Cold-Work Tool Steel and High-Speed Steel

Deutsche Edelstahlwerke

Member of Swiss Steel Group

Supreme quality requires outstanding steel

Today tools made of cold-work and high-speed steel need to fulfil ever-increasing requirements.

On the one hand this is the consequence of more modern production facilities and optimized manufacturing processes. On the other hand these stem from constantly increasing demands made on the quality of the products to be manufactured.

As a consequence, the use of precisely the correct steel with the best performance characteristics for the tool application is decisive. Only when these considerations are borne in mind can the length of a tool's service life be guaranteed and at the same time, ensure an economic production with reduced unit costs.

The correct alloy composition is of utmost importance in order to attain a steel's material properties which will be most appropriate for the application required.

These properties can be fine-tuned through calculating the varying quantities of the elements used in an alloy, such as chromium, molybdenum, tungsten and vanadium. Besides overseeing the optimal proportioning of the main elements, close attention is paid to keeping undesirable accompanying components to an absolute minimum.
This approach enables the supply of cold-work tool steel and high-speed steel for virtually every need and application.
Cold-work tool steels are employed at operating temperatures reaching around 200 °C and are characterized by high levels of wear resistance. They also show good toughness properties depending on the intended application.

High-speed steel consists entirely of high-alloy tool steel, which retain necessary high working hardness of approximately 60 to 67 HRC at operating temperatures of nearly 600 °C. Its operational characteristics partly stem from a high carbide content resulting in very high wear resistance.

Deutsche Edelstahlwerke – the cold-work tool steel and high-speed steel experts

Deutsche Edelstahlwerke now belongs to the world's top-ranking manufacturers of cold-work tool steel and high-speed steel.

This advantageous position is based on the company's experience in steel production spanning more than 150 years, the continuous lead in casting technology and an exceptionally wide range of products and services offered, comprising several thousands of sizes and shapes.

The diversity of materials ranges from ordinary shell-hardenable steel to extremely high-alloy maraging cold-work tool steel. And for every type of application we deliver tailor-made steel grades, which excel themselves through the following properties:
» very good wear resistance
» high compression strength
» excellent toughness

So as to offer tool manufacturers and industrial users optimal conditions, Deutsche Edelstahlwerke has extended its services into customer and application-specific consultation, as well as advice on product development.

Deciding on the perfect tool steel with us starts with consulting our cold-work tool steel and high-speed steel specialists. Together with the toolmaker, the demands on the final product and on the required steel grade are defined.

Deutsche Edelstahlwerke's commitments to ongoing improvements and the refining of present steel, as well as the development of new steel grades are the result of the symbiotic relationship with tool-makers and users.

It is the perfect incentive to engineer and test newly developed materials, alloying concepts and production methods.
Our clients are offered the possibility to be integrated in the decision-making process from the extent to which customer-specific pre-machining should take place right through to the manufacture of components, such as cold rolls.

Deutsche Edelstahlwerke delivers individual sizes ex-warehouse.

Process reliability from consultation to the final product

The requirements made of cold-work tool steel are exceptionally diverse. This is why appropriate adjustments of the different alloy components, as well as a relevant treatment during steel production are imperative so as to produce a steel grade which is in perfect accord with the envisaged application.

So as to ensure that the client's demands are met, we rely on a highly experienced group of specialists in the cold-work tool steel and high-speed steel area. Together with the tool manufacturers, the specialists constitute a perfectly coordinated team to determine which steel grade and quality is most appropriate to each individual demand profile.

To complement our steel specialists' extensive knowledge, we are in a position to rely on very modern production facilities backed up by decades of experience in every area dealing with heat treatment. In addition to this, our active and certified quality assurance system (DIN EN 14001, DIN EN ISO 9001, QS 9000, VDA 6.1 TS 16949 and KTA 1401) guarantees the production of an individually defined steel grade with continuous quality consistency.

Should problems occur in a tool's service life, our technicians are happy to provide necessary support and advice. Through assessment and material testing, they are in the position to produce findings that lead to rapid repairs enabling long-term trouble-free operation.

Precision for the tool manufacturer

Competent advice for our clients ranges from the choice of the most suitable steel grade through to the development of specific tool steel grades. Not only is there a choice between the various forms deliverable from our extensive stock and product range, but clients also determine whether the tool is to be supplied in a pre-machined or ready-to-install state.

Deutsche Edelstahlwerke then rapidly and reliably delivers the chosen steel grade, in any quantity desired – always in consistent quality.

This applies to all important markets worldwide. Our global supply network via the Swiss Steel Group ensures dependable delivery and the finest on-site quality.

We guarantee our clients customized precision from the steel production stage right through to machining – and this tool for tool.

The benefits for tool manufacturers are:

» individual material solutions
» consistently high quality
» reproducible material properties such as microstructure and purity
» good machinability
» low-distortion heat treatment
» very short delivery times
» competent consultancy
» development of new steel grades

Economic benefits for the user

Cost efficiency is achieved through three main criteria: through constantly high quality, long tool lives with reduced costs and a minimization of downtimes together with minimal tool breakage and edge roughness.

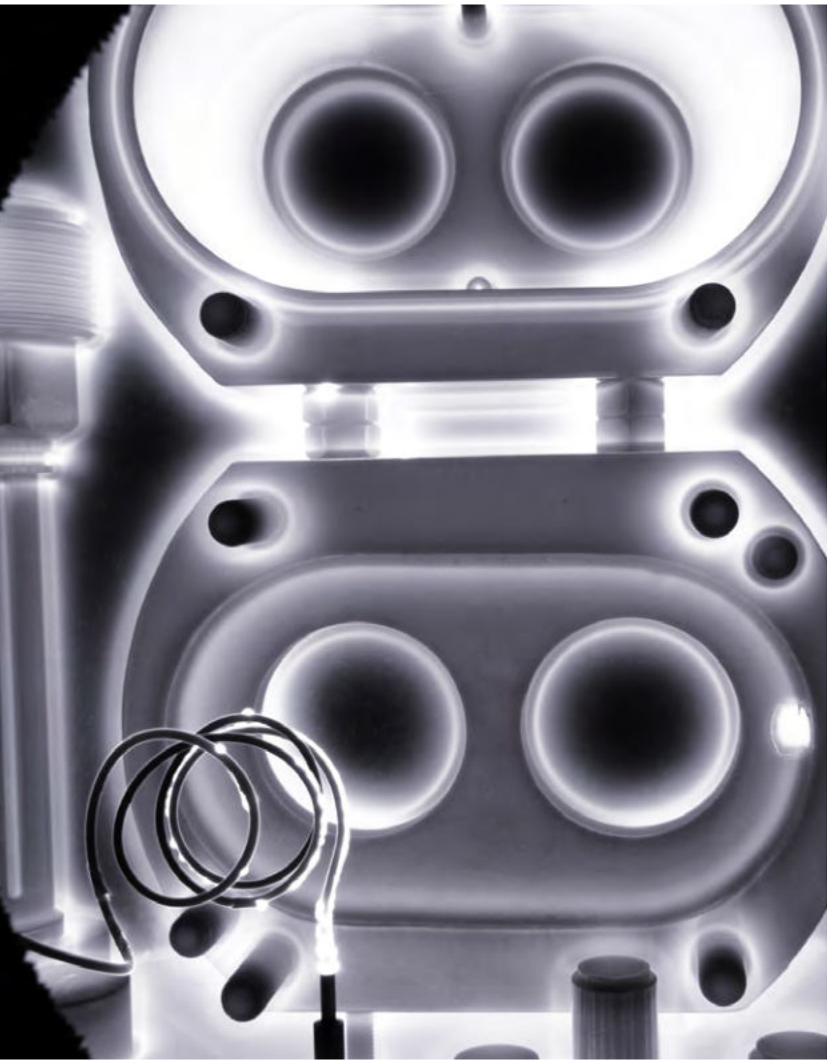
Thanks to the outstanding performance features of our cold-work tool steel and high-speed steel grades, these criteria are met and at the specified degree.

Innovative material technology coupled with decades of experience in the production of high-grade steel long products and our practice-oriented technical consultancy mean production dependability from the very start. This places us in a reliable position to produce steel grades which are precisely tailored to the respective demand profile. From the client's perspective, this creates the chance to reduce unit cost by a more efficient control of their production processes.

The resulting benefits for the user are:
» high wear resistance
» good hardenability
» balanced toughness
» high compression strength
» dimensional stability
» profitable machinability
» long service lives
» low tool costs
» less machine downtime
» higher profitability

Areas of application

The special advantages of Deutsche Edelstahlwerke's cold-work tool steel and high-speed steel grades make them the first choice for numerous industrial tool applications, especially in the areas of:
» cutting, punching and shearing
» coining, pressing and bending
(cold solid forming, cold extrusion and deep drawing)
» rolling
(for cold, straightening and bending rolls)
» comminuting
(granulating, chipping and shredding)
» folding and guiding
» machining
(drilling, sawing and milling)
» tool holders
» hand and power tools



Our technology and experience – your guarantee for premium quality

The purity and homogeneity of our cold-work tool steel and high-speed steel stem from producing them in our modern steelworks at Witten and Siegen. We fulfil our clients' predefined demands by means of precision alloying and using process specifications for melting, shaping and heat treatment.

The tool steels produced by Deutsche Edelstahlwerke are melted in 130-ton electric arc furnaces. A subsequent analytical fine-tuning is carried out in a ladle furnace, followed by vacuum degassing of the steel just before casting.

In order to cast the metallurgically treated molten metal, two processes can be applied depending on the required size of the final product. Usually an optimized vertical continuous casting method is used, but for large forging sizes, ingot casting is employed.

Custom remelting

For tool steel grades having to satisfy especially high levels of toughness, homogeneity and purity standards, Deutsche Edelstahlwerke has several electroslag remelting furnaces (ESRs) and one vacuum-arc remelting furnace (VAR) at its disposal. The decision as to which process and furnace to use is predetermined by the desired quality the remelted steel should have. Electroslag remelting (ESR) produces noticeably refined sulfidic purity in comparison to non-remelted steel. To improve oxidic purity, vacuum-arc remelting (VAR) is applied.

Individually variable heat treatment

The integration of the previous Thyssen hardening shops into the Deutsche Edelstahlwerke group has enabled us to build on decades of tradition in all fields of heat treatment. From a practical point of view, we are now able to manufacture products using the complete production chain – starting with steel production, via pre-machining to refining through to heat treatment. Our one-stop solution is invaluable for the world's most important markets and facilitates fulfilment of the most discerning tool quality prerequisites.

In our hardening shops of the Swiss Steel Group across the continents, we have vacuum-tempering furnaces, inert gas plants and plasma-nitriding plants for thermo-chemical treatments at our disposal. Thanks to computer-controlled process flows, the reproducibility of heat treatment is guaranteed at any time – from the initial inspection of incoming shipments through to the final heat-treated product.

A bonus for our clients

Through the use of a precision-hardening process – a Deutsche Edelstahlwerke development – we are in the position to reduce the deformation of thin components to a minimum (e.g. with guide strips).

Overview of cold-work tool steel and high-speed steel

Cold-work tool steel and high-speed steel	Cutting punching shearing	Coining pressing bending	Rolling	Comminuting	Folding guiding	Machining	Tool holders	Hand and power tools
Cryodur® 1520	●							●
Cryodur® 1730	●				●			●
Cryodur® 2002								●
Cryodur® 2008								●
Cryodur® 2067	●	●	●		●			
Cryodur® 2080	●	●	●					
Cryodur® 2101	●	●			●			
Cryodur® 2201	●	●						
Cryodur® 2210	●							●
Cryodur® 2235	●							●
Cryodur® 2242								●
Cryodur® 2243	●							●
Cryodur® 2249	●							●
Formadur® 2312					●		●	
Cryodur® 2327			●					
Cryodur® 2328								●
Thermodur® 2343	● [1]		● [1]				●	● [1]
Thermodur® 2344	● [1]						●	●
Cryodur® 2357	●	●						●
Cryodur® 2360	●	●	●	●				
Cryodur® 2362		●	●					
Cryodur® 2363	●		●					
Cryodur® 2379	●	●						●
Cryodur® 2381	●							●
Cryodur® 2436	●							
Cryodur® 2510	●	●			●			
Cryodur® 2516	●	●						●
Cryodur® 2550	●	●		●			●	●

[1] *also suitable for thermal stress*

Cold-work tool steel and high-speed steel	Cutting punching shearing	Coining pressing bending	Rolling	Comminuting	Folding guiding	Machining	Tool holders	Hand and power tools
Cryodur® 2709	●							
Thermodur® 2714	● [1]	●	●				●	
Cryodur® 2721	●	●					●	
Cryodur® 2743				●				
Cryodur® 2746				●				
Formadur® 2764							●	
Cryodur® 2766								●
Cryodur® 2767	●	●						●
Cryodur® 2826	●				●		●	●
Cryodur® 2833	●	●						
Cryodur® 2842	●	●			●			
Cryodur® 2990	●	●	●					
Rapidur® 3202						●		
Rapidur® 3207						●		
Rapidur® 3243	●					●		
Rapidur® 3247		●				●		
Rapidur® 3333	●					●		
Rapidur® 3343	●	●	●			●		
Rapidur® 3344	●	●				●		

[1] *also suitable for thermal stress*

Cutting, punching and shearing

The cutting, punching and shearing of metallic and non-metallic materials belong to the most demanding tasks cold-work tool steel tools are subjected to. Besides cutting and shearing, there are virtually no other applications where the tool's properties have such an influence on the process.

The design of cutting, punching or shearing tools is generally determined by three variables – the precision that will be required of it, the nature of the material to be cut and the intended batch volumes in production. Apart from the tool's functional design, an optimal choice of steel as well as heat treatment and where necessary, surface coating will determine the tool's service life.

Specific stresses which, for example, punches and dies are exposed to, are largely dependent on blade clearance. With decreasing clearance, the forces acting on the blades increase significantly resulting in the cutting edges chipping or blunting prematurely. So as to avoid such eventualities, the use of more highly alloyed ledeburitic cold-work tool steel and high-speed steel is recommended.

Where blade clearance increases, the material is drawn into the interstices leading to major bursting and bending stresses on the tools. To prevent this occurence, the materials have to possess a very high toughness potential. This is where Cryodur® 2709, Cryodur® 2746 and Cryodur® 2767 come into play. For the highest demands on wear resistance we recommend our high-speed steel.

High-performance steel for cutting, punching and shearing

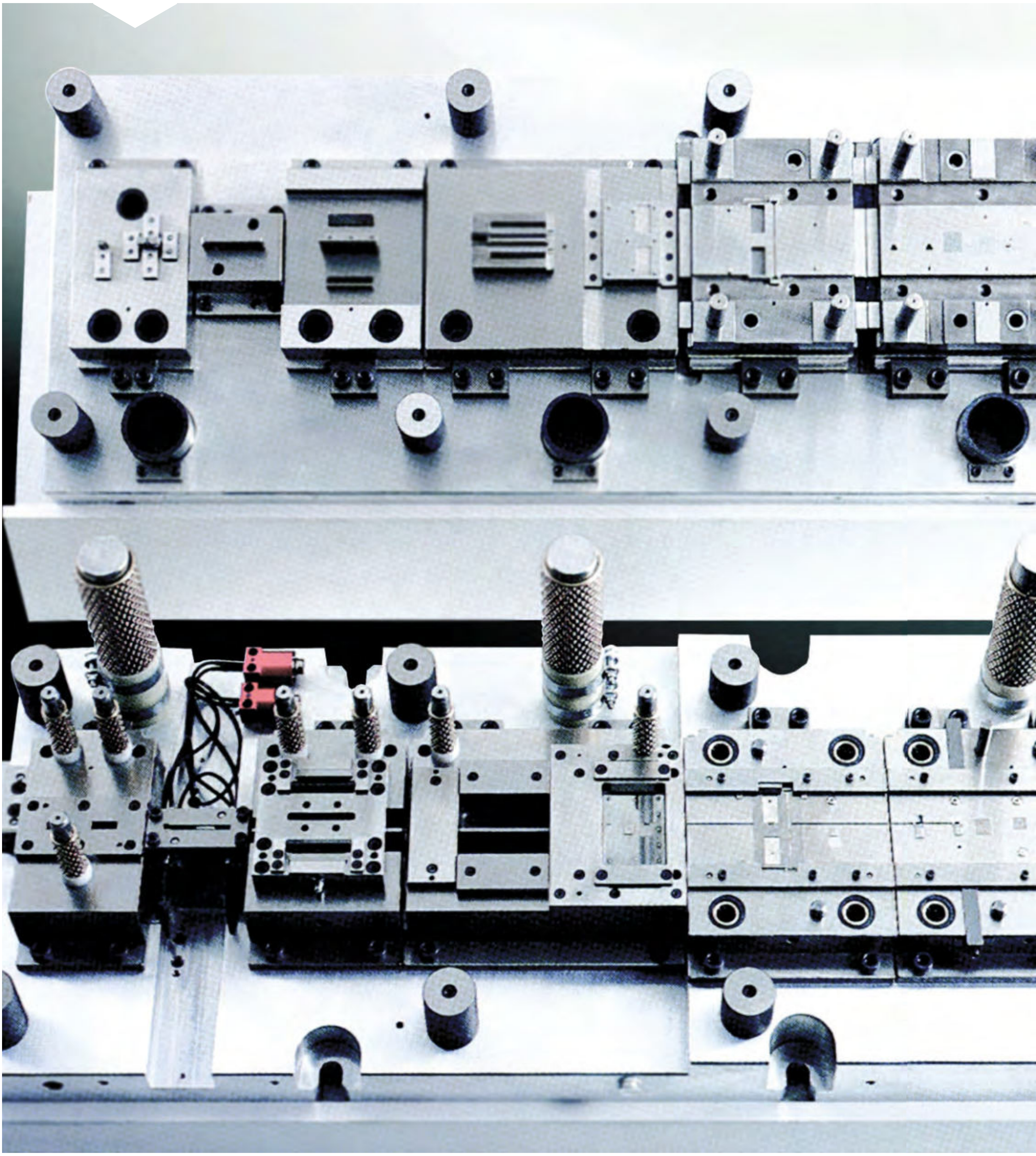
In addition to a wide range of globally established high-quality standard steel grades, Deutsche Edelstahlwerke provides further steels with specific qualities for cutting, punching and shearing. We have highlighted the following steel grades as most representative of our complete range.

