CARMO

Prehardened Cold Work Steel for Car Body Dies

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

UDDEHOLM

General

Carmo is a high-strength, flame-, induction- and through hardening steel delivered prehardend to 240–270 HB.

The surface of the steel can be flame-hardened without water cooling to a hardness of 58 ±2 HRC. The depth of hardness is normally 4–5 mm and the hardened and tempered matrix is a good base for the flame-hardened layer.

The steel can be easily repair welded.

Typical analysis %	C 0,6	Si 0,35	Mn 0,8	Cr 4,5	Mo 0,5	V 0,2
Delivery condition	Prehardened to 240–270 HB					
Colour code	Red/violet					

Applications

Carmo is a cold work tool steel which has been developed together with the automotive industry. Its analysis has been balanced to give **one** universal tool steel for car body dies instead of the several steel grades (flame hardening and through hardening grades) which are normally used.

The steel can be used in the flame-hardened or in the through-hardened condition for blanking and forming of both car body parts (thin sheet) or structural parts (thicker sheet).

Properties

MECHANICAL PROPERTIES

Typical values at room temperature, 270 HB.

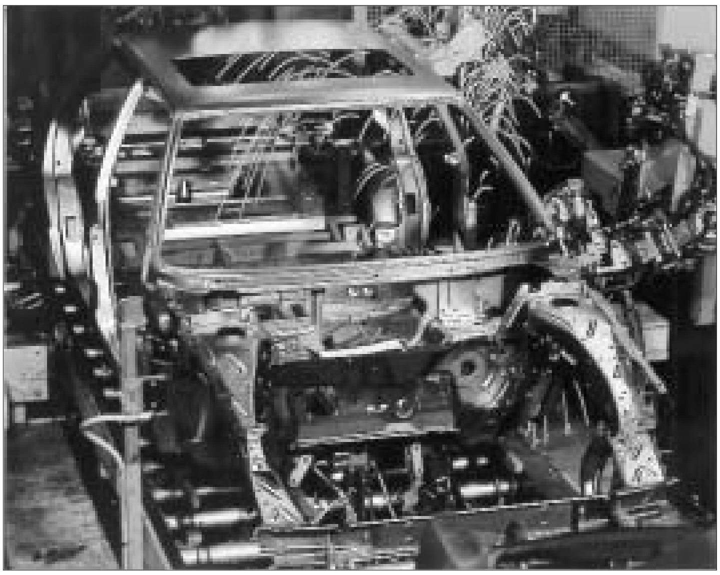
Tensile strength R_m N/mm²	870
Yield point $R_{p0,2}$ N/mm²	670
Elongation A_5 %	15
Reduction of area Z %	50

OTHER IMPORTANT PROPERTIES

Total tooling economy, i.e. minimizing the **total** cost incurred in running the tool—including down-time and maintenance—is important in presswork operations. It is of particular importance in the automotive industry where very large, automated press-lines are operating to a just-in-time concept. This puts very special requirements on the steels used for the tooling:

- high toughness for maximum safety in operation
- high wear resistance to achieve the number of parts required
- easy maintenance to minimize press downtime.

These requirements are fully met by Carmo.
The toughness of Carmo is much better than for the steel types A2 and D2.
The wear resistance of Carmo is very similar to that of A2. Repair welding of Carmo is easy.



Heat-treatment

STRESS RELIEVING

Temperature: 550–650°C (1020–1200°F).

Holding time: 2h. Cooling in furnace to 500°C (930°F), then in air.

HARDENING

For through hardening following temperatures and times are recommended:

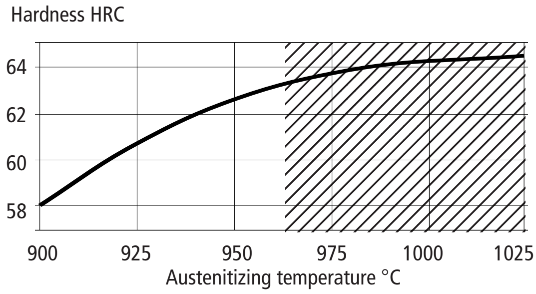
Pre-heating temperature: 600–700°C (1110–1290°F).

Austenitizing temperature: 950–970°C (1740–1780°F), normally 960°C (1760°F).

Holding time: 30–45 minutes.

The tool should be protected against decarburization during hardening.

Hardness as a function of austenitizing temperature



Risk for grain growth and reduced toughness.

