QRO® 90 SUPREME

Hot work tool steel

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

UDDEHOLM

General

QRO 90 Supreme is a high-performance, chromium-molybdenum-vanadium alloyed hot-work tool steel which is characterized by:

- Excellent high temperature strength and hot hardness
- Very good temper resistance
- Unique resistance to thermal fatigue
- Excellent thermal conductivity
- Good toughness and ductility in longitudinal and transverse directions
- Uniform machinability
- Good heat treatment properties

Typical analysis %	C 0,38	Si 0,30	Mn 0,75	Cr 2,6	Mo 2,25	V 0,9
Standard specification	None. Product is covered by patent world wide					
Delivery condition	Soft annealed to approx. 180 HB					
Color code	Orange/light brown					

IMPROVED TOOLING PERFORMANCE

QRO 90 Supreme is a specially premium hot work steel developed by Uddeholm to provide better performance in high temperature tooling. The name "Supreme" implies that by special manufacturing techniques, including electro-slag remelting the steel attains high purity and good mechanical properties. This together with the optimum balance of alloying elements in QRO 90 Supreme gives a properties profile which is unique among hot work die steels. The combination of high temperature strength, temper resistance and thermal conductivity exhibited by QRO 90 Supreme is unparalleled.

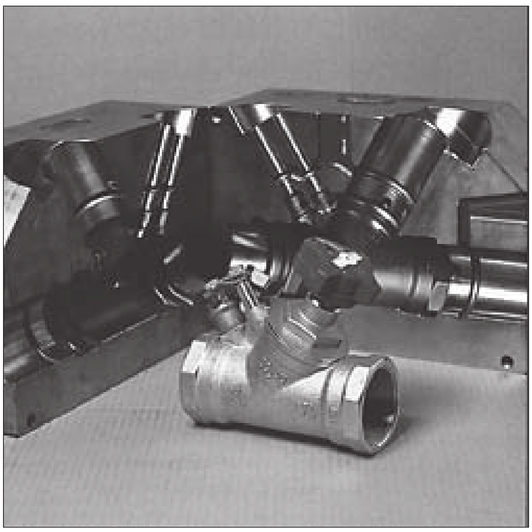


Photo: Bo Dahlgren

Thus QRO 90 Supreme has given improved service life in die casting and extrusion of nonferrous metals and forging and extrusion of steel.

Applications

DIE CASTING DIES AND ASSOCIATED TOOLING

QRO 90 Supreme will normally out-perform other standard hot work steels in both aluminum, brass and copper die casting. Its excellent high temperature strength ensures suppression of heat checking and prolonged die life.
Furthermore its high thermal conductivity gives the opportunity to reduce the cycle time and improve productivity.

QRO 90 Supreme can be used for parts where resistance against heat checking, erosion and bending is required. Typical applications are cores, core pins, inserts, small- to medium-sized dies, shot sleeves, moving parts for aluminum, brass and copper die casting.

EXTRUSION DIES AND EXTRUSION TOOLING

In aluminum extrusion QRO 90 Supreme is recommended for dies when the extruded tonnage is likely to exceed the die life for a standard tool steel e.g.:

- Dies for simple profiles to be produced in long series requiring more than one die
- Dies for complicated or thin walled profiles
- Hollow dies
- Dies for difficult-to-extrude alloys

For extrusion tooling components e.g. liners, dummy blocks, mandrels and stems QRO 90 Supreme gives an improved tool life compared to AISI H13 in aluminum and steel extrusion.

In brass and copper extrusion QRO 90 Supreme has given improved tool life for dummy blocks and die holders compared to AISI H13.
Similar improvements have also been made with liners in QRO 90 Supreme for brass extrusion.

FORGING DIES

QRO 90 Supreme has given many outstanding results for pressforging of steel, and brass, particularly in small- and medium-sized dies. The product is also eminently suitable for progressive forging, upset forging, extrusion forging, powder forging and all processes where heavy water cooling is used.

Properties

All specimens are taken from the centre of a 14" x 5" (356 x 127 mm) bar. Unless otherwise is indicated all specimens were hardened 30 minutes at 1885°F (1030°C), quenched in air and tempered 2 + 2h at 1190°F (645°C). The hardness were 45 ±1 HRC.

