Uddeholm Caldie®

UDDEHOLM

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.

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

Edition 15, 10.2017

SS-EN ISO 9001
SS-EN ISO 14001

Uddeholm Caldie®

CHANGING TOOLING ENVIRONMENT

New and more demanding work materials are continuously implemented in the industry. As a consequence of the introduction of AHSS, Advanced High Strength Steel, the forming tools have to resist higher stress levels and withstand more adhesive and abrasive wear. Many times the tool has to be coated in order to fulfil production requirements, i.e. the tool material also has to be a good substrate material for different type of surface coatings.

THE PROBLEM SOLVER

Uddeholm Caldie is the first ESR-grade and developed with main focus on severe cold work applications.

The excellent combination of compressive strength, wear resistance and chipping/cracking resistance has been achieved by a well balanced chemistry of matrix type and a clean and homogeneous microstructure. Appropriate heat treatment properties and high fatigue strength make Uddeholm Caldie also to a perfect substrate material for surface coatings

A VERSATILE TOOL STEEL

The unique properties profile of Uddeholm Caldie include very good weldability, castability, through hardening properties, machinability and grindability. This means that Uddeholm Caldie provides many different options for eco-nomical toolmaking, tool using and maintenance, especially for larger forming tools.

GENERAL

Uddeholm Caldie is a chromium-molybdenum-vanadium alloyed tool steel which is characterized by:

- very good chipping and cracking resistance
- good wear resistance
- high hardness (>60 HRC) after high temperature tempering
- good dimensional stability in heat treatment and in service
- excellent through-hardening properties
- good machinability and grindability
- excellent polishability
- good surface treatment properties
- good resistance to tempering back
- very good WEDM properties

Typical analysis %	C 0.7	Si 0.2	Mn 0.5	Cr 5.0	Mo 2.3	V 0.5
Standard specification	None					
Delivery condition	Soft annealed to max. 215 HB					
Colour code	White/grey					

APPLICATIONS

Uddeholm Caldie is suitable for short to medium run tooling where chipping and/or cracking are the predominant failure mechanisms and where a high compressive strength (hardness above 60 HRC) is necessary. This makes Uddeholm Caldie an excellent problem solver for severe cold work applications where the combination of a hardness above 60 HRC and a high cracking resistance is of utmost importance e.g. as in the blanking and forming of ultra high strength steel sheets.

Uddeholm Caldie is also very suitable as a substrate steel for applications where surface coatings are desirable or necessary.

COLD WORK APPLICATIONS

- Blanking applications where high ductility and toughness are needed to prevent chipping/cracking
- Cold forging and forming operations where a high compressive strength combined with good resistance to chipping/cracking are necessary
- Machine knives
- Thread rolling dies
- Substrate for surface coatings

UDDEHOLM COMPONENT BUSINESS APPLICATIONS

Uddeholm Caldie can be used in engineering applications where high compressive strength has to be combined with high ductility/toughness. Knives for fragmentation of plastics and metals and roll forming rolls are good examples.

PROPERTIES

The properties below are representative of samples which have been taken from the centre of bars with dimensions 203 x 80 mm and Ø 102 mm. Unless otherwise indicated, all specimens have been hardened at 1025°C (1875°C), gas quenched in a vacuum furnace and tempered twice at 525°C (975°F) for two hours to 60–61 HRC.

PHYSICAL PROPERTIES

Hardened and tempered to 60–61 HRC.

Temperature	20°C (68°F)	200°C (390°F)	400°C (750°F)
Density, kg/m³ lbs/in³	7 820 0.282	–	–
Modulus of elasticity MPa psi	213 000 31.2×10^6	192 000 27.8×10^6	180 000 26.1×10^6
Coefficient of thermal expansion per °C from 20°C per °F from 68°F	– –	11.6×10^{-6} 6.4×10^{-6}	12.4×10^{-6} 6.9×10^{-6}
Thermal conductivity W/m °C Btu in/(ft²h°F)	– –	24 174	28 195
Specific heat J/kg°C Btu/lb°F	460 0.11	–	–

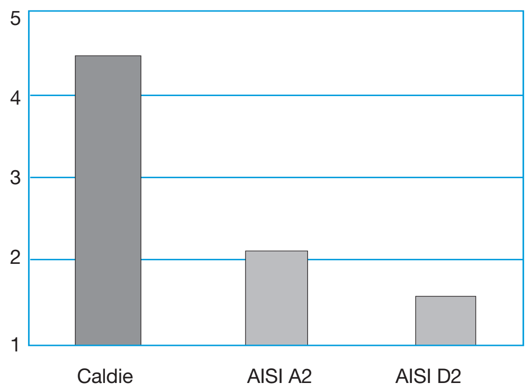
COMPRESSIVE STRENGTH

Approximately compressive strength vs. hardness is shown in the table below.

