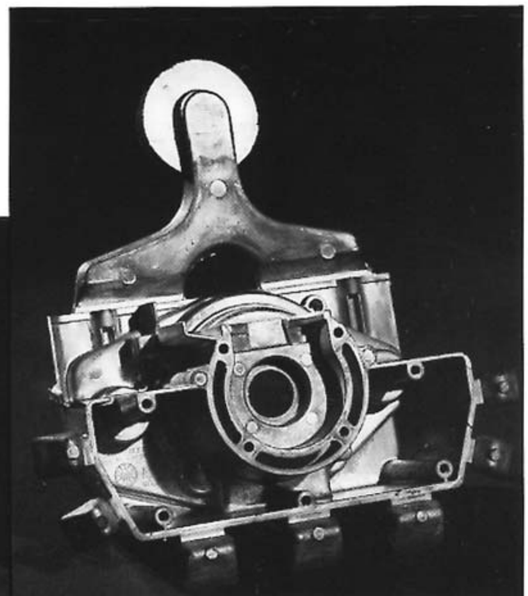

## TEMPERING

Choose the tempering temperature according to the hardness required by reference to the tempering graph. Temper minimum twice with intermediate cooling to room temperature. Lowest tempering temperature 250°C (480°F). Holding time at temperature minimum 2 hours. To avoid "temper brittleness", do not temper in the range 425–550°C (800–1020°F), see graph.

*Tempering graph*

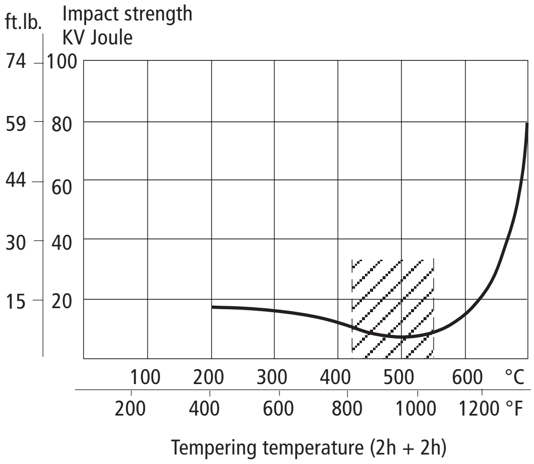




*Approximate impact strength at different tempering temperatures.*

Charpy V specimens, short transverse direction.



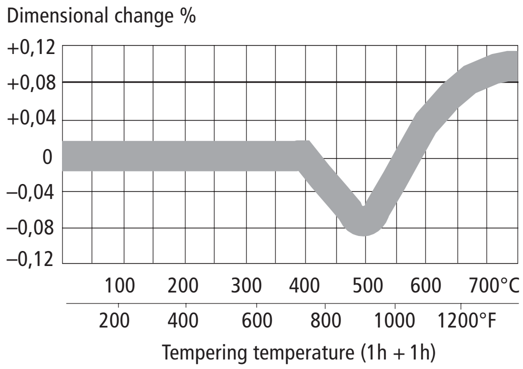

Tempering within the range 425–550°C (800–1020°F) is normally not recommended due to the reduction in toughness properties.

## DIMENSIONAL CHANGES DURING HARDENING

Sample plate, 100 x 100 x 25 mm, 4" x 4" x 1".

| | | Width % | Length % | Thickness % |
|---|---|---|---|---|
| Oil hardened from 1020°C (1870°F) | Min. | –0,08 | –0,06 | ±0 |
| | Max. | –0,15 | –0,16 | +0,30 |
| Air hardened from 1020°C (1870°F) | Min. | –0,02 | –0,05 | ±0 |
| | Max. | +0,03 | +0,02 | +0,05 |
| Vac hardened from 1020°C (1870°F) | Min. | +0,01 | –0,02 | +0,08 |
| | Max. | +0,02 | –0,04 | +0,12 |

## DIMENSIONAL CHANGES DURING TEMPERING




*Note:* The dimensional changes in hardening and tempering should be added.

## 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 increasing with layer thickness. Before nitriding, the tool should be hardened and tempered at a temperature at least 50°C (90°F) above the nitriding temperature.

Nitriding in ammonia gas at 510°C (950°F) or plasma nitriding in a 75% hydrogen/25% nitrogen mixture at 480°C (895°F) both result in a surface hardness of about 1100 $HV_{0,2}$. In general, plasma nitriding is the preferred method because of better control over nitrogen potential; in particular, formation of the so-called white layer, which is not recommended for hot-work service, can readily be avoided. However, careful gas nitriding can give perfectly acceptable results.

