CALDIE

UDDEHOLM
CALDIE

ASSAB

ASSAB	UDDEHOLM	REFERENCE STANDARD		
		AISI	WNr.	JIS
ASSAB DF-2	ARNE	O1	(1.2510)	(SKS 3)
ASSAB DF-3		O1	(1.2510)	(SKS 3)
ASSAB XW-5	SVERKER 3	D6 (D3)	(1.2436)	(SKD 2)
ASSAB XW-10	RIGOR	A2	1.2363	SKD 12
ASSAB XW-41	SVERKER 21	D2	1.2379	SKD 11
ASSAB XW-42		D2	1.2379	SKD 11
CARMO	CARMO		1.2358	
CALMAX	CALMAX		1.2358	
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 6 SUPERCLEAN	VANADIS 6 SUPERCLEAN			
VANADIS 10 SUPERCLEAN	VANADIS 10 SUPERCLEAN			
VANCRON 40 SUPERCLEAN	VANCRON 40 SUPERCLEAN			
ELMAX SUPERCLEAN	ELMAX SUPERCLEAN			
ASSAB 518		P20	1.2311	
ASSAB 618		P20 Mod.	1.2738	
ASSAB 618 HH		P20 Mod.	1.2738	
ASSAB 618 T		P20 Mod.	1.2738 Mod.	
ASSAB 718 SUPREME	IMPAX SUPREME	P20 Mod.	1.2738	
ASSAB 718 HH	IMPAX HH	P20 Mod.	1.2738	
NIMAX	NIMAX			
MIRRAX 40	MIRRAX 40	420 Mod.		
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 Mod.	1.2083 ESR	SUS 420J2
MIRRAX ESR	MIRRAX ESR	420 Mod.		
POLMAX	POLMAX			
RAMAX HH	RAMAX HH	420 F Mod.		
ROYALLOY	ROYALLOY			
PRODAX				
ASSAB PT18				
ASSAB MMXL				
ASSAB MM40				
ALVAR 14	ALVAR 14		1.2714	SKT 4
ASSAB 2714			1.2714	SKT 4
ASSAB 8407 2M	ORVAR 2M	H13	1.2344	SKD 61
ASSAB 8407 SUPREME	ORVAR SUPREME	H13 Premium	1.2344 ESR	SKD 61
DIEVAR	DIEVAR			
HOTVAR	HOTVAR			
QRO 90 SUPREME	QRO 90 SUPREME			
FORMVAR	FORMVAR			
ASSAB 705		4340	1.6582	SNCM8
ASSAB 709		4140	1.7225	SCM4
ASSAB 760		1050	1.1730	S50C

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The information contained herein 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. Each user of ASSAB products is responsible for making its own determination as to the suitability of ASSAB products and services.

Edition 150216

General

Caldie is a chromium-molybdenum-vanadium 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 during heat treatment
- 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					
Colour code	White / Grey					

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 (>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, such 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.

- Blanking
- Cold forging and forming
- Machine knives
- Thread rolling dies
- Substrate for surface coatings
- Fragmentation knives for plastics and metals
- Roll forming rolls

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 60–62 HRC.

PHYSICAL PROPERTIES

Hardened and tempered to 60 - 62 HRC.

Temperature	20°C	200°C	400°C
Density kg/m³	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	-	-

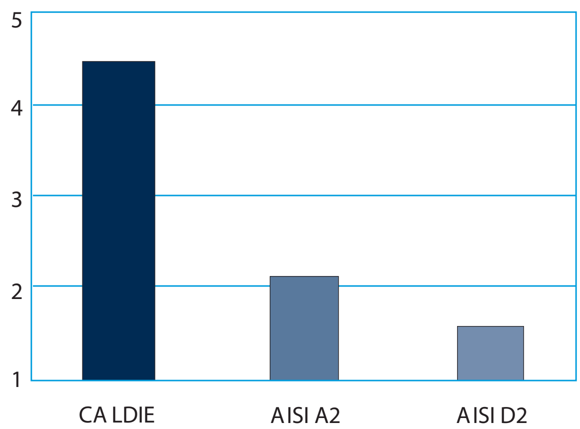
COMPRESSIVE STRENGTH

Approximate compressive strength vs. hardness at room temperature.

