UDDEHOLM
POCKET BOOK

The Uddeholm range of tooling materials

UDDEHOLM
a voestalpine company

CONTENTS

Uddeholm Pocket Book presents, in a concise form, the Uddeholm range of high quality tool steel developed to meet specific needs and applications.

The information in this pocket book 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.

All information concerning the wide range of Uddeholm tool materials can't be given in this booklet. More detailed information and advice is readily available from your nearest Uddeholm office or visit www.uddeholm.com

UDDEHOLM STEEL GRADES — Composition

Uddeholm Grade	Colour code	Typical analysis C	Si	Mn	Cr	Mo	Ni	V	S	
ALVAR 14	White/Black	0.55	0.3	0.7	1.1	0.5	1.7	0.1		
AM CORRAX	–	0.03	0.3	0.3	12.0	1.4	9.2			**Al** 1.6 **W**
ARNE	Yellow	0.95	0.3	1.1	0.6			0.1		0.55
BALDER	Olive green/ Dark red	0.3	0.3	1.2	2.3	0.8	4.0	0.8		
BURE	Yellow/Violet	0.39	1.0	0.4	5.3	1.3		0.9		
CALDIE	White/Grey	0.70	0.2	0.5	5.0	2.3		0.5		
CALMAX	White/Violet	0.60	0.35	0.8	4.5	0.5		0.2		
CARMO	Red/Violet	0.60	0.35	0.8	4.5	0.5		0.2		
CHIPPER[2)]	–	0.50	1.0	0.5	8.0	1.5		0.5		
CORRAX	Black/Grey	0.03	0.3	0.3	12.0	1.4	9.2			**Al** 1.6
DIEVAR	Yellow/Grey	0.35	0.2	0.5	5.0	2.3		0.6		
ELMAX SUPERCLEAN[1)]	Blue/Black	1.70	0.8	0.3	18.0	1.0		3.0		
FERMO[2)]	–	0.48	0.4	0.9	1.5					
FORMAX	Black	0.18	0.3	1.3						
FORMVAR	Violet/ Yellowgreen	0.35	0.2	0.5	5.0	2.3		0.6		
HOLDAX	Yellow/Blue	0.40	0.4	1.5	1.9	0.2			0.07	
IDUN	Brown/ Dark green	0.21	0.9	0.45	13.5	0.2	0.6	0.25		
IMPAX SUPREME	Yellow/Green	0.37	0.3	1.4	2.0	0.2	1.0			
MIRRAX ESR	[3)]	0.25	0.3	0.5	13.3	0.3	1.3	0.3		**+N**
MIRRAX 40	Orange/Green	0.21	0.9	0.45	13.5	0.2	0.6	0.25		**+N**
NIMAX ESR	Blue	0.1	0.3	2.5	3.0	0.3	1.0			
NIMAX	Light blue/ Dark blue	0.1	0.3	2.5	3.0	0.3	1.0			
ORVAR SUPREME	Orange	0.39	1.0	0.4	5.2	1.4		0.9		
ORVAR SUPERIOR	Blue/Grey	0.39	1.0	0.4	5.2	1.4		0.9		
ORVAR 2 M[4)]	Orange/Violet	0.39	1.0	0.4	5.3	1.3		0.9		
POLMAX	Green/Black	0.38	0.9	0.5	13.6			0.3		
QRO 90 SUPREME	Orange/Brown	0.38	0.3	0.8	2.6	2.3		0.9		
RAMAX HH	[5)]	0.12	0.2	1.3	13.4	0.5	1.6	0.2	0.1	**+N**
RIGOR	Red/Green	1.00	0.3	0.6	5.3	1.1		0.2		

Uddeholm Grade	Colour code	Typical analysis C	Si	Mn	Cr	Mo	Ni	V	S
ROYALLOY	[6]	0.05	0.4	1.2	12.6			+N +Cu	0.12
SLEIPNER	Blue/Brown	0.90	0.9	0.5	7.8	2.5		0.5	
SR 1855	Red/Blue	0.95	1.5	0.8	1.0				
STAVAX ESR	Black/Orange	0.38	0.9	0.5	13.6			0.3	
SVERKER 3	Red	2.05	0.3	0.8	12.7				W 1.1
SVERKER 21	Yellow/White	1.55	0.3	0.4	11.3	0.8		0.8	
UHB 11	White	0.50	0.2	0.7					
UNIMAX	Brown/Grey	0.50	0.2	0.5	5.0	2.3		0.5	
VANADIS 4 EXTRA SUPERCLEAN[1]	[7]	1.40	0.4	0.4	4.7	3.5		3.7	
VANADIS 8 SUPERCLEAN[1]	Green/ Light violet	2.3	0.4	0.4	4.8	3.6		8.0	
VANAX SUPERCLEAN[1]	Grey/Dark blue	0.36	0.3	0.3	18.2	1.1		3.5	N 1.55
VANCRON SUPERCLEAN[1]	Green/Dark blue	1.30	0.5	0.4	4.5	1.8		10.0	N 1.8
VIDAR SUPERIOR	[8]	0.36	0.3	0.3	5.0	1.3		0.5	
VIDAR 1	Orange/ Light blue	0.38	1.0	0.4	5.0	1.3		0.4	
VIDAR 1 ESR	Orange/ Dark blue	0.38	1.0	0.4	5.0	1.3		0.4	

High speed steel		C	Cr	Mo	W	V	Co
VANADIS 23 SUPERCLEAN[1]	Violet	1.28	4.2	5.0	6.4	3.1	
VANADIS 30 SUPERCLEAN[1]	Green	1.28	4.2	5.0	6.4	3.1	8.5
VANADIS 60 SUPERCLEAN[1]	Gold	2.30	4.2	7.0	6.5	6.5	10.5

[1] Powder Metallurgy tool steel

[2] Minimum order quantity

[3] Black/Orange with a white line across

[4] M = Microdized

[5] Black/Brown with a white line across

[6] Yellow/Blue with a black line across

[7] Green/White with a black line across.

[8] Red/Orange with a white line across.

International standards comparison chart

Uddeholm Grade	ASSAB	AISI (USA)	BS4659 (GB)	W.-Nr. (Germany)	SS (Sweden)	JIS (Japan)
ALVAR 14	ALVAR 14	–	–	1.2714	–	–
AM CORRAX	AM CORRAX	–	–	–	–	–
ARNE	DF-2	O1	BO1	1.2510	(2140)	SKS 3
BALDER	BALDER	–	–	–	–	–
BURE	BURE	–	–	–	–	–
CALDIE	CALDIE	–	–	–	–	–
CALMAX	CALMAX	–	–	1.2358	–	–
CARMO	CARMO	–	–	1.2358	–	–
CHIPPER	VIKING	–	–	(1.2631)	–	–
CORRAX	CORRAX	–	–	–	–	–
DIEVAR	DIEVAR	–	–	–	–	–
ELMAX SUPER-CLEAN[2)]	ELMAX SUPERCLEAN[1)]	–	–	–	–	–
FERMO	–	–	–	–	–	–
FORMAX	–	–	–	–	2172	–
FORMVAR	FORMVAR	–	–	–	–	–
HOLDAX	–	–	–	1.2312	–	–
IDUN	IDUN	420, mod.	–	–	–	–
IMPAX SUPREME	718 SUPREME	P20 modified	–	(1.2738)	–	–
MIRRAX ESR	MIRRAX ESR	420, mod.	–	–	–	SUS
MIRRAX 40	MIRRAX 40	420, mod.	–	–	–	–
NIMAX ESR	NIMAX ESR	–	–	–	—	
NIMAX	NIMAX	–	–	–	–	–
ORVAR SUPREME	8407 SUPREME	H13 improved	BH13	1.2344	2242	SKD 61
ORVAR SUPERIOR	–	H13 improved	BH13	1.2344	2242	SKD 61
ORVAR 2 M[2)]	8407-2M	H13	BH13	1.2344	2242	SKD 61
POLMAX	POLMAX	420, mod.	–	(1.2083)	2314	SUS 420
QRO 90 SUPREME	QRO 90 SUPREME	–	–	–	–	–
RAMAX HH	RAMAX HH	(420F)	–	–	–	–
RIGOR	XW-10	A2	BA2	1.2363	2260	SKD 12
ROYALLOY	ROYALLOY	–	–	–	–	–
SLEIPNER	ASSAB 88	–	–	–	–	–
SR 1855		–	–	(1.2108)	2092	–
STAVAX ESR	STAVAX ESR	420, mod.	–	(1.2083)	2314	SUS 420

Uddeholm Grade	ASSAB	AISI (USA)	BS4659 (GB)	W.-Nr. (Germany)	SS (Sweden)	JIS (Japan)
SVERKER 3	XW-5	(D6)	BD6	(1.2436)	2312	(SKD 2)
SVERKER 21	XW-42	D2	BD2	1.2379	2310	SKD 11
UHB 11	_	1148	–	1.1730	1650/ 1672	–
UNIMAX	UNIMAX	–	–	–	–	–
VANADIS 4 EXTRA SUPERCLEAN[1)]	VANADIS 4 EXTRA SUPERCLEAN[1)]	–	–	–	–	_
VANADIS 8 SUPERCLEAN[1)]	VANADIS 8 SUPERCLEAN[1)]	–	–	–	–	_
VANAX SUPERCLEAN[1)]	VANAX SUPERCLEAN	–	–	–	–	–
VANCRON SUPERCLEAN[1)]	VANCRON SUPERCLEAN[1)]	–	–	–	–	–
VIDAR SUPERIOR	VIDAR SUPERIOR	(H11)[3)]	(BH 11)	1.2340 (1.2343)[3)]	–	(SKD 6)
VIDAR 1	–	H11	BH11	1.2343	–	SKD 6
VIDAR 1 ESR	VIDAR 1 ESR	H11	BH11	1.2343	–	SKD 6
High speed steel						
VANADIS 23 SUPERCLEAN[1)]	ASSAB 23 SUPERCLEAN[1)]	M3:2	–	1.3395	2725	–
VANADIS 30 SUPERCLEAN[1)]	ASSAB 30 SUPERCLEAN[1)]	(M3:2+Co)	–	1.3294 ~CM3:2 +Co	2726	–
VANADIS 60 SUPERCLEAN[1)]	ASSAB 60 SUPERCLEAN[1)]	–	–	(1.3292)	2727	–

Some equivalents are approximate only ( ).

[1)] Powder Metallurgy tool steel.

[2)] M = Microdized

[3)] W.-Nr. 1.2343 or AISI H11 premium modified.

Basic heat treatment guide*

Uddeholm Grade	HB[1)]	Soft-annealing temp. °C	Austenitizing (hardening) temperature °C	Quenching medium
ALVAR 14	≤250	700	830–900	Oil, step, gas
AM CORRAX[5)]	–	–	–	–
ARNE	~190	780	790–850	Oil, step bath
BALDER	~420[2)]	–	as-del. cond.	–
BURE	~180	850	1020–1050	Gas, step, oil
CALDIE	~215	860	1000–1050	Gas, step
CALMAX	~200	860	950–970	Gas, step, oil
CARMO	~250[2)]	860	950–970	Gas, step, oil
CHIPPER	~225	880	980–1050	Gas, step, oil
CORRAX[4)]	~330	–	–	–
DIEVAR	~160	850	1000–1030	Gas, step, oil
ELMAX SUPERCLEAN[3)]	~280	980	1050–1100	Gas, step, salt
FERMO	~270[2)]	770	flame hard. 850	Oil
FORMAX	~170	–	–	–
FORMVAR	<229	850	1000–1030	Gas, step, oil
HOLDAX	~310[2)]	700	as-del. cond.	–I
IDUN	~420	–	–	–
IMPAX SUPREME	~310[2)]	700	as-del. cond.	–
MIRRAX ESR	~250	740	1000–1025	Gas, step
MIRRAX 40	~380[2)]	–	as-del. cond.	–
NIMAX ESR	~380[2)]	_	as-del. cond.	–
NIMAX	~380[2)]	_	as-del. cond.	–
ORVAR SUPREME	~180	850	1020–1050	Gas, step, oil
ORVAR SUPERIOR	~180	850	1020–1050	Gas, step, oil
ORVAR 2 M[6)]	~180	850	1020–1050	Gas, step, oil
POLMAX	~190	890	1000–1050	Step, salt bath, gas
QRO 90 SUPREME	~180	820	1020–1050	Gas, step, oil
RAMAX HH	~340[2)]	740	as-del. cond.	–
RIGOR	~215	850	925–960	Gas, step
ROYALLOY	~310[2)]	–	as-del. cond.	–
SLEIPNER	~235	850	950–1080	Gas, step
SR 1855	~210	810	850–880	Oil, step, gas
STAVAX ESR	~190	890	1010–1050	Step, salt bath, gas

Uddeholm Grade	HB[1)]	Soft-annealing temp. °C	Austenitizing (hardening) temperature °C	Quenching medium
SVERKER 3	~240	850	920–1000	Gas, step
SVERKER 21	~210	850	990–1080	Gas, step
UHB 11	~200	700	as-del. cond.	–
UNIMAX	~185	850	1000–1025	Gas, step
VANADIS 4 EXTRA SUPERCLEAN[3)]	~230	900	940–1180	Gas, step
VANADIS 8 SUPERCLEAN[3)]	≤270	900	1020–1180	Gas, step
VANAX SUPERCLEAN[3)]	260	980**	1080	Gas, step, oil + deep cooling
VANCRON SUPERCLEAN[3)]	~300	900	950–1150	Gas, step
VIDAR SUPERIOR	~180	850	980–1000	Gas, step, oil
VIDAR 1	~180	850	990–1010	Gas, step, oil
VIDAR 1 ESR	~180	850	990–1010	Gas, step, oil
High speed steel				
VANADIS 23 SUPERCLEAN[3)]	~260	875	1050–1180	Gas, step
VANADIS 30 SUPERCLEAN[3)]	~300	875	1000–1180	Gas, step
VANADIS 60 SUPERCLEAN[3)]	~320	875	1000–1180	Gas, step

* Choice of quenching media depends on the steel grade, the tool's complexity and size. Further heat treatment recommendations is given in the product information brochure available for each steel grade.

Stress relieving: after rough machining the tool should be heated through to 650°C. Holding time: 2h. Cool slowly to 500°C, then freely in air. (Exception: Uddeholm Impax Supreme, Uddeholm Holdax, Uddeholm Mirrax 40, Uddeholm Ramax HH and Uddeholm Fermo use max 550°C as stress relieving temperature. For Uddeholm Nimax use 450°C.)

** In protected atmosphere

[1)] Normal delivery hardness.

[2)] Pre-hardened

[3)] Powder Metallurgy tool steel.

[4)] Solution treated. Higher hardness is obtained by ageing.

[5)] Solution treatment 850°C 30 minutes.