QUENCHING

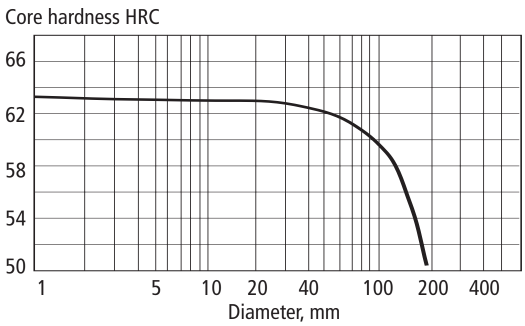
- High speed gas/circulating atmosphere
- Saltbath 200–550°C (390–1020°F)
- Fluidized bed 200–550°C (390–1020°F).

Note 1: Quenching should not be interrupted until the part has cooled down to 25°C (75°F). Otherwise the part may shrink after tempering.

Note 2: Temper immediately after quenching.

Note 3: Quenching in oil is not recommended.

Core hardness as a function of diameter for air cooling

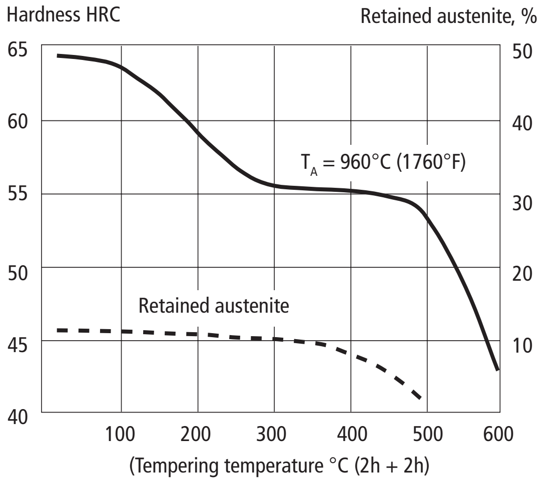


TEMPERING

The tempering temperature for the required hardness may be determined by means of the tempering graph. Temper twice. Lowest tempering temperature 200°C (390°F). Holding time at temperature minimum 2 hours.

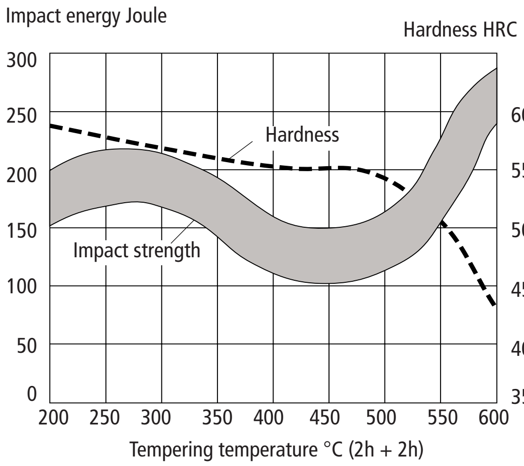
SURFACE HARDNESS AFTER TEMPERING

Tempering graph



IMPACT STRENGTH

Room temperature. Specimen size: 7 x 10 x 55 mm unnotched. Hardened at 960°C (1760°F). Quenched in air. Tempered twice.



Machining recommendations

The machining data provided below are intended as a guideline to help find the optimal conditions. The data were obtained from tests made in the prehardened condition. More detailed information can be found in Uddeholm "Machining Recommendations".

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	130–180	180–230	18–23
f.p.m.	425–590	590–755	60–75
Feed (f) mm/r	0,3–0,6	–0,3	–0,3
i.p.r.	0,012–0,023	–0,012	–0,012
Depth of cut (a_p) mm	2–6	–2	–2
inch	0,08–0,23	–0,08	–0,08
Carbide designation ISO	P20–P30 Coated carbide	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) m/min	140–230	230–270
f.p.m.	460–755	755–885
Feed, (f_z) mm/tooth	0,2–0,4	0,1–0,2
inch/tooth	0,008–0,016	0,004–0,008
Depth of cut, (a_p) mm	2–5	–2
inch	0,08–0,20	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	110–140	130–180	25–30 [1]
f.p.m.	360–460	425–590	82–100 [1]
Feed (f_z) mm/tooth	0,03–0,20 [2]	0,08–0,20 [2]	0,05–0,35 [2]
inch/tooth	0,001–0,008 [2]	0,003–0,008 [2]	0,002–0,014 [2]
Carbide designation ISO	–	P20–P40 Coated carbide	–

[1] For coated HSS end mill v_C = 45–50 m/min. (150–165 f.p.m.).