Hardness HRC	Compressive yield strength R_C0.2 (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 equalisation 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: 600–650°C and 850–900°C. In case of bigger dimensions, a third preheating step at 930°C is recommended.
Austenitising temperature: 1000–1025°C, normally 1020°C. In case of bigger dimensions, use 1000°C.
Holding time: 30 minutes

Protect the part against decarburisation and oxidation.

QUENCHING MEDIA

- High speed gas/circulating atmosphere
- Vacuum furnace (high speed gas with sufficient overpressure)
- Martempering bath at 500–550°C
- Martempering bath at approx. 200–350°C

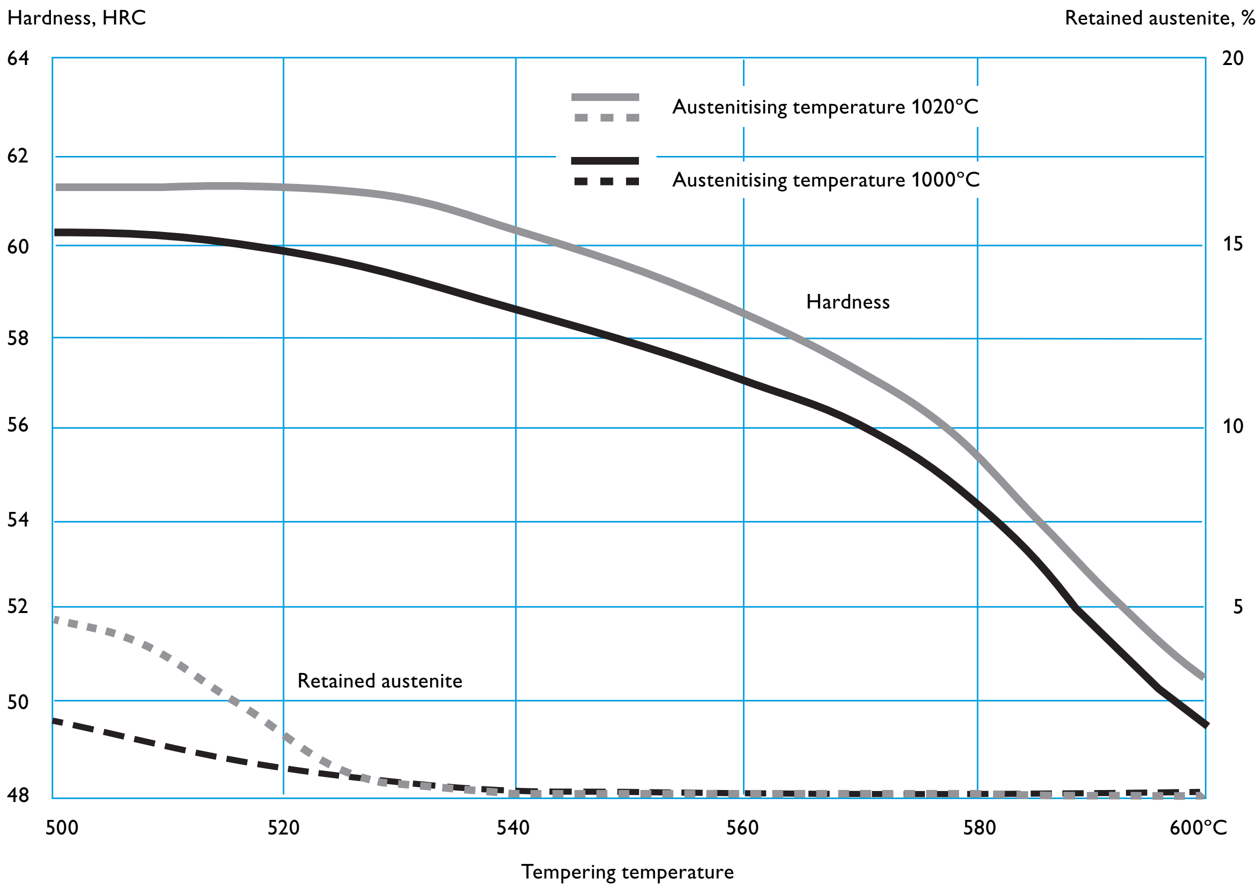
Note: Temper the tool as soon as its temperature reaches 50–70°C.