Cryodur® 2379 is a 12 % ledeburitic chromium steel featuring high wear resistance and toughness. During vacuum heat treatment in particular, it displays its highly developed through-hardening properties. Precision cutting tools are among typical operational applications made of this high-carbon steel for cutting dies.

Cryodur® 2516, a special steel with maximum dimensional stability and outstanding wear resistance combined with a keen cutting edge, is preferred for use in high-performance cutting during thin sheet and strip processing with cutting material thicknesses of up to approximately 3 mm.

Cryodur® 2550 is an oil-hardening, impact-resistant, tungsten-alloyed high-performance steel for cutting dies. Due to its very good toughness and high hardenability, it is employed to cut sheet of medium thicknesses.

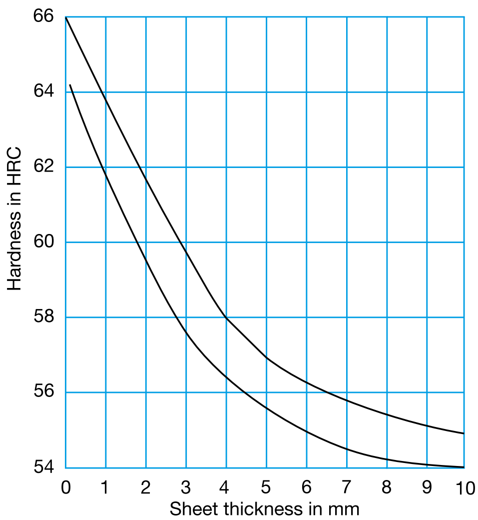
Cryodur® 2990 is characterized by particularly high hardness, strength and adhesive wear resistance. Through improving the toughness compared to Cryodur® 2379, enhanced fracture strength has been achieved resulting in a prolonging of service life. Cryodur® 2990 features good EDM properties, smooth surface treatment and trouble-free inductive hardening.



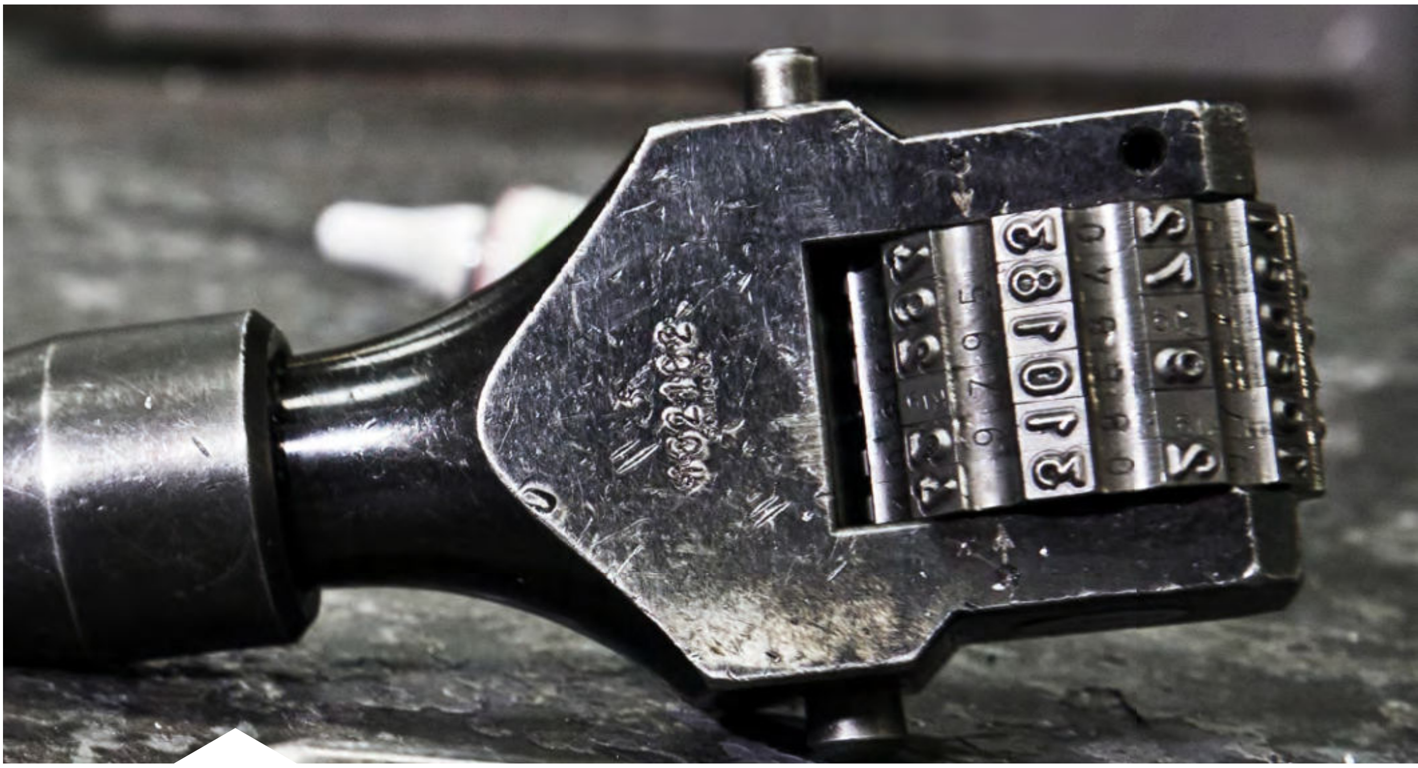
High-performance steel for cutting, punching and shearing

We recommend this grade for rotary cutters, rotary shear blades, punches, dies and progressive die applications.

Rapidur® 3343 is a standard high-speed steel grade with multiple applications. Its balanced alloy composition forms the basis of its high toughness, wear resistance and good cutting edge retention.



Effective working hardness dependent on sheet thickness.
(Above complements adjacent table on 'Grades for cutting, punching and shearing')



Property comparisons and applications

Group-specific property comparisons

Grade	Tensile strength	Through hardening	Toughness	Wear resistance
Cryodur® 2067	● ●	○	●	● ●
Cryodur® 2080	● ● ●	● ●	○	● ● ●
Cryodur® 2101 mod	● ●	● ● ●	●	● ●
Cryodur® 2243 mod	●	●	● ● ●	●
Cryodur® 2360	● ●	● ● ●	● ●	● ●
Cryodur® 2363	● ●	● ●	●	● ●
Cryodur® 2379	● ● ●	● ● ●	●	● ● ●
Cryodur® 2436	● ● ●	● ●	○	● ● ●
Cryodur® 2510	● ●	○	●	● ●
Cryodur® 2516	●	● ● ●	●	● ●
Cryodur® 2550	●	○	● ●	●
Cryodur® 2746	●	● ● ●	● ● ●	●
Cryodur® 2767	●	● ● ●	● ● ●	●
Cryodur® 2842	● ●	○	●	● ●
Cryodur® 2990	● ● ●	● ● ●	● ●	● ●
Rapidur® 3343	● ● ●	● ● ●	●	● ● ●

Grades for cutting, punching and shearing

Material to Process	Thickness	Grade	Working hardness in HRC
Sheet steel, strip steel, aluminium and aluminium alloys, copper and copper alloys	up to 4 mm	Cryodur® 2080 Cryodur® 2436 Cryodur® 2516	58 – 62 58 – 62 59 – 63
	up to 6 mm	Cryodur® 2379 Cryodur®2363	56 – 60 56 – 60
	up to 12 mm	Cryodur® 2510 Cryodur® 2842	56 – 60 56 – 60
	over 12 mm	Cryodur® 2550 Cryodur® 2767 Cryodur® 2243 mod Cryodur® 2101 mod	54 – 58 48 – 52 52 – 59 50 – 58
Transformer and dynamo sheet, dynamo strip	up to 2 mm	Cryodur® 2436	60 – 63
	up to 6 mm	Cryodur® 2379	58 – 62
Austenitic steel grades	up to 4 mm	Cryodur® 2379 Rapidur® 3343	60 – 62 60 – 64
	up to 6 mm	Cryodur® 2379 Rapidur® 3343	58 – 62 58 – 62
	up to 12 mm	Cryodur® 2550	54 – 58
	over 12 mm	Cryodur® 2767	50 – 54
Metallic sheet and strip	up to 4 mm	Cryodur® 2379 Cryodur® 2516 Rapidur® 3343	60 – 62 59 – 63 60 – 64
	up to 6 mm	Cryodur® 2379 Rapidur® 3343	58 – 62 58 – 62
	up to 12 mm	Cryodur® 2379 Rapidur® 3343 Cryodur® 2243 mod Cryodur® 2101 mod	56 – 60 56 – 60 52 – 59 50 – 58
Plastics, wood, rubber, leather, textiles and paper		Cryodur® 2080 Cryodur® 2379 Cryodur® 2436 Cryodur® 2510 Cryodur® 2550 Cryodur® 2842	58 – 63 58 – 62 58 – 63 57 – 61 54 – 58 58 – 63

Coining, pressing and bending

Metals take on new, specified physical qualities through cold solid forming, deep drawing, coining and cold extrusion processing methods.

During cold solid forming, materials are transformed into their final shape by cold forming or extrusion. Depending on the method employed, the forming tools can be exposed to extremely high wear resulting from pressure and abrasion.

The coining or embossing process, especially the minting of coins, creates unusually high demands on the steels used for punches and dies when it comes to purity, compression strength and wear resistance. In the mints where the coins are produced, even the slightest divergences relating to surface, dimensional or gravimetric accuracy result in the tools being taken out of service. This strongly underlines the importance of the tool steel quality employed.

The demands the deep-drawing process makes on the physical formability of the material used are very considerable. At the same time the increasing tendency to reduce material costs is nowadays accompanied by cutbacks in wall thickness. The tools employed in this manufacturing process are subject to exceptional attrition – in particular at the edges and on radii. With respect to production profitability, all these factors require tool properties that comply with the highest standards of dimensional stability, tolerance and surface quality.

Cold extrusion – in particular the production of cold-extruded steel components – places enormous strains on tools when it comes to toughness and wear resistance. This is due to the forces required for this type of cold forming, which lead to immense compression and tensile stresses. This scenario can lead to permanent deformation or even cracking. To reduce these two types of stress, material-related preloads are utilized in the form of reinforcement rings. Our nickel-alloyed Cryodur® 2721 in particular is recommended for such rings. The pelleting process, which necessitates a uniform high dimensional accuracy, more than any other characteristic, requires a fine, nonporous surface. The latter is achieved through the homogeneous microstructure of the pelleter, which enables absolutely perfect micro-engraving. So as to facilitate an uncomplicated removal of the pelletized material without sticking, pelleters may be coated using various methods.

High-performance steel for coining, pressing and bending

Besides their established high-quality standard steel grades featuring a diversity of alloys, Deutsche Edelstahlwerke supplies steel grades with special qualities for coining, pressing and bending tools. The steels in question excel themselves through high toughness and wear resistance. We have chosen five steel grades representative of a larger selection.

Cryodur® 2357 is an air-hardening cold-work tool steel with very good toughness even at high strengths. It is preferentially used for pelleters.

Cryodur® 2550 is an impact-resistant, tungsten-alloyed cold-work tool steel featuring very good toughness combined with high hardenability. This grade is strongly recommended for use with preforming and tablet press punches. When it comes to coining, Cryodur® 2550 has proven itself a good economic alternative to HSS. Where superior toughness is required, nickel-alloyed grades such as Cryodur® 2767 are preferred.

Cryodur® 2767 is a cold-work tool steel, the nickel content of which assures improved hardenabiltiy, toughness and polishability. Its uses include solid embossing tools, bending tools and cutlery dies.

Cryodur® 2842 is a standard grade used for less heavily stressed coining dies with low-profile engraving.

Rapidur® 3343 is a high-speed grade which is universally applicable for cold solid forming and deep-drawing tools and is characterized by high toughness and wear resistance.

Group-specific property comparisons

Grade	Wear resistance	Compression strength	Toughness	Polishability
Cryodur® 2357	●	● ●	● ● ●	● ● ●
Cryodur® 2360	● ●	● ●	● ●	● ●
Cryodur® 2379	● ● ●	● ● ●	○	●
Cryodur® 2550	●	●	● ●	● ●
Cryodur® 2721	○	●	● ● ●	● ● ●
Cryodur® 2767	○	●	● ● ●	● ● ●
Cryodur® 2842	●	●	●	● ●
Cryodur® 2990	● ●	● ● ●	● ●	●
Rapidur® 3343	● ● ●	● ● ●	○	●

Rolling

Cold rolling is a forming process which takes place below recrystallization temperature. It involves further reduction of already hot-rolled strip and a determining of the mechanical and technological properties of the same strip.

Due to specific requirements during processing, cold rolling is regarded as a speciality within the diverse application areas of cold-work tool steel.

Steel supplied by Deutsche Edelstahlwerke for cold-working is largely employed in the classical segments of the cold-rolling industry. They nevertheless have uses in other fields such as back-up rolls, straightening and section-bending rolls.

For the cold forming of strips made from low and high-alloyed steel as well as of strips and foils made of non-ferrous metals, Deutsche Edelstahlwerke produces work rolls for two-high mills together with work and back-up rolls for four-high and six-high mills. We additionally equip cluster mills with work, interior and exterior intermediate rolls.

We manufacture cold rolls on site which are supplied as ready-to-install tools. This enables us to adapt the metallurgical and technological properties of steel grades precisely and individually to our client's specific requirements.

The use of special smelting-reduction processes, such as electroslag remelting (ESR) or vacuum arc remelting (VAR), assures compliance with demands on surface quality, purity and isotropy. Modern forging units guarantee ultimate shaping with high compression of the core area.

Our forging press and radial forging machines enable the production of forged-to-shape blanks with dimensions close to the final gauge. The blanks are supplied annealed or in quenched and tempered condition.

For the finish-machined products, Deutsche Edelstahlwerke is equipped with hardening units for inductive surface hardening and soaking pits for through hardening of the steels. Machining is performed on our modern machining centres.

Every roll is extensively tested as part of our guarantee for consistent premium delivery quality. For any client inquiries and specific advice on applicational use, a qualified team of engineers and steel experts is ready to be of assistance.

High-performance steel for rolls

The following are some of the grades which Deutsche Edelstahlwerke supplies for cold rolls, leveller rolls, section-bending and straightening rolls.

Cryodur® 2327 is a 2 % chromium steel, which on account of its alloy content, offers a balanced ratio of hardening depth, hardness and toughness.
We supply this grade in various alloy variations. For specific demands we offer a remelted quality.

Cryodur® 2326, a 5 % chromium steel, is characterized by improved compression strength in comparison to Cryodur® 2327. Depending on requirements and intended application, Cryodur® 2362 can be used in either through-hardened or case-hardened form. This grade is preferred for intermediate rolls.

Group-specific property comparisons

Grade	Wear resistance	Compression strength	Toughness	Polishability
Cryodur® 2327	● ●	●	● ● ●	● ●
Cryodur® 2362	● ●	● ●	●	○
Cryodur® 2363	● ● ●	● ●	●	○
Cryodur® 2364	● ●	● ●	● ●	● ● ●
Cryodur® 2379	● ● ●	● ● ●	○	○
Rapidur® 3343	● ● ●	● ● ●	●	○

Comminuting

The comminuting of mineral and metallic materials, plastics and wood is a necessary and decisive economic factor for many industrial manufacturing processes.

Whether for the granulating of plastics, wood chipping or metal shredding, the tools, as well as the steel they are made from, have to cope with very considerable wear resistance, impact strength and hardness caused by a broad spectrum of very varied operational conditions.

For the comminuting of plastics, highly wear-resistant ledeburitic chromium steel grades are standard for use with granulating blades. Where exceptional demands are made on the blades, our specialty material Ferro-Titanit® guarantees ultimate wear resistance.

Specially alloyed cold-work tool steel grades have been developed for wood chippers and especially for wood processing. These grades are characterized by appropriate hardness combined with high toughness and high wear resistance.

For shredding – for example with scrap choppers – forged high nickel cold-work tool steels are used, as they best cope with the increasing demands on mechanical properties and toughness.