*ORVAR SUPREME* can also be nitrocarburized in either gas or salt bath. The surface hardness after nitrocarburizing is 900–1000 $HV_{0,2}$.

## DEPTH OF NITRIDING

| Process | Time | Depth mm | Depth inch |
|---|---|---|---|
| Gas nitriding at 510°C (950°F) | 10 h | 0,12 | 0,0047 |
| | 30 h | 0,20 | 0,0079 |
| Plasma nitriding at 480°C (895°F) | 10 h | 0,12 | 0,0047 |
| | 30 h | 0,18 | 0,0071 |
| Nitrocarburizing – in gas at 580°C (1075°F) | 2,5 h | 0,11 | 0,0043 |
| – in salt bath at 580°C (1075°F) | 1 h | 0,06 | 0,0024 |

Nitriding to case depths >0,3 mm (>0,012 inch) is not recommended for hot-work applications. *ORVAR SUPREME* can be nitrided in the soft-annealed condition. The hardness and depth of case will, however, be reduced somewhat in this case.

# Machining recommendations

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

## TURNING

| Cutting data parameters | Turning with carbide: Rough turning | Turning with carbide: Fine turning | Turning with high speed steel: Fine turning |
|---|---|---|---|
| Cutting speed ($v_c$)<br>m/min<br>f.p.m. | 200–250<br>660–820 | 250–300<br>820–985 | 25–30<br>82–100 |
| Feed (f)<br>mm/r<br>i.p.r. | 0,2–0,4<br>0,008–0,016 | 0,05–0,2<br>0,002–0,008 | 0,05–0,3<br>0,002–0,012 |
| Depth of cut ($a_p$)<br>mm<br>inch | 2–4<br>0,08–0,16 | 0,5–2<br>0,02–0,08 | 0,5–2<br>0,02–0,08 |
| Carbide designation ISO | P20–P30<br>Coated carbide | P10<br>Coated carbide or cermet | – |

## 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 | 16–18* | 52–59* | 0,05–0,15 | 0,002–0,006 |
| 5–10 | 3/16–3/8 | 16–18* | 52–59* | 0,15–0,20 | 0,006–0,008 |
| 10–15 | 3/8–5/8 | 16–18* | 52–59* | 0,20–0,25 | 0,008–0,010 |
| 15–20 | 5/8–3/4 | 16–18* | 52–59* | 0,25–0,35 | 0,010–0,014 |

* *For coated HSS drill $v_c$ 28–30 m/min. (92–98 f.p.m.).*

### Carbide drill

| Cutting data parameters | Type of drill: Indexable insert | Solid carbide | Brazed carbide[1] |
|---|---|---|---|
| Cutting speed ($v_c$)<br>m/min<br>f.p.m. | 220–240<br>720–785 | 130–160<br>425–525 | 80–110<br>260–360 |
| Feed (f)<br>mm/r<br>i.p.r. | 0,03–0,10[2]<br>0,001–0,004[2] | 0,10–0,25[2]<br>0,004–0,010[2] | 0,15–0,25[2]<br>0,006–0,010[2] |

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

## MILLING

### Face milling and square shoulder face milling

| Cutting data parameters | Milling with carbide: Rough milling | Milling with carbide: Fine milling |
|---|---|---|
| Cutting speed ($v_c$)<br>m/min<br>f.p.m. | 180–260<br>590–850 | 260–300<br>850–985 |
| Feed ($f_z$)<br>mm/tooth<br>inch/tooth | 0,2–0,4<br>0,008–0,016 | 0,1–0,2<br>0,004–0,008 |
| Depth of cut ($a_p$)<br>mm<br>inch | 2–5<br>0,08–0,20 | –2<br>–0,08 |
| Carbide designation ISO | P20–P40<br>Coated carbide | P10–P20<br>Coated carbide or cermet |

### End milling

| Cutting data parameters | Type of end mill: Solid carbide | Carbide indexable insert | High speed steel |
|---|---|---|---|
| Cutting speed ($v_c$)<br>m/min<br>f.p.m. | 160–200<br>525–660 | 170–230<br>560–755 | 35–40[1]<br>115–130[1] |
| Feed ($f_z$)<br>mm/tooth<br>inch/tooth | 0,03–0,20[2]<br>0,001–0,008[2] | 0,08–0,20[2]<br>0,003–0,008[2] | 0,05–0,35[2]<br>0,002–0,014[2] |
| Carbide designation ISO | – | P20, P30 | – |

[1] *For coated HSS end mill $v_c$ 55–60 m/min. (180–195 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" and can also be obtained from the grinding wheel manufacturer.