PHYSICAL DATA

Hardened and tempered to 45 HRC.
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 N/mm²	 $30,5 \times 10^6$ 210 000	 $26,1 \times 10^6$ 180 000	 $20,3 \times 10^6$ 140 000
Coefficient of thermal expansion per °F from 68°F °C from 20°C	 – –	 $7,0 \times 10^{-6}$ $12,6 \times 10^{-6}$	 $7,3 \times 10^{-6}$ $13,2 \times 10^{-6}$
Thermal conductivity Btu in(ft²h°F) W/m °C	 – –	 230 33	 230 33

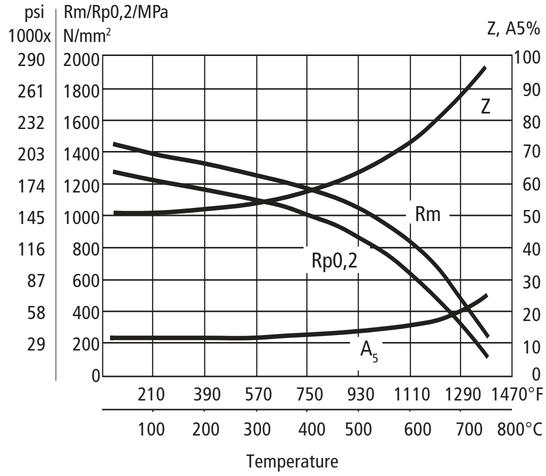
MECHANICAL PROPERTIES

Approximate tensile strength at room temperature.

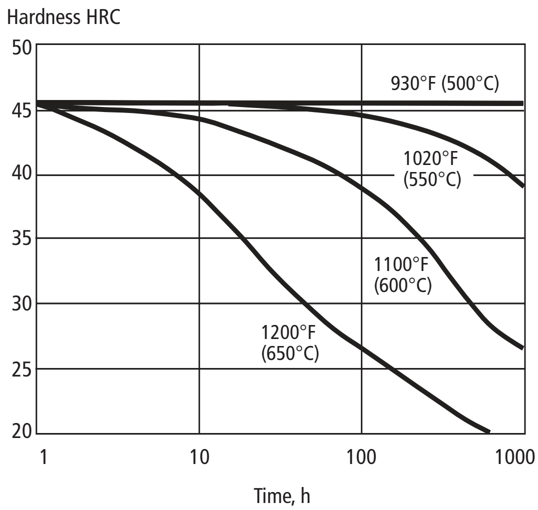
Hardness	48 HRC	45 HRC	40 HRC
Tensile strength Rm	1620 N/mm² 165 kp/mm² 105 tsi 235 000 psi	1470 N/mm² 150 kp/mm² 95 tsi 213 000 psi	1250 N/mm² 128 kp/mm² 81 tsi 181 000 psi
Yield strength Rp0,2	1400 N/mm² 143 kp/mm² 91 tsi 203 000 psi	1270 N/mm² 130 kp/mm² 82 tsi 184 000 psi	1100 N/mm² 112 kp/mm² 71 tsi 160 000 psi

Approximate strength at elevated temperatures

Longitudinal direction

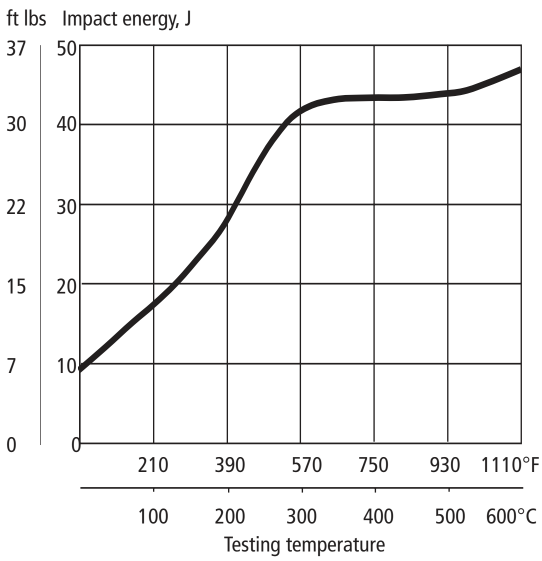


Effect of time at high temperatures on hardness



Effect of testing temperature on impact energy

Charpy V specimens, short transverse direction.