High-performance steel for comminuting

Deutsche Edelstahlwerke supplies a broad assortment of premium quality alloyed cold-work tool steel for granulating, chipping and shredding tools.

Cryodur® 2360, a 7 % chromium steel, has proven particularly successful in wood processing. Its good wear resistance and high hardness are derived from a well-balanced alloy-components ratio – namely molybdenum, vanadium and tungsten – combined with a medium carbon content.

Cryodur® 2379 is a preferred choice for granulating blades to be used for comminuting. This grade offers a balanced ratio of high hardness and good wear resistance.

Cryodur® 2743 is a high nickel cold-work tool steel. Its fine combination of hardness, wear resistance and toughness is particularly noteworthy. Cryodur® 2743 is mainly used for tools in shredders.

Cryodur® 2746 is a high-performance high nickel cold-work tool steel. This air and oil-hardening grade featuring maximum impact resistance is utilized for cold-shear blades, which are primarily for scrap chopping.

Group-specific property comparisons

Grade	Hardness	Wear resistance	Toughness
Cryodur® 2360	●	● ●	● ●
Cryodur® 2379	● ●	● ● ●	●
Cryodur® 2550	●	●	● ●
Cryodur® 2743	● ●	● ●	● ●
Cryodur® 2746	●	●	● ● ●
Cryodur® 2842	● ●	●	●
Rapidur® 3343	● ● ●	● ● ●	●

Guiding and folding

Ongoing improvements and continued developments in machine tool construction have resulted in increasingly complex requirements relating to the quality and profitability of tool systems.
This is well illustrated by hardened guide and sliding rails for machine tools, which are now some of the most important components on the market.
There is an abundance of requirements the steel for such guide rails have to fulfil. Necessary mechanical properties are high abrasive resistance together with good fracture toughness and high dimensional stability when under permanent stress.

It is precisely these properties that distinguish Deutsche Edelstahlwerke's through-hardening cold-work tool steel. In addition, they are easily hardened with as good as no distortion. Their machinability is impeccable and they guarantee a high-quality surface finish.

The efficiency of the steel grades made by Deutsche Edelstahlwerke is equally superior when it comes to modern folding processes.

Present-day folding technology – increasingly supported by intelligent material configurations and profitable nesting software – enables the user of press brakes to manufacture highly accurate folding products.

Ultimately success depends on the degree of application specification and the efficiency of tool systems made from high-performance steel. The steel grades themselves have to ensure the following standards: high wear resistance and flexural fatigue strength, good machinability, good hardenability and virtually stress-free as-delivered condition.

According to customer requirements, Deutsche Edelstahlwerke's high-performance steel grades are delivered stress-relieved and pre-hardened or through-hardened. Alternatively they may be given induction treatment on site at the customer.

High-performance steel for guiding and folding

In the guiding and folding sector Deutsche Edelstahlwerke supplies an extensive variety of high-quality quenched and tempered cold-work tool steel grades. It is worth highlighting the following steel grades from our product range.

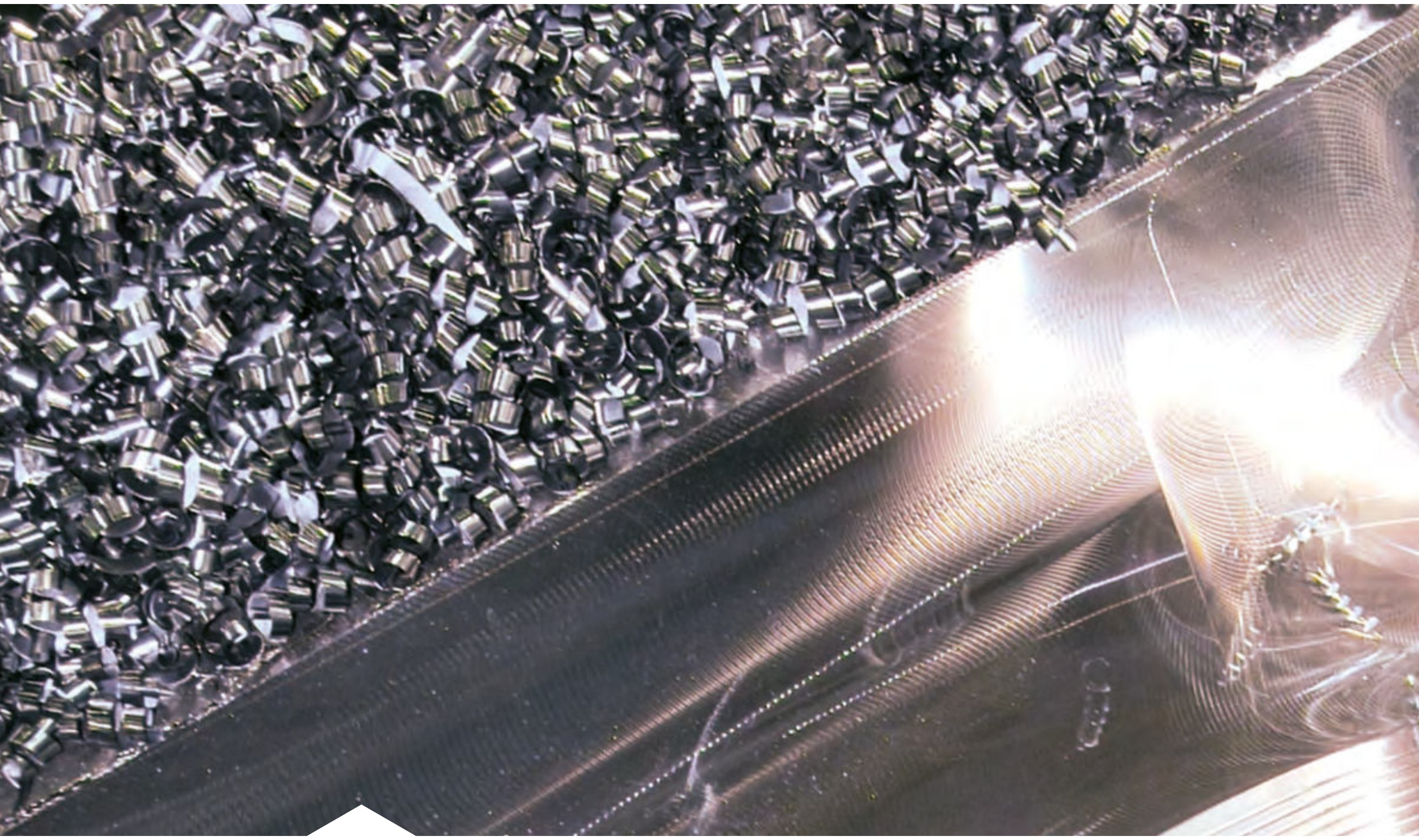
Cryodur® 2067 is characterized by a well-balanced property profile. This grade is most commonly used for guide rails.

Formadur® 2312 is a high-performance brake die steel originally designed for plastic mould construction. The grade, which features very good machinability, is delivered at a hardness of 280 to 325 HB.

Cryodur® 2842 is a universal cold-work tool steel for guide rails. It offers improved through hardening in comparison to the standard guide rail grade Cryodur® 2067.

Group-specific property comparisons

Grade	Machinability	Achievable surface	Wear resistance
Cryodur® 2067	● ●	● ●	● ●
Formadur® 2312	● ● ●	●	●
Cryodur® 2510	● ●	● ● ●	● ●
Cryodur® 2842	● ●	● ● ●	● ●



Machining

The machining process enables the user to obtain components of a desired shape. Boring, turning and sawing are all means to this end.

When selecting a material appropriate for metal-cutting tools, the machining conditions and the properties of the material to be machined need to be taken into account.

This is becoming ever more relevant with demands for higher profitability, longer service life, lighter construction, greater comfortability and product safety. The selection process also generates an increasing use of more metal and plastic-based composites as well as materials of a more tensile nature.

A diverse range of cold-work tool steel is available for machining purposes. Here though, we would primarily like to address the area of high-speed steel.

The latter steel retain its indispensably high-hardness properties up to operating temperatures of 600 °C. In this way, enhanced machining requirements can be realised for longer time periods without a decrease in cutting efficiency or cutting-edge retention. The key characteristics of high-speed steel are high hardenability, fine wear resistance, good toughness and high tempering resistance combined with red hardness.

Different ratios of the alloy components carbon, tungsten or molybdenum, vanadium, cobalt and chromium result in steel with very individual properties. The ensuing diversity places us in a strong position to supply the customer with high-speed steel grades designed for every possible demand and application.

Deutsche Edelstahlwerke has many years of experience at its disposal when it comes to high-speed steel production, with the consequence that we can guarantee higher levels of quality by applying calculated measures when smelting, casting and processing.

High tempering resistance facilitates certain surface treatments such as nitriding. This not only causes a decreased tendency to adhere and to cold lap, but also increases abrasive wear resistance.

The considerable diversity of materials and variations in products and components means that the correct choice of steel grade for metal-cutting tools becomes paramount.

Our long-term experience with material-specific chip formation and wear processes, the knowledge of our material experts as well as a coordinated cooperation with scientists are guarantors for the premium quality of our cold-work tool steel and high-speed grades – regardless for which purpose the steel is planned.

High-performance steel for machining

Deutsche Edelstahlwerke's spectrum of high-performance steel for machining comprises pre-hardened grades, which we deliver in annealed or quenched and tempered condition (HSS). We have highlighted the following steel grades as most representative of our comprehensive range.

Cryodur® 2210, which is primarily used for wood drills, is a chromium-vanadium cold-work tool steel with high wear resistance and good machinability.

Rapidur® 3243 is a tough high-performance high-speed steel grade offering good cutting-edge retention. Its cobalt content results in high red hardness and tempering resistance. Rapidur® 3243 is particularly suitable when thermal stresses and discontinuous cutting are involved. The core uses for this grade are highly stressed twist drills, taps and heavy-duty milling cutters of all kinds.

Rapidur® 3247 is characterized by its high wear resistance, high-temperature strength and toughness. It is largely employed for tools which have to withstand abrasive wear.

Rapidur® 3333 is a high-speed steel with low alloy content which achieves medium-term life times. It is basically used on account of its toughness potential when parts are exposed to large impact loadings and it is frequently employed for circular and long metal saw blades.

Application examples for high-speed steel grades

Treatment Tool	Steel or cast iron			Non-metallic materials			Wood			Plastics		
Stress	**slight**	**medium**	**intense**	**slight**	**medium**	**intense**	**slight**	**medium**	**intense**	**slight**	**medium**	**intense**
Twist drills	3343 -	3343 -	3243 -	3343 -	3343 -	- -	3343 -	3243 3343	3243 -	3343 -	3243 3343	3243 -
Taps	3343 -	3343 -	3243 3344	3343 -	3343 -	3344 -	- -	- -	- -	3343 -	3343 -	3344 -
Screwing dies	3343 -	3343 -	3243 -	3343 -	3343 -	- -	- -	- -	- -	3343 -	3343 -	- -
Milling cutters	3343 3341 -	3243 3245 -	3207 3202 3247	3343 3341 -	3243 3245 -	3207 3202 -	3343 - -	3343 3243 -	3207 3202 -	3343 - -	3243 - -	3207 3202 -
Reamers	3343 -	3343 -	3202 -	3343 -	3344 -	3202 -	- -	- -	- -	3343 -	3344 -	3202 -
Saws and saw segments	3343 3341	3343 3341	3243 3245	3343 3341	3343 3341	3243 3245	3343 -	3343 -	- -	3343 -	3343 -	- -
Tool holder bits	3207 3243 3247	3207 3243 3247	3207 3202 -	3207 3202 -	3207 3202 -	3207 3202 -	3343 3202 -	3344 3202 -	3207 3202 -	3207 3202 -	3207 3202 -	3207 3202 -
Planing tools	3207 -	3207 -	3207 -	3207 3202	3207 3202	3207 3202	3343 -	3343 3344	3207 -	- -	- -	- -
Broaches	3343 -	3343 -	3243 -	3343 -	3343 -	- -	- -	- -	- -	- -	- -	- -

Tool holders

Due to growing product diversity and higher production volumes, the concepts surrounding the purpose and function of a tool have been changing in recent years.

A striking technology which, to a great extent, has contributed to the development of innovative tool holders is shrink fitting. This is now made use of in all machining areas. The more comprehensive, complex and taxing a process becomes, the larger the advantages of shrink-fit technology.
This is best illustrated with long and thin tools used at high revolutions and under extreme demands on the torque transmitted.

Even with shrink-fit chucks, hydraulic chucks, shrink-fit tool holders and carbide-tipped metal-cutting tools, one constant has remained despite all other developments: in the same way that no precision tool holder can perfectly and universally fulfil every requirement simultaneously, there is no single cold-work tool steel grade predestined to suit all demands.

Correspondingly, Deutsche Edelstahlwerke has developed a broad range of high-performance steel grades for tool holders with the following characteristics: high surface hardness, good toughness, compression strength and high wear resistance.

High-performance steel for tool holders

Deutsche Edelstahlwerke supplies an extensive assortment of high-quality steel grades for tool holders, the most representative of which we have highlighted below and to the right.

Thermodur® 2343 and **Thermodur® 2344** are chromium-molybdenum-vanadium alloyed hot-work tool steel grades which have also proven successful as cold-work tool steel with multiple applications. The main characteristics of this steel is good wear resistance, high toughness even at elevated strengths, low dimensional variation and high resistance to thermal fatigue. Thermodur® 2343 and Thermodur® 2344 are preferred for use with tool holders, especially for shrink fit chucks.

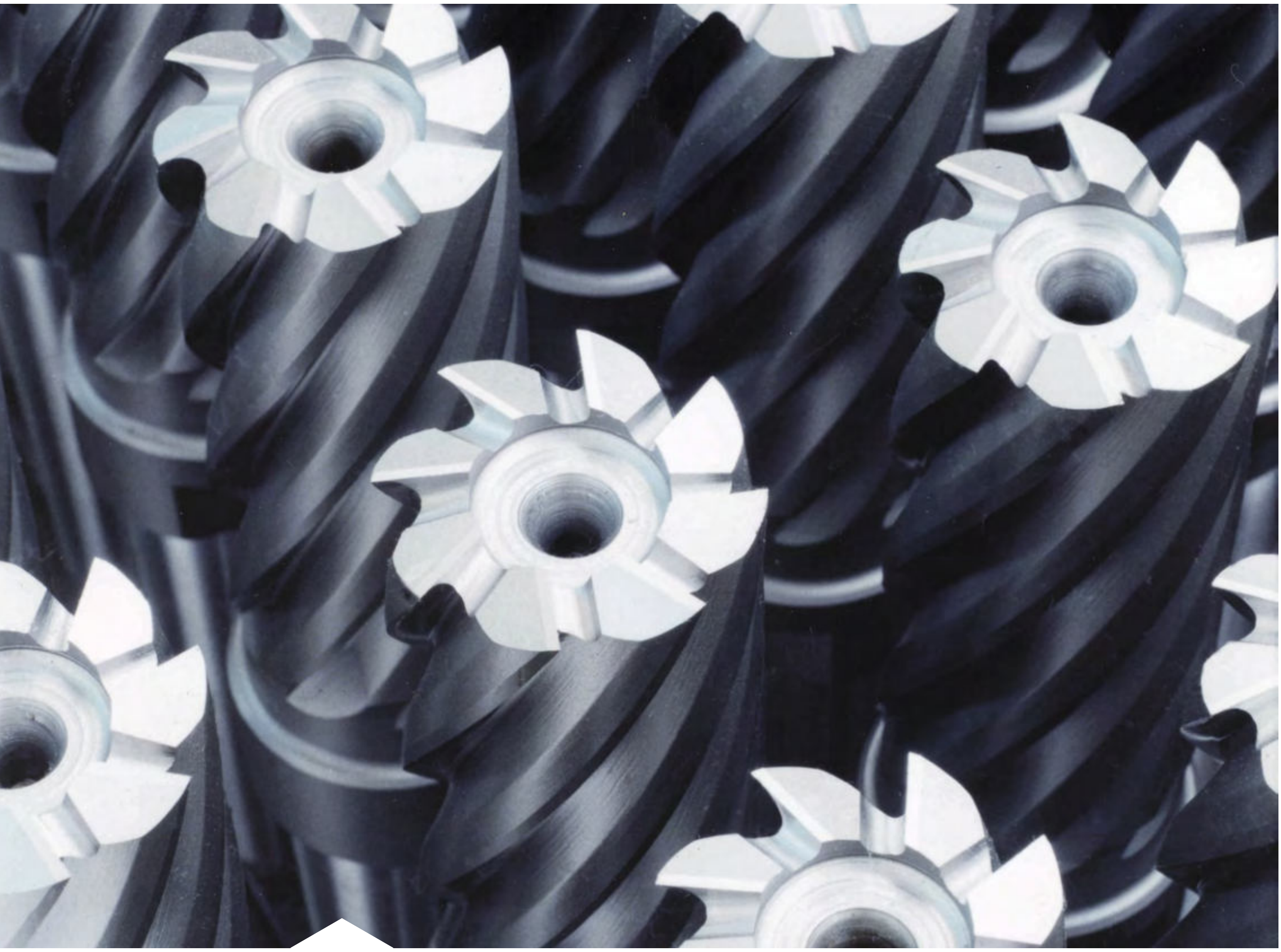
Both grades can be nitrided and are easily polishable. They also possess a very good tempering resistance and are insusceptible to hot cracking. We particularly recommend the use of Thermodur® 2344 for higher demands on wear resistance.

