since 1945
75 years

CALDIE

UDDEHOLM CALDIE

ASSAB

ASSAB	UDDEHOLM a voestalpine company	REFERENCE STANDARD		
		AISI	WNr.	JIS
ASSAB DF-3	ARNE	O1	1.2510	SKS 3
ASSAB XW-10	RIGOR	A2	1.2363	SKD 12
ASSAB XW-42	SVERKER 21	D2	1.2379	(SKD 11)
CALMAX / CARMO	CALMAX / CARMO		1.2358	
VIKING	VIKING / CHIPPER		(1.2631)	
CALDIE	CALDIE			
ASSAB 88	SLEIPNER			
ASSAB PM 23 SUPERCLEAN	VANADIS 23 SUPERCLEAN	(M3:2)	1.3395	(SKH 53)
ASSAB PM 30 SUPERCLEAN	VANADIS 30 SUPERCLEAN	(M3:2 + Co)	1.3294	SKH 40
ASSAB PM 60 SUPERCLEAN	VANADIS 60 SUPERCLEAN		(1.3292)	
VANADIS 4 EXTRA SUPERCLEAN	VANADIS 4 EXTRA SUPERCLEAN			
VANADIS 8 SUPERCLEAN	VANADIS 8 SUPERCLEAN			
VANCRON SUPERCLEAN	VANCRON SUPERCLEAN			
ELMAX SUPERCLEAN	ELMAX SUPERCLEAN			
VANAX SUPERCLEAN	VANAX SUPERCLEAN			
ASSAB 518		P20	1.2311	
ASSAB 618 T		(P20)	(1.2738)	
ASSAB 618 / 618 HH		(P20)	1.2738	
ASSAB 718 SUPREME / 718 HH	IMPAX SUPREME / IMPAX HH	(P20)	1.2738	
NIMAX / NIMAX ESR	NIMAX / NIMAX ESR			
VIDAR 1 ESR	VIDAR 1 ESR	H11	1.2343	SKD 6
UNIMAX	UNIMAX			
CORRAX	CORRAX			
ASSAB 2083		420	1.2083	SUS 420J2
STAVAX ESR	STAVAX ESR	(420)	(1.2083)	(SUS 420J2)
MIRRAX ESR	MIRRAX ESR	(420)		
MIRRAX 40	MIRRAX 40	(420)		
TYRAX ESR	TYRAX ESR			
POLMAX	POLMAX	(420)	(1.2083)	(SUS 420J2)
ROYALLOY	ROYALLOY	(420 F)		
COOLMOULD	COOLMOULD			
ASSAB 2714			1.2714	SKT 4
ASSAB 2344		H13	1.2344	SKD 61
ASSAB 8407 2M	ORVAR 2M	H13	1.2344	SKD 61
ASSAB 8407 SUPREME	ORVAR SUPREME	H13 Premium	1.2344	SKD 61
DIEVAR	DIEVAR			
QRO 90 SUPREME	QRO 90 SUPREME			
FORMVAR	FORMVAR			

( ) - modified grade

Edition 20200409

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

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 Caldie also to a perfect substrate material for surface coatings.

A VERSATILE TOOL STEEL

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

GENERAL

Caldie is a chromium-molybdenumvanadium alloyed tool steel which is characterised 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 approx. 215 HB					

APPLICATIONS

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 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.

Caldie is also very suitable as a substrate steel for applications where surface coatings are desirable or necessary, very good chipping and cracking resistance good wear resistance.

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

COMPONENT BUSINESS APPLICATIONS

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, gas quenched in a vacuum furnace and tempered twice at 525°C for two hours to 60–61 HRC.

PHYSICAL DATA

Hardened and tempered to 60–61 HRC.

Temperature	20 °C	200 °C	400 °C
Density kg/m^3	7 820	-	-
Modulus of elasticity MPa	213 000	192 000	180 000
Coefficient of thermal expansion per °C from 20 °C	-	11.6 x 10^{-6}	12.4 x 10^{-6}
Thermal conductivity W/m°C	-	24	28
Specific heat J/kg°C	460	-	-