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

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	12–14*	40–46*	0,08–0,20	0,003–0,008
5–10	3/16–3/8	12–14*	40–46*	0,20–0,30	0,008–0,012
10–15	3/8–5/8	12–14*	40–46*	0,30–0,35	0,012–0,014
15–20	5/8–3/4	12–14*	40–46*	0,35–0,42	0,014–0,016

** For coated HSS drills v_C = 22–24 m/min. (72–80 f.p.m.).*

Carbide drill

Cutting data parameters	Type of drill: Indexable insert	Solid carbide	Brazed carbide [1]
Cutting speed(v_C) m/min	200–220	110–140	60–80
f.p.m.	655–720	360–460	200–260
Feed (f) mm/r	0,03–0,10	0,10–0,25 [2]	0,15–0,25 [2]
i.p.r.	0,001–0,004	0,004–0,01 [2]	0,006–0,01 [2]

[1] Drills with internal cooling channels and a brazed carbide tip.

[2] Depending on drill diameter.

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	Wheel recommendation Prehardened condition
Surface grinding straight wheel	A 46 HV
Surface grinding segments	A 36 GV
Cylindrical grinding	A 60 LV
Internal grinding	A 60 JV
Profile grinding	A 120 LV

Flame-hardening

Use an oxy-acetylene burner for 1250–2500 l/h with a normal flame.
Temperature: 950 ±30°C (1740 ±50°F).
Hardness: surface 58 ±2 HRC, at a depth of 3–4 mm 400 $HV_{10\ kg}$.
A temperature guide for judgement of the right flame hardening temperature can be obtained from your local Uddeholm office.

Welding recommendations

GENERAL

When cold work steels are welded, there is always a risk of cracking in the weld metal and/or in the heat affected zone (HAZ). However, cracking can be avoided by using a proper welding technique and the right consumables. Wrought material is always easier to weld than castings because it has a higher toughness.

In general, the following is valid:

- Always keep the arc length as short as possible. The coated electrode should be angled at 90° to the joint sides to avoid undercut. In addition, the electrode should be held at an angle of 75–80° to the direction of forward travel.
- Larger repair welds must be made at elevated temperature. The temperature of the workpiece should be held as constant as possible during welding. The best way to keep the tool at constant temperature during welding is to use an insulated box with thermostatically regulated electrical heating elements inside the walls.
- The first two layers should always be welded with the same heat input and with a small diameter electrode (max 3,25 Ø electrode for MMA or max 120A for TIG welding).
- First of all, the parent metal is clad in using an appropriate number of runs. All other runs should then be made up on top of pre-existing weld metal except in those cases where soft metal electrodes of the type 29/9 are used. When a soft weld metal is used, a space of 3 mm must be left below the finished surface so that the hard facing electrode can be used to give the right surface hardness on the welded tool.
- For large weld repairs, the parent metal should be coated with a soft weld metal of the 29/9 type (i.e. 29% Cr, 9% Ni electrodes AWS ER 312 or AWS E312), which gives a tougher weld metal with lower hardness.
- The choice of electrode for welding depends on the hardness required in the weld metal (see table below).
- In order to obtain the required hardness (as given in the table below), the weld should be built up with at least 3 layers plus an additional layer which is ground off after welding has been completed. When welding tool steels, the last layer should always be ground off.
- It should be noted that differences between expected and achieved hardness in the weld metal normally depend on how the grinding of the last layer has been carried out. Grinding should always be carried out before the temperature in the tool sinks too much. If the grinding is too rough so that the weld becomes red hot, microcracks will appear in the weld metal.
- The following heat treatment cycle is recommended for large weld repairs:
  1. Pre-heat the tool to 200–250°C (390–480°F). Keep that temperature during the whole welding operation.
  2. Let the tool cool slowly after welding to 70°C (160°F).
  3. Temper the tool at a temperature 20°C (70°F) below previously used preheating temperature.

JOINT PREPARATION

The importance of careful joint preparation cannot be over-emphasized. Cracks should be ground out so that the joint bottom is rounded and the sides of the joint slope at an angle of at least 30° to the vertical. The width of the joint bottom should be at least 1 mm greater than the electrode diameter (including the coating) which is used.

Further recommendations on welding of tool steels can be found in the Uddeholm brochure "Welding of Tool Steel".