Thermodur® 2714 is a high-performance die steel and due to its good toughness and high compression strength, it is used for the main bodies of carbide-tipped tools.

Cryodur® 2826 is a silicon-manganese alloyed cold-work tool steel with high toughness and good resilience characteristics with the result that it is highly suitable for draw-in collets and spring collets.

Group-specific property comparisons

Grade	Strength	Wear resistance	Toughness	Dimensional stability
Formadur® 2312	●	○	●	● ●
Thermodur® 2343	● ●	● ● ●	● ● ●	● ● ●
Thermodur® 2344	● ● ●	● ● ●	● ● ●	● ● ●
Cryodur® 2550	● ●	● ●	●	● ●
Thermodur® 2714	●	●	● ●	● ●
Cryodur® 2721	●	○	● ● ●	● ● ●
Cryodur® 2826	●	○	● ●	● ●



Hand and power tools

In recent years, the development of hand and power tools has been characterized by the pursuit of the highest possible process reliability and correspondingly high productivity.

Especially in the area of power tools, a trend towards modular tool systems is clearly noticeable, accompanied by an ongoing development in coatings and protection from wear. For years turning and milling technologies have been combined on single machines, so it is a logical consequence that universal tools have followed suit.

So as to remain in the forefront of production, Deutsche Edelstahlwerke delivers a very expansive range of highest quality cold-work tool steel to fulfil the needs created by ever-increasing demands. Whether drills, wood-working tools, screw-driving tools, milling cutters, tool bits for pneumatic and hydraulic hammers or hand tools, our constantly high steel quality ensures uppermost operational safety and maximum service life.

High-performance steel for hand and power tools

The range of high-quality steel for hand and power tools from Deutsche Edelstahlwerke consists of premium and special grades, the most important of which are represented here.

Cryodur® 2210 is a chromium-vanadium alloyed cold-work tool steel with high wear resistance as well as good machinability and metal-cutting performance. Amongst other uses, this grade is employed for sharpening steels, twist drills and ejector pins. Cryodur® 2210 is also supplied in silver steel quality.

Cryodur® 2249, a chromium-silicon-vanadium alloyed special steel, is characterized by high toughness – even when exposed to considerable impact loadings. Cryodur® 2249 is mainly used for pneumatic tool bits.

Cryodur® 2381 is a silicon-molybdenum alloyed high-tensile special steel featuring good resistance to twisting. It is preferred for bits and screwdrivers.

Cryodur® 2766, one of our oil and air- hardening cold-work tool steel, has the propensity to manage enormous fatigue strength and toughness in combination with tremendously high wear resistance. Cryodur® 2766 is also available with a modified composition resulting in even greater toughness.

Group-specific property comparisons

Grade	Strength	Wear resistance	Toughness	Elasticity
Cryodur® 1520	○	●	●	● ● ●
Cryodur® 2002	● ●	● ● ●	○	○
Cryodur® 2008	● ●	● ● ●	○	○
Cryodur® 2210	● ●	● ●	○	○
Cryodur® 2235	●	● ● ●	○	●
Cryodur® 2242	●	●	● ●	● ● ●
Cryodur® 2249	●	●	● ●	● ● ●
Cryodur® 2381	●	● ●	● ●	● ● ●
Cryodur® 2550	● ●	● ● ●	●	●
Cryodur® 2766 mod	○	●	● ● ●	● ● ●

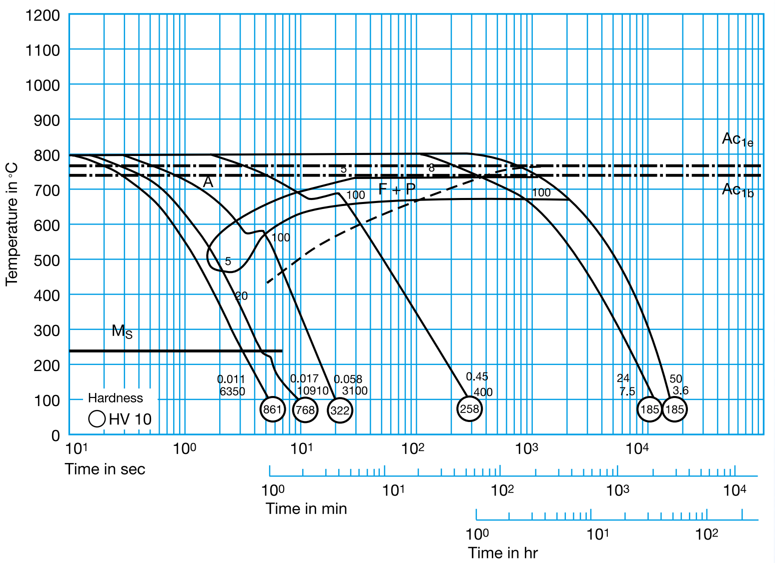
Material Data Sheets

Consecutively the most important materials in the area of cold-work tool steel and high-speed steel with its steel properties, standards, physical properties, applications and heat treatment.

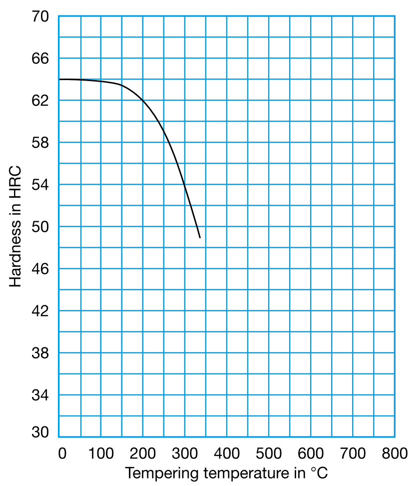
Cryodur® 1520

(C70W)	C 0.70 Si 0.25 Mn 0.25				
Steel properties	Shell-hardenable steel with wear-resistant surface and high core toughness.				
Applications	Trimming dies, pliers, tool bits for pneumatic and hand tools.				
Heat treatment	**Soft annealing °C** 680 - 710	**Cooling** Furnace, from 500 °C air			**Hardness HB** max. 180
	tress-relief annealing °C approx. 600 – 650	**Cooling** Furnace			
	Hardening °C 780 - 810	**Quenching** Water			**Hardness after quenching HRC** 64
	Tempering °C **HRC**	100 64	200 61	300 56	350 49

Time-temperature-transformation diagram



Tempering diagram

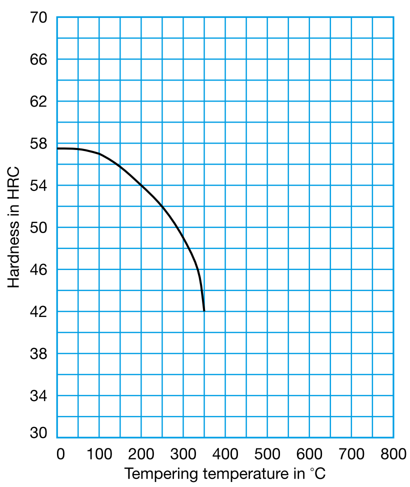


Reference numbers in brackets are not standardized in EN ISO 4957.

Cryodur® 1730

C45U	C 0.45 Si 0.20 Mn 0.70				
Steel properties	Shell-hardenable steel featuring hard surface and tough core.				
Standards	**AISI** 1045				
Applications	Components for tools (e.g. base plates for plastic moulds and pressure casting moulds). Also suitable for hand tools, pliers and agricultural tools of all kinds.				
Heat treatment	**Soft annealing °C** 680 - 710	**Cooling** Furnace			**Hardness HB** max. 207
	Stress-relief annealing °C approx. 600 - 650	**Cooling** Furnace			
	Hardening °C 800 - 830	**Quenching** Water			**Hardness after quenching HRC** 57
	Tempering °C	100	200	300	350
	HRC	57	54	49	42

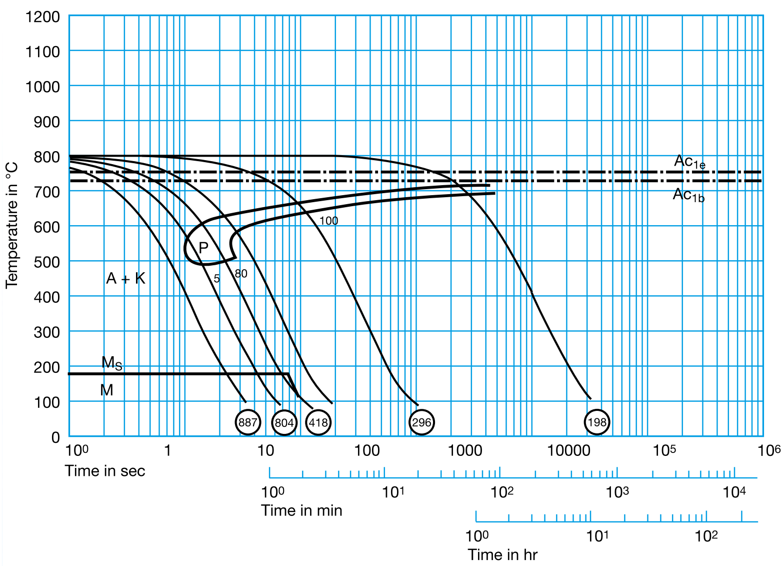
Tempering diagram



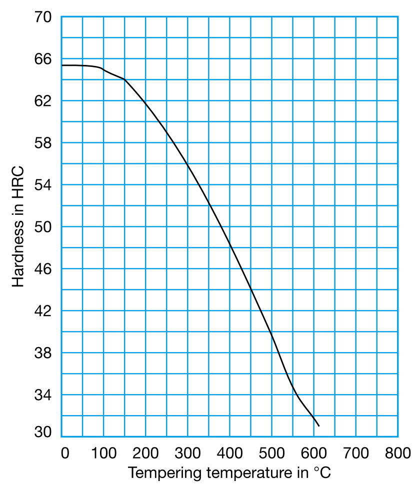
Cryodur® 2002

(125Cr1)	C 1.30 Cr 0.25 Si 0.25 Mn 0.30			
Steel properties	Tool steel with high surface hardness.			
Applications	Cutting tools, drawing dies, files and mandrels.			
Heat treatment	**Soft annealing °C** 700 - 720	**Cooling** Furnace		**Hardness HB** max. 200
	Stress-relief annealing °C approx. 650 - 680	**Cooling** Furnace		
	Hardening °C 770 - 800	**Quenching** Oil: < 10 mm Ø		**Hardness after quenching HRC** 65
	Tempering °C **HRC**	100 64	200 62	300 56
				400 49

Time-temperature-transformation diagram



Tempering diagram

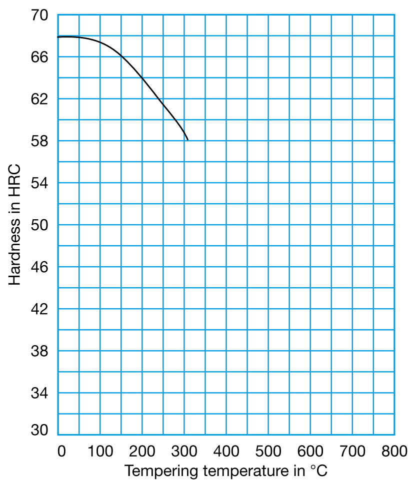


Reference numbers in brackets are not standardized in EN ISO 4957.

Cryodur® 2008

(140Cr3)	C 1.50 Si 0.25 Mn 0.25 Cr 0.85 V 0.20				
Steel properties	Water-hardening special steel.				
Applications	Files.				
Heat treatment	**Soft annealing °C**	**Cooling**			**Hardness HB**
	730 - 760	Furnace			max. 220
	Stress-relief annealing °C	**Cooling**			
	approx. 650 - 680	Furnace			
	Hardening °C	**Quenching**			**Hardness after quenching HRC**
	780 - 820	Water			68
	Tempering °C	100	200	300	
	HRC	63	62	59	

Tempering diagram

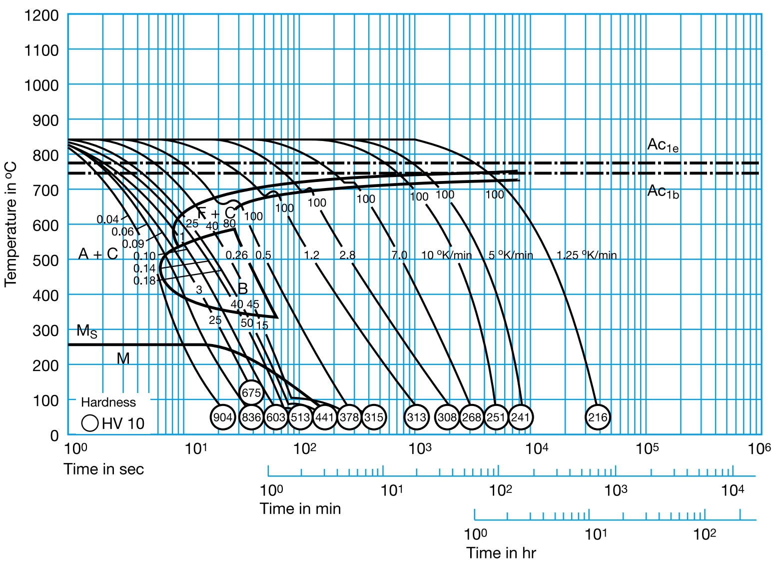


Reference numbers in brackets are not standardized in EN ISO 4957.

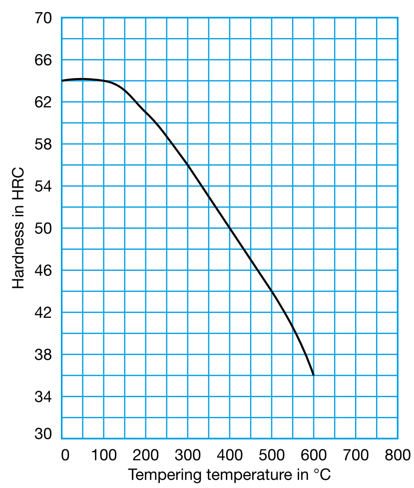
Cryodur® 2067

100Cr6	C 1.00 Si 0.20 Mn 0.35 Cr 1.50					
Steel properties	Oil-hardenable grade with low hardening depth, wear-resistant.					
Standards	**AISI** L1/L3	**AFNOR** Y100C6				
Physical properties	**Thermal conductivity at °C** **W/(m • K)**	20 33.0	350 32.2	700 31.4		
Applications	Cold pilger rolls and jaws, thread cutting tools, gauges, mandrels, wood and paper processing tools, cold extrusion and spinning tools, flanging rolls, shear and rotary shear blades.					
Heat treatment	**Soft annealing °C** 710 - 750	**Cooling** Furnace		**Hardness HB** max. 225		
	Stress-relief annealing °C approx. 650	**Cooling** Furnace				
	Hardening °C 830 - 860	**Quenching** Oil or saltbath, 180 - 220 °C		**Hardness after quenching HRC** 64		
	Tempering °C **HRC**	100 64	200 61	300 56	400 50	500 44	600 36

Time-temperature-transformation diagram



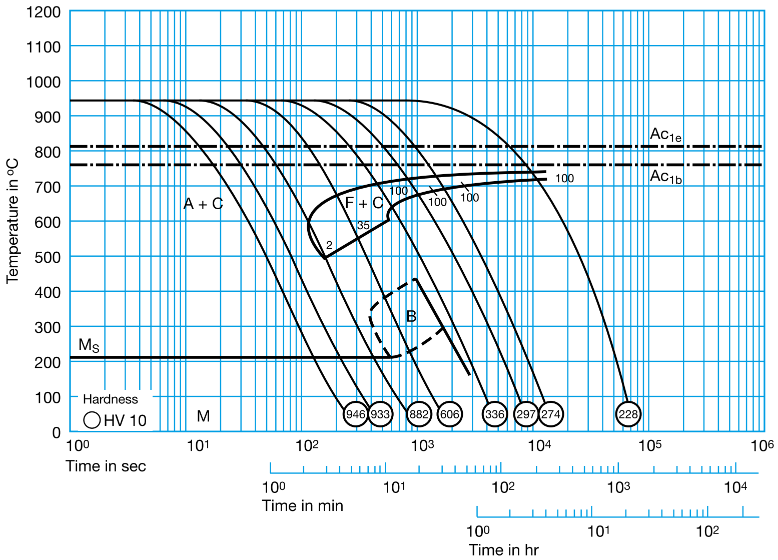
Tempering diagram



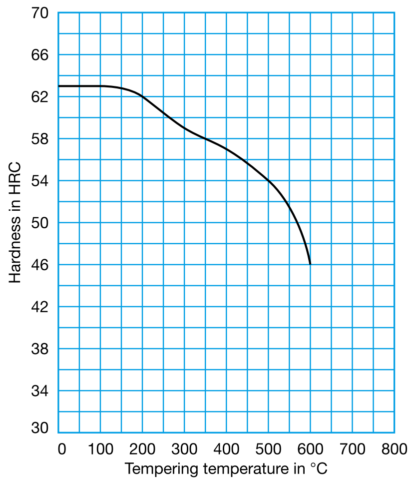
Cryodur® 2080

X210Cr12	C 2.00 Si 0.30 Mn 0.30 Cr 12.00						
Steel properties	12 % ledeburitic chromium tool steel with extreme wear resistance.						
Standards	**AISI** D3	**AFNOR** Z200C12					
Physical properties	**Coefficient of thermal expansion**						
	at°C	20 - 100	20 - 200	20 - 300	20 - 400	20 - 500	20 - 600	20 - 700
	10^{-6} m/(m • K)	10.8	11.7	12.2	12.6	12.8	13.1	13.3
	Thermal conductivity at °C	20	350	700				
	W/(m • K)	16.7	20.5	24.2				
Applications	Cutting tools for sheets up to 4 mm thickness, trimming dies, blanking dies for paper and plastics, shear blades and rotary shear blades for sheet thicknesses up to 2 mm, drawing and deep-drawing tools. Woodworking tools, stone pressing tools, pressure pads and highly wear-resistant plastic moulds, profile rolls.						
Heat treatment	**Soft annealing °C**	**Cooling**			**Hardness HB**		
	800 - 840	Furnace			max. 250		
	Stress-relief annealing °C	**Cooling**					
	approx. 650 – 700	Furnace					
	Hardening °C	**Quenching**			**Hardness after quenching HRC**		
	930 - 960	Oil			64		
	950 - 980	Air (up to 30 mm thickness)			64		
	Tempering °C	100	200	300	400	500	600
	HRC	63	62	59	57	54	46