[6)] M = Microdized

Approx. hardness after hardening and tempering

Uddeholm Grade	Austenitizing temperature °C	HRC at tempering temperature °C, 2 x 2 h					
		200	250	500	525	550	600
ALVAR 14	850[1)]	54	53	45	–	42	38
AM CORRAX	850[2)]	–	–	–	–	–	–
ARNE	830[1)]	62	60	45	43	41	38
BALDER[6)]	–	–	–	–	–	–	–
BURE	1020	52	52	53*	–	52	46
CALDIE	1020	**3 x 525°C***** 60		**3 x 540°C** 59		**3 x 560°C** 56	
CALMAX	960	59	58	53	53	50	43
CARMO	960	59	58	53	53	50	43
CHIPPER	1010	59	57	59*	58	56	48
CORRAX	850[2)]	–	–	–	–	–	–
DIEVAR	1025	53	52	52*	–	52	47
ELMAX SUPERCLEAN[3)]	1080	59	58	60**	59**	58**	–
FERMO	–	–	–	–	–	–	–
FORMAX	–	–	–	–	–	–	–
FORMVAR	1025	53	52	52*	–	52	47
HOLDAX	–	–	–	–	–	–	–
IDUN	–	–	–	–	–	–	–
IMPAX SUPREME	–	–	–	–	–	–	–
MIRRAX ESR	1020	–	50	52**	–	42**	36
MIRRAX 40	–	–	–	–	–	–	–
NIMAX ESR[4)]	–	–	–	–	–	–	–
NIMAX[4)]	–	–	–	–	–	–	–
ORVAR SUPREME	1020	52	52	54*	–	52	46
ORVAR SUPERIOR	1020	52	52	54*	–	52	46
ORVAR 2 MICRODIZED	1020	52	52	54*	–	52	46
POLMAX	1030	53	52	54**	–	43**	37
QRO 90 SUPREME	1020	49	49	51*	–	51*	50[5)]
RAMAX HH	–	–	–	–	–	–	–
RIGOR	950	61	59	56*	55*	53	46
ROYALLOY	–	–	–	–	–	–	–
SLEIPNER	1030	**3 x 525°C***** 62		**3 x 540°C** 60		**3 x 560°C** 58	

Uddeholm Grade	Austenitizing temperature °C	HRC at tempering temperature °C, 2 x 2 h					
		200	250	500	525	550	600
SR 1855	850	63	62	50	48	46	42
STAVAX ESR	1030	53	52	54**	–	43**	37
SVERKER 3	960	60	59	56	53	–	–
SVERKER 21	1020	63	59	60	57	54	48
UHB 11	–	–	–	–	–	–	–
UNIMAX	1020	–	–	–	57***	55	49
VIDAR SUPERIOR	1000	52	51	51*	–	50	45
VIDAR 1	1000	54	53	55*	–	52	46
VIDAR 1 ESR	1000	54	53	55*	–	52	46
VANADIS 4		**3 x 525°C*** **		**3 x 540°C**		**3 x 560°C**	
EXTRA	1020[7)]	61		60		59	
SUPERCLEAN[3)]	1180[8)]	64		64		63	
VANADIS 8	1020[7)]	61		60		59	
SUPERCLEAN[3)]	1180[8)]	64		64		63	
VANAX SUPERCLEAN[3)]	1080°C	60	–	–	–	–	–
VANCRON SUPERCLEAN[3)]	950–1150			**3 x 540°C** 57–65			
High speed steel				**3 x 560°C**			
VANADIS 23 SUPERCLEAN[3)]	1050–1180			60–66			
VANADIS 30 SUPERCLEAN[3)]	1000–1180			60–67			
VANADIS 60 SUPERCLEAN[3)]	1000–1180			64–69			

* This tempering temp. should be avoided due to the risk of temper brittleness.

** For Uddeholm Stavax ESR, Uddeholm Mirrax ESR, Uddeholm Polmax and Uddeholm Elmax SuperClean corrosion resistance is reduced.

*** The lowest tempering temperature when high temperature tempering is 525°C.

1) Quench in oil

2) Solution treatment. Ageing: ~51 HRC after 525°C/4h, ~44 HRC after 575°C/4h, ~41 HRC after 600°C/4h.

3) Powder Metallurgy tool steel

4) The delivery hardness of Uddeholm Nimax ESR and Nimax can not be increased. Tempering shall be avoided as toughness will be reduced.

5) At 650°C 2 x 2h: 42 HRC

6) Uddeholm Balder is delivered pre-hardened, tempered at 590°C (1090°F) /2 x 2h

7) For better toughness

8) For better wear resistance

Blanking, piercing, cropping, bending, forming

Uddeholm grade	Description/Applications
ARNE	A versatile tool steel for low production volume die sets for blanking, forming and deburring and for forming rolls. It is also suitable for gauges, bushes and engineering parts exposed to high stresses.
CALDIE	A modern matrix tool steel for cold work applications with high demands on chipping / cracking resistance and compressive strength. Uddeholm Caldie is a robust tool steel and is suitable for medium production volume tooling for blanking and forming difficult production materials such as advanced high strength steel.
CALMAX	A very versatile steel with adequate wear resistance and very high toughness. It is very suitable for low to medium production volume tooling for blanking thick production materials or in general when the tooling is exposed to high stresses.
RIGOR	A steel with a good combination of toughness, wear resistance and dimensional stability in hardening. It is a general cold work steel for medium production volume tooling.
SLEIPNER	A versatile steel with a very broad properties profile ranging from good wear resistance, compressive strength and good chipping / cracking resistance to good hardenability and machinability. This means that Uddeholm Sleipner is a modern general purpose steel for medium production volume tooling.
SVERKER 3	A steel similar to Uddeholm Sverker 21 but with more and larger carbides. It has an excellent abrasive wear resistance and this means that it is suitable for applications like brick pressing and transformer plate blanking.
SVERKER 21	A 12% chromium steel suitable for medium production volume tooling where the production materials cause abrasive wear and the risk of chipping is not so high.

Cont.

UNIMAX	A problem solver for applications where the demands on chipping / cracking resistance are very high. Uddeholm Unimax is a matrix steel with a unique combination of chipping / cracking resistance and wear resistance.
VANADIS 4 EXTRA SUPERCLEAN	A cold work tool steel produced by the powder metallurgy process. It is characterized by a superior combination of wear and chipping resistance and is particularly suitable for high volume production tooling for production materials such as annealed austenitic stainless steel, mild carbon steel, copper and aluminium.
VANADIS 8 SUPERCLEAN	Uddeholm Vanadis 8 SuperClean is a PM (Powder Metallurgical) tool steel characterized by extremely high wear resistance (abrasive wear profile), high compressive strength, high surface hardness after hardening, very good through hardening properties, good toughness and very good stability in hardening. These characteristics combine to give a steel suitable for the manufacture of very long run tooling where abrasive wear is dominant, e.g. blanking and forming of abrasive material, blanking of electrical steel sheet, blanking of gaskets, paper and foil slitting, granulator knives, extruder screws, etc.
VANADIS 23 SUPERCLEAN	A high speed steel produced by the powder metallurgy process and is characterized by high wear resistance coupled with high chipping resistance and high compressive strength. It is suitable for high volume production tooling for hard to medium hard production materials. It also has a good hot hardness and god temper back resistance, making it a suitable grade for high speed blanking and for cutting tools.
VANCRON SUPERCLEAN	A nitrogen alloyed PM steel for applications where galling is the main failure mechanism. Its very low friction coefficient and surface topography after polishing mean that it is an alternative to tooling where coatings and cemented carbide used to be the only solution.

UHB 11	A bolster steel with medium high carbon content suitable for top and bottom plates and higher strength support parts.
FORMAX	A bolster steel with low carbon content suitable for large top and bottom plates and medium strength supports.
HOLDAX	A pre-hardened bolster steel for support plates and holders.

Steel for special applications

Uddeholm grade	Description/Applications
CARMO	A pre-hardened steel particularly suitable for car body dies. It can be flame / induction hardened or through hardened and has a much better weldability than other cold work tool steel. It is suitable for low production volume tooling in general and for prototype tooling.
SR 1855	A low alloyed tool steel very suitable for profile rolls.
VANCRON SUPERCLEAN	A nitrogen alloyed PM steel which often need not be coated to avoid galling, sticking and adhesive wear.
VANADIS 30 SUPERCLEAN	A high hardness high speed PM steel with improved compressive strength and hot hardness. Mainly used for cutting tools.
VANADIS 60 SUPERCLEAN	A very high hardness high speed PM steel with very high compressive strength, good hot hardness and very high wear resistance. Mainly used for cutting tools.

A comprehensive product brochure is available for each steel grade and contains information on application areas, heat treatment, machining, grinding etc.

Property comparison guide for cold work steel

Uddeholm grade	Hardness	Machin-ability	Grind-ability	Dimension stability
ARNE				
CALMAX				
CALDIE (ESR)				
RIGOR				
SLEIPNER				
SVERKER 21				
SVERKER 3				
UNIMAX				
VANADIS 4 EXTRA				
VANADIS 8				
VANADIS 23				
VANCRON				

Selection chart

Part	Uddeholm grade	Hardness HRC
Punches, dies	ARNE, CALDIE, CALMAX, RIGOR, SVERKER 3, SVERKER 21, SLEIPNER, UNIMAX, VANADIS 4 EXTRA, VANADIS 8, VANCRON	54–64
Top- and bottom plates	FORMAX, UHB 11, HOLDAX	As supplied
Punch backing plate	ARNE	58–60

The tool steel choice and hardness level will depend on the production material type, its thickness and hardness and the intended production volume.

Other “cold work” applications

Application	Uddeholm grade
Cold rolls	CALDIE, ROP 20, SLEIPNER, SVERKER 21, VANADIS 4 EXTRA, VANADIS 8, VANADIS 23, VANCRON
Forming rolls	SVERKER 21, CALDIE, CALMAX, SLEIPNER, VANADIS 4 EXTRA, VANADIS 8, VANCRON
Pressing of ceramics	SVERKER 3, SVERKER 21
Powder metal compaction	CALDIE, UNIMAX, VANADIS 4 EXTRA, VANCRON

Steel selection

When selecting a tool steel for any cold work operation it is important to identify which failure mechanism(s) is/are limiting the tool life:

- wear (abrasive/adhesive)
- chipping/cracking
- plastic deformation

The proper tool steel for the situation can be selected by means of the following comparison chart, which gives the relative resistance to the above failure mechanisms for the Uddeholm cold work tool steel.

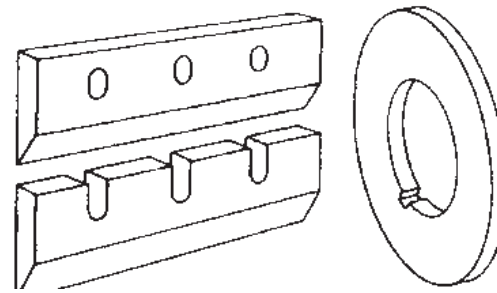
Property comparison guide for cold work steel

Uddeholm Grade	Hardness/ Resistance against plastic deformation	Wear resistance		Fatigue cracking resistance	
		Abrasive	Adhesive	Ductility/ chipping	Toughness/ Gross cracking
ARNE					
CALMAX					
CALDIE (ESR)					
RIGOR					
SLEIPNER					
SVERKER 21					
SVERKER 3					
UNIMAX					
VANADIS 4 EXTRA					
VANADIS 8					
VANADIS 23					
VANCRON					

A rule of thumb is to select a steel with higher performance to avoid premature failures with such consequences as late deliveries and extra costs.

STEEL FOR INDUSTRIAL KNIVES

Close attention is paid to straightness, squareness, tolerance and decarburization levels on Uddeholm tool steel intended for the large-scale production of knives and cutters.



Uddeholm grade	Description/Applications
CHIPPER	Cr-Mo-alloyed steel developed by Uddeholm especially for chipper-knives and other knives exposed for high stresses. Combine toughness with wear resistance very well.
SVERKER 3 SVERKER 21	Steel with high C-Cr-content and an excellent wear resistance. Suitable for wood milling cutters.
VANADIS 4 EXTRA SUPERCLEAN	Cold work tool steel produced by the powder metallurgy process. Superior combination of adhesive wear resistance and toughness.
VANADIS 8 SUPERCLEAN	Cold work tool steel produced by the powder metallurgy process. Very high abrasive wear resistance and fairly good toughness. Tool steel very suitable for severe abrasive conditions and long runs.
VANADIS 23 SUPERCLEAN	High speed steel produced by the powder metallurgy process. Good combination of wear resistance, chipping resistance, hot hardness and compressive strength. Suitable for production materials which cause mixed or abrasive wear.
RIGOR	A tool steel with a good combination of toughness and general wear resistance.
CALDIE	A robust tool steel with a good combination of high compressive strength and wear resistance and high chipping resistance.

Cont.

CALMAX	Tool steel with a properties profile devoted to safe production, i.e. high chipping and cracking resistance and a fairly good wear resistance.
UNIMAX	A really robust tool steel and the best choice for difficult blanking applications with demands on high hardness (max. 58 HRC) and very high chipping resistance.
SLEIPNER	A tool steel with properties well suited for knife applications. Good wear resistance, good resistance to chipping and high compressive strength give a knife with a good edge retention.
ARNE	Low alloyed universal tool steel for short runs. Excellent machinability.

Property comparison chart for Uddeholm tool steel for industrial knives

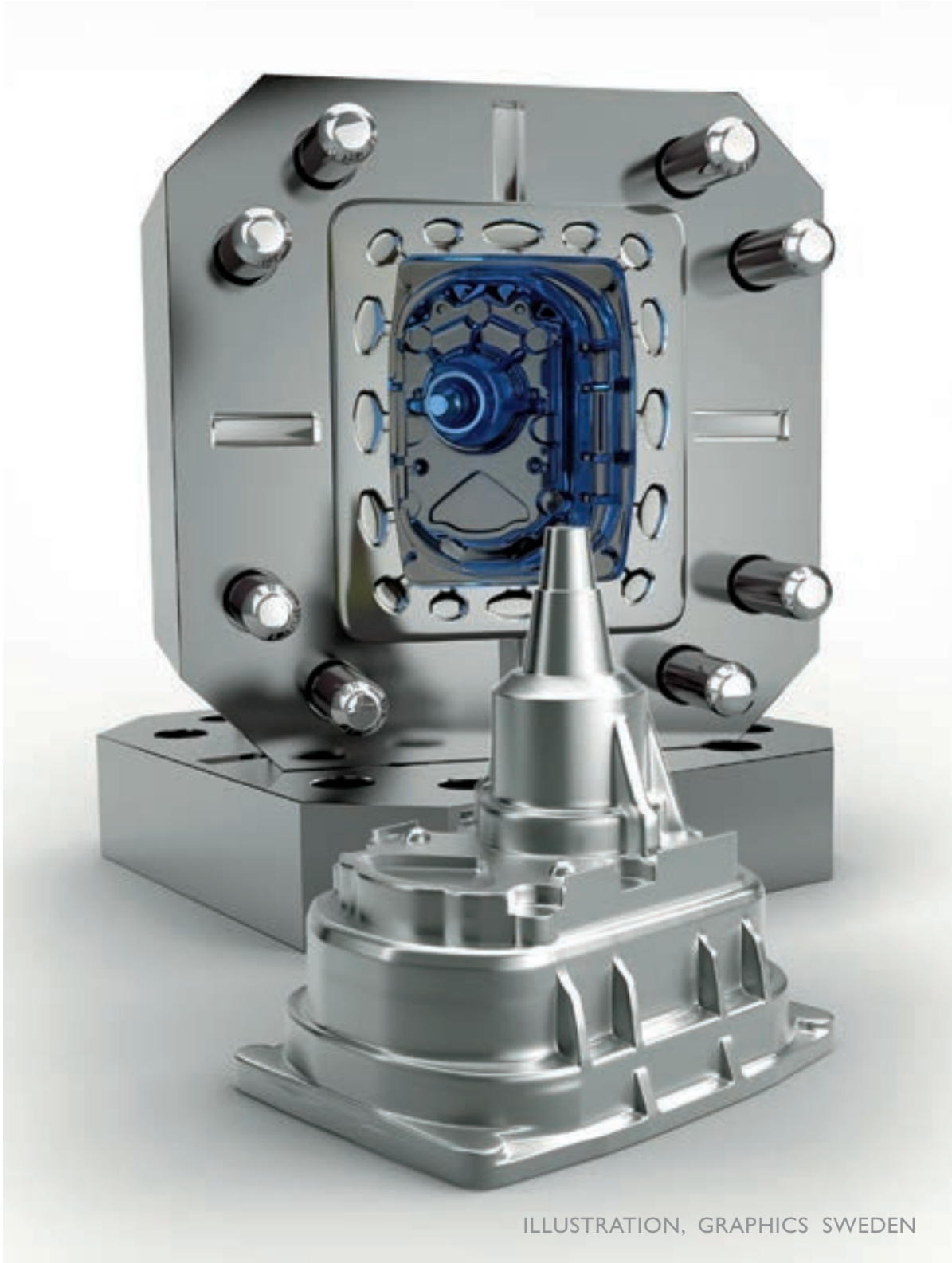
Uddeholm grade	Chipping resistance	Wear resistance	Machinability	Dimensional stability at hardening
ARNE				
CALDIE				
CALMAX				
CHIPPER				
RIGOR				
SLEIPNER				
SVERKER 3				
SVERKER 21				
UNIMAX				
VANADIS 4 EXTRA				
VANADIS 8				
VANADIS 23				