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 1200°F (650°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

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

Austenitizing temperature: 1870–1920°F (1020–1050°C).

Temperature °F	Temperature °C	Soaking* time minutes	Hardness before tempering
1870	1020	30	51±2 HRC
1920	1050	15	52±2 HRC

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

Protect the part against decarburization and oxidation during hardening.

QUENCHING MEDIA

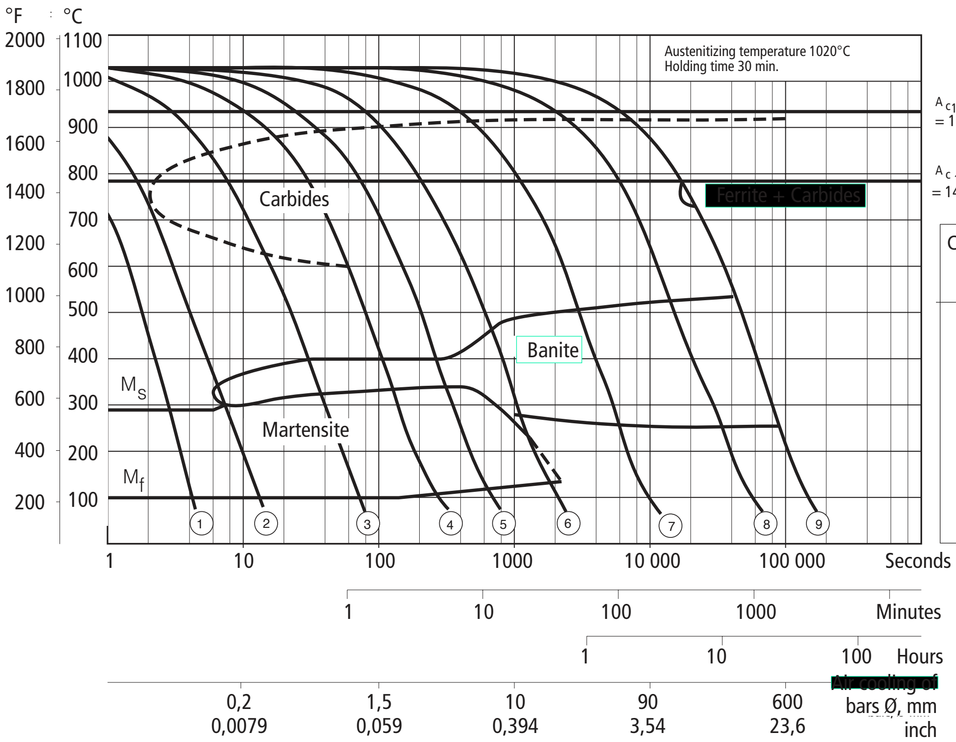
- High speed gas/circulating atmosphere
- Vacuum (high speed gas with sufficient positive pressure). An interrupted quench is recommended
- Martempering bath or fluidized bed at 1020°F (550°C)
- Martempering bath or fluidized bed at approx. 360–430°F (180–220°C)
- Warm oil

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.

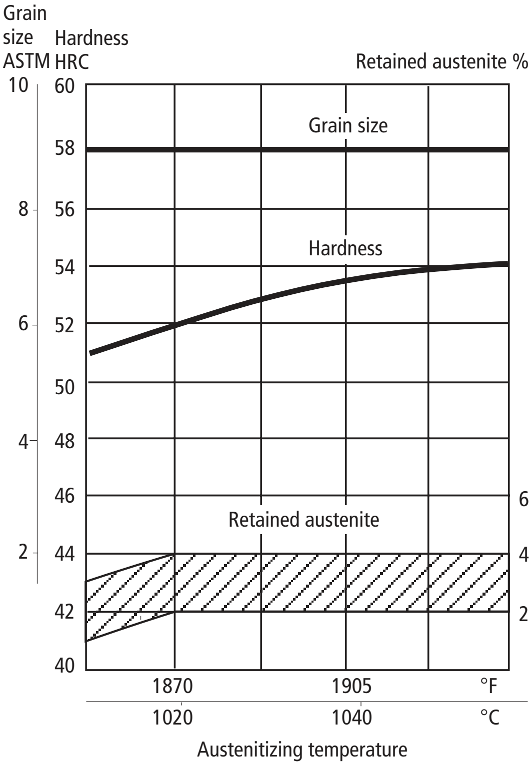
CCT graph

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



Cooling curve No.	Hardness HV_{10}	$T_{800–500}$ (sec)
1	634	1
2	625	3
3	620	16
4	592	55
5	554	138
6	498	415
7	425	2038
8	421	11063
9	417	29182