Time-temperature-transformation diagram



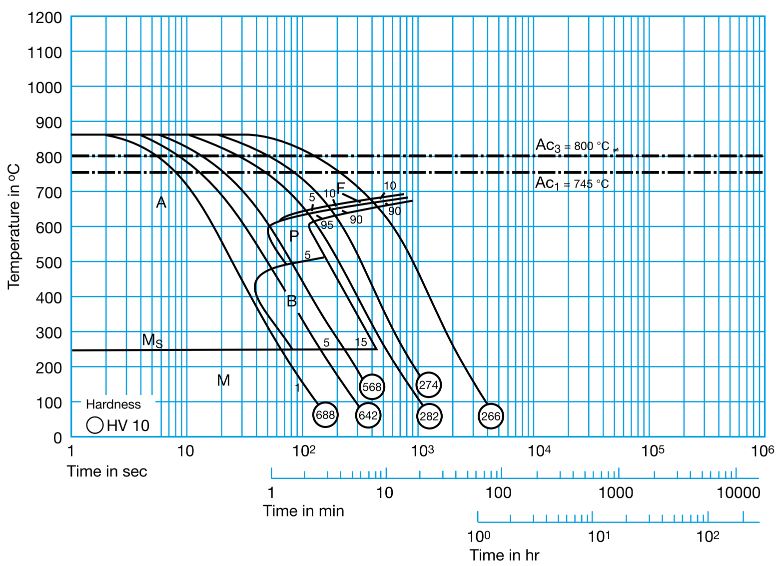
Tempering diagram



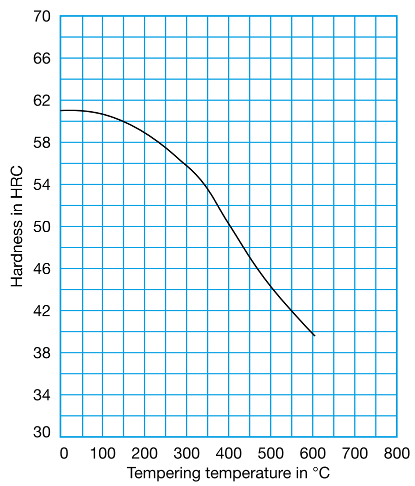
Cryodur® 2101

(62SiMnCr4)	C 0.65 Si 1.10 Mn 1.10 Cr 0.70
Steel properties	Good toughness and wear resistance.
Physical properties	**Coefficient of thermal expansion** **at °C** 20 -100, 20 - 200 **10^{-6} m/(m • K)** 11.8, 12.5 **Thermal conductivity at °C** 20, 350, 700 **W/(m • K)** 31.0, 31.5, 31.9
Applications	Spring collets, shear blades, guide rails and punching tools.
Heat treatment	**Soft annealing °C** 700 - 750 · **Cooling** Furnace · **Hardness HB** max. 225 **Stress-relief annealing °C** approx. 650 - 680 · **Abkühlen** Furnace **Hardening °C** 830 - 860 · **Quenching** Oil or saltbath, 180 – 220 °C · **Hardness after quenching HRC** 61 **Tempering °C** 100, 200, 300, 400, 500, 600 **HRC** 61, 59, 56, 50, 45, 40

Time-temperature-transformation diagram



Tempering diagram

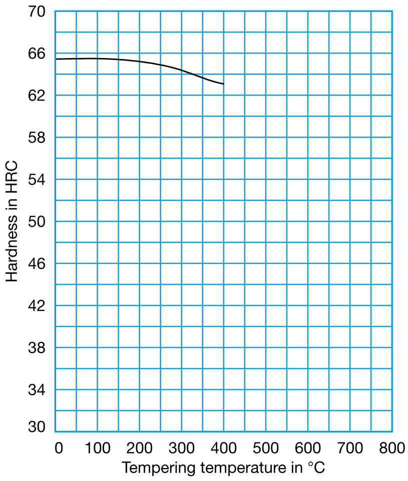


Reference numbers in brackets are not standardized in EN ISO 4957.

Cryodur® 2201

(X165CrV12)	C 1.60 Cr 12.00 V 0.10			
Steel properties	Dimensionally stable, oil-hardenable grade featuring extreme wear resistance combined with sufficient toughness.			
Applications	High-performance steel for cutting, hobbers, thread rolls, metal saws, wood milling machines and similar items.			
Wärmebehandlung	**Soft annealing °C** 800 - 830	**Cooling** Furnace		**Hardness HB** max. 231
	Stress-relief annealing °C approx. 650 - 680	**Cooling** Furnace		
	Hardening °C 960 - 1000	**Quenching** Oil or saltbath, 350 - 400 °C		**Hardness after quenching HRC** 64
	Tempering °C **HRC**	100 64	200 63	300 61
				400 58

Tempering diagram

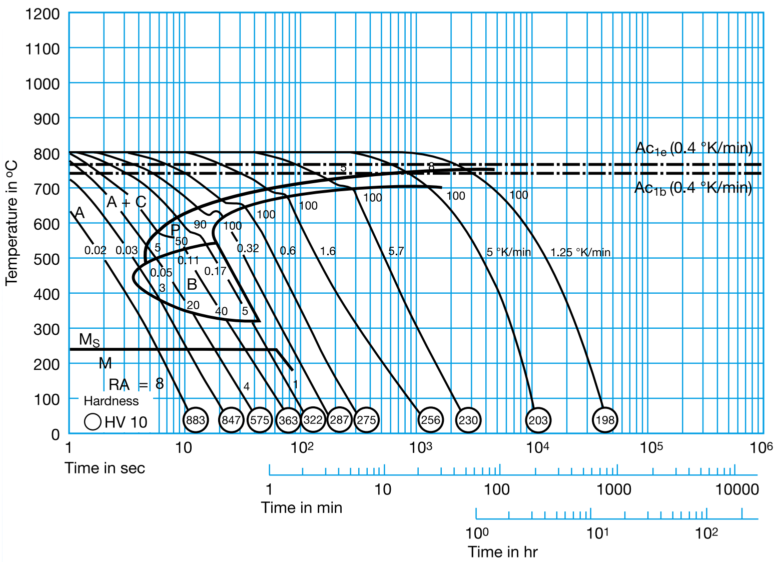


Reference numbers in brackets are not standardized in EN ISO 4957.

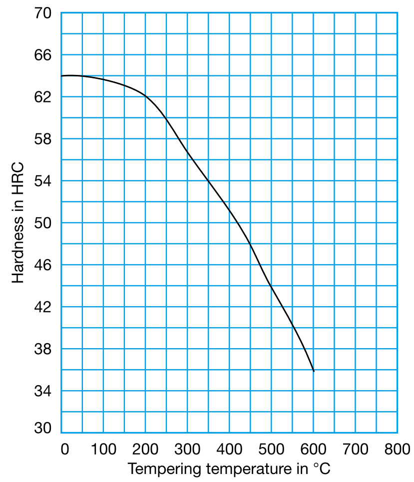
Cryodur® 2210

(115CrV3)	C 1.20 Cr 0.70 V 0.10							
Steel properties	Wear resistant chromium-vanadium alloyed cold-work steel.							
Standards	**AISI** L2							
Physical properties	**Coefficient of thermal expansion**							
	at °C	20 - 100	20 - 200	20 - 300	20 - 400	20 - 500	20 - 600	20 - 700
	10^{-6} m/(m • K)	10.0	12.7	13.7	14.2	14.9	15.8	16.8
	Thermal conductivity at °C	20	350	700				
	W/(m • K)	34.2	32.6	31.0				
Applications	Piercing dies, guide rods, twist drills, ejector pins and wood chisels.							
Heat treatment	**Soft annealing °C**	**Cooling**			**Hardness HB**			
	710 - 750	Furnace			max. 220			
	Stress-relief annealing °C	**Cooling**						
	approx. 650 - 680	Furnace						
	Hardening °C	**Quenching**			**Hardness after quenching HRC**			
	810 - 840	Oil: < 15 mm Ø			64			
	780 - 810	Water: > 15 mm Ø			64			
	Tempering °C	100	200	300	400	500	600	
	HRC	64	62	57	51	44	36	

Time-temperature-transformation diagram



Tempering diagram

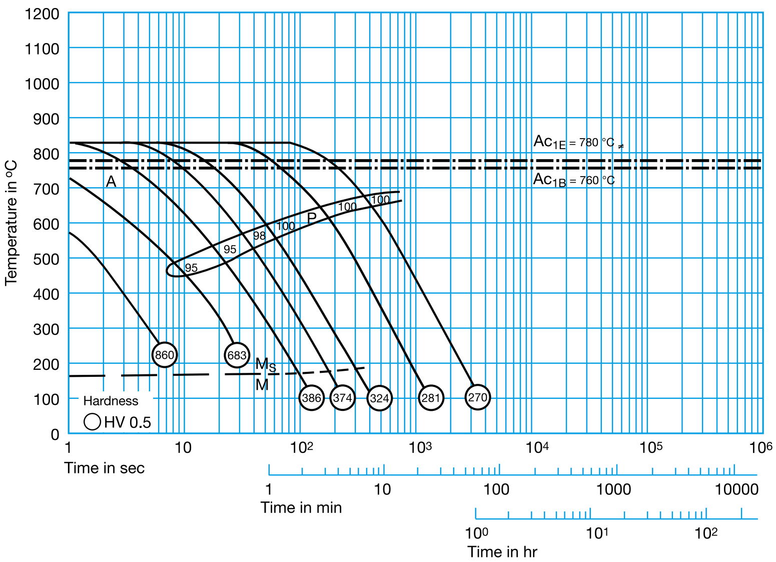


Reference numbers in brackets are not standardized in EN ISO 4957.

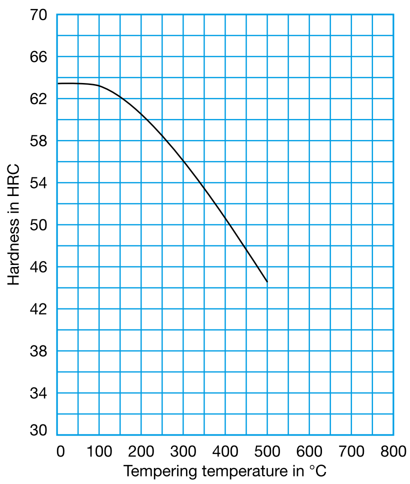
Cryodur® 2235

(80CrV2)	C 0.80 Cr 0.60 V 0.20					
Steel properties	Special steel for woodworking, featuring a keen cutting edge.					
Physical properties	**Thermal conductivity at °C**	20	350	700		
	W/(m • K)	33.5	32.0	31.0		
Applications	Circular and gang saws, machine knives, cutting tools for wood and non-ferrous metals, pliers and wood chisels.					
Heat treatment	**Soft annealing °C**	**Cooling**		**Hardness HB**		
	690 - 730	Furnace		max. 225		
	Stress-relief annealing °C	**Cooling**				
	approx. 650 - 680	Furnace				
	Hardening °C	**Quenching**		**Hardness after quenching HRC**		
	800 - 830	Oil		63		
	Tempering °C	100	200	300	400	500
	HRC	63	61	57	52	45

Time-temperature-transformation diagram



Tempering diagram

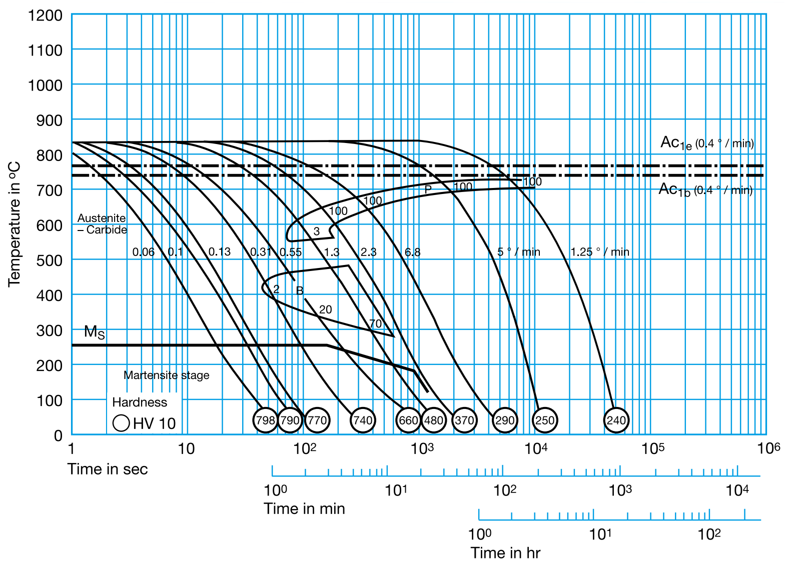


Reference numbers in brackets are not standardized in EN ISO 4957.

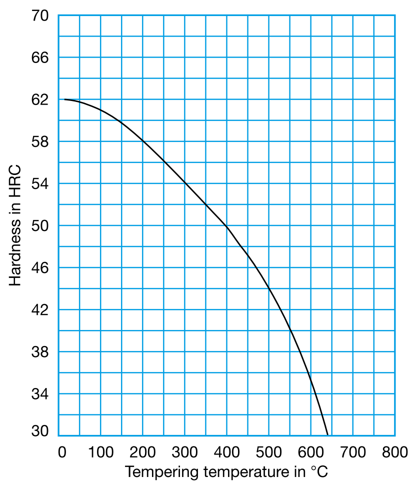
Cryodur® 2242

(59CrV4)	C 0.59 Mn 0.90 Cr 1.00 V 0.10				
Steel properties	Wear resistant, high toughness.				
Applications	Special steel for hand chisels of all types, including flat, cross-cut and pointed chisels for the treatment of hard materials. Also fo screwdrivers and other hand tools.				
Heat treatment	**Soft annealing °C** 710 - 740	**Cooling** Furnace			**Hardness HB** max. 230
	Stress-relief annealing °C approx. 650 - 680	**Cooling** Furnace			
	Hardening °C 810 - 850	**Quenching** Oil			**Hardness after quenching HRC** 62
	Tempering °C **HRC**	100 61	200 58	300 55	400 50

Time-temperature-transformation diagram



Tempering diagram

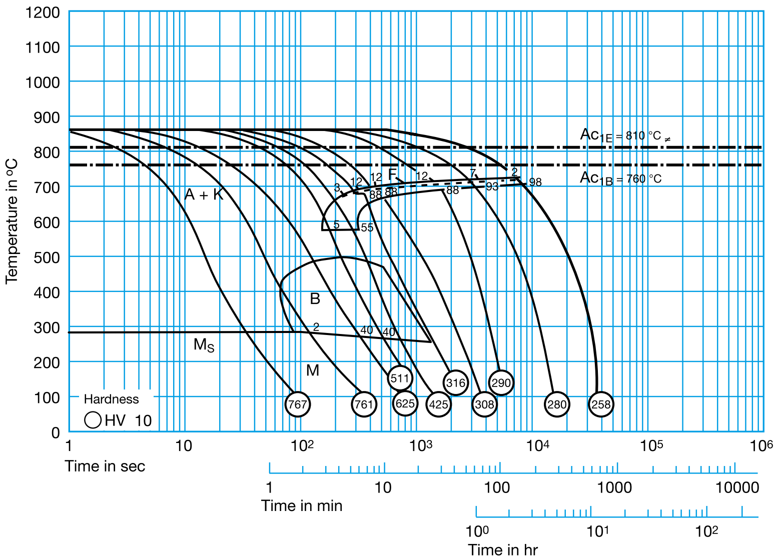


Reference numbers in brackets are not standardized in EN ISO 4957.