Selection chart

Part			Uddeholm grade	HRC
Chipper knives			CHIPPER	56–58
Flaker knives			CHIPPER	56–58
Reducer knives			CHIPPER	56–58
Planer knives			SVERKER 21, SLEIPNER	58–60
Shear knives, hot			CALDIE, ORVAR 2 MICRODIZED, UNIMAX	52–54
	cold	thin stock	SVERKER 21	58–60
		thick stock	CALDIE, RIGOR, VANADIS 4 EXTRA CALMAX, SLEIPNER, UNIMAX	56–58 54–58
Circular slitting knives			SVERKER 21, RIGOR, SLEIPNER, VANADIS 4 EXTRA, VANADIS 8, UNIMAX	58–62 56–64 54–58
Plastic granulator knives			RIGOR, SVERKER 21, SLEIPNER, VANADIS 4 EXTRA, ELMAX CALDIE, VANADIS 8 UNIMAX	58–60 58–64 54–58
Tobacco knives			ARNE	58–60
Fragmentation knives			CALMAX, RIGOR, SVERKER 21, SLEIPNER, VANADIS 4 EXTRA, VANADIS 8, UNIMAX	55–64
Paper knives			SVERKER 21, VANADIS 4 EXTRA, VANADIS 8	58–64
Food processing knives		stainless	CORRAX, STAVAX ESR, RAMAX, ELMAX	37–61
		non stainless	VANADIS 4 EXTRA, VANADIS 8	56–64
Custom knives			ELMAX, VANADIS 4 EXTRA	56–62
Rotary die cutting knives			SVERKER 21, SLEIPNER, VANADIS 4 EXTRA, VANADIS 8	58–64

STEEL FOR DIE CASTING DIES

Uddeholm grade	Description/Applications
DIEVAR	A premium Cr-Mo-V alloyed hot work die steel with good high temperature strength and excellent hardenability, toughness and ductility. Suitable for medium to large dies in aluminium die casting. It meets the requirements of NADCA #207-2011.
UNIMAX	A premium Cr-Mo-V alloyed steel with a good toughness and ductility up to a hardness of 58 HRC.
ORVAR SUPREME ORVAR SUPERIOR	Premium Cr-Mo-V-alloyed hot work die steel (H13) with good resistance to thermal fatigue. The steel are produced by a special melting and refining technique and meet the requirements of NADCA #207–2011.
VIDAR SUPERIOR	A premium Cr-Mo-V alloyed hot work die steel (H11 modified) with good resistance to cracking and meets the requirements of NADCA #207–2011.
QRO 90 SUPREME	A premium hot work die steel with high hot yield strength and good temper resistance. Especially suited for die casting of copper, brass and for small inserts and cores in aluminium die casting.
QRO 90 HT	A pre-hardened Uddeholm QRO 90 Supreme material supplied at 37–41 HRC and suitable for core pins.
IMPAX SUPREME	A pre-hardened Ni-Cr-Mo-steel supplied at ~310 HB suitable for die casting of zinc, lead and tin. Also used as a holder material and prototype dies.
HOLDAX	A pre-hardened steel with very good machinability supplied at ~310 HB for clamping and holding plates.



ILLUSTRATION, GRAPHICS SWEDEN

Qualitative comparison of resistance to different die failures

Uddeholm grade	Heat checking	Gross cracking	Erosion	Indentation
DIEVAR				
UNIMAX				
ORVAR SUPREME				
ORVAR SUPERIOR				
VIDAR SUPERIOR				
QRO 90 SUPREME				

The longer the bar, the better.
Further information is given in the brochure "Uddeholm tool steel for die casting" and in the product information brochure available for each steel grade.

Selection chart—Die casting

Die part	Tin/Lead/Zinc	Aluminium/ Magnesium	Copper, Brass
Clamping plates Holder plates	HOLDAX/ IMPAX SUP. pre-hardened ~310 HB	HOLDAX/ IMPAX SUP. pre-hardened ~310 HB	HOLDAX/ IMPAX SUP. pre-hardened ~310 HB
Die Inserts	IMPAX SUP. ~310 HB ORVAR SUP. / SUPERIOR 46–52 HRC UNIMAX 52–56 HRC	ORVAR SUP. / SUPERIOR 42–48 HRC VIDAR SUPERIOR 42–48 HRC DIEVAR 44–50 HRC UNIMAX*	QRO 90 SUP. 40–46 HRC ORVAR SUP. / SUPERIOR 40–46 HRC
Fixed inserts Cores	ORVAR SUP. / SUPERIOR 46–52 HRC	DIEVAR 46–50 HRC ORVAR SUP. / SUPERIOR VIDAR SUPERIOR 44–48 HRC QRO 90 SUP. 42–48 HRC	QRO 90 SUP. 40–46 HRC

SUP. = Supreme

* For small Mg die inserts where a good erosion resistance is needed

Die part	Tin/Lead/Zinc	Aluminium/ Magnesium	Copper, Brass
Core pins	ORVAR SUP. 46–52 HRC	QRO 90 SUP.* 44–48 HRC QRO 90 HT*	QRO 90 SUP. 42–46 HRC QRO 90 HT
Sprue parts	ORVAR SUP. 48–52 HRC	ORVAR SUP. / SUPERIOR 46–48 HRC QRO 90 SUP. 44–46 HRC	QRO 90 SUP. 42–46 HRC
Nozzle	ORVAR SUP. 35–44 HRC STAVAX ESR 40–44 HRC	ORVAR SUP. / SUPERIOR 42–48 HRC QRO 90 SUP. 42–46 HRC	QRO 90 SUP. 40–44 HRC ORVAR SUP. / SUPERIOR 42–48 HRC
Ejector pins	QRO 90 SUP. / ORVAR SUP. 46–50 HRC (nitrided)	QRO 90 SUP. / ORVAR SUP. 46–50 HRC (nitrided)	QRO 90 SUP. / ORVAR SUP. 46–50 HRC (nitrided)
Plunger **Shot sleeve**	ORVAR SUP. 42–46 HRC (nitrided)	ORVAR SUP. / SUPERIOR QRO 90 SUP. 42–48 HRC (nitrided)	QRO 90 SUP. / ORVAR SUP. / SUPERIOR 42–46 HRC (nitrided)

SUP. = Supreme * Surface treatment is recommended.

STEEL FOR EXTRUSION DIES

Uddeholm grade	Description/Applications
ORVAR 2 MICRODIZED	A Cr-Mo-V-alloyed hot work steel (H13) with good high temperature strength and good resistance to abrasion. The steel is widely used for extrusion tooling.
VIDAR 1	A Cr-Mo-V-alloyed hot work steel (H11) with a good combination of high temperature strength, good toughness and good resistance to abrasion.
QRO 90 SUPREME	A premium hot work steel with very good strength and hot hardness at elevated temperatures. The steel can be recommended for all types of extrusion tooling subjected to maximum working temperatures.
FORMVAR	A high performance hot work tool steel with very good resistance to hot wear and plastic deformation.
DIEVAR	A premium Cr-Mo-V alloyed hot work steel with good high temperature strength and excellent toughness and ductility. Recommended in dies and extrusion components where the demands on toughness and ductility are the highest..
UNIMAX	A premium Cr-Mo-V alloyed steel with a good toughness and ductility up to a hardness of 58 HRC.
ALVAR 14	Cr-Ni-Mo-alloyed hot work steel used for support parts for extrusion tooling, e.g. backers and bolsters.
IMPAX SUPREME	Pre-hardened Ni-Cr-Mo-alloyed steel supplied at approx. 310 HB and suitable for mantles.

ILLUSTRATION, GRAPHICS SWEDEN

Qualitative comparison of resistance to different tool failures

Uddeholm grade	Hot wear	Plastic deformation	Premature cracking	Heat checking
ORVAR 2 M				
VIDAR 1				
QRO 90 SUP.				
FORMVAR				
DIEVAR				
UNIMAX				

The longer the bar, the better. M = Microdized. SUP. = Supreme.
Further information is given in the brochure “Uddeholm tool steel for extrusion”.

Selection chart—Extrusion

Tool part	Aluminium, Magnesium	Copper alloys	Steel
Support tools (at lower temp.)	IMPAX SUP. ~310 HB	IMPAX SUP. ~310 HB	IMPAX SUP. ~310 HB
Wedge block	IMPAX SUP. ~310 HB ALVAR 14 300–400 HB	IMPAX SUP. ~310 HB ALVAR 14 300–400 HB	IMPAX SUP. ~310 HB ALVAR 14 300–400 HB
Bolster	ALVAR 14 45 HRC	ALVAR 14 45 HRC	ALVAR 14 45 HRC
Die ring	FORMVAR ORVAR 2 M 40–44 HRC	QRO 90 SUP. 40–44 HRC	QRO 90 SUP. 40–44 HRC
Die	FORMVAR VIDAR 1/ORVAR 2M/ QRO 90 SUP. 45–50 HRC DIEVAR 46–52 HRC UNIMAX 52–58 HRC	QRO 90 SUP. 45–49 HRC	QRO 90 SUP. 44–46 HRC

SUP. = Supreme, M = Microdized

Tool part	Aluminium, Magnesium	Copper alloys	Steel
Mantle Intermediate liner	IMPAX SUP. ~310 HB ORVAR 2 M 37–43 HRC VIDAR 1 37–43	IMPAX SUP. ~310 HB ORVAR 2 M 37–43 HRC	IMPAX SUP. ~310 HB ORVAR 2 M 37–43 HRC
Liner	ORVAR 2 M 44–48 HRC QRO 90 SUP. 44–48 HRC VIDAR 1 44–48 HRC DIEVAR 44–50 HRC	QRO 90 SUP. 44–48 HRC	ORVAR 2 M 44–48 HRC
Dummy block	QRO 90 SUP. 44–48 HRC DIEVAR 46–52 HRC ORVAR 2 M 46–50	QRO 90 SUP. 44–48 HRC	QRO 90 SUP. 44–48 HRC
Stem	ORVAR 2 M 46–50 HRC	ORVAR 2M 46–50 HRC	ORVAR 2M 46–50 HRC
Mandrel	ORVAR 2 M 46–50 HRC QRO 90 SUP. 46–49 HRC	QRO 90 SUP. 45–49 HRC DIEVAR 46–52 HRC	QRO 90 SUP 45–49 HRC

SUP. = Supreme, M = Microdized

STEEL FOR FORGING DIES

Uddeholm grade	Description/Applications
DIEVAR	A premium Cr-Mo-V alloyed hot work steel with good high temperature strength and excellent hardenability, toughness and ductility. Recommended in dies where the demands on toughness and ductility are the highest. It meets the requirements of NADCA #207-2011.
UNIMAX	A premium Cr-Mo-V alloyed steel with good toughness and ductility up to a hardness of 58 HRC.
ORVAR 2 MICRODIZED	Cr-Mo-V-alloyed hot work die steel (H13) with good high temperature strength and hot wear resistance.
ORVAR SUPREME / ORVAR SUPERIOR	Premium Cr-Mo-V-alloyed hot work die steel (H13) with good resistance to thermal fatigue. The steel are produced by a special melting and refining technique. They meet the requirements of NADCA #207-2011.
VIDAR SUPERIOR	A Cr-Mo-V-alloyed hot work die steel (H11) modified with good resistance to cracking. It meets the requirements of NADCA #207-2011.
QRO 90 SUPREME	A premium hot work die steel with very good strength and hot hardness at elevated temperatures. Recommended for inserts and stamping of copper alloys.
FORMVAR	Uddeholm Formvar is a solid upgrade choice from H11/H13 forging dies. With good tempering back resistance and hot yield strength.
ALVAR 14	Cr-Ni-Mo-alloyed hot work steel. Normally delivered in pre-hardened condition for solid die blocks.
VANADIS 8* / VANADIS 4 EXTRA* / VANADIS 30*	PM-produced steels. Recommended for forging applications where very good wear resistance is needed.

* Uddeholm PM SuperClean tool steels


KOD 12467
UNIMAX

Qualitative comparison of resistance to different tool failures

Uddeholm grade	Hot wear	Plastic deformation	Premature cracking	Heat checking
DIEVAR				
UNIMAX				
ORVAR 2 M				
ORVAR SUPREME				
ORVAR SUPERIOR				
VIDAR SUPERIOR				
QRO 90 SUPREME				
FORMVAR				
ALVAR 14				

The longer the bar, the better. Further information is given in the brochure "Uddeholm tool steel for forging applications".

Selection chart—Forging

Forging application		Steel grade	Hardness range	Cavity depth
Hammer forging	Solid die blocks	ALVAR 14 – pre-hardened	400–440 HB 360–400 HB 320–360 HB ≤320 HB	Max. 20 mm (0.8 inch) Max. 50 mm (2 inch) Max. 150 mm (6 inch) Very deep
	Inserts	VIDAR SUPERIOR DIEVAR ORVAR SUPREME ORVAR SUPERIOR	38–50 HRC	
Press forging	Dies	DIEVAR VIDAR SUPERIOR ORVAR SUPREME ORVAR SUPERIOR QRO 90 SUPREME UNIMAX FORMVAR	38–57 HRC	
Warm forging	Tools	UNIMAX DIEVAR FORMVAR *	50–58 HRC	
Progressive forging	Tools	QRO 90 SUPREME UNIMAX DIEVAR FORMVAR *	48–54 HRC	
Upset forging	Tools	UNIMAX DIEVAR FORMVAR	46–56 HRC	

* Uddeholm PM grades can be used in some tool parts. Higher hardnesses can be used.

MATERIALS FOR PLASTIC MOULDS

Uddeholm grade	Description/Applications
IMPAX SUPREME	A pre-hardened Ni-Cr-Mo-steel, supplied at ~310 HB, with excellent polishing and photo-etching properties. Suitable for a wide range of injection moulds, blow moulds and extrusion dies.
NIMAX ESR	A low carbon steel, delivery hardness ~380 HB. Excellent toughness, machinability and weldability. The ESR process also gives excellent polishability and etching properties.
NIMAX	A low carbon steel, delivery hardness ~380 HB. Excellent toughness, machinability and weldability. Good polishing and etching properties.
STAVAX ESR	A through hardening corrosion resistant mould steel with a very good polishability. Recommended for medium and small moulds.
POLMAX	A through hardening corrosion resistant mould steel with an excellent polishability.
MIRRAX ESR	A through hardening corrosion resistant mould steel with a very good polishability. Recommended for medium and large moulds.
MIRRAX 40	A pre-hardened corrosion resistant mould steel supplied at ~380 HB, with good machinability, very good tough-nesss and excellent polishability.
UNIMAX	A steel with very good hardenability suitable for surface treatment. Excellent combination of wear resistance and toughness. Recommended for long run moulds and for moulding of reinforced plastics.
CORRAX	A precipitation hardening steel with extremely good corrosion resistance.
AM CORRAX	A precipitation hardening steel with extremely good corrosion resistance. Delivered as powder for additive manufacturing (AM) to be used in the same applications as conventional Corrax

Cont.

ILLUSTRATION, GRAPHICS, SWEDEN

ORVAR SUPREME	A versatile through hardening 5% Cr mould and die steel with good wear resistance and polishability.
VIDAR 1 ESR	General plastic moulds, specially large moulds with requirements on high toughness in combination with very good polishability and texturing properties.
RIGOR	A through hardening steel recommended for very long production runs of smaller complicated moulding.
ELMAX SUPERCLEAN VANADIS 4 EXTRA SUPERCLEAN VANADIS 8 SUPERCLEAN	Powder metallurgically produced mould steel characterized by very good dimension stability, good polishability and wear resistance. Uddeholm Elmax is corrosion resistant, Uddeholm Vanadis 4 Extra has the highest toughness and Uddeholm Vanadis 8 the best wear resistance. Recommended for long production runs of smaller and complicated shapes and/or abrasive plastics.
VANCRON SUPERCLEAN	Uddeholm Vancron is a good alternative to surface coating in order to reduce galling, sticking and adhesive wear and reduce friction. It also has a high polishability.
HOLDAX	A pre-hardened holder steel, supplied at ~310 HB, with a very good machinability.
ROYALLOY[1)]	A pre-hardened corrosion resistant holder steel, with good machinability, high tensile strength and excellent weldability.
RAMAX HH	Pre-hardened corrosion resistant holder steel, supplied at ~340 HB and can be used for dies and calibers for plastic extrusion as well as for holders/bolsters.
ALUMEC 89[2)]	High strength Al-alloy supplied at ~160 HB. Recommended for blow moulds, prototype moulds and for short runs with low demands on strength and wear resistance.