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

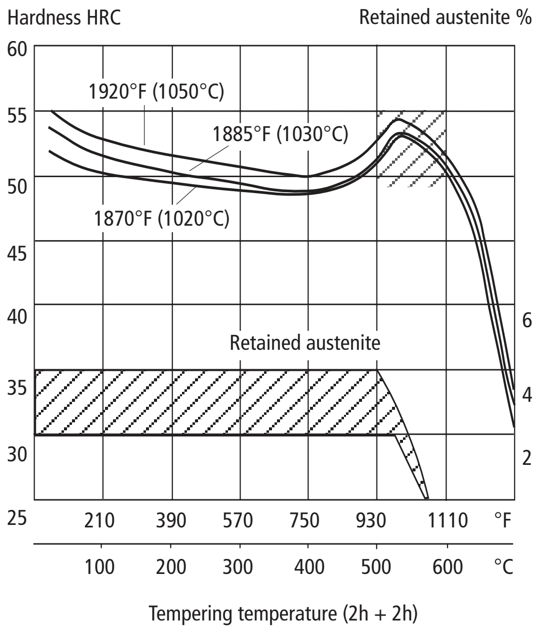


TEMPERING

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 1110°F (600°C). Holding time at temperature minimum 2 hours. To avoid "temper brittleness" do not temper in the range 930–1110°F (500–600°C).

Tempering graph

Air cooling of specimens 1" x 1" x 1 1/2" (25 x 25 x 40 mm). Larger sections, which contain bainite after hardening, are characterized by a lower initial hardness and displacement of the secondary-hardening peak to higher temperatures. During overtempering, however, the curves are more or less identical from about 45 HRC down, irrespective of section size.

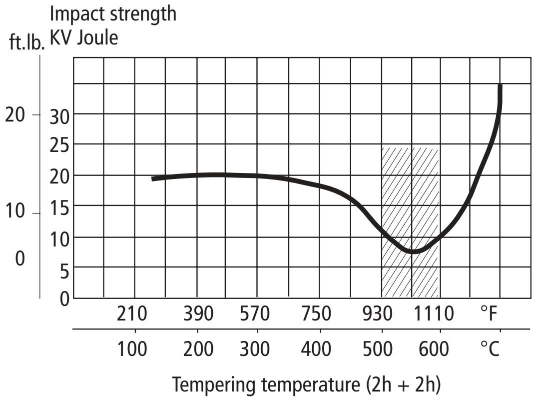


Core pins in QRO 90 HT (prehardened QRO 90 Supreme)

Shot sleeves in QRO 90 Supreme

Approximate impact strength at different tempering temperatures

Longitudinal specimens, heat treated after machining.



Tempering within the range 930–1110°F (500-–600°C) is normally not recommended due to the reduction in toughness properties.

DIMENSIONAL CHANGES DURING HARDENING AND TEMPERING

During hardening and tempering the die is exposed to thermal as well as transformation stresses. This will inevitably result in dimensional changes and in the work case distortion. It is therefore recommended to always leave a 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 die size, the die design as well as the cooling rate after hardening.
For QRO 90 Supreme it is recommended to leave a machining allowance of 0,3 per cent of the dimension in length, width and thickness.

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 minimum 50–90°F (25–50°C) above the nitriding temperature.

Nitriding in ammonia gas at 950°F (510°C) or plasma nitriding in a 75% hydrogen/25% nitrogen mixture at 895°F (480°C) both result in a surface hardness of about 1000 $HV_{0,2}$. 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.

QRO 90 Supreme can also be nitrocarburized in either gas or salt bath. The surface hardness after nitrocarburizing is 800–900 $HV_{0,2}$.