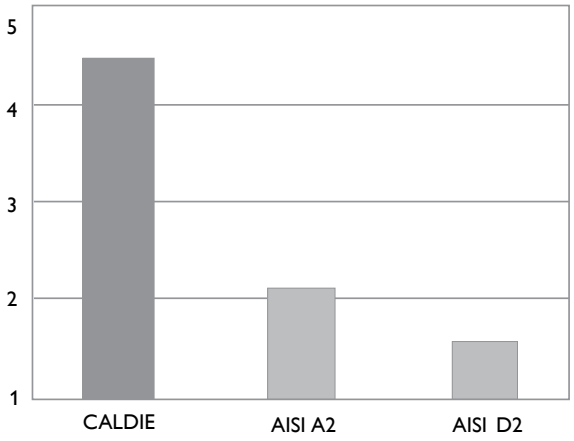
COMPRESSIVE STRENGTH

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

Hardness HRC	Compressive yield strength Rc $_{0.2}$ MPa
58	2230
60	2350
61	2430

CHIPPING RESISTANCE

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



HEAT TREATMENT

SOFT ANNEALING

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

STRESS RELIEVING

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

HARDENING

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

Austenitising temperature: 1000 - 1050 °C, normally 1020°C, in case of bigger dimensions (>150 mm cross section).

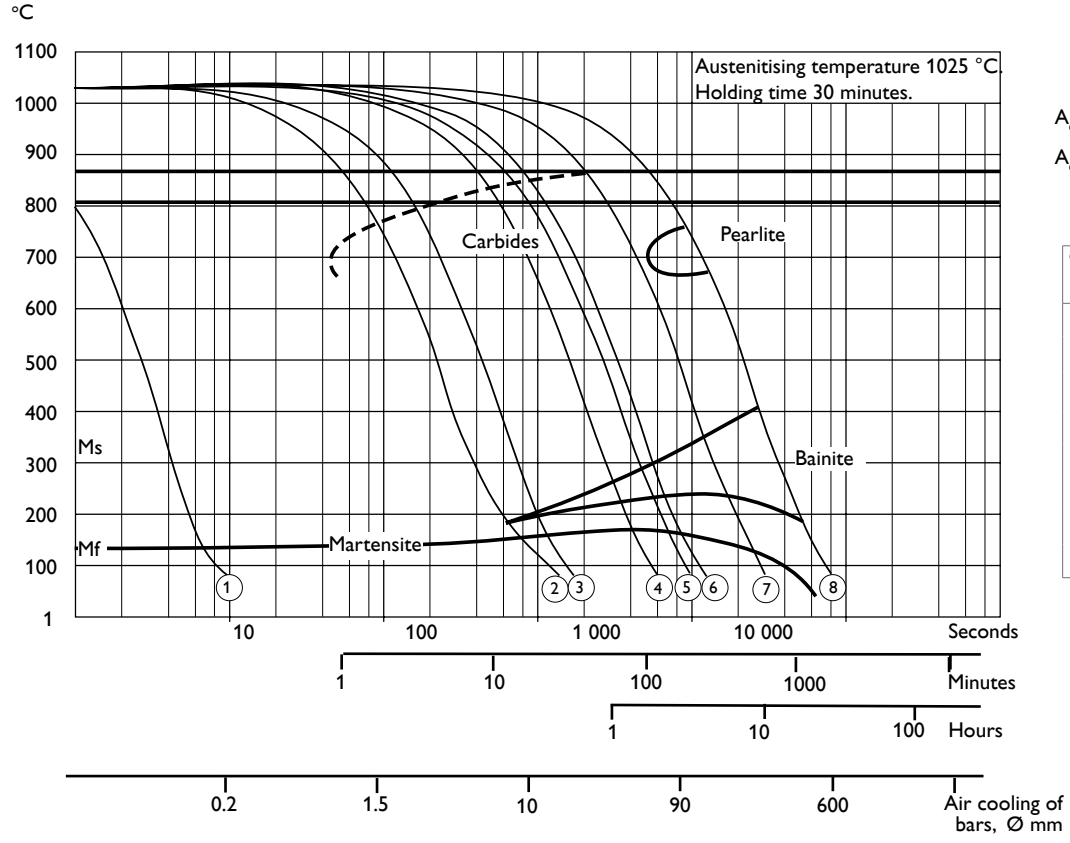
Holding time: 30 minutes after the tool is heated through.

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 decarburisation and oxidation during hardening.

CCT-GRAPH

Austenitising temperature 1025 °C. Holding time 30 minutes.



A_{C1f} = 870 °C

A_{C1s} = 805 °C

Cooling Curve No.	Hardness HV 10	$T_{800-500}$ sec
1	824	2
2	813	140
3	803	280
4	803	1 030
5	792	1 596
6	690	2 325
7	525	5 215
8	464	13 850

QUENCHING MEDIA

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

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.