### Wheel recommendation

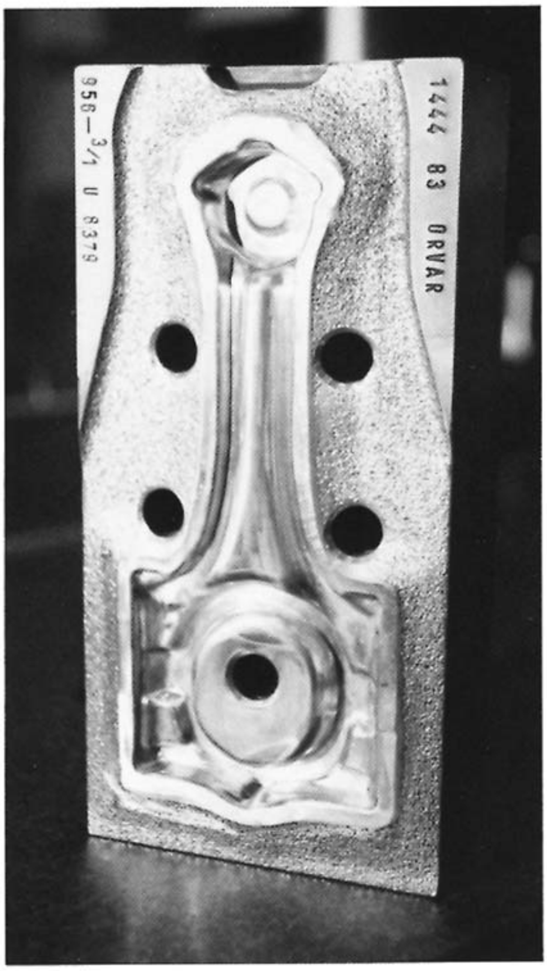
| Type of grinding | Soft annealed condition | Hardened condition |
|---|---|---|
| Face grinding straight wheel | A 46 HV | A 46 HV |
| Face grinding segments | A 24 GV | A 36 GV |
| Cylindrical grinding | A 46 LV | A 60 KV |
| Internal grinding | A 46 JV | A 60 IV |
| Profile grinding | A 100 LV |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

## Welding

Welding of tool steel can be performed with good results if proper precautions are taken regarding elevated temperature, joint preparation, choice of consumables and welding procedure.

| **Welding method** | TIG | MMA |
|---|---|---|
| Working temperature | 325–375°C<br>620–710°F | 325–375°C<br>620–710°F |
| Filler metal | QRO 90 TIG-WELD | QRO 90 WELD |
| Hardness after welding | 50–55 HRC | 50–55 HRC |
| **Heat treatment after welding** | | |
| Hardened condition | Temper at 20°C (40°F) below the original tempering temperature. | |
| Soft annealed condition | Soft-anneal the material at 850°C (1560°F) in protected atmosphere. Then cool in the furnace at 10°C (20°F) per hour to 650°C (1200°F) then freely in air. | |

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




## Electrical-discharge machining

If spark-erosion 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. 25°C (50°F) below the previous tempering temperature.

## Hard-chromium plating

After plating, parts should be tempered at 180°C (360°F) for 4 hours within 4 hours of plating to avoid the risk of hydrogen embrittlement.

## Photo-etching

*ORVAR SUPREME* is particularly suitable for texturing by the photo-etching method. Its high level of homogeneity and low sulphur content ensures accurate and consistent pattern reproduction.

## Polishing

*ORVAR SUPREME* exhibits good polishability in the hardened and tempered condition. Polishing after grinding can be effected using aluminium oxide or diamond paste.

Typical procedure:

1. Rough grinding to 180–320 grain size using a wheel or stone.
2. Fine grinding with abrasive paper or powder down to 400–800 grain size.
3. Polish with diamond paste grade 15 (15µm grain size) using a polishing tool of soft wood or fibre.
4. Polish with diamond paste 3 (3µm grain size) using a polishing tool of soft wood or fibre.
5. When demands on surface finish are high, grade 1 (1µm grain size) diamond paste can be used for final polishing with a fibre polishing pad.

## Further information

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