DEPTH OF NITRIDING

Process	Time	Depth inch	Depth mm
Gas nitriding at 950°F (510°C)	10 h 30 h	0,0063 0,0106	0,16 0,27
Plasma nitriding at 895°F (480°C)	10h 30 h	0,0070 0,0106	0,18 0,27
Nitrocarburizing – in gas at 1075°F (580°C)	2,5 h	0,0078	0,20
– in salt bath at 1075°F (580°C)	1 h	0,0051	0,13

Nitriding to case depths >0,012 inch (0,3 mm) is not recommended for hot-work applications. It should be noted that QRO 90 Supreme exhibits better nitridability than AISI H13. For this reason, the nitriding times for QRO 90 Supreme should be shortened in relation to H13, otherwise there is considerable risk that the case depth will be too great.

QRO 90 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. More information can be found in the Uddeholm publication "Cutting data recommendations".

TURNING

Cutting data parameters	Turning with carbide Rough turning	Turning with carbide Fine turning	Turning with HSS Fine turning
Cutting speed (v_c) f.p.m.	656–820	820–984	82–98
m/min	200–250	250–300	25–30
Feed (f) i.p.r.	0,008–0,016	0,002–0,008	0,002–0,01
mm/r	0,2–0,4	0,05–0,2	0,05–0,3
Depth of cut (a_p) inch	0,08–0,16	0,02–0,08	0,02–0,08
mm	2–4	0,5–2	0,5–2
Carbide designation US	C6–C5	C7–C6	–
ISO	P20–P30 Coated carbide	P10–P20 Coated carbide or cermet	–

DRILLING

High speed steel twist drill

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

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

Carbide drill

Cutting data parameters	Type of drill: Indexable insert	Solid carbide	Brazed carbide[1)
Cutting speed, v_c f.p.m.	722–787	427–525	262–361
m/min	220–240	130–160	80–110
Feed, f i.p.r.	0,002–0,01[2)	0,004–0,01[2)	0,006–0,01[2)
mm/r	0,05–0,25[2)	0,1–0,25[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	Milling with carbide Fine milling
Cutting speed (v_c) f.p.m.	590–853	853–984
m/min	180–260	260–300
Feed (f_z) inch/tooth	0,008–0,016	0,004–0,008
mm/tooth	0,2–0,4	0,1–0,2
Depth of cut (a_p) inch	0,08–0,2	–0,08
mm	2–5	–2
Carbide designation US	C6–C5	C7–C6
ISO	P20–P40 Coated carbide	P10–P20 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.	525–656	558–755	115–131[1)
m/min	160–200	170–230	35–40[1)
Feed (f_z) inch/tooth	0,001–0,008[2)	0,003–0,008[2)	0,002–0,014[2)
mm/tooth	0,03–0,2[2)	0,08–0,2[2)	0,05–0,35[2)
Carbide designation US	–	C6–C5	–
ISO	–	P20–P30	–

1) For coated HSS end mill v_c =180–197 f.p.m. (55–60 m/min.)
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 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 24GV	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

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. 50°F (25°C) below the previous tempering temperature.

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	620–710°F (325–375°C)	620–710°F (325–375°C)
Filler metals	QRO 90 TIG-WELD	QRO 90 WELD
Post welding cooling	35–70°F/h (20–40°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 20–40°F (10–20°C) below the original tempering temp.	
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".

Dummy blocks in QRO 90 Supreme

Hard-chromium plating

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

Further information

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

UDDE[redacted]

AUSTRIA
UDDEHOLM
Hansaallee 321
D-40549 Düsseldorf
Telephone: +49 211 535 10
Telefax: +49 211 535 12 80

BELGIUM
UDDEHOLM N.V.
Waterstraat 4
B-9160 Lokeren
Telephone: +32 9 349 11 00
Telefax: +32 9 349 11 11

CROATIA
BOHLER UDDEHOLM Zagreb
d.o.o za trgovinu
Zitnjak b.b
10000 Zagreb
Telephone: +385 1 2459 301
Telefax: +385 1 2406 790

CZECHIA
BOHLER UDDEHOLM CZ s.r.o.
Division Uddeholm
U silnice 949
161 00 Praha 6 Ruzyne
Czech Republic
Telephone: +420 233 029 850,8
Telefax: +420 233 029 859

DENMARK
UDDEHOLM A/S
Kokmose 8, Bramdrupdam
DK-6000 Kolding
Telephone: +45 75 51 70 66
Telefax: +45 75 51 70 44