TEMPERING

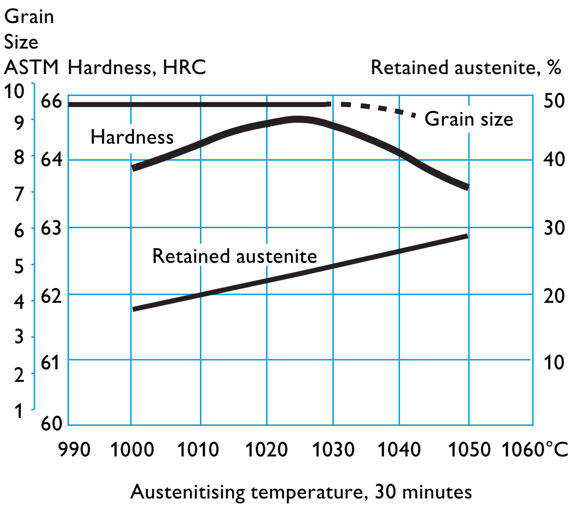
Choose the tempering temperature according to the hardness required by reference to the tempering graph below.

Temper at least twice with intermediate cooling to room temperature. The lowest tempering temperature which should be used is 525°C. The minimum holding time at temperature is 2 hours.

Tempering graph



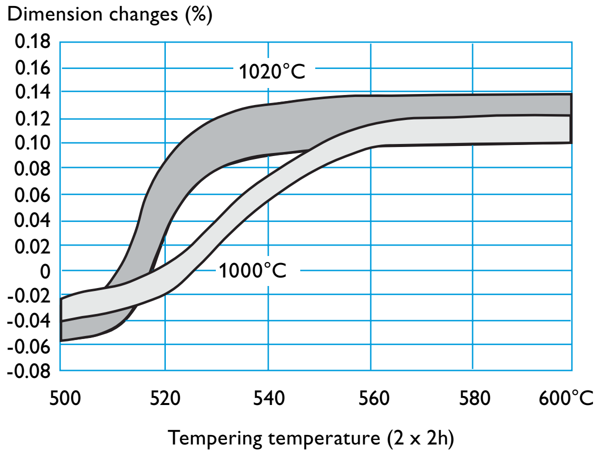
Hardness, grain size and retained austenite as a function of austenitising temperature