Hardness HRC	Compressive yield strength, Rc0,2 (MPa)
58	2230
60	2350
61	2430

CHIPPING RESISTANCE

Relative chipping resistance for Uddeholm Caldie, AISI A2 and AISI D2 is shown below.



HEAT TREATMENT

SOFT ANNEALING

Protect the steel and heat through to 820°C (1510°F wait for equalization of the temperature (equalization time related to the size of the tool). Then cool in the furnace at 10°C (20°F) per hour to 650°C (1200°F), then freely in air to room temperature.

STRESS RELIEVING

After rough machining the residual stresses should be relieved by tempering at 650°C (1200°F), holding time 2 hours. Cool slowly in the furnace to 500°C (930°F), then freely in air to room temperature.

HARDENING

Preheating temperature: 600–650°C (1110–1200°F) and 850–900°C (1560–1650°F). In case of bigger dimensions (>150 mm cross section) a third preheating step at 930°C (1700°F) is recommended.

Austenitizing temperature: 1000–1050°C (1830–1920°F), normally 1020°C (1870°F), in case of bigger dimensions (>150 mm cross section) 1000°C (1830°F).

Holding time: 30 minutes after the tool is heated through.

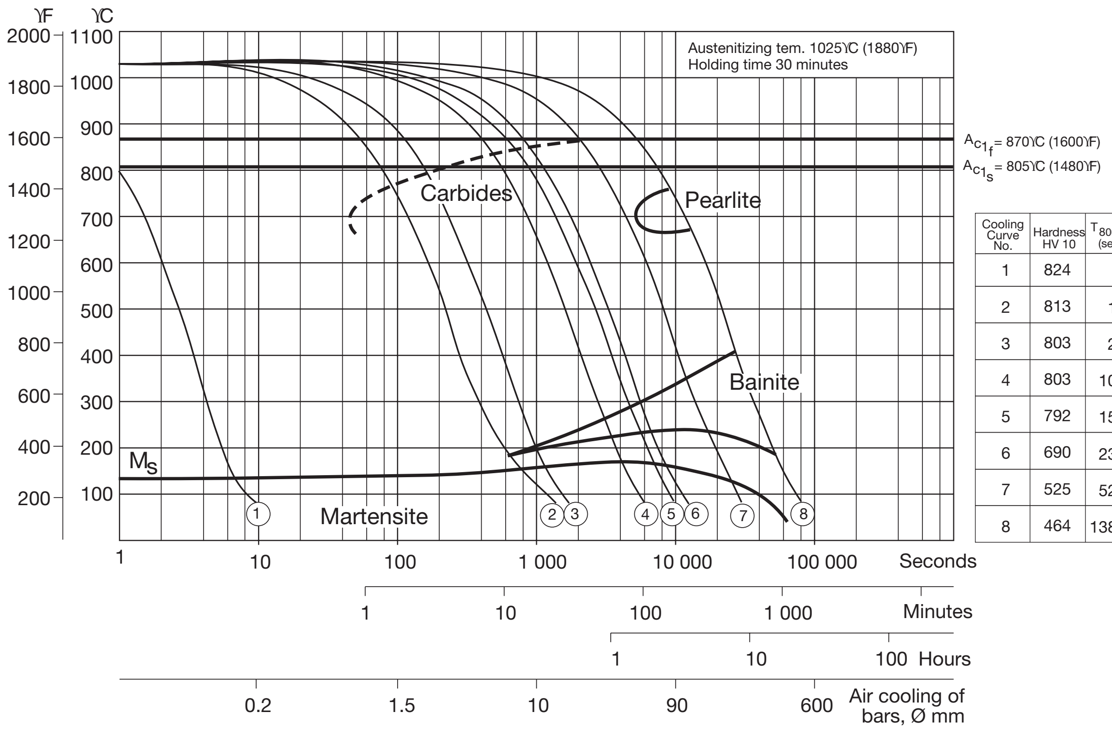
Note: Holding time = time at hardening temperature after the tool is fully heated through. A holding time of less than recommended time will result in loss of hardness.

