UDDEHOLM BALDER®

UDDEHOLM

UDDEHOLM BALDER

Reliable and efficient steel is essential for good results. The same goes for achieving high productivity and high availability. When choosing the right steel many parameters must be considered, by using superior steel your productivity and your product performance can be greatly improved. With excellent machinability you will spend less time to finish your product, this makes it easier to meet your deadline.

Uddeholm Balder is a steel grade which provides several benefits in applications with high demands on mechanical properties in combination with excellent machinability.

SUPERIOR MACHINABILITY

Superior machinability will give you the advantage of shorter machining time. In turn this means that it will be easier for you to meet your customer demands on delivery time. You will also benefit from lower cutting tool cost and increased availability of your machines. The excellent machinability will be most evident when end milling with small milling cutters and drilling and tapping of small holes.

GOOD MECHANICAL PROPERTIES AT HIGH TEMPERATURES

Uddeholm Balder is an excellent choice for products where good high-temperature strength, temper resistance and high-temperature fatigue are required. It has also very good resistance to abrasion at both low and high temperatures.

UDDEHOLM STEEL FOR INDEXABLE INSERT CUTTING TOOLS

Uddeholm Balder provides longer life and better performance of indexable insert cutting tools such as drills and milling cutters. Uddeholm Balder is eminently suitable for cutting tools subjected to high temperatures and severe chip wear and with high demands on machinability in prehardened condition.

Classified according to EU Directive 1999/45/EC
For further information see our "Material Safety Data Sheets".

Edition 1, 10.2014
The latest revised edition of this brochure is the English version, which is always published on our web site www.uddeholm.com

General

Uddeholm Balder is a chromium-molybdenum-vanadium-nickel alloyed high performance tool steel which is characterized by:

- Very good high-temperature strength
- Superb temper resistance
- Excellent machinability
- Good toughness and ductility
- Good resistance to abrasion at both low and high temperatures

Machinability of the Uddeholm Balder is improved, specially in hardened and tempered condition, which facilitates such operations as drilling and tapping of small holes. It is suitable for induction-hardening and can also be given a PVD coating without reducing the hardness of the tool.

Typical analysis %	C 0.3	Si 0.3	Mn 1.2	Cr 2.3	Mo 0.8	V 0.8	Ni 4.0
Standard specification	None						
Delivery condition	Hardened to 42–45 HRC Soft annealed on demand						
Colour code	Brown/dark red – hardened Brown/dark blue – soft annealed						

Properties

The reported properties are representative of samples which have been taken from the centre of a 200 mm (8") bar. Unless otherwise is indicated, all specimens are in delivery condition hardened to 42–45 HRC

Physical properties

Data at room and elevated temperatures.

Temperature	20°C (68°F)	400°C (750°F)	600°C (1110°F)
Density kg/m^3 lbs/in^3	7 810 0.281	7 700 0.277	7 640 0.275
Modulus of elasticity N/mm^2 psi	210 000 30.5×10^6	180 000 26.1×10^6	140 000 20.3×10^6
Coefficient of thermal expansion per °C from 20°C per °F from 68°F	– –	12.0×10^{-6} 6.6×10^{-6}	13.0×10^{-6} 7.2×10^{-6}
Coefficient of thermal conductivity W/m °C Btu in/(ft^2h°F)	– –	29 204	30 211
Specific heat capacity J/kg °C Btu/In°F	435 0.104	– –	– –

Applications

Uddeholm Balder is intended for applications with severe demands on high-temperature strength of the material, while also requiring excellent machinability.

Examples of applications are:

- Indexable insert drills and milling cutters
- Milling chucks and tool tapers
- Engineering components with severe demands on high temperature strength

Indexable insert milling cutter.