DIMENSIONAL CHANGES

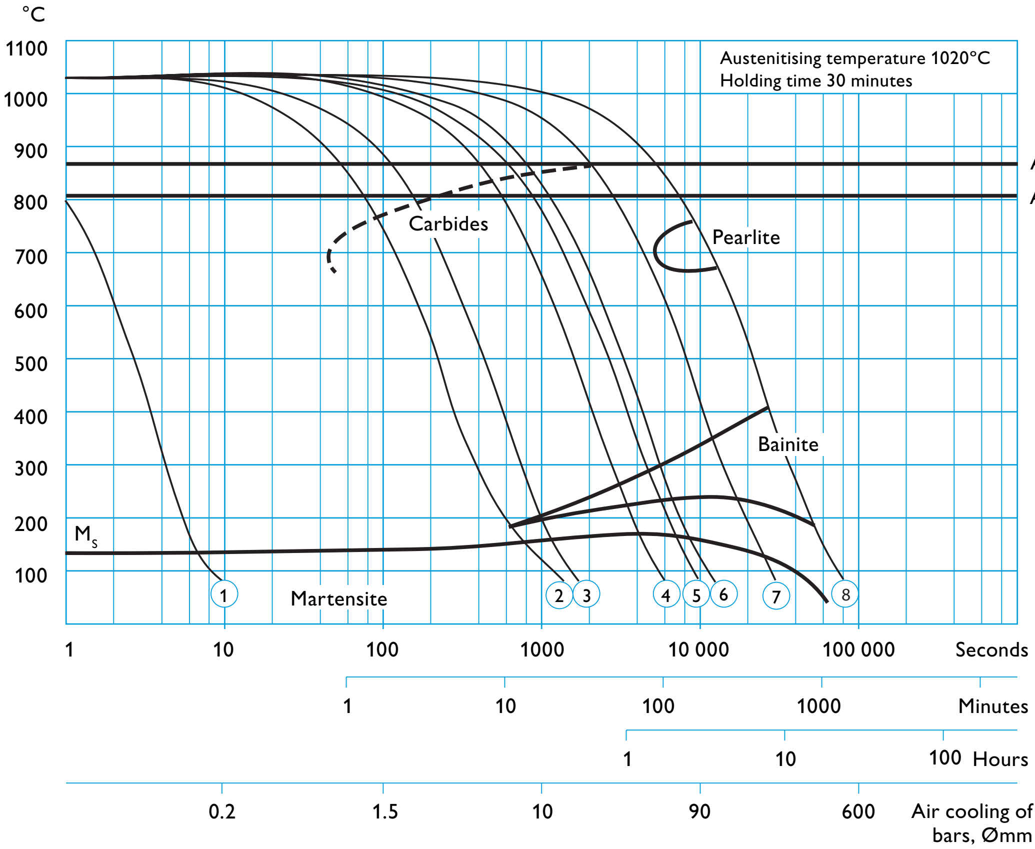
The dimensional changes have been measured after austenitising at 1000°C/30 min. and 1020°C/30 min., followed by gas quenching in N_2 at a cooling rate of 1.1°C/s between 800–500°C in a cold chamber vacuum furnace.

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



CCT graph

Austenitising temperature 1025°C. Holding time 30 minutes.



Cooling Curve No.	Hardness HV 10	$T_{800-500}$ (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

Machining recommendations

The cutting data below are to be considered as guiding values and as starting points for developing your own best practice.

Condition: Soft annealed condition ~220 HB

TURNING

Cutting data parameters	Turning with carbide		Turning with HSS†
	Rough turning	Fine turning	Fine turning
Cutting speed (v_c) m/min	140 - 190	190 - 240	15 - 20
Feed (f) mm/r	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	-

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 HSS drill, v_c~ 35–40 m/min*

Carbide drill

Cutting data parameters	Type of drill		
	Indexable insert	Solid carbide	Brazed carbide[1]
Cutting speed (v_c) m/min	160 - 200	110 - 140	60 - 90
Feed (f) mm/r	0.05 - 0.15[2]	0.10 - 0.25[2]	0.15 - 0.25[2]

[1] Drill with interntal 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	Fine milling
Cutting speed (v_c) m/min	130 - 160	160 - 200
Feed (f_z) 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 milling		
	Solid carbide	Carbide indexable insert	High speed steel
Cutting speed (v_c) m/min	110 - 140	100 - 140	18 - 23[1]
Feed (f) mm/tooth	0.01 - 0.2[2]	0.06 - 0.20[2]	0.01 - 0.30[2]
Carbide designation ISO	-	P20 - P30	-

[1] For coated HSS end mill, v_c~ 32–38 m/min

GRINDING

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 KV

Electrical discharge machining

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 be ground/polished and the tool retempered at approx. 25°C lower than the original tempering temperature.