The tool should be protected against decarburization and oxidation during hardening.

Further information can be found in the Uddeholm brochure “Heat treatment of tool steels”.

CCT-GRAPH

Austenitizing temperature 1025°C (1880°F). Holding time 30 mintues.



Cooling Curve No.	Hardness HV 10	T_{800-50} (sec)
1	824	2
2	813	140
3	803	280
4	803	1030
5	792	1596
6	690	2325
7	525	5215
8	464	13850

QUENCHING MEDIA

- Vacuum (high speed gas with sufficient overpressure minimum 2 bar)
- Martempering bath or fluidized bed at approx. 200–550°C (390–1020°F)
- Forced air/gas

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

In order to obtain the optimum properties for the tool, the cooling rate should be as fast as possible with regards to acceptable distortion.

A slow quench rate will result in loss of hardness compared with the given tempering curves.

Martempering should be followed by forced air cooling if wall thickness is exceeding 50 mm (2”).

TEMPERING

Choose the tempering temperature according to the hardness required by reference to the tempering graph below. Temper at least twice with intermediate cooling to room temperature. For highest dimensional stability and ductility, a minimum temperature of 540°C (1000°F) and three tempers is strongly recommended.

Tempering at a lower temperature than 540°C (1000°F) may increase the hardness and compressive strength to some extent but also impair cracking resistance and dimensional stability. However, if lowering the tempering temperature, do not temper below 520°C (970°F). When tempering twice the minimum holding time at temperature is 2 hours. When tempering three times the minimum holding time is 1 hour.

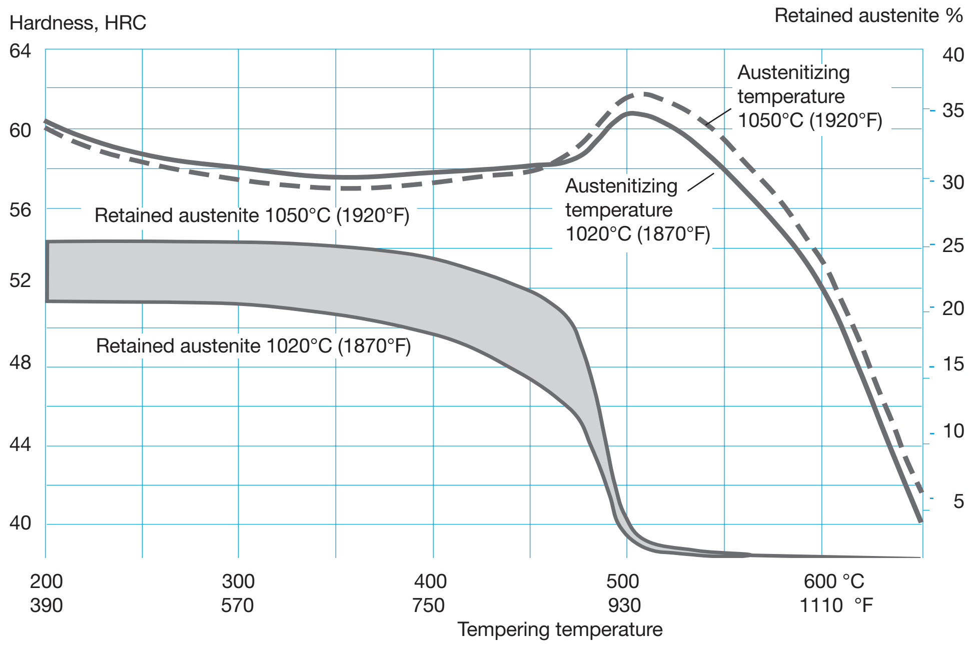
TEMPERING TABLE

Hardening temp.	Tempering temperature 540°C	550°C	560°C
1000°C* (1830°F*)	57–59 HRC	56–58 HRC	54–56 HRC
1020°C (1870°F)	58–60 HRC	57–59 HRC	55–57 HRC
1050°C (1920°F)	59–61 HRC	58–60 HRC	56–58 HRC

For high dimensional stability min. 540°C (1000°F) and 3 x 1 h should be used.