Mechanical properties

TENSILE STRENGTH

Hardness	310 HB*	44 HRC**	47 HRC***
Ultimate tensile strength Rm, MPa kp/mm² tsi psi	 1 030 105 67 149 000	 1440 147 93 208 000	 1600 163 103 232 000
Yield tensile strength Rp0,2, MPa kp/mm² tsi psi	 760 77 49 110 000	 1230 125 79 178 000	 1320 134 85 191 000
Elongation A5, %	15	12	12
Reduction of area Z, %	53	52	52

COMPRESSIVE STRENGTH

Hardness	310 HB*	44 HRC**	47 HRC***
Yield compression strength, Rc0.2 MPa kp/mm² tsi psi	 855 87 55 124 000	 1 380 141 89 200 000	 1 470 150 95 213 000

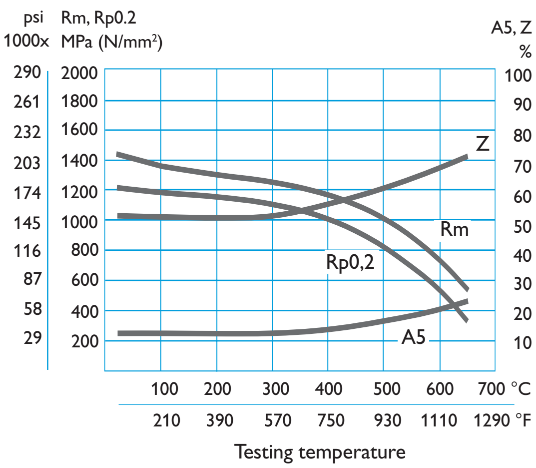
* Soft annealed condition.

** Delivery condition

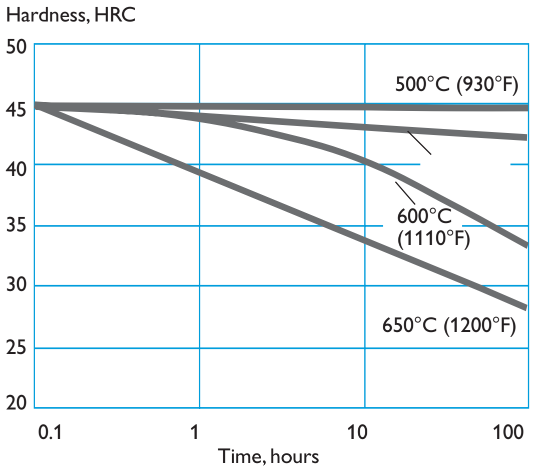
*** 1020°C (1870°F) / 30 min., air quenching, 550°C (1020°F) / 2 x 2 h.

TENSILE PROPERTIES AT ELEVATED TEMPERATURE

Longitudinal direction.



TEMPER RESISTANCE



Heat treatment

Soft annealing

Protect the steel and heat through to 650°C (1200°F), holding time 24 hours. Then cool freely in air.

Stress relieving

When machining hardened and tempered material in delivery condition, after rough machining the tool should be heated through to 550°C (1025°F) holding time 2 hours. Cool freely in air.

When machining soft annealed material, 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) and then freely in air.

Hardening

Pre-heating temperature: 500–650°C (930–1200°F), normally in two pre-heating steps.

Austenitizing temperature: 900–1050°C (1650–1920°F), normally 960–1020°C (1760–1870°F).