Surface treatment

Tool steels 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 a method for applying wear-resistant surface coating at a temperature of around 1000°C.

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.

Welding

Welding of die components can be performed, with acceptable results, as long as proper precautions are taken during the preparation of the joint, the filler material selection, the preheating 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[1]	200 - 250°C	200 - 250°C
Filler material	Caldie TIG-Weld UTP A696 UTP ADUR600 UTP A73G2	UTP 69 UTP 67S UTP 73G2
Maximum interpass temperature[2]	350°C	350°C
Post weld cooling	20 - 40°C/h for the first two hours and 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 h	
Soft annealed condition	Soft anneal according to the "Heat treatment" recommendation.	

[1] Preheating temperature must be established throughout the die and must be maintained for the entire welding process, to prevent weld cracking

[2] The temperature of the tool in the weld area immediately before the second and subsequent pass of a multiple pass weld. When exceeded, there is a risk of distortion of the tool or soft zones around the weld.

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

Further information

For further information, i.e., steel selection, heat treatment, application and availability, please contact our ASSAB office nearest to you.

Relative comparison of ASSAB cold work tool steels

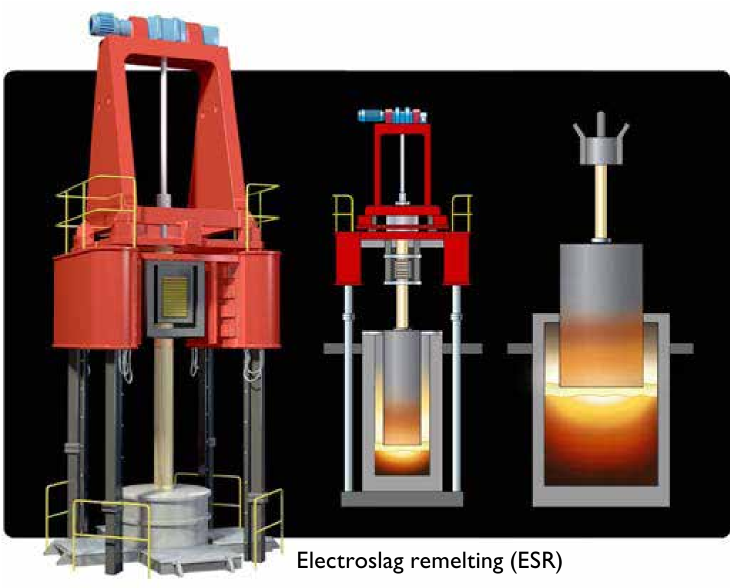
MATERIAL PROPERTIES AND RESISTANCE TO FAILURE MECHANISMS

ASSAB grade	Hardness/ Resistance to plastic deformation	Machinability	Grindability	Dimension stability	Resistance to		Fatigue cracking resistance	
					Abrasive wear	Adhesive wear	Ductility/ resistance to chipping	Toughness/ gross cracking
ASSAB DF-3								
CALMAX								
CALDIE (ESR)								
ASSAB XW-10								
ASSAB 88								
ASSAB XW-42								
ASSAB XW-5								
VANADIS 4 EXTRA								
VANADIS 10								
VANCRON 40								
ASSAB PM 23								
ASSAB PM 30								
ASSAB PM 60								
AISI M2								

The ESR Tool Steel Process

The starting material for our tool steel is carefully selected from high quality recyclable steel. Together with ferroalloys and slag formers, the recyclable steel is melted in an electric arc furnace. The molten steel is then tapped into a ladle.

The deslagging unit removes oxygen-rich slag. Then deoxidation, alloying and heating of the steel bath are carried out in the ladle furnace. Vacuum degassing removes elements such as hydrogen, nitrogen and sulphur.