[1)] Uddeholm RoyAlloy is produced and patented by Edro Specialty Steels, USA.

[2)] Arconic is owner of the trade mark Alumec 89.

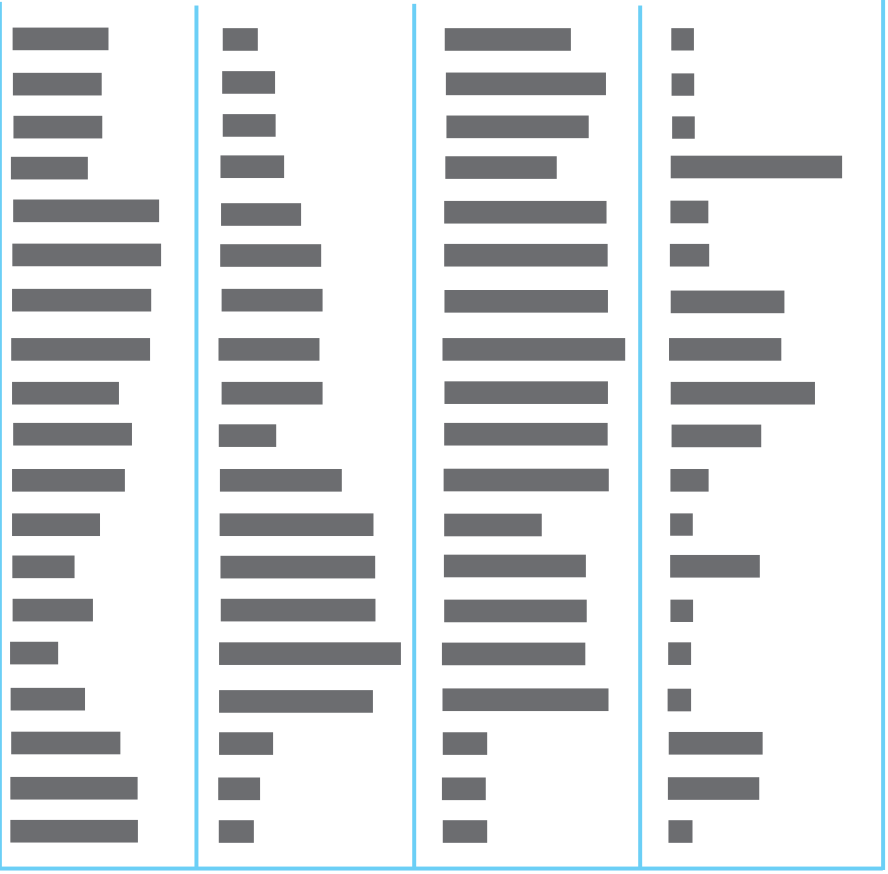
Cont.

COOL-MOULD	High strength Beryllium-Copper alloy, supplied at 40 HRC. The Coolmould alloy is suitable mould material for a variety of moulding situations where a combination of high thermal conductivity, corrosion resistance and good polishability is needed.

For more detailed recommendations, see the application brochure "Steel for Moulds" or the product information brochure available for each steel grade.

Property comparison guide for mould steel

Uddeholm grade	Machin-ability*	Wear resistance	Polishability	Corrosion resistance
IMPAX SUPREME				
NIMAX ESR				
NIMAX				
CORRAX				
VIDAR 1 ESR				
ORVAR SUPREME				
STAVAX ESR				
POLMAX				
MIRRAX ESR				
MIRRAX 40				
UNIMAX				
RIGOR				
ELMAX				
VANADIS 4 EXTRA				
VANADIS 8				
VANCRON				
RAMAX HH				
ROYALLOY				
HOLDAX				



* The Uddeholm mould steel Impax Supreme, Nimax ESR, Nimax, Mirrax 40, RoyAlloy, Holdax and Ramax HH are tested in pre-hardened condition. Uddeholm Corrax is tested in solution treated condition.

General recommendations

Process	Material	Recommended Steel grade	Hardness HRC (HB)
Injection moulding	Thermoplastics – pre-hardened mould steel	ALUMEC 89	(~160)
		IMPAX SUPREME	33(~310)
		RAMAX HH	37(~340)
		NIMAX ESR	40(~380)
		NIMAX	40(~380)
		MIRRAX 40	40(~380)
	– through hardened mould steel	CORRAX	36–50
		MIRRAX ESR	45–50
		ORVAR SUPREME	45–52
		VIDAR 1 ESR	45–52
		STAVAX ESR	45–52
		POLMAX	45–52
		UNIMAX	50–58
		ELMAX	56–60
		VANADIS 4 EXTRA	58–64
	Thermoset plastics	UNIMAX	52–58
		ELMAX	56–60
		RIGOR	58–60
		VANADIS 4 EXTRA	58–64
Com-pression/ Transfer moulding	Thermoset plastics	MIRRAX ESR	45–50
		STAVAX ESR	45–52
		ORVAR SUPREME	45–52
		UNIMAX	52–58
		ELMAX	56–60
		VANADIS 4 EXTRA	58–62
Blow moulding	General	ALUMEC 89	(~160)
		IMPAX SUPREME	33(~310)
		NIMAX	40(~380)
	PVC	CORRAX	36–50
		RAMAX HH	37(~340)
		MIRRAX 40	40(~380)
		MIRRAX ESR	45–50
		STAVAX ESR	45–52

Process	Material	Recommended Steel grade	Hardness HRC (HB)
Extrusion	General	IMPAX SUPREME	33(~310)
		NIMAX	40(~380)
	PVC	CORRAX	36–50
		RAMAX HH	37(~340)
		MIRRAX 40	40(~380)
		MIRRAX ESR	45–50
		STAVAX ESR	45–52
Holder material	1. High strength, pre-hardened, free-machining	HOLDAX	33(~310)
	2. As, 1, plus corrosion resistance for low maintenance production runs. Also for "hygienic" operating conditions. No plating required.	ROYALLOY	(~310)
		RAMAX HH	37(~340)

Special recommendations

Special req. or demand	Example	Recommended Steel grade	Hardness HRC (HB)
Large mould size	For automotive components, panels, bumpers, fascias, etc.	ALUMEC 89	(~160)
		IMPAX SUPREME	33(~310)
		CORRAX	36–46
		ORVAR SUPREME	36–50
		VIDAR 1 ESR	36–50
		MIRRAX ESR	36–50
		MIRRAX 40	40(~380)
		NIMAX ESR	40(~380)
		NIMAX	40(~380)
	As above but with lower demands on the surface finish	HOLDAX	33(~310)
		RAMAX HH	37(~340)

Special recommendations

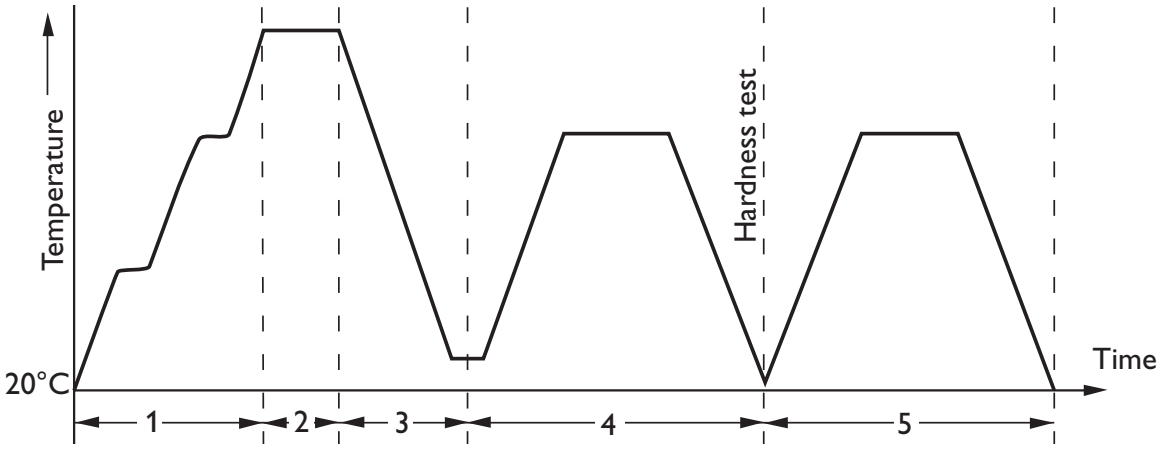
Special req. or demand	Example	Recommended Steel grade	Hardness HRC (HB)
High surface finish	For moulding optical/medical parts, clear covers/panels	NIMAX ESR	40(~380)
		MIRRAX 40	40(~380)
		MIRRAX ESR	45–50
		STAVAX ESR	45–52
		POLMAX	45–52
		ORVAR SUPREME	45–52
		VIDAR 1 ESR	45–52
		UNIMAX	54–58
		ELMAX	56–60
		VANADIS 4 EXTRA	58–62
Complex shapes	1. For *large* automobile/household components	IMPAX SUPREME	33(~310)
		CORRAX	34–46
		MIRRAX ESR	36–50
		MIRRAX 40	40(~380)
		NIMAX ESR	40(~380)
		NIMAX	40(~380)
		VIDAR 1 ESR	45–50
	2. For *small* parts with *low* wear demands	IMPAX SUPREME	33(~310)
		CORRAX	34–46
		MIRRAX 40	40(~380)
		NIMAX ESR	40(~380)
		NIMAX	40(~380)
	3. For *small* parts with *high* wear demands, e.g. electrical/electronic mouldings	MIRRAX ESR	48–50
		ORVAR SUPREME	50–52
		STAVAX ESR	50–52
		UNIMAX	54–58
		ELMAX	56–60
		VANADIS 4 EXTRA	58–64
		RIGOR	60–62
		VANADIS 8	60–64
Abrasive moulding materials	Reinforced/filled moulding materials	MIRRAX ESR	48–50
		ORVAR SUPREME	50–52
		STAVAX ESR	50–52
		UNIMAX	54–58
		ELMAX	56–60
		RIGOR	58–62
		VANADIS 4 EXTRA	58–64
		VANADIS 8	60–64

Special req. or demand	Example	Recommended Steel grade	Hardness HRC (HB)
Long production runs	For thermoplastic parts, including disposable cutlery, containers and packaging	MIRRAX ESR STAVAX ESR ORVAR SUPREME VIDAR 1 ESR UNIMAX ELMAX VANADIS 4 EXTRA	45–50 45–52 45–52 45–52 54–58 56–60 58–64
Corrosive	1. For corrosive moulding materials 2. For humid moulding/mould storage conditions 3. General resistance to surface staining/rusting 4. Resistance to corrosion of cooling channels	ROYALLOY CORRAX RAMAX HH MIRRAX 40 MIRRAX ESR STAVAX ESR ELMAX	(~310) 34–50 37(~340) 40(~380) 45–50 45–52 56–60
Photo-etching	1. Pre-hardened steel	IMPAX SUPREME MIRRAX 40 NIMAX ESR NIMAX	33(~310) 40(~380) 40(~380) 40(~380)
	2. Through-hardened steel	MIRRAX ESR ORVAR SUPREME VIDAR 1 ESR STAVAX ESR UNIMAX ELMAX VANADIS 4 EXTRA	45–50 45–52 45–52 45–52 54–58 56–60 58–64
High thermal conductivity	For injection and blow moulds, cores and inserts; parts for hot runner systems	COOLMOULD	~40

NOTES

PRINCIPLES OF HARDENING

Hardening normally means heating and quenching, followed by tempering. The following heat treatment sequence and guide-lines should be observed.



1 **Preheating.** Heat slowly! Rapid heating increases the risk of distortion.

2 **Austenitizing (hardening) temperature.** Protect against decarburization by heating in a salt bath, protective atmosphere or vacuum. Decarburization of the surface increases the risk of cracking and low hardness.

3 **Quenching.** Use the quenching medium specified for the grade concerned, i.e. water, oil, air, etc., to achieve the optimum as-quenched hardness. Oil hardening steel can be quenched in a step bath with good results. Steel which can be hardened in oil or air should preferably be cooled in air for minimum distortion.
Note: large blocks, however, should be quenched quickly enough to obtain a correct microstructure in the centre of the block. Discontinue cooling at approx. 50–70°C and *temper immediately.*

4, 5 **Tempering.** Heat slowly to reduce the risk of distortion and cracking! Holding time at temperature min. 2 hours. After the first temper, allow the material to cool to room temperature! Temper *twice* in the case of tool steel and *three times* in the case of Uddeholm Vancron SuperClean and high speed steel. If extremely high austenitizing temperatures, >1100°C (2010°F), are used all Uddeholm Vanadis SuperClean grades should be tempered three times at 540°C (1000°F) in order to reduce the amount of retained austenite and to optimize the microstructure.

PM Steel for improved production economy

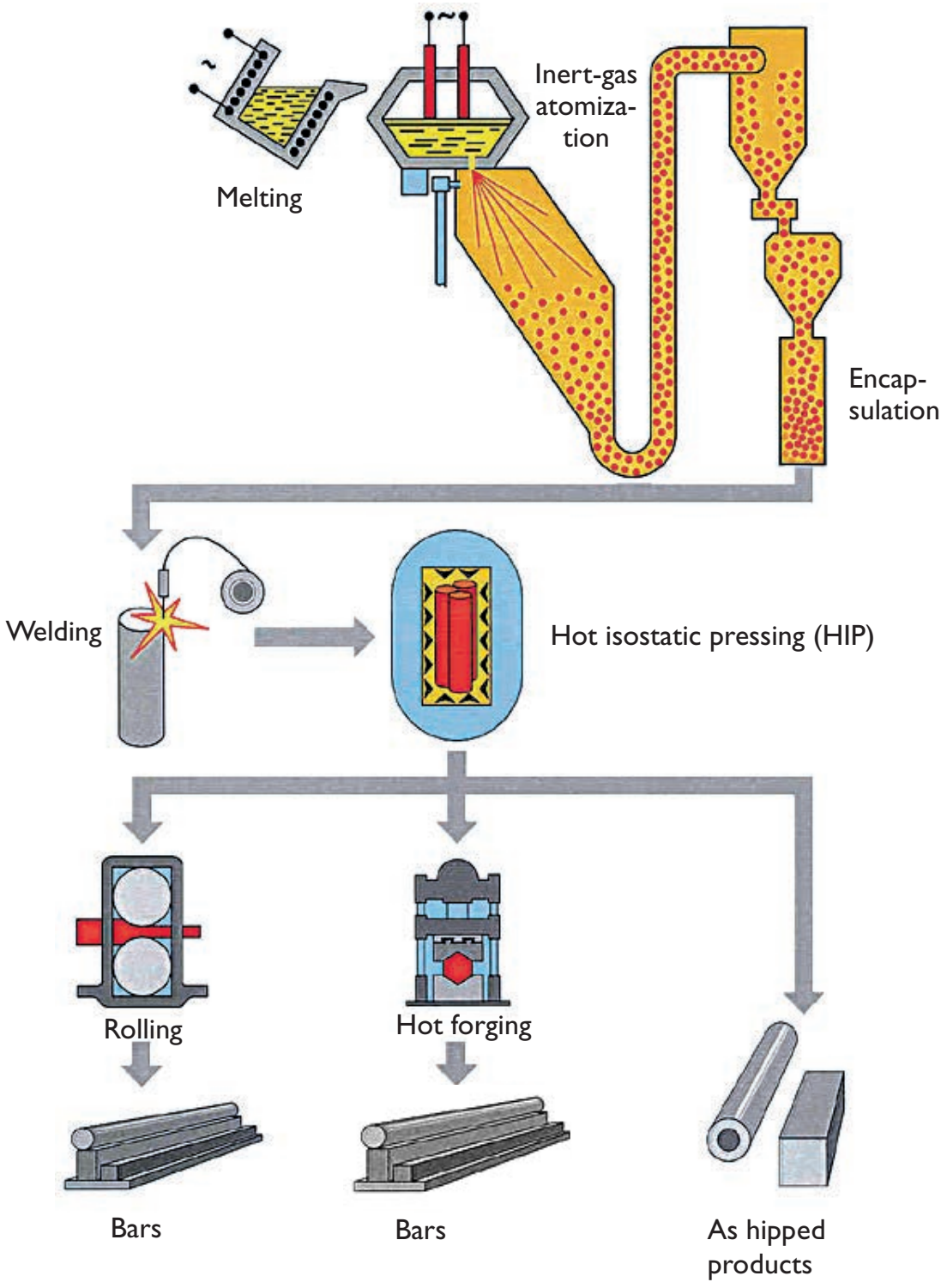
The powder metallurgy (PM) process is a rapid solidification process for the manufacturing of high-speed steel and tool steel. This method eliminates the problems which arise when steel solidifies in ingot moulds, such as local variations in chemical composition and microstructure in the form of segregations.