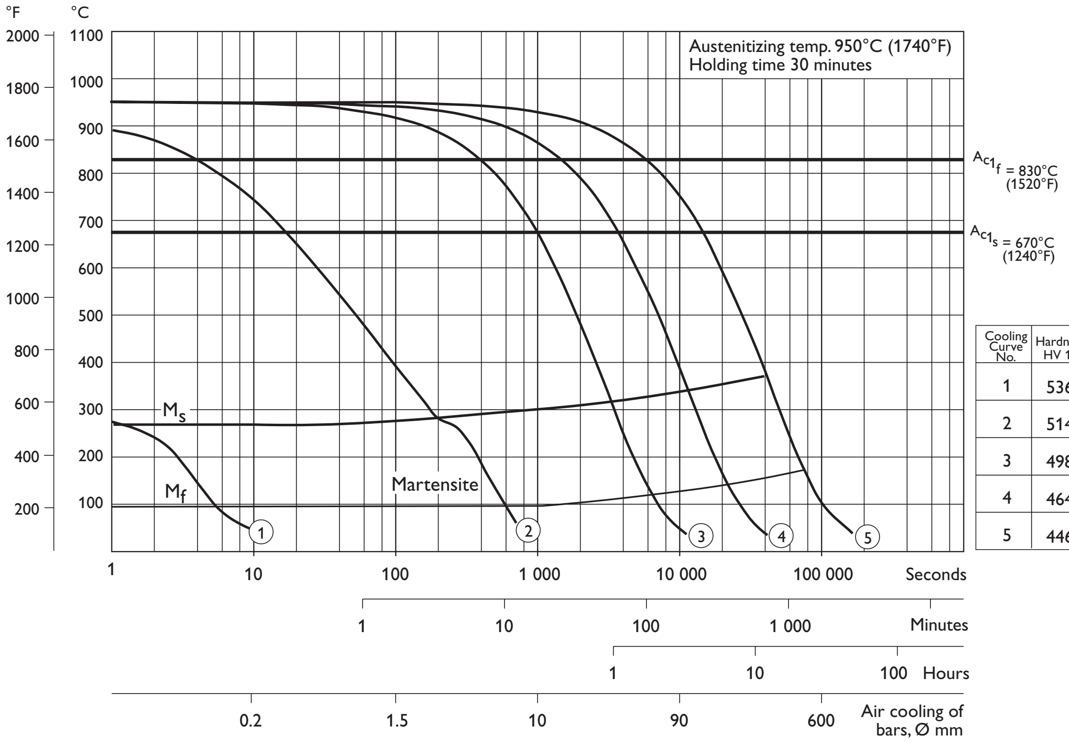
Temperature °C	°F	Soaking time* minutes	Hardness before tempering
960	1760	30	49 ±1 HRC
1000	1830	30	50 ±1 HRC
1020	1870	30	51 ±1 HRC

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

Protect the part from decarburization during hardening.

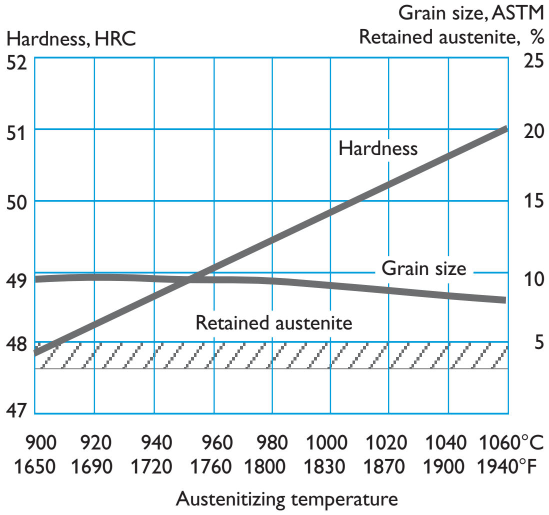
CCT GRAPH

Austenitizing temperature 950°C (1740°F). Holding time 30 minutes.



Cooling Curve No.	Hardness HV 10	$T_{800-500}$ (sec)
1	536	1
2	514	43
3	498	1380
4	464	5175
5	446	20200

HARDNESS, GRAIN SIZE AND RETAINED AUSTENITE AS FUNCTIONS OF AUSTENITIZING TEMPERATURE



Quenching media

- High speed gas/circulating atmosphere
- Vacuum (high speed gas with sufficient positive pressure). An interrupted quench at 320–450°C (610–840°F) 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. 180–200°C (360–390°F), then cool in air
- Warm oil, approx. 80°C (180°F)