ESTONIA
UDDEHOLM TOOLING AB
Silikatsiidi 7
EE-0012 Tallinn
Telephone: +372 655 9180
Telefax: +372 655 9181

FINLAND
OY UDDEHOLM AB
Ritakuja 1, PL 57,
FIN-01741 VANTAA
Telephone: +358 9 290 490
Telefax: +358 9 2904 9249

FRANCE
UDDEHOLM S.A.
12 Rue Mercier, Z.I. de Mitry-Compans
F-77297 Mitry Mory Cedex
Telephone: +33 (0)1 60 93 80 10
Telefax: +33 (0)1 60 93 80 01

Branch office
UDDEHOLM S.A.
77bis, rue de Vesoul
La Nef aux Métiers
F-25000 Besançon
Telephone: +33 381 53 12 19
Telefax: +33 381 53 13 20

GERMANY
UDDEHOLM
Hansaallee 321
D-40549 Düsseldorf
Telephone: +49 211 535 10
Telefax: +49 211 535 12 80

Branch offices
UDDEHOLM
Falkenstraße 21
D-65812 Bad Soden/TS.
Telephone: +49 6196 659 60
Telefax: +49 6196 659 625

UDDEHOLM
Albstraße 10
D-73765 Neuhausen
Telephone: +49 715 898 65-0
Telefax: +49 715 898 65-25

GREAT BRITAIN, IRELAND
UDDEHOLM UK LIMITED
European Business Park
Taylors Lane, Oldbury
West Midlands B69 2BN
Telephone: +44 121 552 55 11
Telefax: +44 121 544 29 11
Dublin Telephone: +353 1 45 14 01

[redacted]
COMPANY
20, Athinon Street
G-Piraeus 18540
Telephone: +30 2 10 41 72 109/41 29 820
Telefax: +30 2 10 41 72 767

SKLERO S.A.
Steel Trading Comp. and
Hardening Shop
Frixou 11/Nikif. Ouranou
G-54627 Thessaloniki
Telephone: +30 31 51 46 77
Telefax +30 31 54 12 50

HUNGARY
UDDEHOLM TOOLING/BOK
Dunaharaszti, Jedlik Ányos út 25
H-2331 Dunaharaszti 1.Pf. 110
Telephone/Telefax: +36 24 492 690

ITALY
UDDEHOLM Italia S.p.A.
Via Palizzi, 90
I-20157 Milano
Telephone: +39 02 35 79 41
Telefax: +39 02 390 024 82

LATVIA
UDDEHOLM TOOLING AB
Deglava street 50
LV-1035 Riga
Telephone: +371 7 701 983, -981, -982
Telefax: +371 7 701 984

LITHUANIA
UDDEHOLM TOOLING AB
BE PLIENAS IR METALAI
T. Masiulio 18b
LT-3014 Kaunas
Telephone: +370 37 370613, -669
Telefax: +370 37 370300

THE NETHERLANDS
UDDEHOLM B.V.
Isolatorweg 30
NL-1014 AS Amsterdam
Telephone: +31 20 581 71 11
Telefax: +31 20 684 86 13

NORWAY
UDDEHOLM A/S
Jernkroken 18
Postboks 85, Kalbakken
N-0902 Oslo
Telephone: +47 22 91 80 00
Telefax: +47 22 91 80 01

POLAND
INTER STAL CENTRUM
Sp. z. o.o./Co. Ltd.
ul. Kolejowa 291, Dziekanów Polski
PL-05-092 Lomianki
Telephone: +48 22 429 2260
Telefax: +48 22 429 2266

PORTUGAL
F RAMADA Aços e Industrias S.A.
P.O. Box 10
P-3881 Ovar Codex
Telephone: +351 56 58 61 11
Telefax: +351 56 58 60 24

ROMANIA
BÖHLER Romania SRL
Uddeholm Branch
Str. Atomistilor Nr 14A
077125 Magurele Jud Ilfov
Telephone: +40 214 575007
Telefax: +40 214 574212

RUSSIA
UDDEHOLM TOOLING CIS
25 A Bolshoy pr PS
197198 St. Petersburg
Telephone: +7 812 233 9683
Telefax: +7 812 232 4679

SLOVAKIA
UDDEHOLM Slovakia
Nástrojové ocele, s.r.o
KRÁCINY 2
036 01 Martin
Telephone: +421 842 4 300 823
Telefax: +421 842 4 224 028