TIG Welding Consumables for wrought Carmo

Condition of material	Consumables	Hardness as welded	Hardness after re-hardening	Preheating[1] temperature
Hardened Pre-hardened	UTPA 651 CastoTig 680[2] UTPA 73G2 UTPA 67S UTPA 696 CALMAX/CARMO TIG-WELD[3]	240 HB 230 HB 53–56 HRC 55–58 HRC 60–64 HRC 58–61 HRC	Austenitic Austenitic 57 HRC 52 HRC 58–61 HRC	200–250°C (390–480°F)

MMA (SMAW) Consumables for wrought Carmo

Condition of material	Consumables	Hardness as welded	Hardness after re-hardening	Preheating[1] temperature
Hardened	Avesta P7[4]	ca 270 HB	Austenitic	
Pre-hardened	Castolin 680S[4]	ca 220 HB	Austenitic	
	UTP 65D	ca 250 HB	Austenitic	
	UTP 67S	55–58 HRC	52 HRC	
	UTP 73G2	55–58 HRC		200–250°C (390–480°F)
	CALMAX/ CARMO WELD[3]	58–61 HRC	58–61 HRC	

Remarks:

[1] The tool should cool slowly after welding.

[2] TIG rods of the type AWS ER 312.

[3] Calmax/Carmo TIG-Weld/Weld consumables corresponds to the chemical composition of Carmo/Calmax, i.e. similar heat treatment respons.

[4] MMA-Consumables of the type AWS E 312.

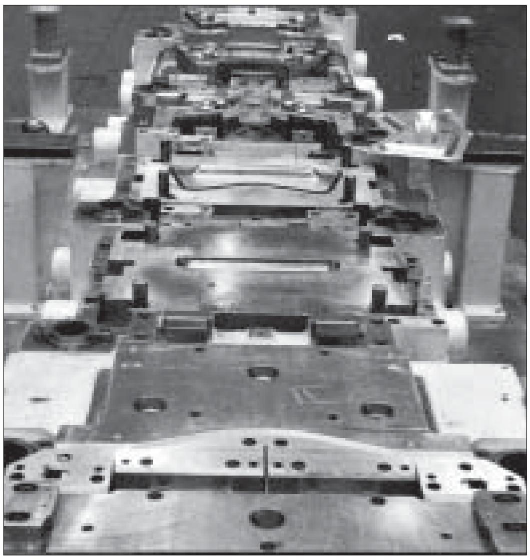
Cold work applications

TYPICAL APPLICATION AREAS

- General blanking and forming
- Heavy duty blanking and forming
- Deep drawing
- Coining
- Cold extrusion dies with complicated geometry
- Rolls
- Shear blades
- Prototype tooling.

TRADITIONAL PRESSWORK STEELS

The majority of presswork tools used today are manufactured using traditional tool steels such as O1, A2, D2, D3 and D6.
These steels offer an apparent adequate wear resistance and their hardness range is suitable for most applications. However, the poor toughness, flame- and induction hardenability and weldability of these grades often results in low productivity and high maintenance costs due to unexpected tool failure. For this reason, the new general presswork tool steel Carmo has been developed. The aim of Carmo is to secure an optimal tooling economy, i.e. the lowest tooling costs per part produced.

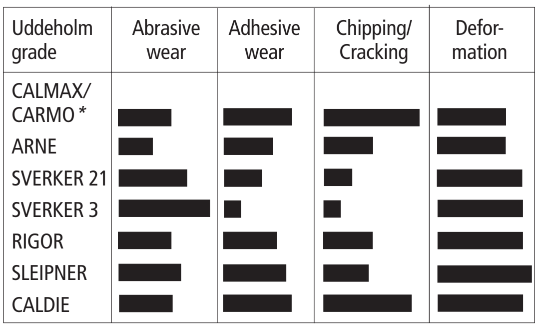


Tool for producing floor parts.

TODAYS DEMANDS

The presswork industry has gone through some considerable changes in the last decades. Stainless steel and surface coated strip have been commercialized and high speed presses have been developed. To these technological advances just in time (JIT) manufacture and the moves toward increased productivity and tool life guarantees must be added. The traditional presswork tool steels are still routinely specified and selected but often result in poor tool performance and productivity.
The well balanced properties profile of Carmo is much better matched to modern work materials and manufacturing methods. Carmo offers the high degree of safety which is essential for optimal tooling performance and maximum productivity.

RESISTANCE TO FAILURE MECHANISMS



** Carmo is delivered in prehardened condition in order to improve the flame-/induction hardenability, which is thenormal hardening procedure for Carmo. But Carmo can however also be through hardened. All other steels in this table are normally through hardened.*

Further information

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

UDDEHOLM EUROPE

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

GREECE
UDDEHOLM STEEL TRADING
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, Dzieканów 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

SLOVENIA
UDDEHOLM Italia S.p.A.
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

UDDEHOLM SOUTH AMERICA

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
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Edition: 3, 06.2005