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

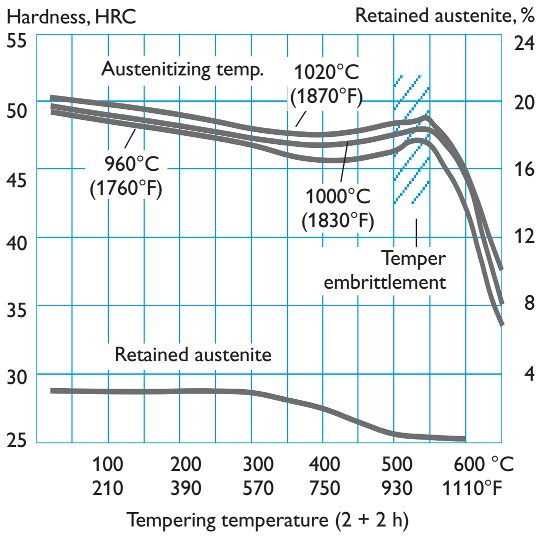
Note 2: In order to obtain the optimum properties of the tool, the cooling rate should be fast, but not at a level that gives excessive distortion or cracks.

Tempering

Choose the tempering temperature according to the required hardness by reference to the tempering graph. Temper twice with intermediate cooling to room temperature. The lowest tempering temperature is 200°C (390°F). Holding time at temperature is minimum 2 hours.

To avoid “temper brittleness”, do not temper in the range 500–550°C (930–1020°F), see graph.

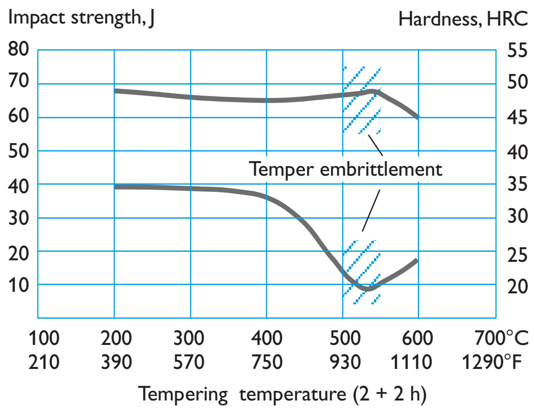
TEMPERING GRAPH



Above tempering curves are obtained after heat treatment of samples with a size of 15 x 15 x 40 mm, cooling in forced air. Lower hardness can be expected after heat treatment of tools and dies due to factors like actual tool size and heat treatment parameters.

EFFECT OF TEMPERING TEMPERATURE ON ROOM TEMPERATURE CHARPY V-NOTCH IMPACT ENERGY

Longitudinal direction.



Dimensional changes

During hardening and tempering the component is exposed to both thermal and transformation stresses. These stresses will result in distortion. 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.

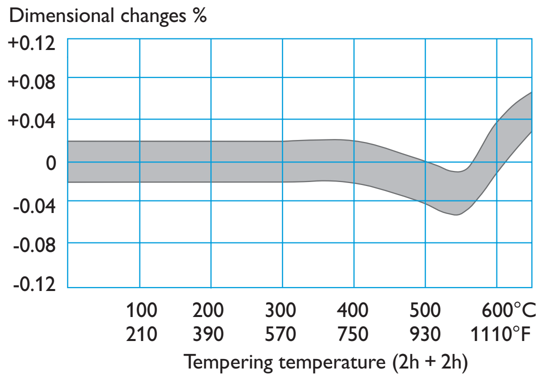
The dimensional changes were measured after austenitizing at 1020°C (1870°F) for 30 minutes following by quenching.

Sample plate 100 x 100 x 100 mm, 4” x 4” x 4”.

DIMENSIONAL CHANGES DURING HARDENING

		Width %	Length %	Thickness %
Oil hardened from 1020°C (1870°F)	min max	+0.02 +0.27	-0.14 +0.10	+0.04 +0.28
Air hardened from 1020°C (1870°F)	min max	+0.01 +0.15	-0.09 -0.19	-0.03 +0.11
Vacuum hardened from 1020°C (1870°F)	min max	+0.09 +0.13	-0.03 -0.08	+0.11 +0.20

DIMENSIONAL CHANGES DURING TEMPERING



Note: The dimensional changes occurring during hardening and tempering are cumulative.

Indexable insert end milling cutter.

Surface treatment

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.