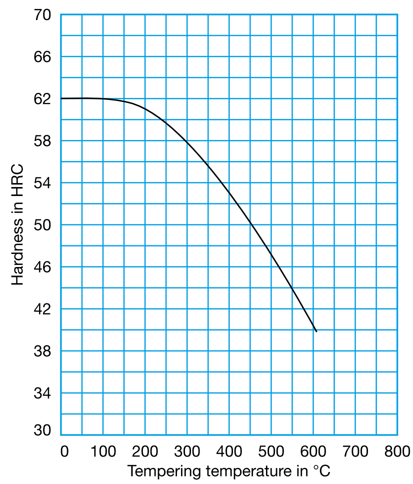
Cryodur® 2243

(61CrSiV5)	C 0.60 Si 0.90 Mn 0.80 Cr 1.10 V 0.10						
Steel properties	Wear resistant, high toughness.						
Physical properties	**Thermal conductivity at °C**	20	350	700			
	W/(m • K)	33.5	32.0	31.0			
Applications	Cold heading dies, shear blades, section-cutting shear blades and trimming dies, punching tools and bolting tools.						
Heat treatment	**Soft annealing °C**	**Cooling**			**Hardness HB**		
	700 - 740	Furnace			max. 220		
	Stress-relief annealing °C	**Cooling**					
	approx. 650 - 680	Furnace					
	Hardening °C	**Quenching**			**Hardness after quenching HRC**		
	850 - 880	Oil or saltbath, 180 – 220 °C			62		
	Tempering °C	100	200	300	400	500	600
	HRC	62	61	57	52	47	40

Time-temperature-transformation diagram



Tempering diagram

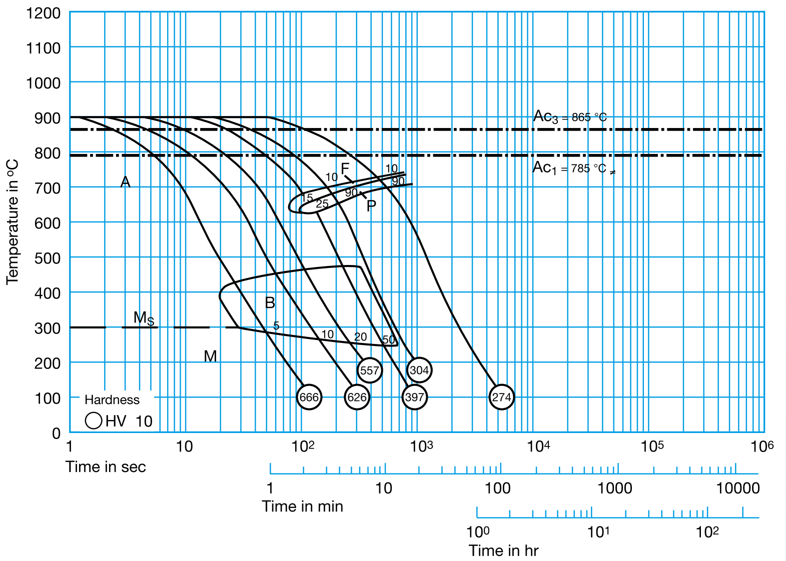


Reference numbers in brackets are not standardized in EN ISO 4957.

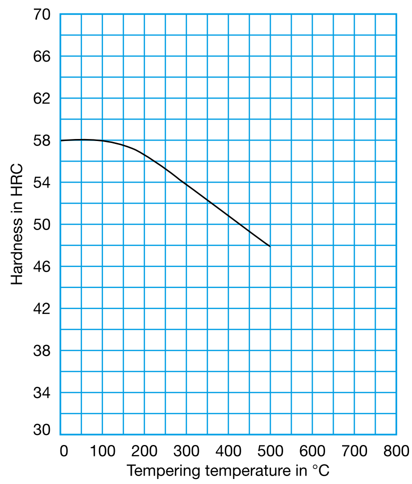
Cryodur® 2249

(45SiCrV6)	C 0.45 Si 1.35 V 0.10 Cr 1.35				
Steel properties	Tough, impact-resistant tool steel.				
Applications	Pneumatic chipping hammers, punching tools, riveting hammers, punches and woodworking tools.				
Heat treatment	**Soft annealing °C** 710 - 750	**Cooling** Furnace		**Hardness HB** max. 219	
	Stress-relief annealing °C approx. 650 - 680	**Cooling** Furnace			
	Hardening °C 860 - 890	**Quenching** Oil		**Hardness after quenching HRC** 58	
	Tempering °C	100	200	300	400	500
	HRC	58	57	53	51	49

Time-temperature-transformation diagram



Tempering diagram

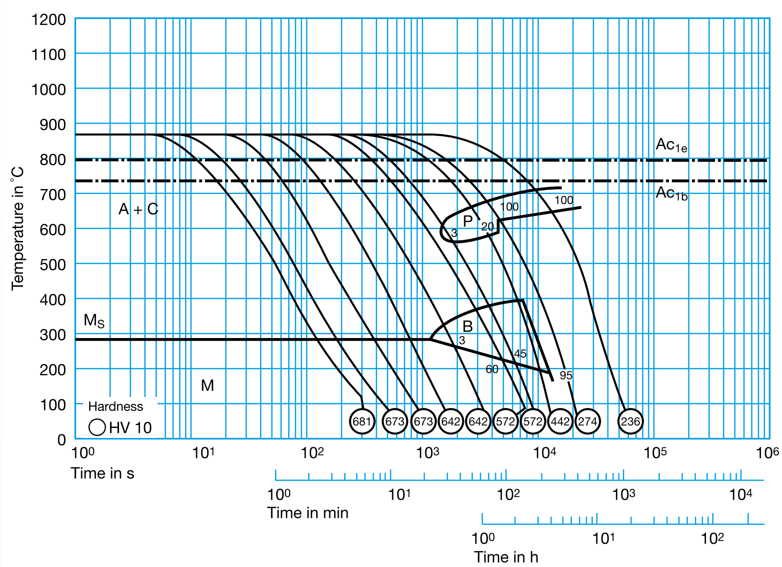


Reference numbers in brackets are not standardized in EN ISO 4957.

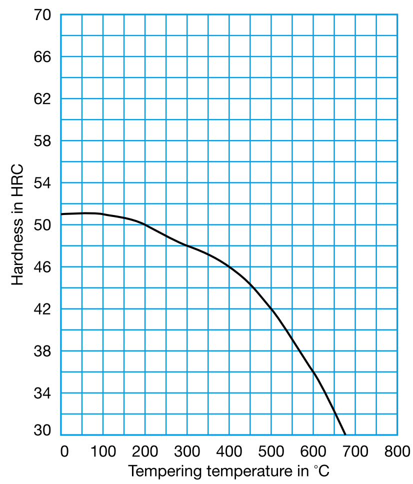
Formadur® 2312

40CrMnMoS8-6[1)]	C 0.40 Si 0.35 Mn 1.50 Cr 1.90 Mo 0.20 S 0.05
Steel properties	Quenched and tempered plastic mould steel with a hardness in as-delivered condition of 280 to 325 HB. Improved machinability in comparison with Formadur® 2311. Polishable.
Standards	**AISI** P20+S
Physical properties	**Coefficient of thermal expansion**
	at °C: 20 - 100, 20 - 200, 20 - 300
	10^{-6} m/(m • K) Annealed: 12.5, 13.4, 13.9
	10^{-6} m/(m • K) Quenched and tempered: 12.3, 13.0, 13.7
	Thermal conductivity °C: 100, 150, 200, 250, 300
	W/(m • K) Annealed: 40.2, 40.9, 40.3, 40.0, 39.0
	W/(m • K) Quenched and tempered: 39.8, 40.4, 40.4, 39.9, 39.0
Applications	Plastic moulds, mould frames for plastic and pressure casting moulds, recipient sleeves, brake dies.
Heat treatment	**Soft annealing °C** 710 - 740; **Cooling** Furnace; **Hardness HB** max. 235
	Stress-relief annealing °C (Annealed) approx. 600; **Stress-relief annealing °C** (Quenched and tepered) approx. 30 – 50 under tempering temperature; **Cooling** Furnace
	Hardening °C 840 - 870; **Quenching** Oil or saltbath, 180 – 220 °C; **Hardness after quenching HRC** 51
	Tempering °C: 100, 200, 300, 400, 500, 600, 700
	HRC: 51, 50, 48, 46, 42, 36, 28

Time-temperature-transformation diagram



Tempering diagram

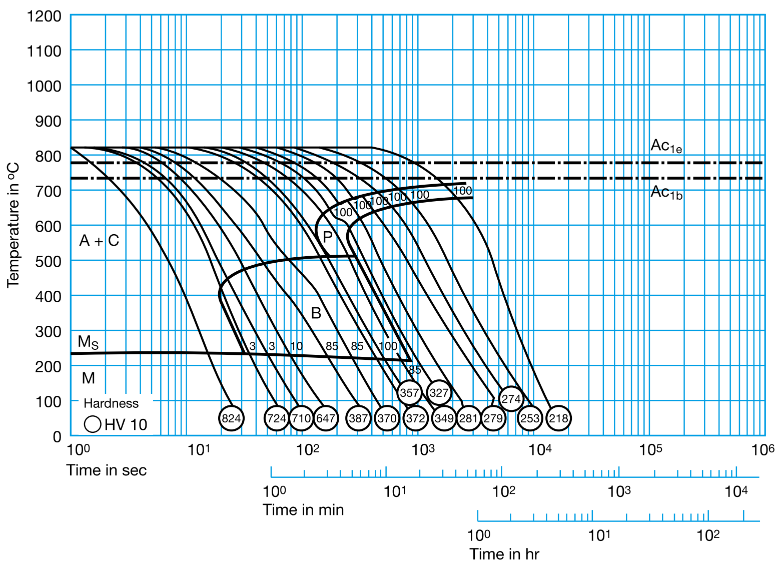


[1)] *S can be raised between 0.05 and 0.1 % whereas Ni can be left out completely.*

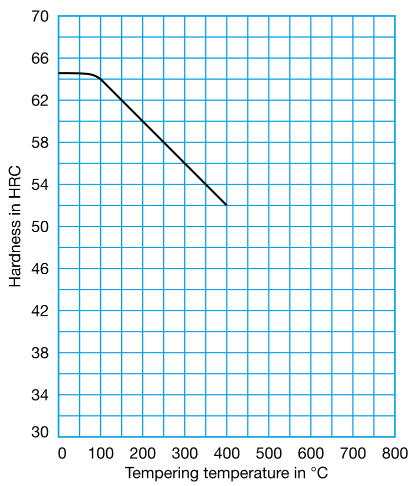
Cryodur® 2327

(~86CrMoV7)	C 0.83 Si 0.45 Mn 0.40 Cr 1.90 Mo 0.30				
Steel properties	Cr-Mo alloyed shell-hardenable grade with high wear resistance.				
Applications	Standard cold-roll steel for rolls of all sizes, backup rolls and work rolls.				
Wärmebehandlung	**Soft annealing °C** 710 - 750	**Cooling** Furnace			**Hardness HB** max. 250
	Hardening °C 830 - 850	**Quenching** Water			**Hardness after quenching HRC** 64 - 65
	Tempering °C **HRC**	100 64	200 60	300 56	400 52

Time-temperature-transformation diagram



Tempering diagram

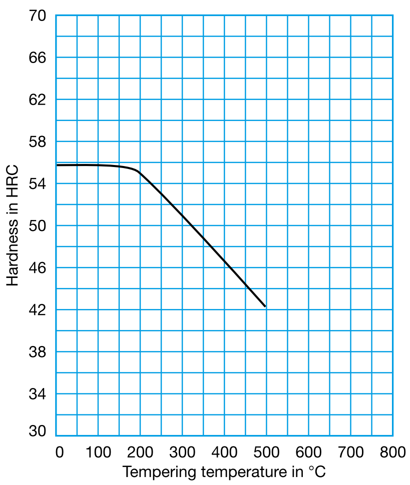


Reference numbers in brackets are not standardized in EN ISO 4957.

Cryodur® 2328

(45CrMoV7)	C 0.45 Mn 0.90 Cr 1.80 Mo 0.30 V 0.05					
Steel properties	Air-hardening steel of great hardness and toughness.					
Applications	Special steel for chisels.					
Heat treatment	**Soft annealing °C** 690 - 730	**Cooling** Furnace		**Hardness HB** max. 248		
	Stress-relief annealing °C approx. 650	**Cooling** Furnace				
	Hardening °C 840 - 860	**Quenching** Air		**Hardness after quenching HRC** 55		
	Tempering °C **HRC**	100 55	200 55	300 52	400 49	500 45	600 38

Tempering diagram

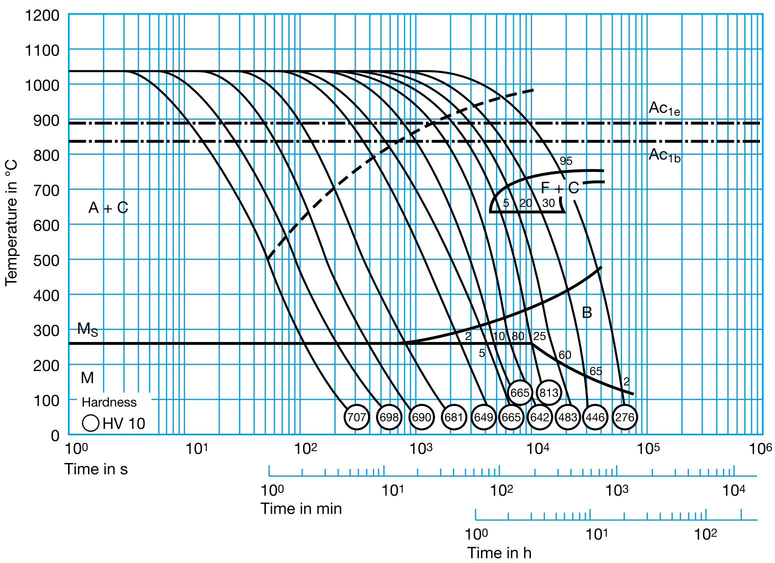


Reference numbers in brackets are not standardized in EN ISO 4957.

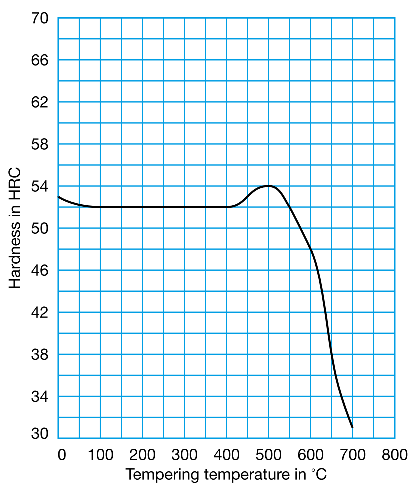
Thermodur® 2343

X37CrMoV5-1	C 0.38 Si 1.00 Cr 5.30 Mo 1.30 V 0.40
Steel properties	High hot tensile strength and toughness. Good thermal conductivity and insusceptibility to hot cracking. Can be water-cooled to a limited extent.
Standards	**AISI** H11 **AFNOR** Z38CDV5
Physical properties	**Coefficient of thermal expansion** **at °C**: 20 - 100, 20 - 200, 20 - 300, 20 - 400, 0 - 500, 20 - 600, 20 - 700 **10⁻⁶ m/(m • K)**: 11.8, 12.4, 12.6, 12.7, 12.8, 12.9, 12.9 **Thermal conductivity at °C**: 20, 350, 700 **W/(m • K) Annealed**: 29.8, 30.0, 33.4 **W/(m • K) Quenched and tempered**: 26.8, 27.3, 30.3
Applications	Besides applications typical for the area of hot-work steels, this grade is mainly used for ejector pins, tool holders and shrink fit chucks.
Heat treatment	**Soft annealing °C** 750 - 800 — **Cooling** Furnace — **Hardness HB** max. 230 **Stress-relief annealing °C** approx. 600 - 650 — **Cooling** Furnace **Hardening °C** 1000 - 1030 — **Quenching** Air, oil or saltbath, 500 – 550 °C — **Hardness after quenching HRC** 54 **Tempering °C**: 100, 200, 300, 400, 500, 550, 600, 650, 700 **HRC**: 52, 52, 52, 52, 54, 52, 48, 38, 31