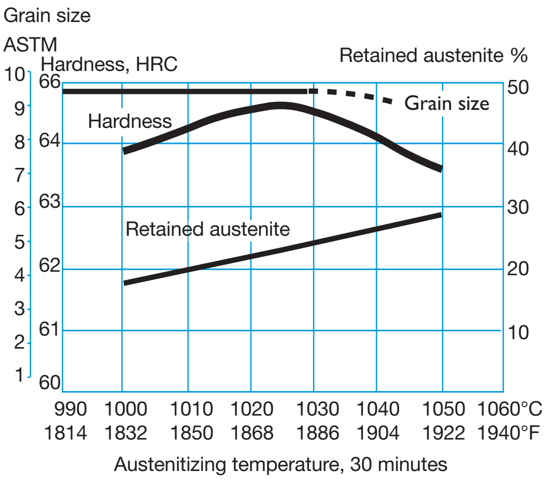
*Hardening temp. 1000°C (1830°F) should be used for cross sections >150 mm (6" thick).

TEMPERING GRAPH



The tempering curves are obtained after heat treatment of samples with a size of 15 x 15 x 40 mm, cooling in forced air ($T_{800-500}$ = 300 sec.). Lower hardness can be expected after heat treatment of tools and dies due to factors like actual tool size and heat treatment parameters.

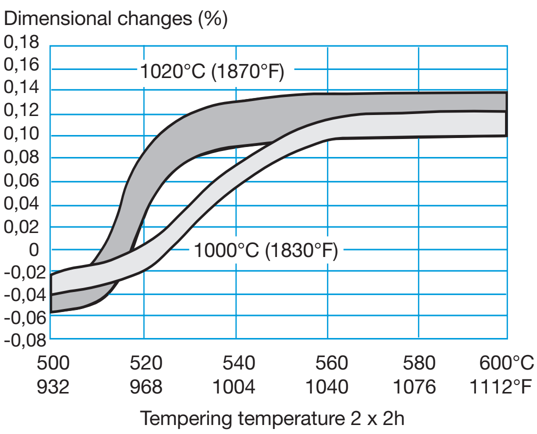
HARDNESS, GRAIN SIZE AND RETAINED AUSTENITE AS A FUNCTION OF AUSTENITIZING TEMPERATURE



DIMENSIONAL CHANGES

The dimensional changes have been measured after austenitizing at 1000°C (1830°F)/30 min. and 1020°C (1870°F)/30 min. followed by gas quenching in N_2 at a cooling rate of 1.1°C/s between 800–500°C (1470–930°F) in a cold chamber vacuum furnace.

Specimen size: 100 x 100 x 100 mm (3.9" x 3.9" x 3.9"). Values for all directions are within the marked areas.



SURFACE TREATMENTS

Tool steel may be given a surface treatment in order to reduce friction and increase wear resistance. The most commonly used treatments are nitriding and surface coating with wear resistant layers produced via PVD or CVD.

The high hardness and toughness together with a good dimensional stability makes Uddeholm Caldie suitable as a substrate steel for various surface coatings.

NITRIDING AND NITROCARBURIZING

Nitriding and nitrocarburizing result in a hard surface layer which is very resistant to wear and galling.

The surface hardness after nitriding is approximately 1000–1200 $HV_{0.2kg}$. The thickness of the layer should be chosen to suit the application in question.

PVD

Physical vapour deposition, PVD, is a method of applying a wear-resistant coating at temperatures between 200–500°C (390–930°F).

CVD

Chemical vapour deposition, CVD, is used for applying wear-resistant surface coatings at a temperature of around 1000°C (1830°F).

CUTTING DATA 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 recommendation".

The recommendations in following tables are valid for Uddeholm Caldie in soft annealed condition max. 215 HB.

TURNING

Cutting data parameters	Turning with carbide		Turning with high speed steel
	Rough turning	Fine turning	Fine turning
Cutting speed (v_c) m/min f.p.m.	140–190 460–620	190–240 620–785	15–20 50–65
Feed (f) mm/rev 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 US	P20–P30 C6–C5 Coated carbide	P10 C7 Coated carbide or cermet	– –

MILLING

FACE- AND SQUARE SHOULDER MILLING

Cutting data parameters	Milling with carbide	
	Rough milling	Fine milling
Cutting speed (v_c) m/min f.p.m.	130–160 430–525	160–200 525–656
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	2–4 0.08–0.16	0.5–2 0.02–0.08
Carbide designation ISO US	P20–P40 C6–C5 Coated carbide	P10–20 C7–C6 Coated carbide or cermet