Nitriding in ammonia gas at 510°C (950°F) or plasma nitriding in a 75% hydrogen/25% nitrogen mixture at 480°C (895°F) 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 very brittle, can readily be avoided. However, careful gas nitriding can give perfectly acceptable results.

Uddeholm Balder can also be nitrocarburized in either gas or salt baths to produce a surface hardness of 900–1000 $HV_{0.2}$.

NITRIDING DEPTH

Process	Time hours	Nitriding depth mm	inch
Gas nitriding at 510°C (950°F)	10 30 60	0.12 0.20 0.28	0.005 0.008 0.011
Plasma nitriding at 480°C (895°F)	10 30 60	0.12 0.18 0.22	0.004 0.007 0.009

Nitriding to case depths more than 0,3 mm (0,012 inch) is not recommended for components intended for high-temperature applications. Uddeholm Balder can also be nitrided in the soft-annealed condition, although the hardness and depth of the nitrided layer will be somewhat reduced.

Case hardening

The intention with the case hardening is to obtain a hard wear resistant surface and a tough core. The surface will achieve a hardness of 60 ±2 HRC and the core a hardness of 50 ±2 HRC.

Final grinding operations, in order to achieve correct dimensions, should be performed as a last operation after case hardening.

Pre-oxidation is done in order to avoid uneven carburization. If different furnaces are used for pre-oxidation and carburization, the part has to be transferred between the furnaces as quick as possible.

ALTERNATIVE 1

Pre-oxidation: 400°C (750°F), holding time 1 hour.

Carburizing:
900°C (1650°F), carbon potential 0.75, holding time is set due to requested case hardened depth.

Cooling: air, then liquid nitrogen -196°C (-320 °F).

Tempering: 260°C (500°F), holding time 2 x 1 hour.

ALTERNATIVE 2

Pre-oxidation: 400°C (750°F), holding time 1 hour.

Carburizing:
Step 1. 880°C (1615°F), carbon potential 0.6, holding time 3 hours. Time is set due to requested case hardened depth.

Step 2. 880°C (1615°F), carbon potential 0.4, holding time 10 minutes.

Step 3. 840°C (1545°F), carbon potential 0.4, holding time 20 minutes.

Cooling: air, then cold water 5°C (40°F).

Tempering: 180°C (355°F), holding time 2 x 1 hour.

Carburizing time in step 1	Case hardening depth approx. mm	inch
2 hours 4 hours 16 hours	~0.4 ~0.7 ~1.3	~0.016 ~0.028 ~0.051

Cutting data recommendations

The cutting data below for Uddeholm Balder are to be considered as guiding values, which should be adapted to existing local conditions.

Delivery condition: hardened and tempered 42–45 HRC

Turning

Cutting data parameters	Turning with carbide	
	Rough turning	Fine turning
Cutting speed (v_c) m/min f.p.m.	90–110 290–360	110–130 360–430
Feed (f) mm/r i.p.r	0.2–0.4 0.008–0.016	0.05–0.2 0.002–0.008
Depth of cut (a_p) mm inch	2–4 0.08–0.16	0.5–2 0.02–0.08
Carbide designaton ISO	P10–P15 Coated carbide	P10 Coated carbide or cermet

Milling

FACE AND SQUARE SHOULDER MILLING

Cutting data parameter	Milling with carbide	
	Rough milling	Fine milling
Cutting speed (v_c) m/min f.p.m.	70–90 230–290	90–110 290–360
Feed (f_z) mm/tooth inch/tooth	0.15–0.25 0.006–0.01	0.10–0.20 0.004–0.008
Depth of cut (a_p) mm inch	2–4 0.08–0.16	–2 –0.08
Carbide designation ISO	P20–P40 Coated carbide	P10–P20 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.	90–110 290–360	110–130 360–430	8–10[2] 26–33[2]
Feed (f_z) mm/tooth inch/tooth	0.03–0.15[1] 0.0012–0.006	0.08–0.15[1] 0.003–0.006	0.05–0.20[1] 0.002–0.008
Carbide designation ISO	"Micrograin" Coated carbide	P15–P30 Coated carbide	–

[1] Depending on radial depth of cut and cutter diameter
[2] For coated HSS end mill v_c = 10–15 m/min. (33–49 f.p.m.)