The PM steel is melted in the usual manner, but when it is tapped, the steel is fragmented by high speed gas jets into a shower of steel droplets which quickly solidify into powder. Each particle can be regarded as a tiny ingot, free of segregations thanks to the rapid cooling. The tiny particles are then compacted to form billets which can be fabricated by means of ordinary methods such as forging and rolling to the desired dimensions.

The PM tool steel Uddeholm Vanadis 4 Extra SuperClean, Uddeholm Vanadis 8 SuperClean, Uddeholm Vanadis 23 SuperClean and Uddeholm Elmax SuperClean are produced by a special PM process which gives an extremely clean tool steel, with improved properties over standard PM steel, like better polishability, toughness and bend strength. Uddeholm Vancron SuperClean is a nitrided PM steel offering advantages like low friction, antigalling and good resistance against adhesive wear and is an alternative to a surface coated PM steel in this respect.

- Dimensional changes are reduced during hardening due to the absence of segregations
- Tools made of PM steel feature a high and uniform level of performance
- PM steel permit sharper cutting edges on press tools
- PM steel are more ductile due to their lack of segregations
- The absence of segregations permits higher contents of alloying elements as well as more effective use of them compared to conventionally produced steel resulting in dramatically increase in performance.
- Desirable characteristics such as abrasion resistance can be enhanced without sacrificing other vital properties

The PM route for producing tool steel



UDDEHOLM COMPONENT BUSINESS

Uddeholm Component Business markets the Uddeholm product range in other applications and components than in the traditional tool steel business, where the product characteristics of Uddeholm's premium tool steel lead to lower maintenance costs and contribute to enhanced performance and optimum overall economy.

Uddeholm Component Business applications and components can be found within any industry where there are high demands on properties such as wear resistance, strength, corrosion and heat resistance.

Wear resistance

Wear costs industrial companies a lot of money every year largely due to abrasion. Within this area the key is to optimize strength and abrasion resistance. Uddeholm's product range includes steel grades with a high level of combined durability and toughness. Certain grades for cold work tools are especially well suited to withstand wear due to their structure containing hard phase particles.

Strength

When it comes to comparing the strength of different steel grades it is soon evident that Uddeholm's tool steel show far better strength values compared to engineering steel grades. The advantage here is that the adaptive hardness of the material through quenching and tempering can be exploited according

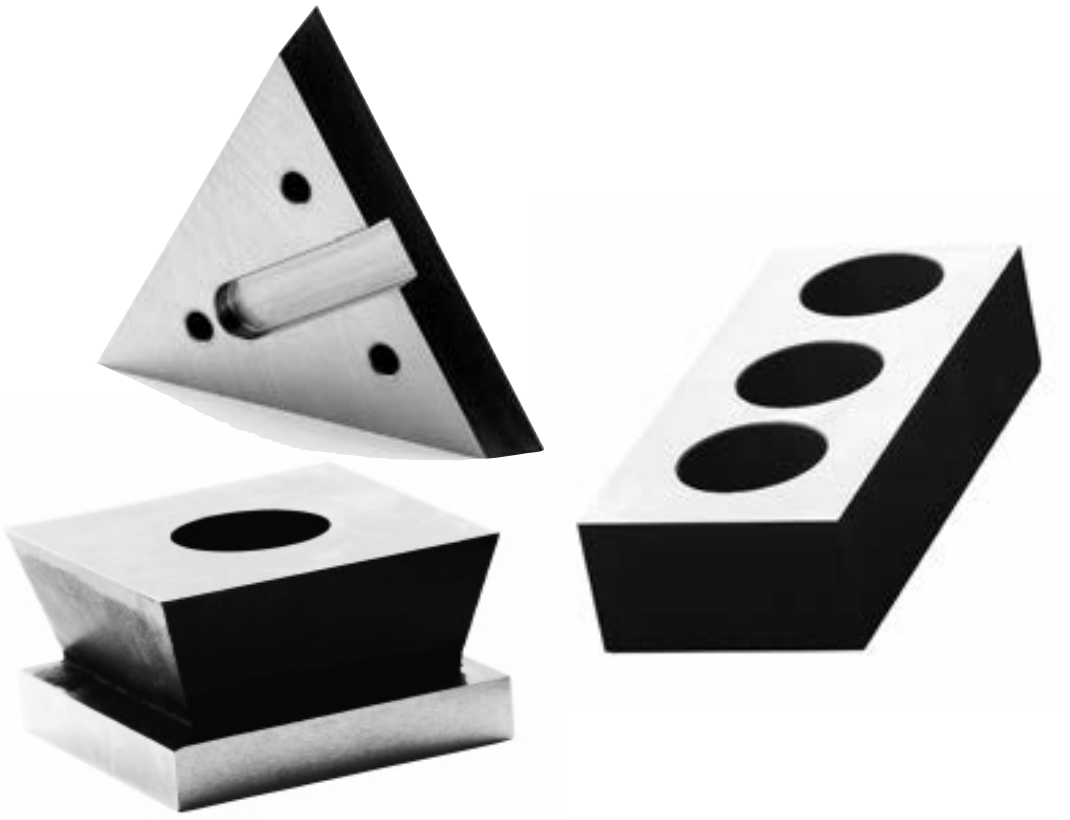
to specific demands. High fatigue strength can be achieved when combining the high strength and cleanliness of the steel. Uddeholm's ESR grades are a good example of this. This means a longer life for the finished component and these properties also enable weight reductions, which lead to lower costs and higher performance.

Corrosion resistance

Uddeholm's range of corrosion resistant steel often used for plastic moulds provides a unique combination of strength, corrosion resistance and durability, which enable brand new technical design solutions. This means that components do not need to be surface treated and the material can be used in environments where corrosion would normally be an issue.

Heat resistance

Uddeholm's steel grades are also used in hot forging tools and consequently developed to withstand high temperatures. This property means major improvements in strength for parts that are exposed to heat during a long period of time, i.e. they are not losing strength and hardness as often is the case for engineering steel due to tempering back.



PRE-MACHINED TOOL STEEL

In tool manufacture, material cost represents only a small fraction (approx. 10%) of the total cost of the tool. Machining represents a considerably larger portion. It has been calculated that rough machining prior to heat treatment accounts for about 20% of the total cost. Some of the rough machining is less qualified and should not have to be done by skilled toolmakers.

Uddeholm has therefore invested in considerable resources for further processing of the tool steel. In order to give the customer a steel which is less expensive overall, we grind the tool steel in long runs to a standardised tool size and to a surface finish on which the toolmaker can layout directly. The pre-machined bar is delivered wrapped in protective paper in easy-to-handle 1-metre lengths.

From "black" to pre-machined—the advantages are many

Advantages for the toolmaker:

- Time saving
- Less consumption of material
- Surface defects, flaws and cracks and decarburization eliminated
- Own personnel can be used for more qualified jobs
- Simpler handling
- Cleaner handling (the chips stay at Uddeholm)
- Lower set-up costs
- Less tool wear
- Lower stock-keeping costs

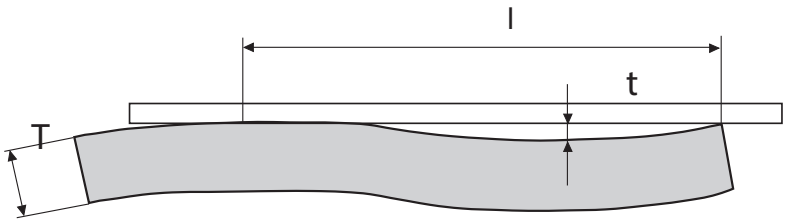
All in all, this means better overall economy for the customer, i.e. greater and faster production at a lower cost.

Tolerances

Width +0.4/+0.8 mm
Maximum deviation in width on a 1000 mm long bar 0.1 mm.

Thickness +0.4/+0.65 mm
Maximum deviation in thickness on a 1000 mm long bar 0.1 mm..

Flatness and straightness
Maximum deviation (t) divided by the length (l) according to the figure below, may not exceed t/l = 0.0004 = 0.4 mm/m.

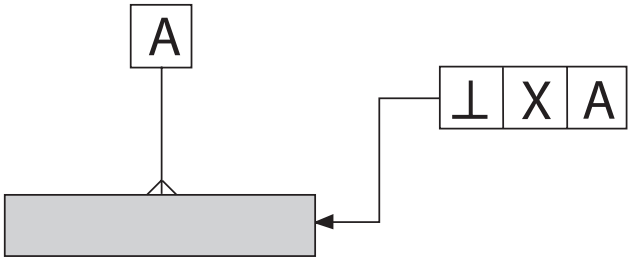


Surface finish

On the flat surfaces: Ra max 2.5 µm.
On the edge surfaces: Ra max 6.3 µm.

Corner squareness

Material with a thickness up to 80 mm maximum deviation “X” = 0.1 mm. Thickness above 80 mm maximum deviation “X” = 0.15 mm.



MACHINING SERVICES

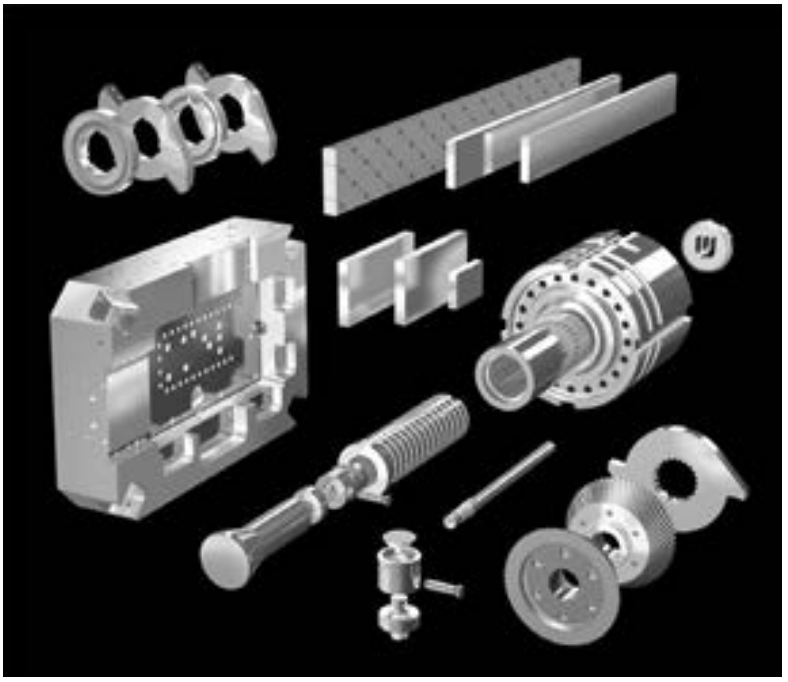
In addition to supplying a high proportion of our steel in the machined condition, in many cases we can offer following custom machining services.

Flat and square bars

- Surface milling: non standard sizes of large moulds and holder blocks
- Cavity milling: machining of cavities and holes according to customer drawings
- Drilling: holes for pillars/bushes and cooling channels
- Grinding, fine milling: fine machined bars in non standard sizes

Round bars

- Turning, Peeling: non standard sizes
- Centerless grinding: non standard sizes
- Hollow bar: non standard sizes



Machining on order of semifinished or finished parts in annealed or hardened condition

- Components for extrusion like containers, stems and dummy blocks
- Machine components shafts, wheels, knives etc.

HINTS ON IMPROVED TOOL PERFORMANCE

Hot work tools

- Pre-heat tools to minimize thermal shock
- Minimize thermal fluctuations in the tool by using appropriate cooling methods
- Lubricate working surfaces to reduce contact with hot metal and aid release of parts
- Ensure tools are fully supported for maximum stability and to avoid deflection

Cold work tools

- Pay careful attention to tool-setting and press alignment
- Ensure tools are fully supported for maximum stability and to avoid deflection
- Use lubricants as appropriate
- Re-grind tools regularly before major re-grinding is necessary. Use coolant to avoid overheating or grinding cracks
- Re-temper after re-grinding operations
- Tooling subjected to repeated heavy loading will benefit from a low-temperature stress-tempering operation after a long production run at 25–30°C below tempering temperature
- Do not use tools for blanking strip thicknesses which are greatly different from those for which they were designed

Plastic moulds

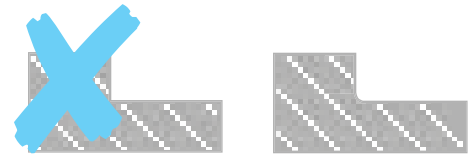
- Stress temper after the rough machining but before fine machining for best results regarding dimensional changes, etching and welding
- Reduce the risk for corrosion on the mould surfaces and the risk for reduced cooling efficiency because of rust in cooling channels by using a corrosion resistant tool steel
- Wear due to reinforcement in the plastic can be reduced by changing to a more wear resistant tool steel or in some cases by surface treatment
- Reduce the risk for galling by using different material and/or different hardness on the two sliding metal surfaces
- Too low clamping force increases the risk for flashes and for deformation of the edges of the parting line

HINTS ON BASIC TOOL DESIGN

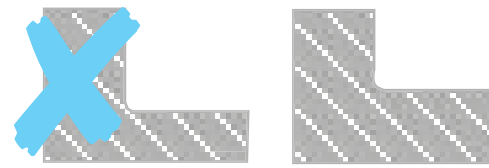
- Design around standard sizes wherever possible. Uddeholm normally supplies oversized bar with a machining allowance to finish at a convenient nominal size, e.g. 125 x 25 mm
- Use adequate overall dimensions!

Unmachined cross section:
133 x 28 mm
Pre-machined cross section:
125 x 25 mm with machining allowance

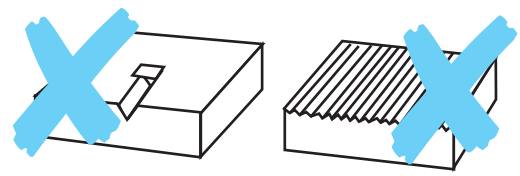
- Avoid sharp corners!



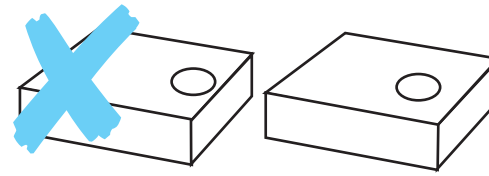
- Avoid uneven sections!



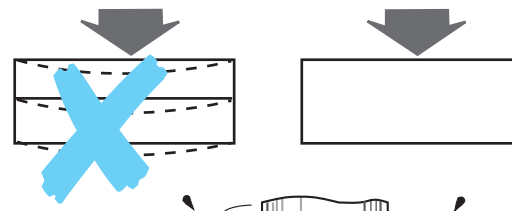
- Avoid potential stress raising marks, e.g. cold stamps, rough machining!



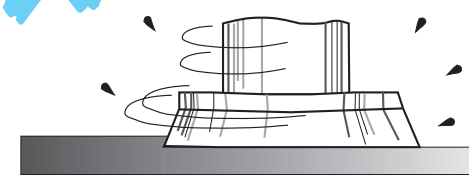
- Leave sufficient stock thickness between holes and plate edges!



- Solid blocks resist deflection!



- Remove surface decarburization!



HINTS ON TOOL HEAT TREATMENT

- Check thermocouples regularly
- Stress relieve tools after rough-machining
- Fully pre-heat
- Quench in the correct medium
- Temper immediately after quenching
- Double temper (or tripple)
- Don't hurry the heat treatment operation
- Don't forget to protect tools against decarburization or carburization
- Don't over-heat, over-soak
- Don't re-harden tools without annealing first

For further information see the Uddeholm brochure "Heat treatment of tool steel".