END MILLING

Cutting data parameters	Type of milling		
	Solid carbide	Carbide indexable insert	High speed steel
Cutting speed (v_c) m/min f.p.m.	110–140 360–460	100–140 330–460	18–23[1)] 60–75[1)]
Feed (f_z) mm/tooth inch/tooth	0.01–0.20[2)] 0.0003–0.008[2)]	0.06–0.20[2)] 0.002–0.008[2)]	0.01–0.30[2)] 0.0003–0.012[2)]
Carbide designation ISO US	–	P20–P30 C6–C5	– –

[1)] For coated high speed steel end mill v_c = 32–38 m/min. (105–125 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/rev	Feed (f) i.p.r.
– 5	–3/16	15–20*	49–66*	0.05–0.10	0.002–0.004
5–10	3/16–3/8	15–20*	49–66*	0.10–0.20	0.004–0.008
10–15	3/8–5/8	15–20*	49–66*	0.20–0.30	0.008–0.012
15–20	5/8–3/4	15–20*	49–66*	0.30–0.35	0.012–0.014

* For coated high speed steel drill v_c = 35–40 m/min. (110–130 f.p.m.)

CARBIDE DRILL

Cutting data parameters	Type of drill		
	Indexable insert	Solid carbide	Carbide tipped[1)]
Cutting speed (v_c) m/min f.p.m.	160–200 525–655	110–140 360–460	60–90 19–295
Feed (f) mm/rev i.p.r.	0.05–0.15[2)] 0.002–0.006[2)]	0.08–0.20[3)] 0.003–0.008[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”.

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 60 KV	A 60 KV
Internal grinding	A 46 JV	A 60 IV
Profile grinding	A 100 KV	A 120 JV

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 pre-heating of the tool, the controlled cooling of the tool and the post weld heat treatment processes. The following guidelines summarize the most important welding process para-meters.

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

Welding method	TIG	MMA
Preheating temperature	200–250°C (390–485°F)	200–250°C (390–485°F)
Filler material	Caldie TIG-Weld UTP A696 UTP ADUR600 UTP A 73G2	Caldie Weld UTP 69 UTP 67S UTP 73G2
Maximum interpass temperature	400°C (750°F)	400°C (750°F)
Post weld cooling	20–40°C/h (40–80°F/h) for the first 2 hours and then freely in air.	
Hardness after welding	54–62 HRC	55–62 HRC
Post weld heat treatment		
Hardened condition	Temper at 510°C (950°F) for 2 hours	
Soft annealed condition	Soft-anneal according to the “Heat treatment recommendations”	

Minor repairs can be made at room temperature with the TIG-method.

ELECTRICAL DISCHARGE MACHINING — EDM

If EDM is performed in the hardened and tempered condition, finish with “fine-sparking”, i.e. low current, high frequency.

For optimal performance the EDM'd surface should the be ground/polished and the tool re-tempered at approx. 25°C (50°F) lower than the original tempering temperature.

Further information is given in the Uddeholm brochure “EDM of Tool Steel”.

FLAME HARDENING

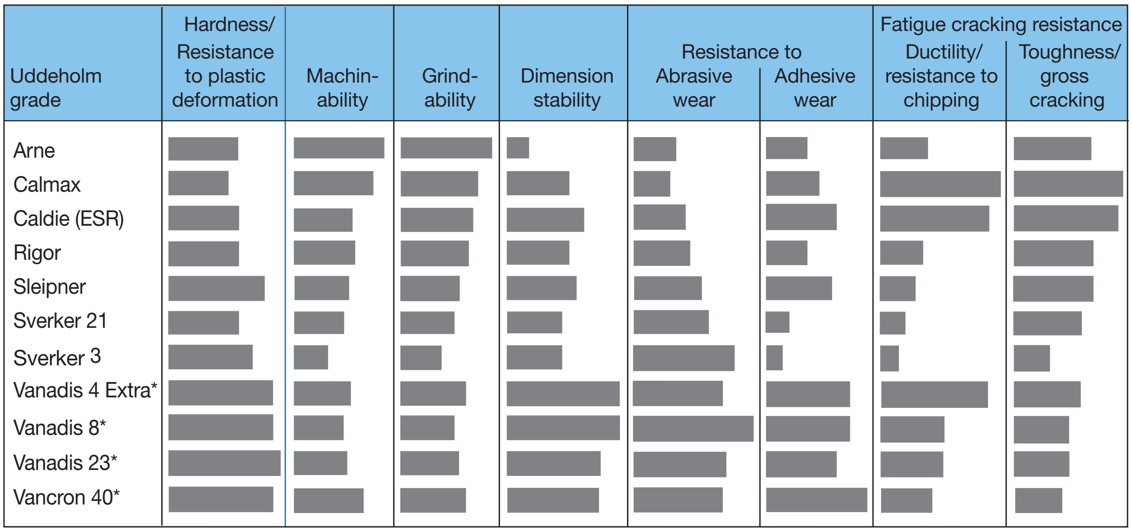
Use oxy-acetylene equipment with a capacity of 800–1250 l/h.