Drilling

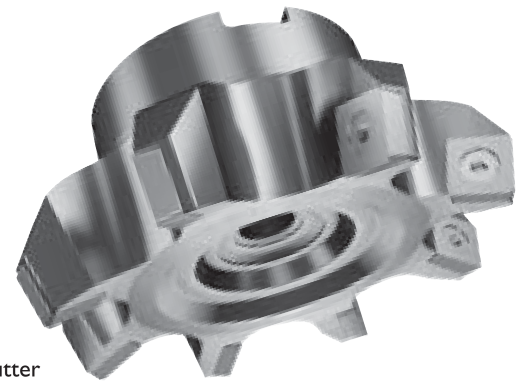
TiCN-COATED HIGH SPEED STEEL DRILL

Drill diameter Ø mm	Drill diameter Ø 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	12–17	40–55	0.03–0.15	0.001–0.006
5–10	3/16–3/8	12–17	40–55	0.15–0.20	0.006–0.008
10–15	3/8–5/8	12–17	40–55	0.20–0.25	0.008–0.01 0
15–20	5/8–3/4	12–17	40–55	0.25–0.30	0.010–0.012

CARBIDE DRILL

Cutting data parameters	Type of drill		
	Indexable insert	Solid carbide	Carbide tip[1]
Cutting speed , (v_c) m/min f.p.m.	100–120 330–390	90–110 300–360	50–60 165–200
Feed (f) mm/r i.p.r	0.05–0.10[2] 0.002–0.004[2]	0.05–0.15[3] 0.002–0.006[3]	0.10–0.15[4] 0.004–0.006[4]

[1] Drill with replaceable or brazed carbide tip
[2] Feed rate for drill diameter 20–40 mm (0.8"–1.6")
[3] Feed rate for drill diameter 5–20 mm (0.2"–0.8")
[4] Feed rate for drill diameter 10–20 mm (0.4"–0.8")



Indexable insert face milling cutter

Soft annealed condition ~310 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) m/min f.p.m.	120–170 390–560	170–220 560–720	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	P10–P15 Coated carbide	P10 Coated carbide or cermet	–

Milling

FACE AND SQUARE SHOULDER MILLING

Cutting data parameter	Milling with carbide Rough milling	Milling with carbide Fine milling
Cutting speed (v_c) m/min f.p.m.	80–150 260–490	150–190 490–620
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	2–5 0.08–0.2	–2 –0.08
Carbide designation ISO	P20–P40 Coated carbide	P10–P20 Coated carbide or cermet

END MILLING

Cutting data parameters	Type of end mill Solid carbide	Type of end mill Carbide indexable insert	Type of end mill High speed steel
Cutting speed (v_c) m/min f.p.m.	120–140 390–460	130–150 430–490	25–30[1] 80–100
Feed (f_z) mm/tooth inch/tooth	0.03–0.20[2] 0.0012–0.008	0.08–0.20[2] 0.003–0.008	0.05–0.35[2] 0.002–0.014
Carbide designation ISO	"Micrograin" Coated carbide	P20–P30 Coated carbide	–

[1] For coated HSS end mill v_c = 40–45 m/min. (130–150 f.p.m.)
[2] Depending on radial depth of cut and cutter diameter

Drilling

HIGH SPEED STEEL TWIST DRILL

Drill diameter Ø mm	Drill diameter Ø 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	20–22*	65–70*	0.08–0.20	0.003–0.008
5–10	3/16–3/8	20–22*	65–70*	0.20–0.30	0.008–0.012
10–15	3/8–5/8	20–22*	65–70*	0.30–0.35	0.012–0.014
15–20	5/8–3/4	20–22*	65–70*	0.35–0.40	0.014–0.016

* For coated HSS drill v_c = 30–35 m/min. (100–115 f.p.m)