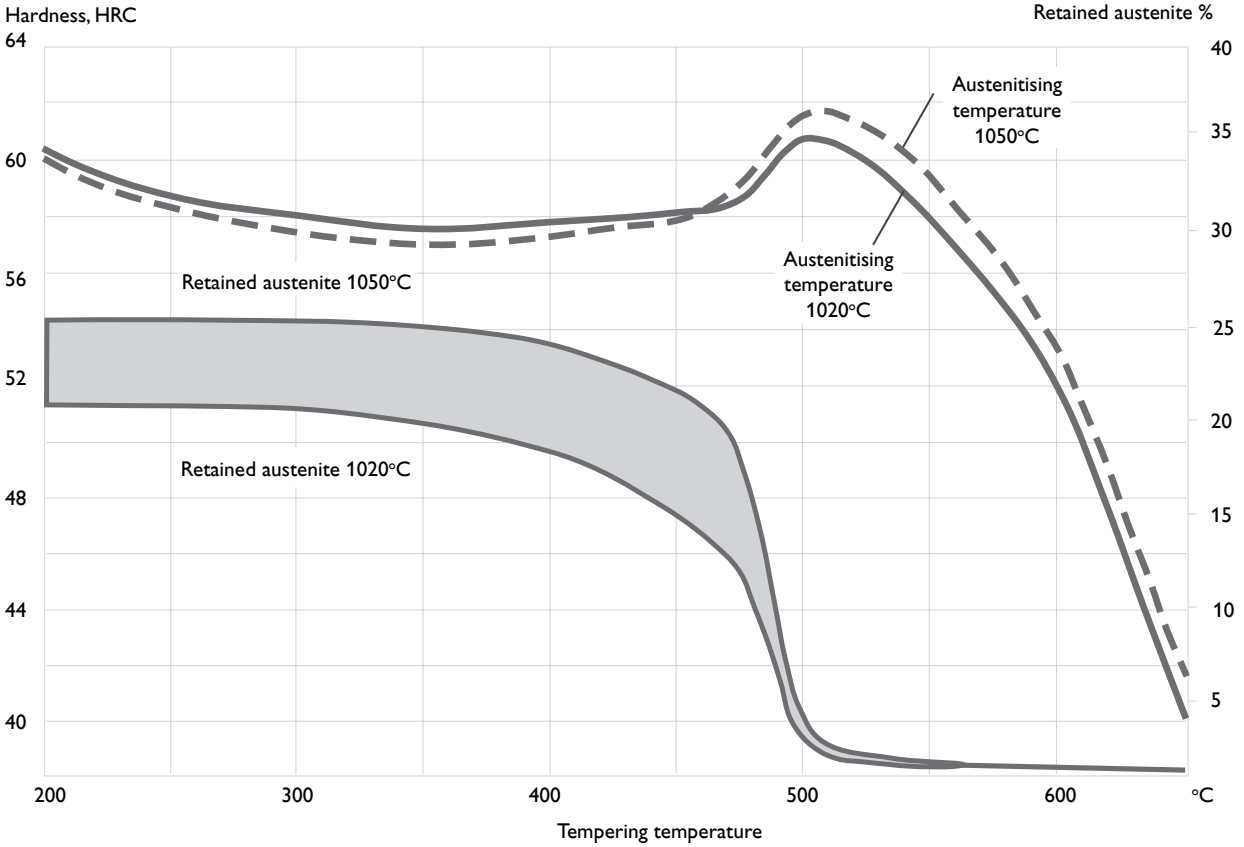
For highest dimensional stability and ductility, a minimum temperature of 540°C and three tempers is strongly recommended.

Tempering at a lower temperature than 540°C 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. When tempering twice the minimum holding time at temperature is 2 hours. When tempering three times the minimum holding time is 1 hour.

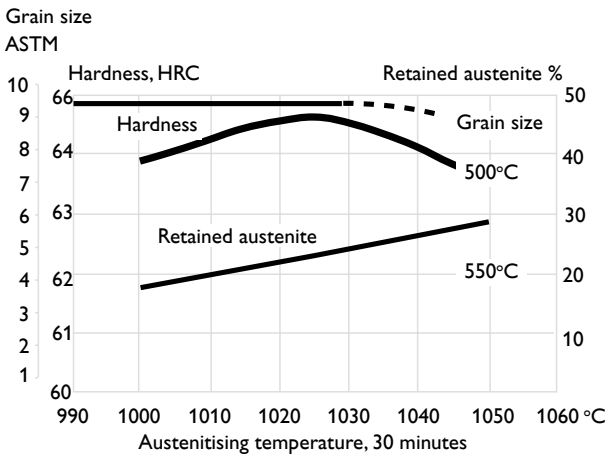
TEMPERING TABLE

Hardening temp. °C	Tempering temperatures		
	540°C	550°C	560°C
1000	57 - 59 HRC	56 - 58 HRC	54 - 56 HRC
1020	58 - 60 HRC	57 - 59 HRC	55 - 57 HRC
1050	59 - 61 HRC	58 - 60 HRC	56 - 58 HRC