Oxygen pressure 2.5 bar, acetylene pressure 1.5 bar. Adjust to give neutral flame. Temperature: 980–1020°C (1795–1870°F). Cool freely in air.

The hardness at the surface will be 58–62 HRC and 41 HRC (400 HB) at a depth of 3–3.5 mm (0.12"–0.14").

RELATIVE COMPARISON OF UDDEHOLM COLD WORK TOOL STEEL

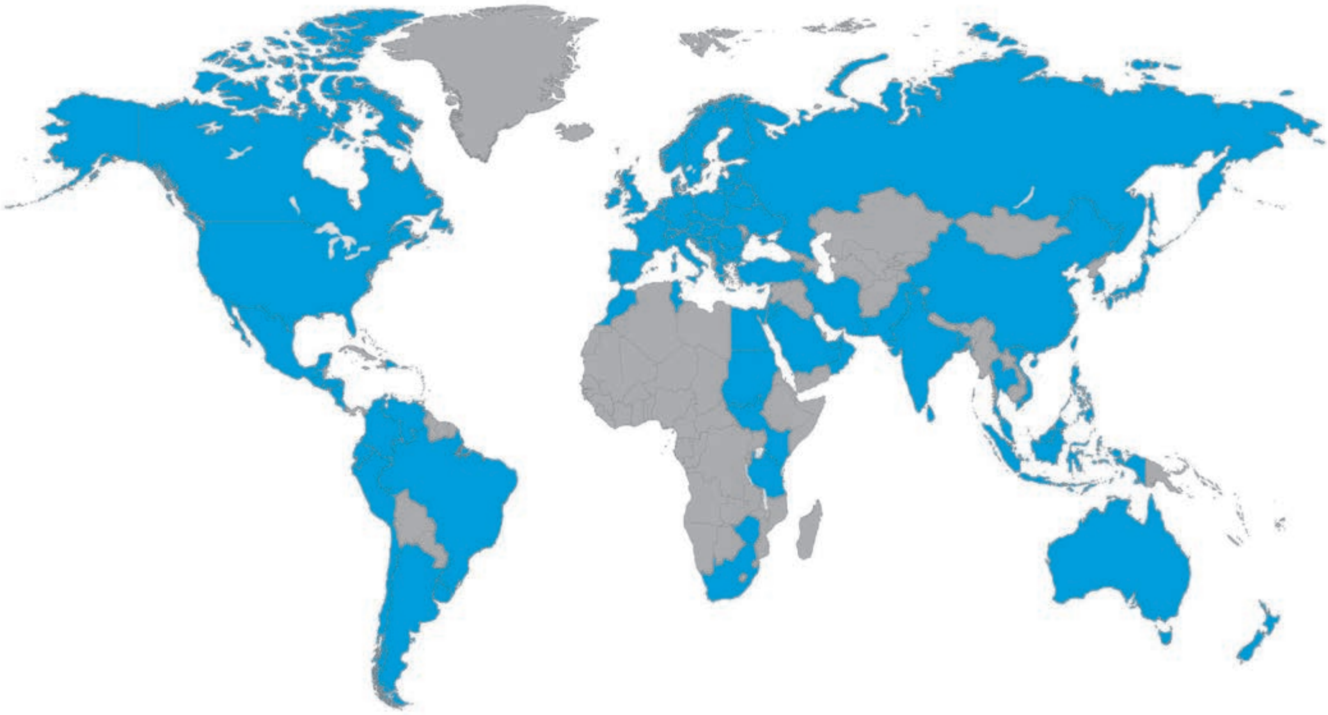
MATERIAL PROPERTIES AND RESISTANCE TO FAILURE MECHANISMS



* Uddeholm PM SuperClean

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. We secure our position as the world's leading supplier of tooling materials.

UDDEHOLM 1710 / 75 STROKIRK KNAPPEN

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. We secure our position as the world's leading supplier of tooling materials. We act worldwide. For us it is all a matter of trust – in long-term partnerships as well as in developing new products.

For more information, please visit www.uddeholm.com

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