CARBIDE DRILL

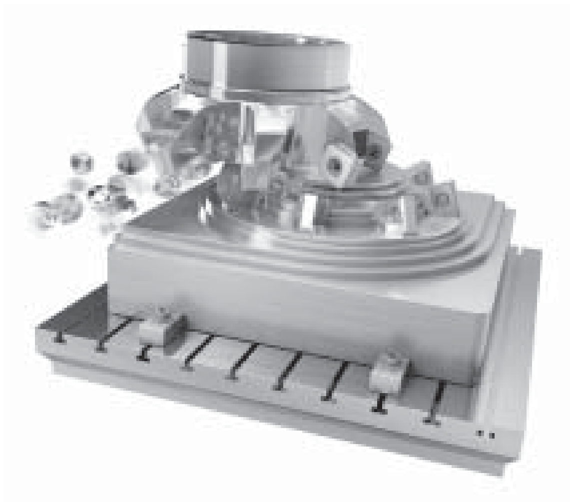
Cutting data parameters	Type of drill Indexable insert	Type of drill Solid carbide	Type of drill Carbide tip[1]
Cutting speed (v_c) m/min f.p.m.	180–200 600–670	120–150 390–490	90–120 295–390
Feed (f) mm/r i.p.r.	0.06–0.15[2] 0.002–0.006[2]	0.08–0.30[3] 0.003–0.012[3]	0.15–0.25[4] 0.006–0.01[4]

[1] Drill with replaceable or brazed carbide tip
[2] Feed rate for drill diameter 20–40 mm (0.8"–1.6")
[3] Feed rate for drill diameter 5–20 mm (0.2"–0.8")
[4] Feed rate for drill diameter 10–20 mm (0.4"–0.8")

Grinding

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

Type of grinding	Soft annealed condition	Hardened condition
Face grinding straight wheel	A 46 HV	A 46 GV
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 KV	A 120 JV



Flame, induction and laser hardening

Uddeholm Balder can be flame or induction hardened to a hardness of approx. 54–56 HRC. Austenitizing temperature is 1000–1100°C (1830–2010°F). Cooling in air is preferable. Tempering at 180–220°C (360–430°F) is recommended after flame, induction or laser hardening. Holding time 2 x 1 hour.

PVD coating

Uddeholm Balder can be given a PVD coating without reducing the hardness of the component.

Hard-chromium plating

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

Electrical-discharge machining, EDM

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 component should then be given an additional temper at approx. 550°C (1025°F), holding time 2 hours.