HINTS ON REPAIR WELDING

Even with the very best equipment and properly designed consumables, tool steel cannot be welded successfully unless considerable care is exercised in both joint preparation and in the actual welding operation. Recommended procedures are given in some detail on the product information brochures for the Uddeholm Weld range.

The following supplementary points can be made:

1. All dirt and grease must be thoroughly removed
2. On finished tools, protect surrounding area from spatter
3. Careful joint preparation is vital and welding should be performed immediately
4. Tools must be slowly pre-heated before welding
5. The principle is to put down a number of small cross section runs with low heat input, to clad the joint in weld metal, before increasing size of run and heat input for the remaining joint filling
6. Cool the tool slowly down to 50–70°C (120–160°F)

7. If welding has been performed on soft-annealed material, a soft annealing should be performed after finishing
8. If welding has been performed on material in hardened condition, a tempering should be performed after welding

For welding Uddeholm tool steel the following consumables are recommended:

Coated electrode:
Impax Weld, QRO 90 Weld, Caldie Weld and Calmax/Carmo Weld

TIG filler rod:
Impax TIG-Weld, Nimax TIG-Weld, Stavax TIG-Weld, Mirrax TIG-Weld, Unimax TIG-Weld, QRO 90 TIG-Weld, Dievar TIG-Weld, Calmax/Carmo TIG-Weld, Corrax TIG-Weld, Caldie TIG-Weld, RoyAlloy TIG-Weld and Coolmould TIG-Weld.

Laser filler rod:
Nimax Laser Weld, Stavax Laser Weld and Dievar Laser Weld.

For further information see the Uddeholm brochure "Welding of tool steel".

HINTS ON GRINDING TOOL STEEL

As in all machining operations operator technique and experience, tool and machine type and condition all play a part in a successful grinding operation.

- Ensure that the part is firmly secured to avoid vibration
- Use properly dressed, soft, open-grained grinding wheels wherever possible
- Restrict the peripheral speed and use plenty of coolant
- Refer to the grinding wheel manufacturer for specific advice on wheel selection and use
- Re-temper tools after re-grinding operations
- Remove any "feather-edge" after grinding
- Don't use excessive pressure when grinding, to avoid burning and grinding cracks
- Don't grind tools in the untempered condition

For further information see the Uddeholm brochure "Grinding of tool steel".

Electro Discharge Machining (EDM'ing)

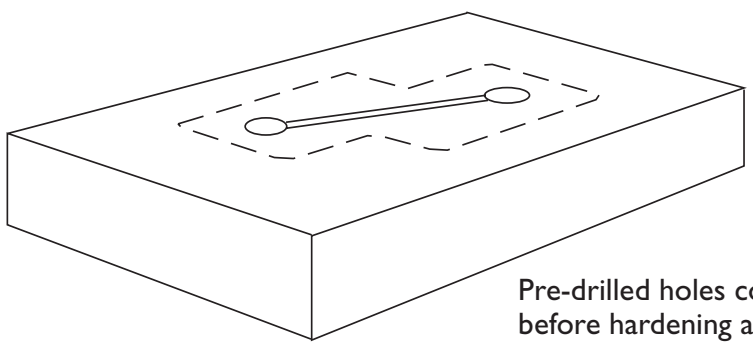
When spark eroding cavities, one or two important points should be noted in order to obtain satisfactory results. During the operation the surface layer of the steel is re-hardened and consequently in a brittle state. This may result in fatigue cracking and shortened tool life. To avoid this problem the following precautions should be taken:

- Finish the EDM operation by "fine" sparking (i.e. low amperage, high frequency)
- The affected surface layer should be removed by polishing or stoning
- If the spark-eroded surface texture is to be used in the finished mould it should be re-tempered at a temperature 15–20°C below that used previously
- If the spark-eroded surface is to be textured by photo-etching it is important that all of the surface layer affected is carefully removed by stoning etc.

For further information see the Uddeholm brochure "EDM of tool steel".

Wire erosion

Complicated shapes can be easily cut from hardened steel blocks by this process. However, hardened steel always contains stresses, and when large volumes of steel are removed in a single operation, distortion may be caused or even cracking especially if the tool is low temperature tempered. These difficulties can be reduced by drilling holes joined by a saw-cut slot in the proposed aperture, before heat treatment; this allows the work piece to adjust to the final shape and stress pattern, during heat treatment.



Pre-drilled holes connected by a saw-cut, before hardening and tempering will help to prevent distortion or cracking when wire-eroding thick sections.

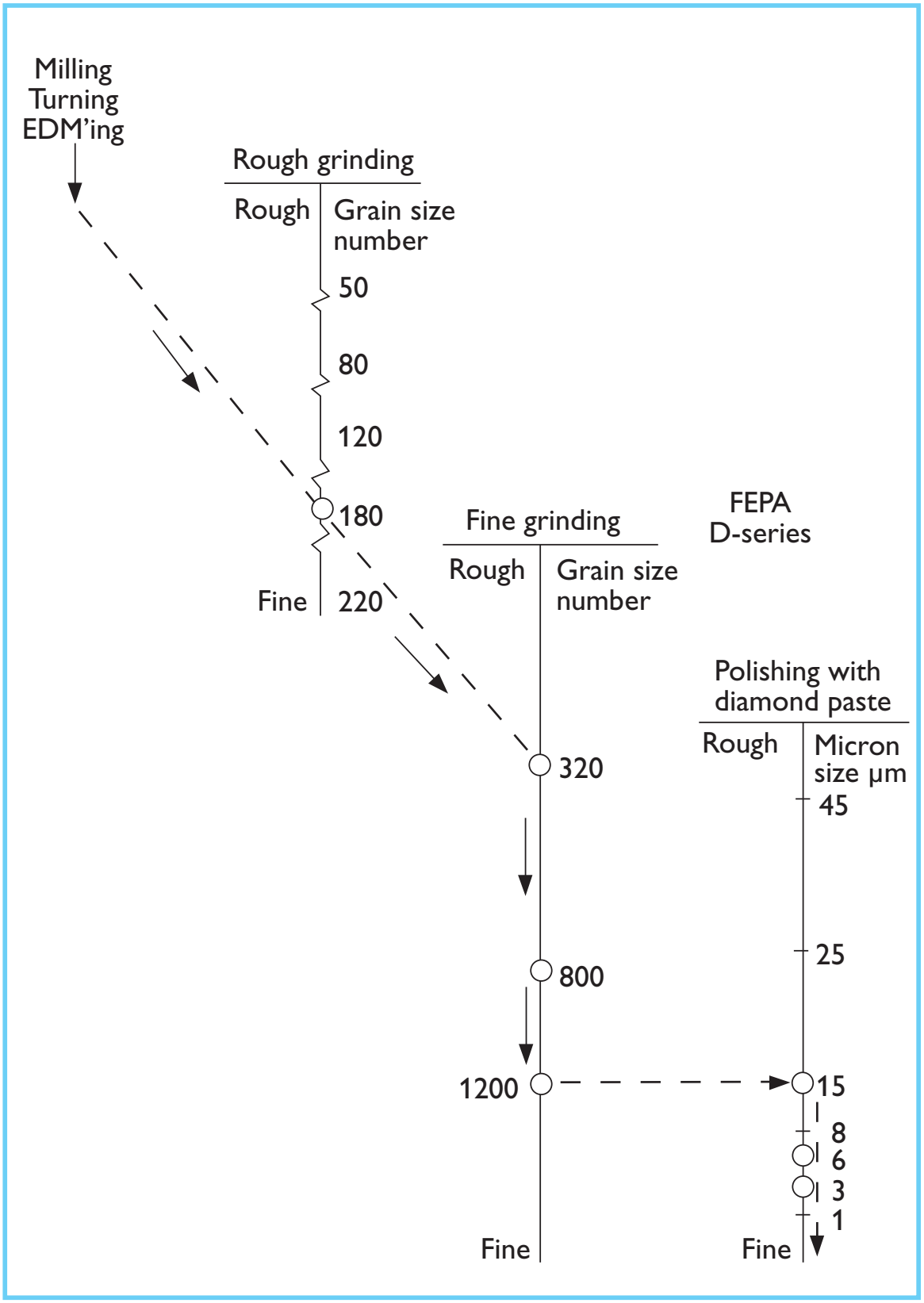
HINTS ON POLISHING MOULD STEEL

In spite of an increasing number of mechanical polishing aids, the skilled technique and judgement of an experienced polisher is still an essential ingredient in obtaining the required surface finish as quickly as possible.

- Choose a good quality mould steel. All Uddeholm mould steel are vacuum de-gassed and/or electro-slag-refined (ESR) during manufacture to give a clean and homogeneous structure suitable for producing high surface finishes
- Carefully heat treat parts to be hardened, to give a uniform hardness and steel structure, this will help to give consistent polishing results.
- Follow a recommended polishing sequence
- Ensure absolute cleanliness at every stage of the polishing process.
- Do not transfer abrasive particles from one polishing step to the next
- Avoid excessive pressure when using mechanical polishing equipment

For further information see the Uddeholm brochures “Polishing of mould steel” and “Defect chart and hints for high gloss polishing of steel surfaces”.

A highly polished mould for production of car headlights.
Illustration Graphics, Sweden.



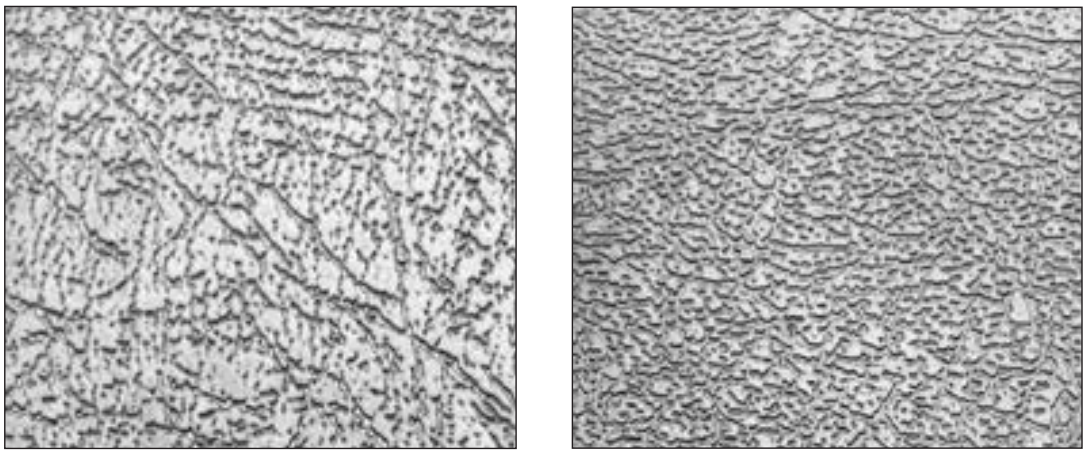
A typical polishing sequence.

HINTS ON PHOTO-ETCHING

Uddeholm Impax Supreme pre-hardened mould steel and Uddeholm Orvar Supreme yield particularly good and consistent results after photo-etching due to the very low sulphur content.

- If a number of parts are included in a tool and these are to be etched with the same pattern, the starting material and the rolling direction should be the same for these parts
- Complete the machining operation by stress-relieving, followed by finish-machining
- When etching heavy sections of Uddeholm Impax Supreme an extra tempering at 550°C before the etching is recommended
- Spark-eroded surfaces should always be ground or polished, otherwise re-hardened surface layers from the spark-erosion will cause a poor etching result
- Flame-hardening should be done after photo-etching
- In some cases, a welded tool can be photo-etched, provided that the same material is used in the weld as in the tool itself. In such cases the welded area should be indicated to the photo-etching company
- If a tool is to be nitrided this must be done after photo-etching
- The surface area of a mould cavity is greatly increased by texturing, which may cause ejection problems. Early consultation with the photo-etching specialist is recommended to determine the optimum draft angel for the shape and pattern concerned

For further information see the brochure “Photo-etching of tool steel”.



Examples of photo-etched pattern.

HARDNESS CONVERSION TABLE

These conversions are based on EN-ISO 18265:2013.

Approx. comparison between hardness and ultimate tensile strength.

Rockwell HRC	Brinell* HBW	Vickers HV10	Approx. UTS	
			N/mm²	kp/mm²
26	259	273	873	89
27	265	279	897	92
28	272	286	919	94
29	279	294	944	96
30	287	302	970	99
31	295	310	995	101
32	303	318	1024	104
33	311	327	1052	107
34	320	336	1082	110
35	328	345	1111	113
36	337	355	1139	116
37	346	364	1168	119
38	354	373	1198	122
39	363	382	1227	125
40	373	392	1262	129
41	382	402	1296	132
42	392	412	1327	135
43	402	423	1362	139
44	413	434	1401	143
45	424	446	1425	145
46	436	459	1478	151
47	448	471	1524	155
48	460	484	1572	160
49	474	499	1625	166
50	488	513	1675	171
51	502	528	1733	177
52	518	545	1793	183
53	532	560	1845	188
54	549	578	1912	195
55	566	596	1979	202
56	585	615	2050	209
57	603	634	2121	216
58		654		
59		675		
60		698		
61		720		
62		746		
63		773		
64		800		

* 10 mm all, 3000 kg load

CONVERSION FACTORS AND FORMULAE

Length

To convert	to	multiply by
in	mm	25.40
in	cm	2.540
in	m	0.0254
mm	in	0.0394
cm	in	0.3937
ft	m	0.3048
m	ft	3.281
yd	m	0.9144
m	yd	1.094
miles	km	1.609
km	miles	0.6214

Mass (weight)

To convert	to	multiply by
lb	kg	0.4536
lb	ton[1)]	0.0004536
kg	lb	2.205
kg	tons[2)]	0.00098
tons[2)])	kg	1016
tons[2)]	ton[1)]	1.016
ton[1)]	tons[2)]	0.9844
kg/m	lb/ft	0.672
kg/m	kg/ft	0.3281
kg/ft	kg/m	0.3048
kg/ft	lb/m	7.23
lb/ft	kg/m	1.48

[1)] 1 ton (metric) = 1000 kg = 2205 lbs

[2)] 1 ton (UK) = 1016 kg = 2240 lbs
1 short ton (USA) = 907 kg = 2000 lbs
1 long ton (USA) = 1 ton (UK) =1016 kg = 2240 lbs

Area

To convert	to	multiply by
mm^2	in^2	0.00155
in^2	mm^2	645.16
cm^2	in^2	0.1550
in^2	cm^2	6.452
ft^2	m^2	0.0929
m^2	ft^2	10.76
m^2	yd^2	1.196
yd^2	m^2	0.8361

Area of circle: $\pi \cdot r^2 \approx 0.7854 \cdot D^2$

Volume

To convert	to	multiply by
in^3	mm^3	16.3862
cm^3	in^3	0.06103
in^3	ft^3	0.000578
ft^3	in^3	1728
ft^3	m^3	0.02832
m^3	ft^3	35.3147
gal (UK)	l	4.546
l	gal (UK)	0.219969

Temperature conversion

°C to °F: multiply by 1.8, then add 32

°F to °C: substract 32, then multiply by 0.56

Exact formulae:

$$°F = \frac{°C \cdot 9}{5} + 32$$

$$°C = (°F - 32) \cdot \frac{5}{9}$$

Pressure, tensile strength

To convert	to	multiply by
tons/in^2	N/mm^2	15.5
tons/in^2	kp/mm^2	1.57
tons/in^2	lb/in^2	2240
N/mm^2	kp/mm^2	0.102
N/mm^2	lb/in^2	145
N/mm^2	tons/in^2	0.065
kp/mm^2	lb/in^2	1422.34
kp/mm^2	tons/in^2	0.635
kp/mm^2	N/mm^2	9.81
lb/in^2	tons/in^2	0.00045
lb/in^2	N/mm^2	0.0069
lb/in^2	kp/mm^2	0.000703
lb/in^2	MPa	0.00689
MPa	lb/in^2	145
bar	ln/in^2	14.51

Steel weights

Metric sizes

Flats and squares: W(mm) x T(mm) x L(m) x 0.00785 = weight in kg.
Rounds: D^2(mm) x L(m) x 0.0062 = weight in kg.

Inch sizes

Flats and squares: W(in) x T(in) x L(in) x 0.2833 = weight in lbs.
Rounds: D^2(in) x L(in) x 0.2225 = weight in lbs.