TEMPERING GRAPH



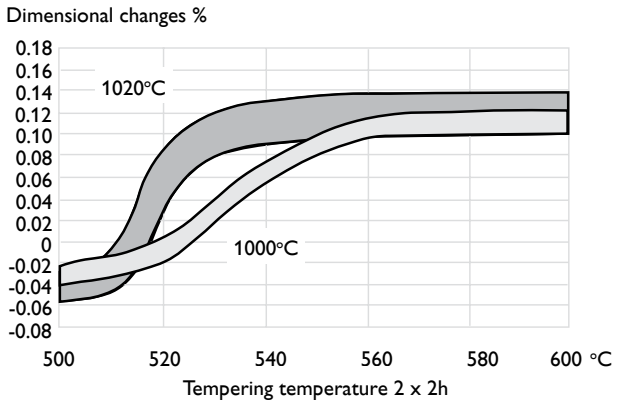
HARDNESS, GRAIN SIZE AND RETAINED AUSTENITE AS A FUNCTION OF AUSTENITISING TEMPERATURE



DIMENSIONAL CHANGES

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

Specimen size: 100 x 100 x 100 mm. 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 Caldie suitable as a substrate steel for various surface coatings.

NITRIDING AND NITROCARBURISING

Nitriding and nitrocarburising 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.

CVD

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

MACHINING RECOMMENDATIONS

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

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

TURNING

Cutting data parameters	Turning with carbide		Turning with high speed steel Fine turning
	Rough turning	Fine turning	
Cutting speed (v_c), m/min	140 – 190	190 - 240	15 - 20
Feed (f) mm/rev	0.2 – 0.4	0.05 – 0.2	0.05-0.3
Depth of cut (a_p) mm	2 - 4	0.5 – 2	0.5 – 3
Carbide designation ISO	P20 – P30 Coated carbide	P10 Coated carbide or cermet	-

MILLING

FACE AND SQUARE SHOULDER MILLING

Cutting data parameter	Turning with carbide	
	Rough milling	Fine milling
Cutting speed (V_c) m/min	130 – 160	160 – 200
Feed (f) mm/tooth	0.2 – 0.4	0.1 – 0.2
Depth of cut (a_p) mm	2 – 4	0.5 – 2
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	100 – 140	18 – 23 [1]
Feed (f_z) mm/tooth	0.01 – 0.20 [2]	0.06 – 0.20 [2]	0.01 – 0.30 [2]
Depth of cut (a_p) mm	-	P20, P30	-

[1] For coated high speed steel end mill Vc = 32 – 38 m/min
[2] Depending on radial depth of cut and cutter diameter

DRILLING

HIGH SPEED STEEL TWIST DRILL

Drill diameter mm	Cutting speed (v_c) m/min	Feed (f) mm/r
≤ 5	15 - 20 *	0.05 – 0.10
5 – 10	15 - 20 *	0.10 – 0.20
10 – 15	15 - 20 *	0.20 – 0.30
15 – 20	15 - 20 *	0.30 – 0.35

* For coated high speed steel drill V_c = 35 - 40 m/min

CARBIDE DRILL

Cutting data parameters	Type of drill		
	Indexable insert	Solid carbide	Carbide tip[1]
Cutting speed (v_c), m/min	160 – 200	110 – 140	60 – 90
Feed (f_z) mm/tooth	0.05 – 0.15 [2]	0.08 – 0.20 [3]	0.15 – 0.25 [4]

[1] Drill with replaceable or brazed carbide tip
[2] Feed rate for drill diameter 20 – 40 mm
[3] Feed rate for drill diameter 5 – 20 mm
[4] Feed rate for drill diameter 10 – 20 mm

GRINDING

A general grinding wheel recommendation is given below. More information can be found in the publication ”Grinding of tool steel”.

Type of grinding	Soft annealed	Hardened
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 summarise the most important welding process parameters.

Welding method	TIG	MMA
Preheating temperature	200 - 250 °C	200 - 250 °C
Filler material	Caldie TIG-Weld	Caldie Weld
Maximum interpass temperature	400 °C	400 °C
Post weld cooling	20 - 40 °C/h the first 2 h then freely in air.	
Hardness after welding	54 - 62 HRC	55 - 62 HRC
Heat treatment after welding:		
Hardened condition	Temper at 510 °C for 2 hours.	
Soft annealed condition	Soft-anneal according to the Heat treatment recommendations"	

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 lower than the original tempering temperature.

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. 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.