Welding

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

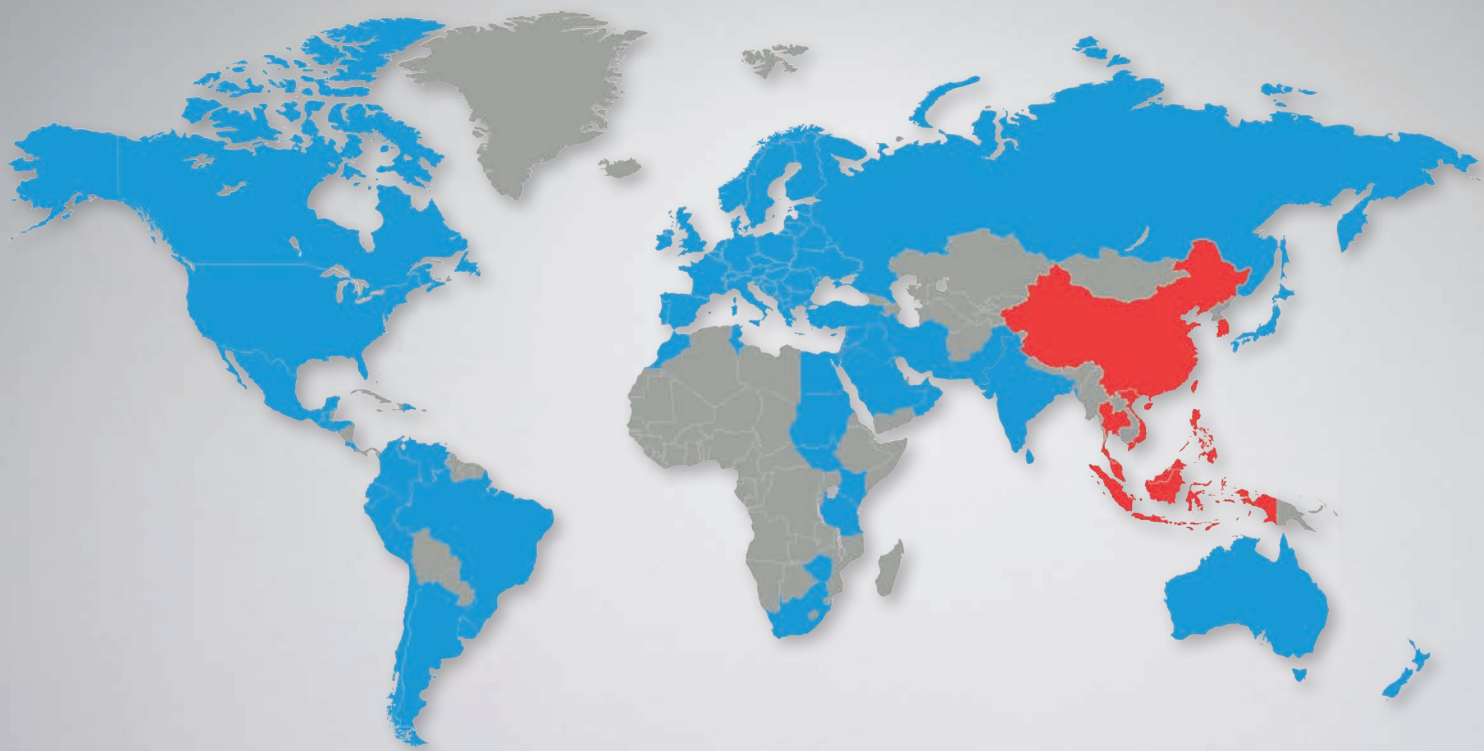
Welding method	TIG	MMA
Preheating temperature*	325–375°C 620–710°F	325–375°C 620–710°F
Consumables	DIEVAR TIG-WELD QRO 90 TIG-WELD UTP A 73G2	QRO 90 WELD UTP 73G2
Cooling rate	20–40°C/h (35–70°F/h) the first 2–3 hours, then freely in air.	
Hardness as welded	48–53 HRC (DIEVAR, QRO 90) 53–56 HRC (A 73G2)	48–53 HRC (QRO 90) 55–58 HRC (73G2)
Heat treatment after welding		
Hardened and tempered condition	Temper at 550°C (1025°F), holidng time 2 hours.	
Soft annealed condition	Soft anneal the material at 650°C (1200°F) 24 hours. Cool freely in air.	

* Preheating can be excluded in cases where you could expect low stress level (minor welds).

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

Further information

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



Network of excellence

UDDEHOLM is present on every continent. This ensures you high-quality Swedish tool steel and local support wherever you are. ASSAB is our exclusive sales channel, representing Uddeholm in the Asia Pacific area. Together we secure our position as the world's leading supplier of tooling materials.

UDDEHOLM 141004.300

UDDEHOLM is the world's leading supplier of tooling materials. This is a position we have reached by improving our customers' everyday business. Long tradition combined with research and product development equips Uddeholm to solve any tooling problem that may arise. It is a challenging process, but the goal is clear – to be your number one partner and tool steel provider.

Our presence on every continent guarantees you the same high quality wherever you are. ASSAB is our exclusive sales channel, representing Uddeholm in the Asia Pacific area. Together we secure our position as the world's leading supplier of tooling materials. We act worldwide, so there is always an Uddeholm or ASSAB representative close at hand to give local advice and support. For us it is all a matter of trust – in long-term partnerships as well as in developing new products. Trust is something you earn, every day.

For more information, please visit www.uddeholm.com, www.assab.com or your local website.