Time-temperature-transformation diagram



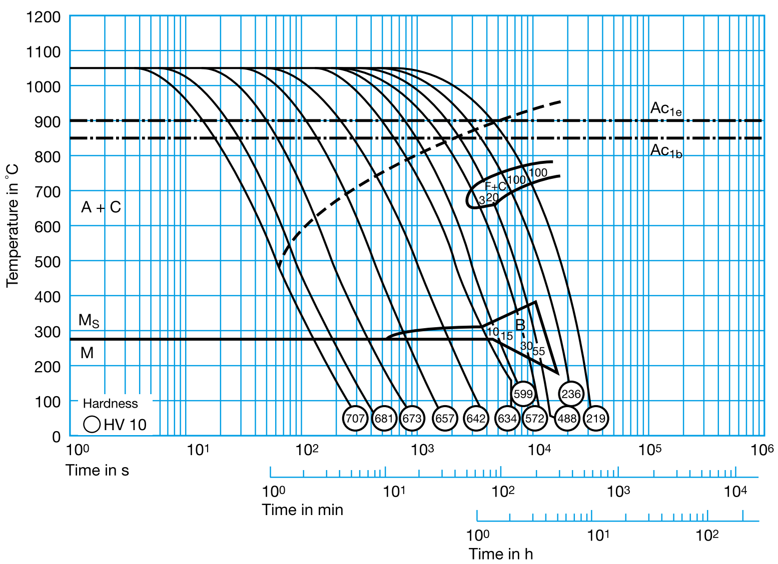
Tempering diagram



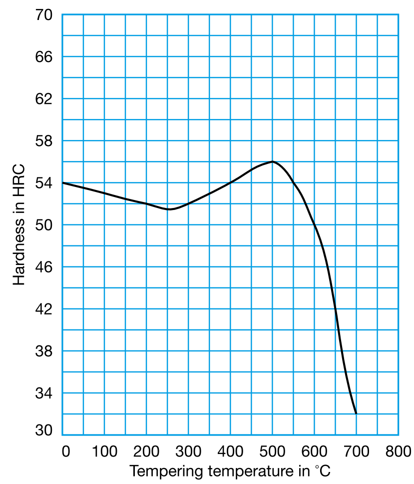
Thermodur® 2344

X40CrMoV5-1	C 0.40 Si 1.00 Cr 5.30 Mo 1.40 V 1.00								
Steel properties	High hot-wear resistance and hot tensile strength as well as good toughness, thermal conductivity and insusceptibility to hotcracking. Can be water-cooled to a limited extent.								
Standards	**AISI** H13			**AFNOR** Z40CDV5					
Physical properties	**Coefficient of thermal expansion**								
	at °C			20 - 100	20 - 200	20 - 300	20 - 400	20 - 500	20 - 600	20 - 700
	10^{-6} m/(m • K)			10.9	11.9	12.3	12.7	13.0	13.3	13.5
	Thermal conductivity at °C			20	350	700				
	W/(m • K) Annealed			27.2	30.5	33.4				
	W/(m • K) Quenched and tempered			25.5	27.6	30.3				
Applications	Besides applications typical for the area of hot-work steels, this grade is mainly used for ejector pins, tool holders and shrink fit chucks.								
Heat treatment	**Soft annealing °C** 750 - 800	**Cooling** Furnace		**Glühhärte HB** Max. 230					
	Stress-relief annealing °C approx. 600 - 650	**Cooling** Furnace							
	Hardening °C 1020 - 1050	**Quenching** Air, oil or saltbath, 500 – 550 °C		**Hardness after quenching HRC** 54					
	Tempering °C	100	200	300	400	500	550	600	650	700
	HRC	53	52	52	54	56	54	50	42	32

Time-temperature-transformation diagram



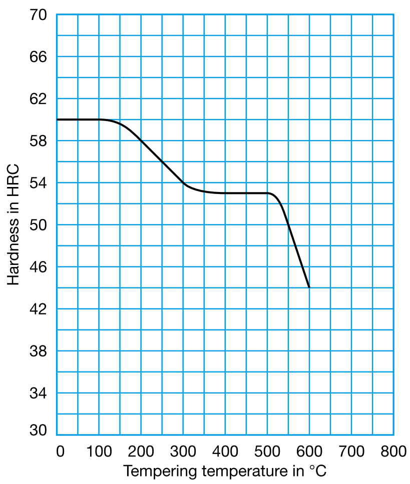
Tempering diagram



Cryodur® 2357

(50CrMoV13-15)	C 0.50 Si 0.30 Mn 0.70 Cr 3.35 Mo 1.60 V 0.25						
Steel properties	High toughness and wear resistance, high compression strength combined with dimensional stability and good polishability.						
Standards	**AISI** S7						
Physical properties	**Coefficient of thermal expansion**						
	at °C	20 - 200	20 - 400				
	10^{-6} m/(m • K)	12.2	12.5				
	Thermal conductivity at °C	20	200	400			
	W/(m • K)	28.9	30.0	31.0			
Applications	Cold-work tool steel for punching tools, moulds, scrap shears, piercing dies, hobbers, coining dies, deburring tools, plastic moulds and pelleters.						
Heat treatment	**Soft annealing °C**	**Cooling**			**Hardness HB**		
	810 - 850	Furnace			approx. 220		
	Stress-relief annealing °C	**Cooling**					
	approx. 600	Furnace					
	Hardening °C	**Quenching**			**Hardness after quenching HRC**		
	920 - 970	Air or oil			60 - 62		
	Tempering °C	100	200	300	400	500	550	600
	HRC	60	58	54	53	53	50	44

Tempering diagram

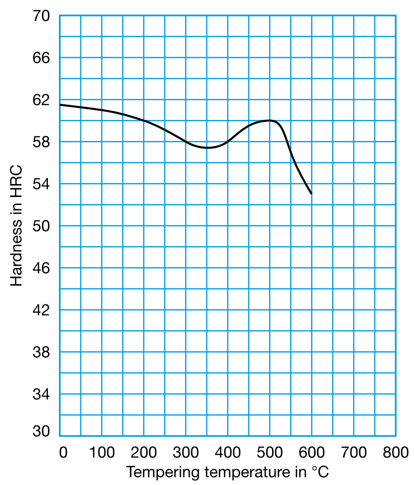


Reference numbers in brackets are not standardized in EN ISO 4957.

Cryodur® 2360

(~X48CrMoV8-1-1)	C 0.50 Si 1.20 Mn 0.35 Cr 7.30 Mo 1.50 V 0.50							
Steel properties	Cryodur® 2360 is a 7 % chromium steel that derives its high wear resistance from a balanced combination of the alloying elements. The medium V concentration of 0.5 % generates a sufficiently high hardenability combined with high toughness, even at comparatively low operating temperatures below RT.							
Applications	This grade is especially suitable for use with chipper knives, blade holders, veneer slicing blades, blade inserts, billet-shear blades and reinforcements. All require a combination of high hardness and toughness as do large cold extrusion tools of complex geometry.							
Heat treatment	**Soft annealing °C** 830 - 830	**Cooling** Furnace			**Hardness HB** max. 240			
	Stress-relief annealing °C approx. 650	**Cooling** Furnace						
	Hardening °C 1030 - 1070	**Quenching** Air, oil or saltbath, 550 °C			**Hardness after quenching HRC** 60 - 61			
	Tempering °C	100	200	300	400	500	550	600
	HRC	61	60	58	58	60	57	53

Tempering diagram

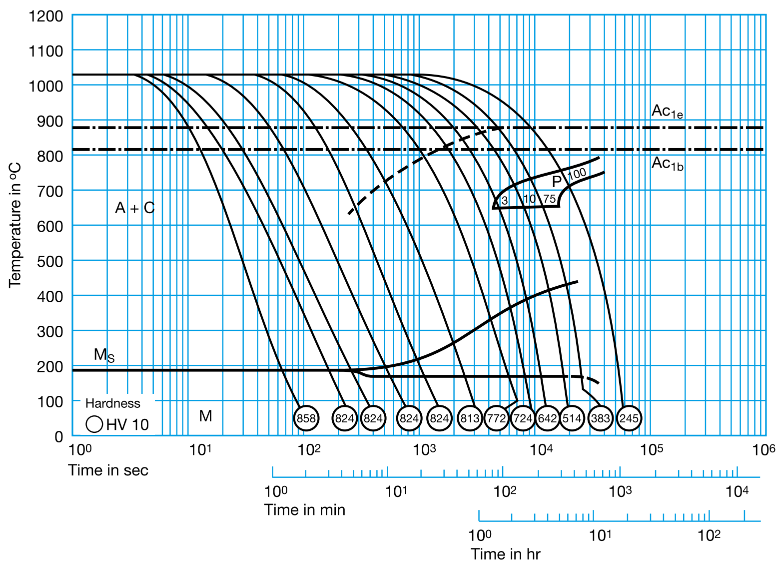


Reference numbers in brackets are not standardized in EN ISO 4957.

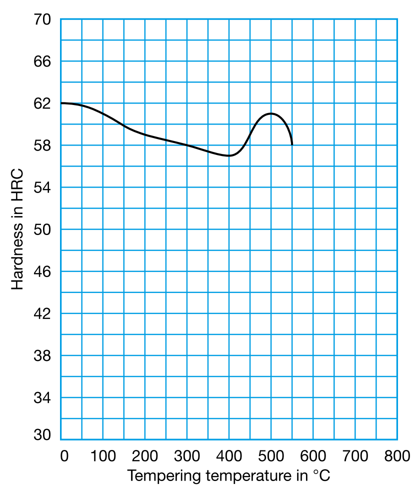
Cryodur® 2362

(~X63CrMoV5-1)	C 0.65 Si 1.10 Mn 0.40 Cr 5.20 Mo 1.40 V 0.50					
Steel properties	Cr-Mo alloyed through-hardening grade with high tempering resistance.					
Applications	Intermediate rolls for cluster mills.					
Heat treatment	**Soft annealing °C**	**Cooling**		**Hardness HB**		
	800 - 840	Furnace		max. 250		
	Hardening °C	**Quenching**		**Hardness after quenching HRC**		
	980 - 1020	Oil or saltbath		61 - 63		
	Tempering °C	100	200	300	400	500	550
	HRC	61	59	58	57	61	58

Time-temperature-transformation diagram



Tempering diagram

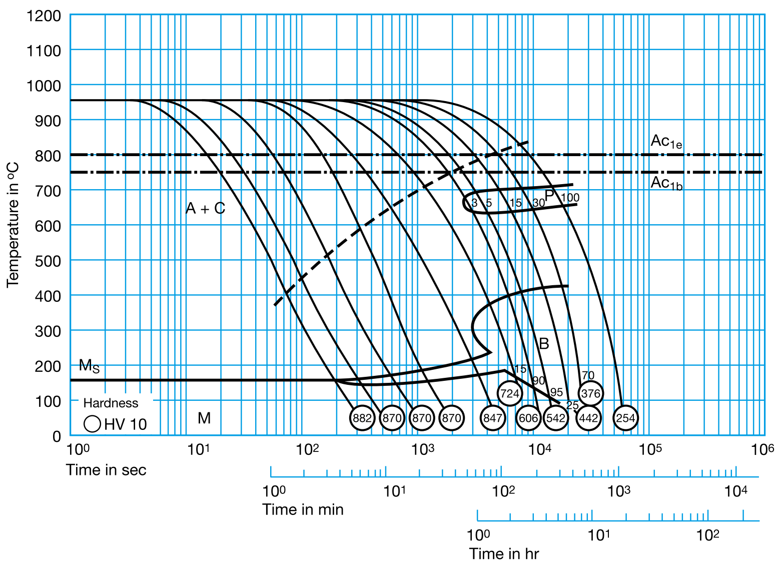


Reference numbers in brackets are not standardized in EN ISO 4957.

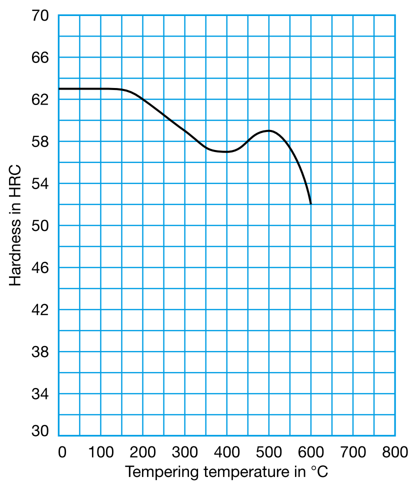
Cryodur® 2363

X100CrMoV5	C 1.00 Si 0.30 Mn 0.50 Cr 5.00 Mo 0.95 V 0.20						
Steel properties	High dimensional stability during heat treatment. High wear resistance and toughness.						
Standards	**AISI** A2	**AFNOR** Z100CDV5					
Physical properties	**Thermal conductivity at °C** **W/(m • K)**	20 15.8	350 26.7	700 29.1			
Applications	Cutting tools, rolls, shear blades, cold pilger mandrels, cold stamping tools, moulds for plastics processing.						
Heat treatment	**Soft annealing °C** 800 - 840	**Cooling** Furnace			**Hardness HB** max. 231		
	Stress-relief annealing °C approx. 650	**Cooling** Furnace					
	Hardening °C 930 - 970	**Quenching** Air, oil or saltbath, 500 – 550 °C			**Hardness after quenching HRC** 63		
	Tempering °C **HRC**	100 63	200 62	300 59	400 57	500 59	600 52

Time-temperature-transformation diagram



Tempering diagram



Cryodur® 2379

X153CrMoV12	C 1.55 Si 0.30 Mn 0.35 Cr 12.00 Mo 0.75 V 0.90
Steel properties	12 % ledeburitic chromium steel. Combines maximum wear resistance, good toughness, outstanding cutting edge retention and tempering resistance. It can be nitrided after special heat treatment.
Standards	**AISI** D2 **AFNOR** Z160CDV12
Applications	Threading rolls and dies, cold extrusion tools, trimming, cutting and stamping tools for sheet thicknesses up to 6 mm, precision cutting tools for sheet thicknesses up to 12 mm, cold pilger mandrels, circular-shear blades, deep-drawing tools, pressure pads and highly wear-resistant plastic moulds.

Physical properties

Coefficient of thermal expansion				
at °C	20 - 100	20 - 200	20 - 300	20 - 400
10^{-6} m/(m • K)	10.5	11.5	11,9	12.2

Thermal conductivity at °C	20	350	700
W/(m • K)	16.7	20.5	24.2

Heat treatment

Soft annealing °C	Cooling	Hardness HB
830 - 860	Furnace	max. 250
Stress-relief annealing °C	**Cooling**	
650 - 700	Furnace	
Hardening °C	**Quenching**	**Hardness after quenching HRC**
1000 - 1050	Air, oil or saltbath, 500 – 550 °C	63

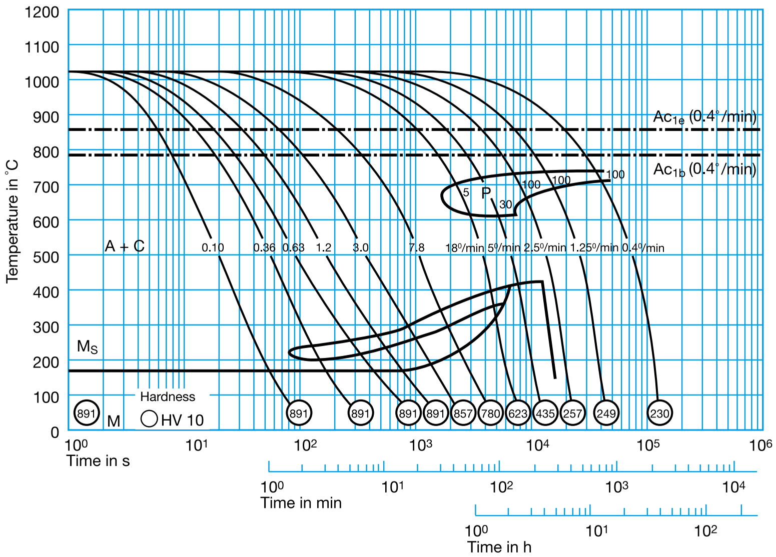
Tempering °C (three times)	100	200	300	400	500	525	550	600
HRC	63	61	58	58	58	60	56	50

Special heat treatment

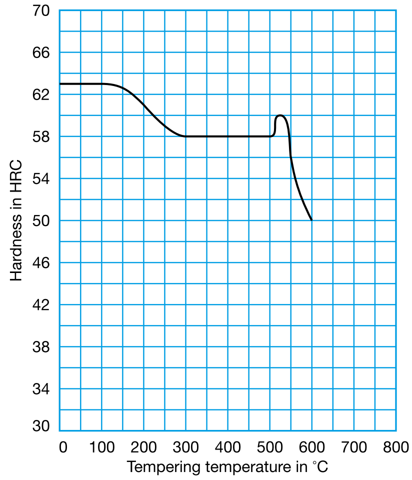
Hardening °C	Quenching	Hardness after quenching HRC
1050 - 1080	Air, oil or saltbath, 500 – 550 °C	61

Tempering °C (three times)	100	200	300	400	500	525	550	600
HRC	61	60	58	59	62	62	57	50

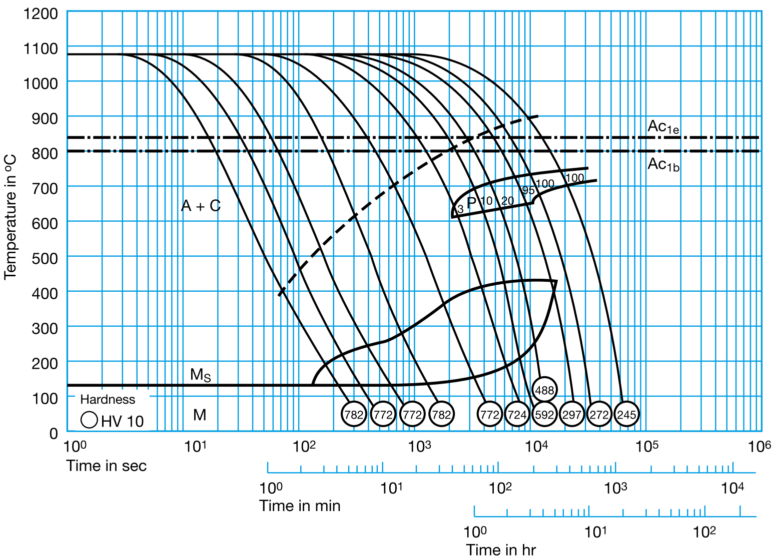
Time-temperature-transformation diagram
Hardening temperature: 1030 °C