Electroslag remelting (ESR)

ESR PLANT

In uphill casting, a controlled flow of molten steel from the ladle filled the prepared moulds, and solidifies into ingots.

Subsequently, the steel can go directly to our rolling mill or to the forging press. Our premium steel grades go to our ESR furnace, where they are melted once again in an electroslag remelting process. This is done by melting a consumable electrode immersed in an overheated slag bath. Controlled solidification in the steel bath results in an ingot of high homogeneity, thereby removing macrosegregation. Melting under a protective atmosphere gives an even better steel cleanliness.

HOT WORKING

From the ESR plant, the steel goes to the rolling mill or to our forging press to be formed into round or flat bars.

Prior to delivery, all bar materials are heat treated to either soft annealed condition, or hardened and tempered condition.

MACHINING

Before putting into stock, flat bar profiles are machined to the required size and exact tolerance. Whilst larger round dimensions are turned in lathe, where the steel bars rotate against a stationary cutting tool. Peeling is performed on smaller round dimensions via cutting tools that revolve around the bars for removal of surface defects.

To safeguard the quality and integrity of our tool steels, we perform surface inspection and ultrasonic testing on all bars. We then cut off and discard the bar ends and any defects that are found during inspection.

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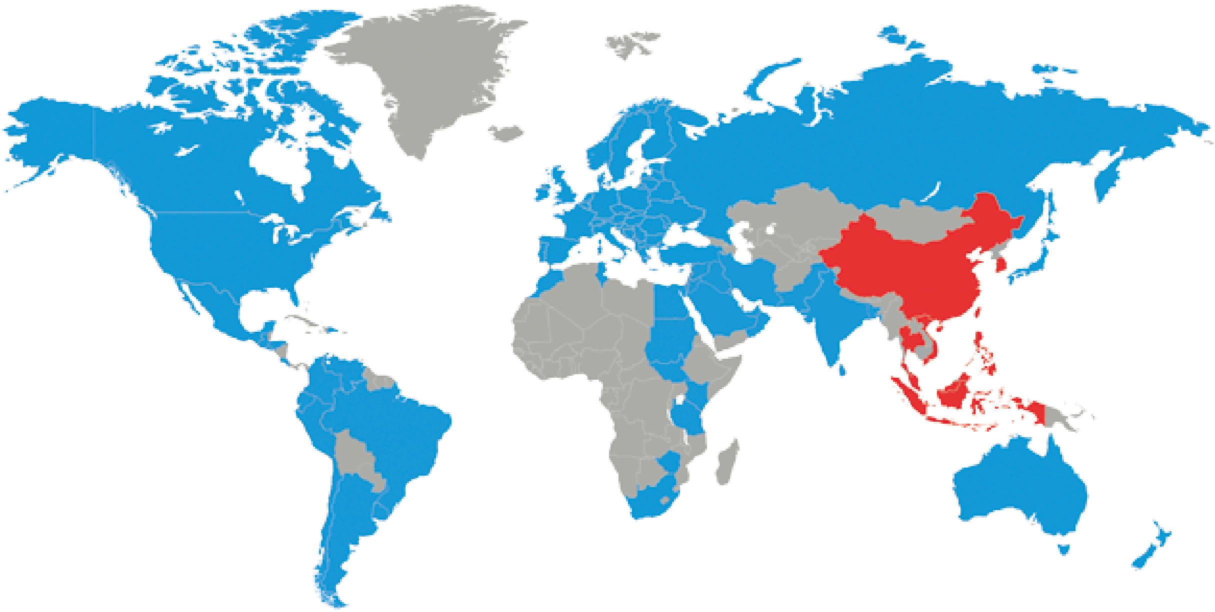

Choosing the right steel is of vital importance. ASSAB engineers and metallurgists are always ready to assist you in your choice of the optimum steel grade and the best treatment for each application. ASSAB not only supplies steel products with superior quality, we offer state-of-the-art machining, heat 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 steels 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

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