NOTES

SI–UNITS OF MEASUREMENT

Factors and prefixes

Quantity	Name	Symbol	Derivation
The seven basic units			
Length	metre	m	
Mass	kilogram	kg	
Time	second	s	
El.current	ampere	A	
Temperature	kelvin	K	
Lum.intensity	candela	cd	
Mol. w. in gr.	mole	mol	
Two supplementary units			
Plane angle	radian	rad	
Solid angle	steradian	sr	
Derived units with own names			
Force	newton	1 N	= 1 kg · m/s^2
Pressure	pascal	1 Pa	= 1 N/m^2
Energy, work	joule	1 J	= 1 Nm
Power	watt	1 W	= 1 J/s
Additional units permitted until further notice			
Volume	litre	1 l	= 10^{-3} m^3
Mass	ton	1 t	= 10^3 kg
Energy	watt-hour	1 Wh	= 3600 Ws (J)
Pressure	bar	1 bar	= 100 kPa

Multiple	Factor	Prefix	Symbol
1 000 000 000 000	10^{12}	tera	T
1 000 000 000	10^9	giga	G
1 000 000	10^6	mega	M
1 000	10^3	kilo	k
100	10^2	hekto	h
10	10^1	deka	da
0,1	10^{-1}	deci	d
0,01	10^{-2}	centi	c
0,001	10^{-3}	milli	m
0,000 001	10^{-6}	mikro	µ
0,000 000 001	10^{-9}	nano	n
0,000 000 000 001	10^{-12}	piko	p
0,000 000 000 000 001	10^{-15}	femto	f
0,000 000 000 000 000 001	10^{-18}	atto	a

Conversion factors

SI-units and permitted units

Other units

Length

	m	mm	in (inch)	ft (foot)	yd (yard)
1 m =	1	10^3	39.3701	3.2808	1.0936
1 mm =	10^{-3}	1	$39.37 \cdot 10^{-3}$	$3.281 \cdot 10^{-3}$	$1.094 \cdot 10^{-3}$
1 in (inch) =	$25.4 \cdot 10^{-3}$	25.4	1	$83.33 \cdot 10^{-3}$	$27.78 \cdot 10^{-3}$
1 ft (foot) =	0.3048	304.8	12	1	0.3333
1 yd (yard) =	0.9144	914.4	36	3	1
1 mile. eng. =	$1.6093 \cdot 10^3$	$1.6093 \cdot 10^6$	$63.36 \cdot 10^3$	$5.28 \cdot 10^3$	$1.76 \cdot 10^3$
1 naut. mil =	$1.852 \cdot 10^3$	$1.852 \cdot 10^6$	$72.91 \cdot 10^3$	$6.076 \cdot 10^3$	$2.025 \cdot 10^3$

1 km = 0.6214 mile, eng. = 0.5396 naut. mile
1 Å (Ångström) = 10^{-10} m = 10^{-4} µm

Area

	m^2	mm^2	in^2	ft^2	yd^2
1 m^2 =	1	10^6	$1.55 \cdot 10^3$	10.76	1.196
1 mm^2 =	10^{-4}	1	$1.55 \cdot 10^{-3}$	$10.76 \cdot 10^{-6}$	$1.196 \cdot 10^{-6}$
1 in^2 =	$0.645 \cdot 10^{-3}$	645.16	1	$6.944 \cdot 10^{-3}$	$0.772 \cdot 10^{-3}$
1 ft^2 =	$92.9 \cdot 10^{-3}$	$92.9 \cdot 10^3$	144	1	0.1111
1 yd^2 =	0.8361	$836.1 \cdot 10^3$	$1.296 \cdot 10^3$	9	1
1 acre =	$4.047 \cdot 10^3$	$4.047 \cdot 10^9$	$6.273 \cdot 10^6$	$43.56 \cdot 10^3$	$4.84 \cdot 10^3$
1 $mile^2$ eng. =	$2.58999 \cdot 10^6$	$2.58999 \cdot 10^{12}$	$4.014 \cdot 10^9$	$27.88 \cdot 10^6$	$3.0976 \cdot 10^6$

1 km^2 = 247.1 acre = 0.3861 $mile^2$ eng.

Volume

	m^3	dm^3	in^3	ft^3	Yd^3
1 m^3 =	1	10^3	$61.0237 \cdot 10^3$	35.3147	1.308
1 l = l dm^3 =	10^{-3}	1	61.02	$35.31 \cdot 10^{-3}$	$1.3 \cdot 10^{-3}$
1 in^3 =	$16.387 \cdot 10^{-6}$	$16.387 \cdot 10^{-3}$	1	$0.579 \cdot 10^{-3}$	$21.43 \cdot 10^{-6}$
1 ft^3 =	$28.317 \cdot 10^{-3}$	28.317	$1.728 \cdot 10^3$	1	$37.04 \cdot 10^{-3}$
1 yd^3 =	0.76455	764.55	$46.656 \cdot 10^3$	27	1
1 gallon UK =	$4.546 \cdot 10^{-3}$	4.5461	277.4	0.1605	$5.946 \cdot 10^{-3}$
1 gallon US =	$3.785 \cdot 10^{-3}$	3.7854	231	0.1337	$4.951 \cdot 10^{-3}$

1 l = 1 dm^3 = 0.219969 gallon UK = 0.264172 gallon US

1 cm^3 = 0.061 in^3

Velocity

	m/s	km/h	ft/s	mile/h	kn (knpo)
1 m/s =	1	3.6	3.2808	2.2369	1.9438
1 km/h =	0.2778	1	0.9113	0.6214	0.54
1 ft/s =	0.3048	1.0973	1	0.6818	0.5925
1 mile/h =	0.447	1.6093	1.4666	1	0.869
1 kn (knop) =	0.5144	1.852	1.6878	1.1508	1

1 knop = 1 nautical mile/h; 1 mach = ca $1.2 \cdot 10^3$ km/h; 1 mph = 1 mile/h

Mass (weight)

	kg	g	lb (pound)	slug	oz (ounce)
1 kg =	1	10^3	2.2046	$68.52 \cdot 10^{-3}$	35.274
1 g =	10^{-3}	1	$2.2 \cdot 10^{-3}$	$68.52 \cdot 10^{-6}$	$35.274 \cdot 10^{-3}$
1 lb (pound) =	0.4536	453.59	1	$31.08 \cdot 10^{-3}$	16
1 slug =	14.594	$14.5939 \cdot 10^3$	32.17	1	514.8
1 oz (ounce) =	$28.35 \cdot 10^{-3}$	28.35	$62.5 \cdot 10^{-3}$	$1.943 \cdot 10^{-3}$	1
1 long cwt GB =	50.8023	$50.8023 \cdot 10^3$	112	3.481	$1.792 \cdot 10^3$
1 long ton. GB =	$1.016 \cdot 10^3$	$1.016 \cdot 10^6$	$2.24 \cdot 10^3$	69.62	$35.84 \cdot 10^3$
1 short cwt. USA =	45.3592	$45.3592 \cdot 10^3$	100	3.108	$1.6 \cdot 10^3$
1 short ton USA =	907.185	$907.185 \cdot 10^3$	$2 \cdot 10^3$	62.16	$32 \cdot 10^3$

1 long ton UK = 20 long cwt. UK 1 short ton US = 20 short cwt. US

1 kg = $0.9842 \cdot 10^{-3}$ long ton UK = $1.1023 \cdot 10^{-3}$ short ton US

1 kg = $19.684 \cdot 10^{-3}$ long cwt. UK = $22.046 \cdot 10^{-3}$ short cwt US

Density

	kg/m³	g/cm³	lb/in.³	lb/ft³
1 kg/m³ =	1	10^{-3}	$36.13 \cdot 10^{-6}$	$62.43 \cdot 10^{-3}$
1 g/cm³ =	10^3	1	$36.13 \cdot 10^{-3}$	62.428
1 lb/in³ =	$27.6799 \cdot 10^3$	27.68	1	$1.728 \cdot 10^3$
1 lb/ft³ =	16.0185	$16.02 \cdot 10^{-3}$	$0.579 \cdot 10^{-3}$	1

m^3/kg called specific volume

Force

	N	dyne	kp	lbf
1 N =	1	$0.1 \cdot 10^{6}$	0.10197	0.2248
1 dyn =	$10 \cdot 10^{-6}$	1	$1.02 \cdot 10^{-6}$	$2.248 \cdot 10^{-6}$
1 kp =	9.80665	$980.665 \cdot 10^{3}$	1	2.2046
1 lbf =	4.448	$444.8 \cdot 10^{3}$	0.4536	1

The unit kilopond (kp) has also been called kilogram-force (kgf)

Moment of force

	Nm	kpm	lbf · in	lbf · ft
1 Nm =	1	0.102	8.851	0.7376
1 kpm =	9.8067	1	86.7962	7.233
1 lbf · in =	0.113	$11.521 \cdot 10^{-3}$	1	$83.33 \cdot 10^{-3}$
1 lbf · ft =	1.356	0.1383	12	1

Power

	W	kpm/s	kcal/h	hk	ft · lbf/s
1 W =	1	0.102	0.8598	$1.36 \cdot 10^{-3}$	0.7376
1 kpm/s =	9.80665	1	8.432	$13.33 \cdot 10^{-3}$	7.233
1 kcal/h =	1.163	0.1186	1	$1.581 \cdot 10^{-3}$	0.8578
1 hk =	735.5	75	632.5	1	542.5
1 ft · lbf/s =	1.356	0.1383	1.166	$1.843 \cdot 10^{-3}$	1
1 hp UK. US =	745.7	76.04	641.2	1.1014	550
1 Btu/h =	0.2931	$29.89 \cdot 10^{-3}$	0.252	$398.5 \cdot 10^{-6}$	0.2162

1 kcal/s = $4.1868 \cdot 10^{3}$W 1W = $238.8 \cdot 10^{-6}$ kcal/s = $1.341 \cdot 10^{-3}$hp

Pressure (stress)

	Pa= N/m²	N/mm²= MPa	bar	kp/mm²	lbf/in²(psi)
1 Pa= 1 N/m² =	1	10^{-6}	$10 \cdot 10^{-6}$	$0.102 \cdot 10^{-6}$	$0.145 \cdot 10^{-3}$
1 N/mm²=1 MPa	10^{6}	1	10	0.102	145
1 bar =	$100 \cdot 10^{3}$	0.1	1	$10.2 \cdot 10^{-3}$	14.5
1 kp/mm² =	$9.807 \cdot 10^{6}$	9.807	98.07	1	$1.4211 \cdot 10^{3}$
1 kp/mm²= at =	$98.07 \cdot 10^{3}$	$98.07 \cdot 10^{-3}$	0.9807	$10 \cdot 10^{-3}$	14.21
1 lb/in² = psi =	$6.895 \cdot 10^{3}$	$6.895 \cdot 10^{-3}$	$68.95 \cdot 10^{-3}$	703	1
1 torr =	133.3	$133.3 \cdot 10^{-6}$	$1.333 \cdot 10^{-3}$	$13.6 \cdot 10^{-3}$	$19.34 \cdot 10^{-3}$
1 atm =	$101.3 \cdot 10^{3}$	0.1013	1.013	$10.33 \cdot 10^{-3}$	14.7

1 mm Hg = 13.6 mm water gauge
1 mm water gauge = 9.81 Pa
1 dyne/cm² = 10Pa

1 Pa = $7.501 \cdot 10^{-3}$ torr = $9.868 \cdot 10^{-6}$ atm
1 torr = 1 mm Hg at 0°C and 9.81 m/s²
1 atm = 760 mm Hg (torr) = $1.013 \cdot 10^{3}$ milibar

Power

	J	kWh	kpm	kcal	ft· lbf
1 J =	1	$0.278 \cdot 10^{-6}$	0.102	$0.239 \cdot 10^{-3}$	0.7376
1 kWh =	$3.6 \cdot 10^{6}$	1	$367.1 \cdot 10^{3}$	859.8	$2.655 \cdot 10^{6}$
1 kpm =	9.80665	$2.724 \cdot 10^{-6}$	1	$2.342 \cdot 10^{-3}$	7.233
1 kcal =	$4.1868 \cdot 10^{3}$	$1.163 \cdot 10^{-3}$	426.9	1	$3.088 \cdot 10^{3}$
1 ft · lbf =	1.356	$376 \cdot 10^{-9}$	0.1383	$323.8 \cdot 10^{-3}$	1
1 erg =	$0.1 \cdot 10^{-6}$	$27.78 \cdot 10^{-15}$	$10.2 \cdot 10^{-9}$	$23.88 \cdot 10^{-12}$	$73.76 \cdot 10^{-9}$
1 Btu =	$1.055 \cdot 10^{3}$	$0.293 \cdot 10^{-3}$	107.6	0.2522	778.2

1 eV = $0.1602 \cdot 10^{-18}$ J 1 J = $6.242 \cdot 10^{18}$ eV = 10^{7} erg = $0.3777 \cdot 10^{-6}$ hkh 1 hkh = $2.648 \cdot 10^{6}$ J

ISO-tolerances

The tolerance range IT in mm, is given according to the international ISO-system

Diameter mm		IT 8	IT 9	IT 10	IT 11	IT 12	IT 13	IT 14
over	up to							
	3	0.014	0.025	0.040	0.060	0.100	0.140	0.250
3	6	0.018	0.030	0.048	0.075	0.120	0.180	0.300
6	10	0.022	0.036	0.058	0.090	0.150	0.220	0.360
10	18	0.027	0.043	0.070	0.110	0.180	0.270	0.430
18	30	0.033	0.052	0.084	0.130	0.210	0.330	0.520
30	50	0.039	0.062	0.100	0.160	0.250	0.390	0.620
50	80	0.046	0.074	0.120	0.190	0.300	0.460	0.740
80	120	0.054	0.087	0.140	0.220	0.350	0.540	0.870
120	180	0.063	0.100	0.160	0.250	0.400	0.630	1.000
180	250	0.072	0.115	0.185	0.290	0.460	0.720	1.150
250	315	0.081	0.130	0.210	0.320	0.520	0.810	1.300
315	400	0.089	0.140	0.230	0.360	0.570	0.890	1.400
400	500	0.097	0.155	0.250	0.400	0.630	0.970	1.550
500	630	0.110	0.175	0.280	0.440	0.700	1.100	1.750
630	800	0.125	0.200	0.320	0.500	0.800	1.250	2.000

Tolerance location. External dimensions, shafts:
h = minus only
js = half minus, half plus
k = plus only

Inside dimensions, holes:
H = plus only
JS = half plus, half minus
K = minus only

CONVERSION TABLE

Temperature scales

Refer to the center column and find the number of degrees to be converted. If °F is to be converted to °C, the required figure is to be found in the left-hand column under C; for converting °C to °F refer to the right-hand column.