[redacted]
Via Palizzi, 90
I-20157 Milano
Telephone: +39 02 35 79 41
Telefax: +39 02 390 024 82

SPAIN
UDDEHOLM
Guifré 690-692
E-08918 Badalona, Barcelona
Telephone: +34 93 460 1227
Telefax: +34 93 460 0558

Branch office
UDDEHOLM
Barrio San Martin de Arteaga, 132
Pol.Ind. Torrelarragoiti
E-48170 Zamudio
(Bizkaia)
Telephone: +34 94 452 13 03
Telefax: +34 94 452 13 58

SWEDEN
UDDEHOLM TOOLING
SVENSKA AB
Aminogatan 25
SE-431 53 Mölndal
Telephone: +46 31 67 98 50
Telefax: +46 31 27 02 94

SWITZERLAND
HERTSCH & CIE AG
General Wille Strasse 19
CH-8027 Zürich
Telephone: +41 1 208 16 66
Telefax: +41 1 201 46 15

UDDEHOLM NORTH AMERICA

USA
UDDEHOLM
4902 Tollview Drive
Rolling Meadows IL 60008
Telephone: +1 847 577 22 20
Telefax: +1 847 577 80 28

UDDEHOLM
548 Clayton Ct.,
Wood Dale IL 60191
Telephone: +1 630 350 10 00
Telefax: +1 630 350 08 80

UDDEHOLM
9331 Santa Fe Springs Road
Santa Fe Springs, CA 90670
Telephone: +1 562 946 65 03
Telefax: +1 562 946 77 21

UDDEHOLM
220 Cherry Street
Shrewbury, MA 01545
Telephone: +1 508 845 1066
Telefax: +1 508 845 3471

CANADA
UDDEHOLM LIMITED
2595 Meadowvale Blvd.
Mississauga, Ontario L5N 7Y3
Telephone: +1 905 812 9440
Telefax: +1 905 812 8659

MEXICO
ACEROS BOHLER UDDEHOLM,
S.A. de C.V.
Calle 8 No 2, Letra "C"
Fraccionamiento Industrial Alce Blanco
C.P. 52787 Naucalpan de Juarez
Estado de Mexico
Telephone: +52 55 9172 0242
Telefax: +52 55 5576 6837

UDDEHOLM
Lerdo de Tejada No.542
Colonia Las Villas
66420 San Nicolas de Los Garza, N.L.
Telephone: +52 8-352 5239
Telefax: +52 8-352 5356

[redacted]

ARGENTINA
UDDEHOLM S.A
Mozart 40
1619-Centro Industrial Garin
Garin-Prov. Buenos Aires
Telephone: +54 332 744 4440
Telefax: +54 332 745 3222

BRAZIL
UDDEHOLM ACOS ESPECIAIS Ltda.
Estrada Yae Massumoto, 353
CEP 09842-160
Sao Bernardo do Campo - SP Brazil
Telephone: +55 11 4393 4560, -4554
Telefax: +55 11 4393 4561

UDDEHOLM SOUTH AFRICA
UDDEHOLM Africa (Pty) Ltd.
P.O. Box 539
ZA-1600 Isando/Johannesburg
Telephone: +27 11-974 2781
Telefax: +27 11-392 2486

UDDEHOLM AUSTRALIA
BOHLER-UDDEHOLM Australia
129-135 McCredie Road
Guildford NSW 2161
Private Bag 14
Telephone: +61 2 9681 3100
Telefax: +61 2 9632 6161

Branch offices
Sydney, Melbourne, Adelaide,
Brisbane, Perth, Newcastle,
Launceston, Albury, Townsville

ASSAB

ASSAB INTERNATIONAL
Skytteholmsvägen 2
P O Box 42
SE-171 11 Solna
Sweden
Telephone: +46 8 564 616 70
Telefax: +46 8 25 02 37

Subsidiaries
India, Iran, Turkey, United Arab
Emirates

Distributors in
Africa, Latin America, Middle East

ASSAB PACIFIC
ASSAB Pacific Pte. Ltd
171, Chin Swee Road
No. 07-02, San Centre
Singapore 169877
Telephone: +65 534 56 00
Telefax: +65 534 06 55

Subsidiaries
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