FURTHER INFORMATION

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

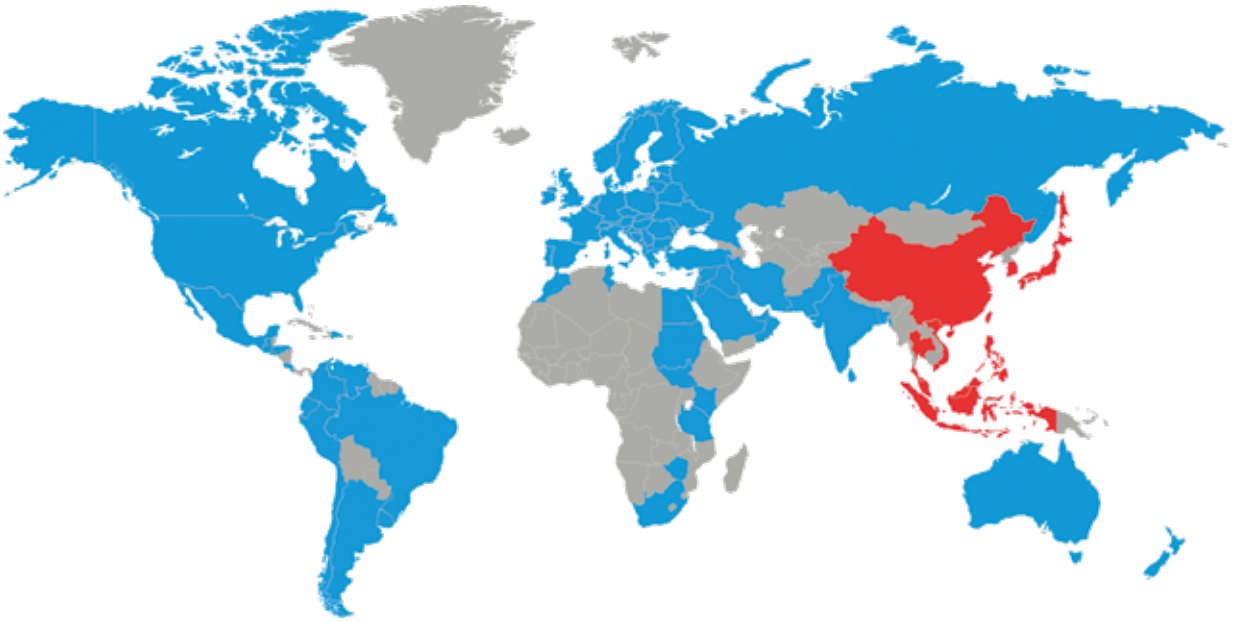
RELATIVE COMPARISON OF THE RESISTANCE TO FAILURE MECHANISMS

ASSAB Grade	Hardness/ Resistance to plastic deformation	Machinability	Grindability	Dimension stability	Resistance to		Fatigue cracking resistance	
					Abrasive wear	Adhesive wear/Galling	Ductility/ resistance to chipping	Toughness/ gross cracking
Conventional cold work tool steel								
ASSAB DF-3								
ASSAB XW-10								
ASSAB XW-42								
Calmax								
Caldie (ESR)								
ASSAB 88								
Powder metallurgical tool steel								
Vanadis 4 Extra*								
Vanadis 8*								
Vancron*								
Powder metallurgical high speed steel								
ASSAB PM 23*								
ASSAB PM 30*								
ASSAB PM 60*								
Conventional high speed steel								
ASSAB M2								

* ASSAB PM SuperClean Tool Steel

ASSAB
SUPERIOR TOOLING SOLUTIONS
A ONE-STOP SHOP

ASSAB is unmatched as a one-stop product and service provider that offers superior tooling solutions. In addition to the supply of tool steel and other special steel, our range of comprehensive value-added services, such as machining, heat treatment and coating services, span the entire supply chain to ensure convenience, accountability and optimal usage of steel for customers. We are committed to achieving solutions for our customers, with a constant eye on time-to-market and total tooling economy.



Choosing the right steel is of vital importance. ASSAB engineers and metallurgists are always ready to assist you in your choice of the optimum steel grade and the best treatment for each application. ASSAB not only supplies steel products with superior quality, we offer state-of-the-art machining, heat treatment and surface treatment services to enhance steel properties to meet your requirement in the shortest lead time. Using a holistic approach as a one-stop solution provider, we are more than just another tool steel supplier.

ASSAB and Uddeholm are present on every continent. This ensures you that high quality tool steel and local support are available wherever you are. Together we secure our position as the world's leading supplier of tooling materials.

For more information, please visit
www.assab.com

UDDEHOLM
a voestalpine company

ASSAB