C	°	F	C	°	F	C	°	F
– 17.8	0	32	132	270	518	299	570	1058
– 15.0	5	41	138	280	526	302	575	1067
– 12.2	10	50	143	290	554	304	580	1076
– 9.4	15	59	149	300	572	307	585	1085
– 6.7	20	68	154	310	590	310	590	1094
– 3.9	25	77	160	320	608	313	595	1103
– 1.1	30	86	166	330	626	316	600	1112
1.7	35	95	171	340	644	318	605	1121
4.4	40	104	177	350	662	321	610	1130
7.2	45	113	182	360	680	324	615	1139
10.0	50	122	188	370	698	327	620	1148
12.8	55	131	193	380	716	329	625	1157
15.6	60	140	199	390	734	332	630	1166
18.3	65	149	204	400	752	335	635	1175
21.1	70	158	210	410	770	338	640	1184
23.9	75	167	216	420	788	341	645	1193
26.7	80	176	221	430	806	343	650	1202
29.4	85	185	227	440	824	346	655	1211
32.2	90	194	232	450	842	349	660	1220
35.0	95	203	238	460	860	352	665	1229
37.8	100	212	243	470	878	354	670	1238
43	110	230	249	480	896	357	675	1247
49	120	248	254	490	914	360	680	1256
54	130	266	260	500	932	363	685	1265
60	140	284	263	505	941	366	690	1274
66	150	302	266	510	950	368	695	1283
71	160	320	268	515	959	371	700	1292
77	170	338	271	520	968	377	710	1310
82	180	356	274	525	977	382	720	1328
88	190	374	277	530	986	388	730	1346
93	200	392	279	535	995	393	740	1364
99	210	410	282	540	1004	399	750	1382
104	220	428	285	545	1013	404	760	1400
110	230	446	288	550	1022	410	770	1418
116	240	464	291	555	1031	416	780	1436
121	250	484	293	560	1040	421	790	1454
127	260	500	296	565	1049	427	800	1472

C	°	F	C	°	F	C	°	F
432	810	1490	671	1240	2264	910	1670	3038
438	820	1508	677	1250	2282	916	1680	3056
443	830	1526	682	1260	2300	921	1690	3074
449	840	1544	688	1270	2318	927	1700	3092
454	850	1562	693	1280	2336	932	1710	3110
460	860	1580	699	1290	2354	938	1720	3128
466	870	1598	704	1300	2372	943	1730	3146
471	880	1616	710	1310	2390	949	1740	3164
477	890	1634	716	1320	2408	954	1750	3182
482	900	1652	721	1330	2426	960	1760	3200
488	910	1670	727	1340	2444	966	1770	3218
493	920	1688	732	1350	2462	971	1780	3236
499	930	1706	738	1360	2480	977	1790	3254
504	940	1724	743	1370	2498	982	1800	3272
510	950	1742	749	1380	2516	988	1810	3290
516	960	1760	754	1390	2534	993	1820	3308
521	970	1778	760	1400	2552	999	1830	3326
527	980	1796	766	1410	2570	1004	1840	3344
532	990	1814	771	1420	2588	1010	1850	3362
538	1000	1832	777	1430	2606	1016	1860	3380
543	1010	1850	782	1440	2624	1021	1870	3398
549	1020	1868	788	1450	2642	1027	1880	3416
554	1030	1886	793	1460	2660	1032	1890	3434
560	1040	1904	799	1470	2678	1038	1900	3452
566	1050	1922	804	1480	2696	1043	1910	3470
571	1060	1940	810	1490	2714	1049	1920	3488
577	1070	1958	816	1500	2732	1054	1930	3506
582	1080	1976	821	1510	2750	1060	1940	3524
588	1090	1994	827	1520	2768	1066	1950	3542
593	1100	2012	832	1530	2786	1071	1960	3560
599	1110	2030	838	1540	2804	1077	1970	3578
604	1120	2048	843	1550	2822	1082	1980	3596
610	1130	2066	849	1560	2840	1093	2000	3632
616	1140	2084	854	1570	2858	1121	2050	3722
621	1150	2102	860	1580	2876	1149	2100	3812
627	1160	2120	866	1590	2894	1177	2150	3902
632	1170	2138	871	1600	2912	1204	2200	3992
638	1180	2156	877	1610	2930	1232	2250	4082
643	1190	2174	882	1620	2948	1260	2300	4172
649	1200	2192	888	1630	2966	1288	2350	4262
654	1210	2210	893	1640	2984	1316	2400	4352
660	1220	2228	899	1650	3002	1343	2450	4442
666	1230	2246	904	1660	3020	1371	2500	4532

WEIGHT TABLES

The tables apply for unalloyed steel, density 7.85. Alloyed steel is somewhat heavier; high speed steel, for example, is approx. 10% heavier.

Flat bars kg/m

Width mm	Thickness mm										
	2	3	4	6	8	10	12	16	20	25	30
10	0.16	0.23	0.31	0.47	0.63	0.79	–	–	–	–	–
25	0.39	0.59	0.79	1.18	1.57	1.96	2.36	3.14	3.93	4.91	–
30	0.47	0.71	0.94	1.41	1.88	2.36	2.83	3.77	4.71	5.89	7.07
40	0.63	0.94	1.26	1.88	2.51	3.14	3.77	5.02	6.28	7.85	9.42
50	0.79	1.18	1.57	2.36	3.14	3.93	4.71	6.28	7.85	9.81	11.8
60	0.94	1.41	1.88	2.83	3.77	4.71	5.65	7.54	9.42	11.8	14.1
70	1.10	1.65	2.20	3.30	4.40	5.50	6.59	8.79	11.0	13.7	16.5
80	1.26	1.88	2.51	3.77	5.02	6.28	7.54	10.1	12.6	15.7	18.8
90	1.41	2.12	2.83	4.24	5.65	7.07	8.48	11.3	14.1	17.7	21.2
100	1.57	2.36	3.14	4.71	6.28	7.85	9.42	12.6	15.7	19.6	23.6
110	1.73	2.59	3.45	5.18	6.91	8.64	10.4	13.8	17.3	21.6	25.9
120	1.88	2.83	3.77	5.65	7.54	9.42	11.3	15.1	18.8	23.6	28.3
130	2.04	3.06	4.08	6.12	8.16	10.2	12.3	16.3	20.4	25.5	30.6
140	2.20	3.30	4.40	6.59	8.79	11.0	13.2	17.6	22.0	27.5	33.0
150	2.36	3.53	4.71	7.07	9.42	11.8	14.1	18.8	23.6	29.4	35.3
160	2.51	3.77	5.02	7.54	10.1	12.6	15.1	20.1	25.1	31.4	37.7
170	2.67	4.00	5.34	8.01	10.7	13.4	16.0	21.4	26.7	33.4	40.0
180	2.83	4.24	5.65	8.48	11.3	14.1	17.0	22.6	28.3	35.3	42.4
190	2.98	4.48	5.97	8.95	11.9	14.9	17.9	23.9	29.8	37.3	44.8
200	3.14	4.71	6.28	9.42	12.6	15.7	18.8	25.1	31.4	39.3	47.1
250	3.93	5.89	7.85	11.8	15.7	19.6	23.6	31.4	39.3	49.1	58.9
300	4.71	7.07	9.42	14.1	18.8	23.6	28.3	37.7	47.1	58.9	70.7
350	5.50	8.24	11.0	16.5	22.0	27.5	33.0	44.0	55.0	68.7	82.4
400	6.28	9.42	12.6	18.8	25.1	31.4	37.7	50.2	62.8	78.5	94.2
450	7.07	10.6	14.1	21.2	28.3	35.3	42.4	56.5	70.7	88.3	106
500	7.85	11.8	15.7	23.6	31.4	39.3	47.1	62.8	78.5	98.1	118
550	8.64	13.0	17.3	25.9	34.5	43.2	51.8	69.1	86.4	108	130
600	9.42	14.1	18.8	28.3	37.7	47.1	56.5	75.4	94.2	118	141
700	11.0	16.5	22.0	33.0	44.0	55.0	65.9	87.9	110	137	165
800	12.6	18.8	25.1	37.7	50.2	62.8	75.4	101	126	157	188
900	14.1	21.2	28.3	42.4	56.5	70.7	84.8	113	141	177	212
1000	15.7	23.6	31.4	47.1	62.8	78.5	94.2	126	157	196	236
1200	18.8	28.3	37.7	56.5	75.4	94.2	113	151	188	236	283

Flat bars kg/m

Width mm	Thickness mm										
	32	40	50	60	70	80	90	100	120	125	140
10	–	–	–	–	–	–	–	–	–	–	–
25	–	–	–	–	–	–	–	–	–	–	–
30	7.54	–	–	–	–	–	–	–	–	–	
40	10.0	12.6	–	–	–	–	–	–	–	–	–
50	12.6	15.7	19.6	–	–	–	–	–	–	–	–
60	15.1	18.8	23.6	28.3	–	–	–	–	–	–	–
70	17.6	22.0	27.5	33.0	38.5	–	–	–	–	–	–
80	20.1	25.1	31.4	37.7	44.0	50.2	–	–	–	–	–
90	22.6	28.3	35.3	42.4	49.5	56.5	63.6	–	–	–	–
100	25.1	31.4	39.3	47.1	55.0	62.8	70.7	78.5	–	–	–
110	27.6	34.5	43.2	51.8	60.5	69.1	77.7	86.4	–	–	–
120	30.1	37.7	47.1	56.5	65.9	75.4	84.8	94.2	113	–	–
130	32.7	40.8	51.0	61.2	71.4	81.6	91.9	102	125	128	–
140	35.2	44.0	55.0	65.9	76.9	87.9	98.9	110	132	137	154
150	37.7	47.1	58.9	70.7	82.4	94.2	106	118	141	147	165
160	40.2	50.2	62.8	75.4	89.7	101	113	126	151	157	176
170	42.7	53.4	66.7	80.1	93.4	107	120	134	160	167	187
180	45.2	56.5	70.7	84.8	98.9	113	127	141	170	177	198
190	47.7	59.7	74.6	89.5	104	119	134	149	179	186	209
200	50.2	62.8	78.5	94.2	110	126	141	157	188	196	220
250	62.8	78.5	98.1	118	137	157	177	196	236	245	275
300	75.3	94.2	118	141	165	188	212	236	283	294	330
350	87.9	110	137	165	192	220	247	275	330	343	385
400	100	126	157	188	220	251	283	314	377	393	440
450	113	141	177	212	247	283	318	353	424	442	495
500	126	157	196	236	275	314	353	393	471	491	550
550	138	173	216	259	302	345	389	432	518	540	605
600	151	188	236	283	330	377	424	471	565	589	659
700	176	220	275	330	385	440	495	550	659	687	769
800	201	251	314	377	440	502	565	628	754	785	879
900	226	283	353	424	495	565	636	707	848	883	989
1000	251	314	393	471	550	628	707	785	942	981	1099
1200	301	377	471	565	659	754	848	942	1130	1178	1319

Cont.

Flat bars kg/m

Width mm	Thickness mm										
	150	180	200	250	300	350	400	450	500	550	600
160	188	–	–	–	–	–	–	–	–	–	–
170	200	–	–	–	–	–	–	–	–	–	–
180	212	254	–	–	–	–	–	–	–	–	–
190	224	269	–	–	–	–	–	–	–	–	–
200	236	283	314	–	–	–	–	–	–	–	–
250	294	353	393	491	–	–	–	–	–	–	–
300	353	424	471	589	707	–	–	–	–	–	–
350	412	495	550	687	824	962	–	–	–	–	–
400	471	565	628	786	942	1099	1256	–	–	–	–
450	530	636	707	883	1060	1236	1413	1590	–	–	–
500	589	707	785	981	1178	1374	1570	1766	1963	–	–
550	648	775	864	1079	1295	1511	1727	1943	2159	2375	–
600	707	848	942	1178	1413	1649	1884	2120	2355	2591	2826
700	824	989	1099	1374	1649	1923	2198	2473	2748	3022	3297
800	942	1130	1256	1570	1884	2198	2512	2826	3140	3454	3768
900	1060	1272	1413	1766	2120	2473	2826	3179	3533	3886	4239
1000	1176	1413	1570	1963	2355	2748	3140	3533	3925	4318	4710
1200	1413	1696	1884	2355	2826	3297	3768	4239	4710	5181	5652

Round and square bars, kg/m

Size mm	●	■	Size mm	●	■	Size mm	●	■
1	0.006	0.008	43	11.4	14.5	85	44.5	56.7
2	0.025	0.031	44	11.9	15.2	86	45.6	58.1
3	0.055	0.071	45	12.5	15.9	87	46. 6	59.4
4	0.10	0.13	46	13.1	16.6	88	47.7	60.8
5	0.15	0.20	47	13.6	17.3	89	48.8	62.2
6	0.22	0.28	48	14.2	18.1	90	49.9	63.6
7	0.30	0.38	49	14.8	18.9	91	51.1	65.0
8	0.39	0.50	50	15.4	19.6	92	52.2	66.4
9	0.50	0.64	51	16.0	20.4	93	53.3	67.9
10	0.62	0.79	52	16.7	21.2	94	54.5	69.4
11	0.75	0.95	53	17.3	22.1	95	55.6	70.9
12	0.89	1.13	54	18.0	22.9	96	56.8	72.4
13	1.04	1.33	55	18.7	23.8	97	58.0	73.9
14	1.21	1.54	56	19.3	24.6	98	59.2	75.4
15	1.39	1.77	57	20.0	25.5	99	60.4	76.9
16	1.58	2.01	58	20.7	26.4	100	61.7	78.5
17	1.78	2.27	59	21.5	27.3	105	68.0	86.6
18	2.00	2.54	60	22.2	28.3	110	74.6	95.0
19	2.23	2.83	61	22.9	29.2	115	81.5	104
20	2.47	3.14	62	23.7	30.2	120	88.8	113
21	2.72	3.46	63	24.5	31.2	125	96.3	123
22	2.98	3.80	64	25.3	32.2	130	104	133
23	3.26	4.15	65	26.1	33.2	135	112	143
24	3.55	4.52	66	26.9	34.2	140	121	154
25	3.85	4.91	67	27.7	35.2	145	130	165
26	4.17	5.31	68	28.5	36.3	150	139	177
27	4.49	5.72	69	29.4	37.4	155	148	189
28	4.83	6.15	70	30.2	38.5	160	158	201
29	5.19	6.60	71	31.1	39.6	165	168	214
30	5.55	7.07	72	32.0	40.7	170	178	227
31	5.92	7.54	73	32.8	41.8	175	189	240
32	6.31	8.04	74	33.8	43.0	180	200	254
33	6.71	8.55	75	34.7	44.2	185	211	269
34	7.13	9.07	76	35.6	45.3	190	223	283
35	7.55	9.62	77	36.6	46.5	195	234	299
36	7.99	10.2	78	37.5	47.8	200	247	314
37	8.44	10.8	79	38.5	49.0	205	259	330
38	8.90	11.3	80	39.5	50.2	210	272	346
39	9.38	11.9	81	40.5	51.5	215	285	363
40	9.86	12.6	82	41.5	52.8	220	298	380
41	10.6	13.2	83	42.5	54.1	225	312	397
42	10.9	13.9	84	43.5	55.4	230	326	415

Cont.

Round and square bars, kg/m

Size mm	●	■	Size mm	●	■
235	340	434	445	1221	1555
240	355	452	450	1248	1590
245	370	471	455	1276	1625
250	385	491	460	1305	1661
255	401	510	465	1333	1697
260	417	531	470	1362	1734
265	433	551	475	1391	1771
270	449	572	480	1420	1809
275	466	594	485	1450	1847
280	483	615	490	1480	1885
285	501	638	495	1511	1923
290	518	660	500	1541	1963
295	537	683	550	1865	2375
300	555	707	600	2219	2826
305	573	730	650	2605	3317
310	592	754	700	3021	3847
315	612	779	750	3468	4416
320	631	804	800	3946	5024
325	651	829	850	4454	5672
330	671	855	900	4994	6359
335	692	881	1000	6165	7850
340	713	907			
345	734	934			
350	755	962			
355	777	989			
360	799	1017			
365	821	1046			
370	844	1075			
375	867	1104			
380	890	1134			
385	914	1164			
390	938	1194			
395	962	1225			
400	986	1256			
405	1011	1288			
410	1036	1320			
415	1062	1352			
420	1088	1385			
425	1114	1418			
430	1140	1451			
435	1167	1485			
440	1194	1520			

DESIGNATIONS

HB	Hardness Brinell
HRB	Hardness Rockwell B
HRC	Hardness Rockwell C
HV	Hardness Vickers

KCU	Impact toughness in kpm/cm^2 at use of U-notched specimen
KU	Impact toughness in Joule at use of Charpy U-notched specimen
KV	Impact toughness in Joule (earlier in kpm) at use of V-notched specimen

N	Newton, unit for force

A_5	Elongation in percentage of length after fracture. Measuring length when round specimens are used: L=5d. Diameter: d, is the original diameter.

R_m	Tensile strength	R_{mb}	Bending strength
$R_{p0.2}$	0.2% proof strength	R_m	Compressive strength

Z	Reduction of area (%)

SOME TECHNICAL INFORMATION FROM UDDEHOLMS AB

Tool steel application
Uddeholm steel for cold work tooling
Uddeholm steel for die casting
Uddeholm steel for extrusion
Uddeholm steel for forging applications
Uddeholm steel for moulds
Uddeholm component business
Stamping with Uddeholm Vancron 40 SuperClean

Treatment of tool steel
EDM of tool steel
Grinding tool steel
Heat treatment of tool steel
Photo-etching of tool steel
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