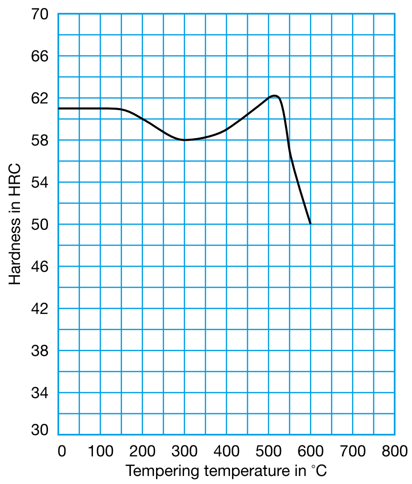
Tempering diagram



Time-temperature-transformation diagram
Hardening temperature: 1080 °C



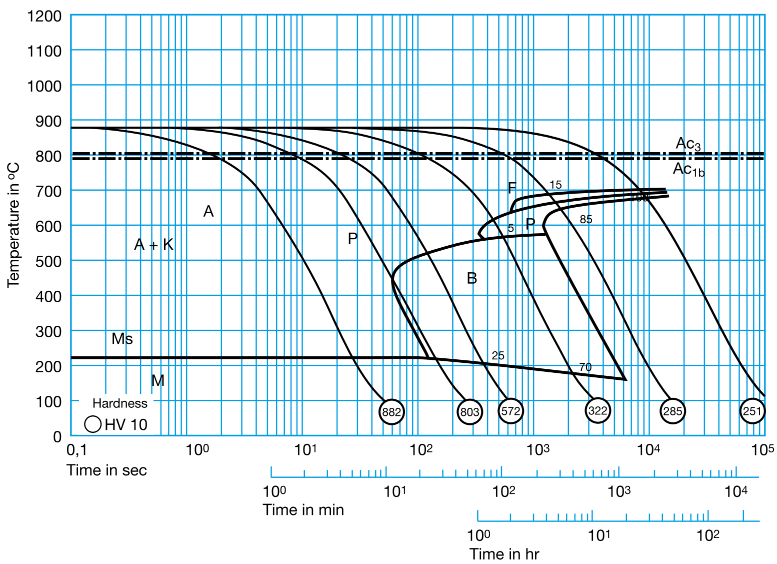
Tempering diagram



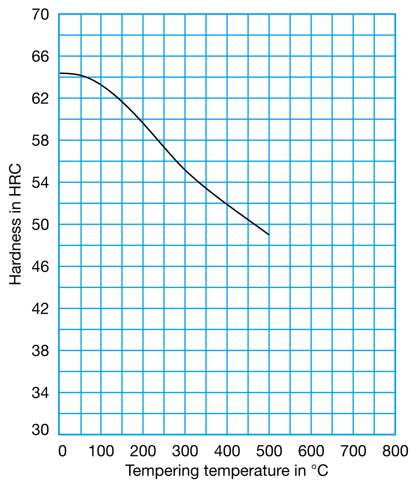
Cryodur® 2381

(73MoV5-2)	C 0.73 Si 1.20 Mn 0.50 Mo 0.55 V 0.20					
Steel properties	High tensile special steel with good resistance to twisting.					
Standards	**AISI** ~S2					
Applications	Screwdrivers, bits, low-stressed tools for the cutting, punching and folding of sheet.					
Heat treatment	**Soft annealing °C**	**Cooling**		**Hardness HB**		
	700 - 750	Furnace		max. 230		
	Stress-relief annealing °C	**Cooling**				
	650 - 680	Furnace				
	Hardening °C	**Quenching**		**Hardness after quenching HRC**		
	840 - 860	Oil		64		
	Tempering °C	100	200	300	400	500	600
	HRC	64	60	56	52	48	45

Time-temperature-transformation diagram



Tempering diagram

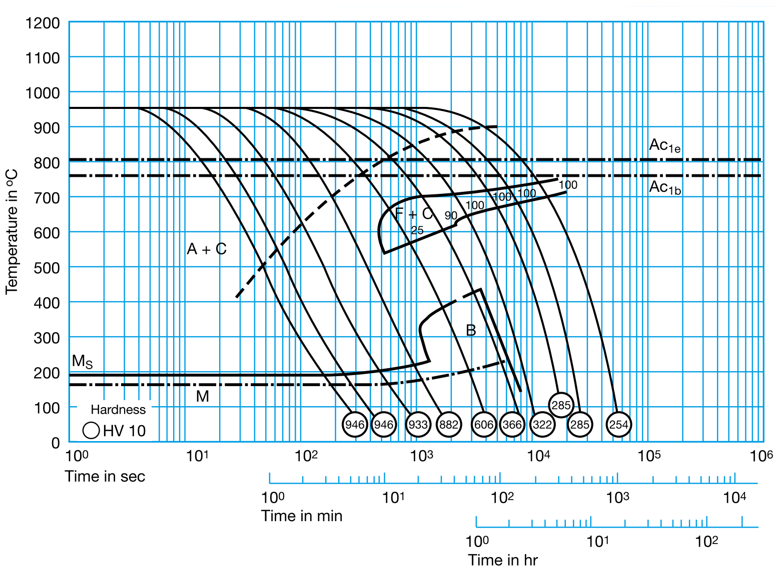


Reference numbers in brackets are not standardized in EN ISO 4957.

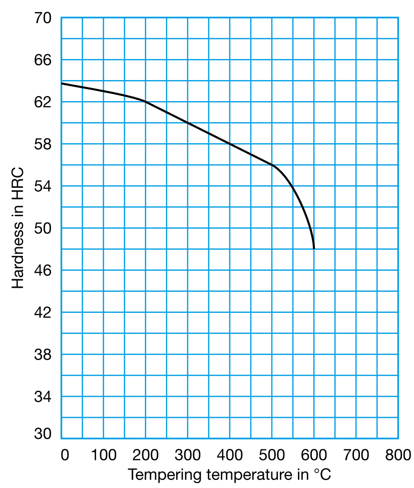
Cryodur® 2436

X210CrW12	C 2.10 Si 0.35 Mn 0.35 Cr 12.00 W 0.70							
Steel properties	12 % ledeburitic chromium steel with very high wear resistance and cutting edge retention as well as improved hardenability in comparison to Cryodur® 2080.							
Standards	**AISI** ~D6	**AFNOR** Z210CW12-01						
Physical properties	**Coefficient of thermal expansion**							
	at °C	20 - 100	20 - 200	20 - 300	20 - 400	20 - 500	20 - 600	20 - 700
	10^{-6} m/(m • K)	10.9	11.9	12.3	12.6	12.9	13.0	13.2
	Thermal conductivity at °C	20	350	700				
	W/(m • K)	16.7	20.5	24.2				
Applications	Heavy-duty blanking dies for cutting transformer and dynamo sheets up to 2 mm thickness as well as for paper and plastics, deep-drawing tools, drawing dies and mandrels, shear blades, stone pressing tools.							
Heat treatment	**Soft annealing °C**	**Cooling**			**Hardness HB**			
	800 - 840	Furnace			max. 250			
	Stress-relief annealing °C	**Cooling**						
	650 - 700	Furnace						
	Hardening °C	**Quenching**			**Hardness after quenching HRC**			
	950 - 980	Air, oil or saltbath, 500 – 550 °C			64			
	Tempering °C	100	200	300	400	500	600	
	HRC	63	62	60	58	56	48	

Time-temperature-transformation diagram



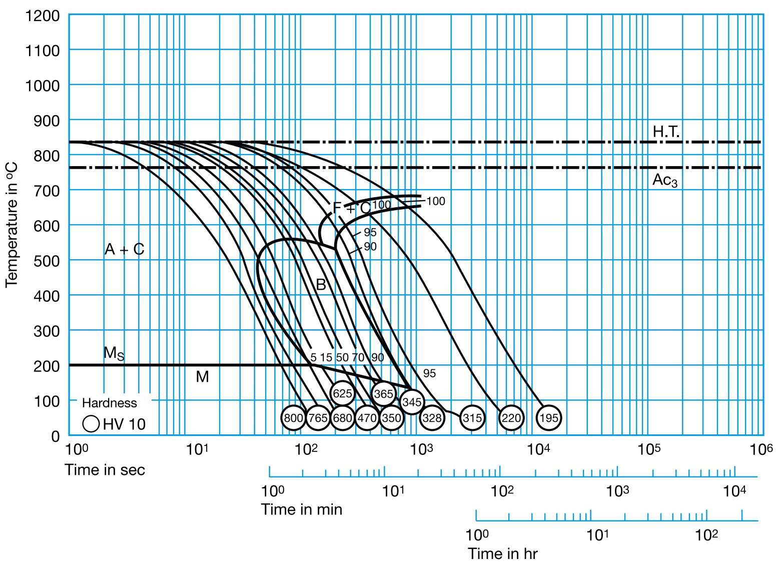
Tempering diagram



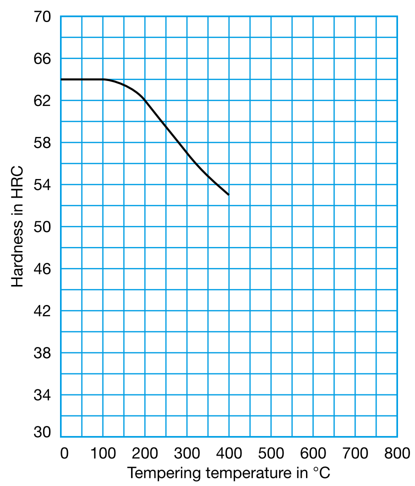
Cryodur® 2510

(100MnCrW4)	C 0.95 Si 0.20 Mn 1.10 Cr 0.60 V 0.10 W 0.60
Steel properties	Good cutting edge retention, high hardenability and dimensional stability during heat treatment.
Standards	**AISI** O1 **AFNOR** 90MWCV5
Physical properties	**Thermal conductivity at °C** 20 / 350 / 700 **W/(m • K)** 33.5 / 32.0 / 30.9
Applications	Blanking and stamping dies for cutting sheets up to 6 mm thickness, threading tools, drills, broaches, gauges, measuring tools, plastic moulds, shear blades, guide rails.
Heat treatment	**Soft annealing °C** 740 - 770 · **Cooling** Furnace · **Hardness HB** max. 230 **Stress-relief annealing °C** approx. 650 · **Cooling** Furnace **Hardening °C** 780 - 820 · **Quenching** Oil or saltbath, 180 - 220 °C · **Hardness after quenching HRC** 64 **Tempering °C** 100 / 200 / 300 / 400 **HRC** 64 / 62 / 57 / 53

Time-temperature-transformation diagram



Tempering diagram

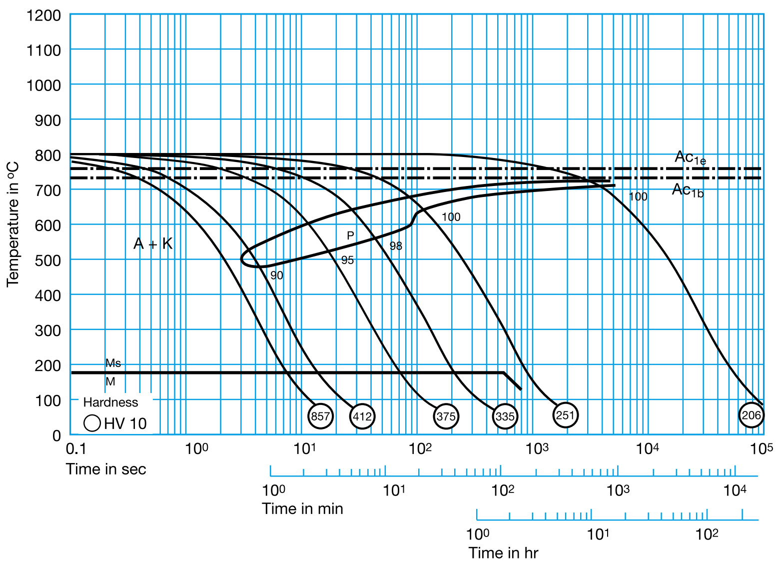


Reference numbers in brackets are not standardized in EN ISO 4957.

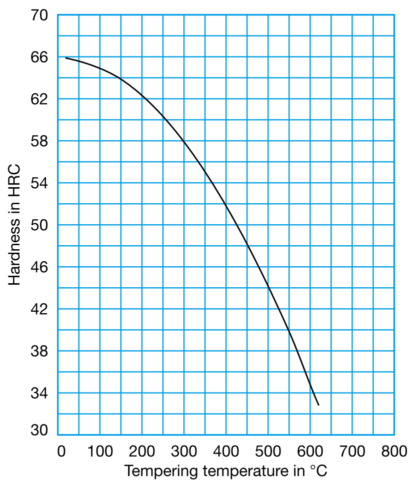
Cryodur® 2516

(120WV4)	C 1.20 Cr 0.20 V 0.10 W 1.00				
Steel properties	Water-hardening steel featuring good cutting edge retention and high hardenability.				
Applications	Thread cutting tools, twist drills, dentist's drills and metal saws.				
Heat treatment	**Soft annealing °C** 700 - 720	**Cooling** Furnace			**Hardness HB** max. 230
	Stress-relief annealing °C 650 - 680	**Cooling** Furnace			
	Hardening °C 780 - 820	**Quenching** Oil or water			**Hardness after quenching HRC** 66
	Tempering °C	100	200	300	400
	HRC	65	62	57	51

Time-temperature-transformation diagram



Tempering diagram

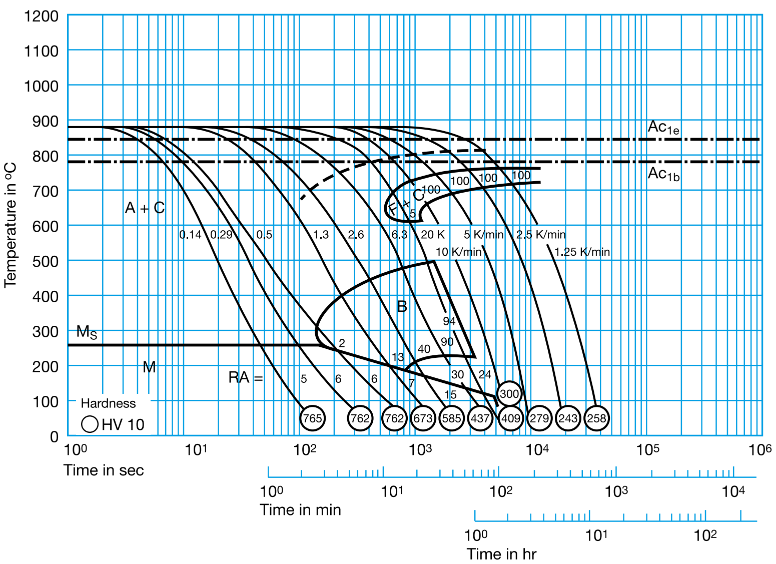


Reference numbers in brackets are not standardized in EN ISO 4957.

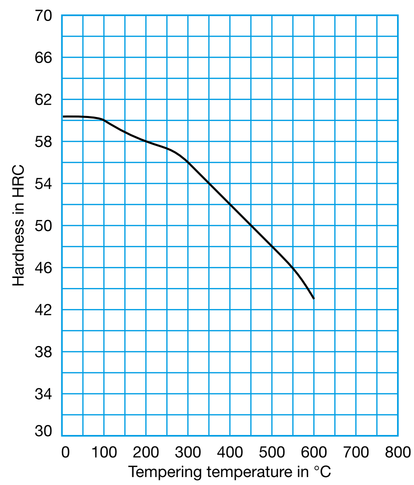
Cryodur® 2550

60WCrV8	C 0.60 Si 0.60 Mn 0.35 Cr 1.10 V 0.20 W 2.00						
Steel properties	Impact-resistant oil-hardenable steel, characterized by very good toughness in combination with high hardenability.						
Standards	**AISI** ~S1	**AFNOR** 55WC20					
Physical properties	**Coefficient of thermal expansion**						
	at °C	20 - 100	20 - 200	20 - 300	20 - 400	20 - 500	20 - 600	20 - 700
	10^{-6} m/(m • K)	11.8	12.7	13.1	13.5	14.0	14.3	14.5
	Thermal conductivity at °C	20	350	700				
	W/(m • K)	34.2	32.6	30.9				
Applications	Blanking dies for cutting sheets up to 12 mm thickness, trimming and splitting dies, cold piercing punches, pre-forming punches, shear blades, chipping knives, pneumatic chisels, coining tools, cold shear blades, ejectors.						
Heat treatment	**Soft annealing °C** 710 - 750	**Cooling** Furnace	**Hardness HB** max. 225				
	Stress-relief annealing °C approx. 650	**Cooling** Furnace					
	Hardening °C 870 - 900	**Quenching** Oil or saltbath, 180 – 220 °C	**Hardness after quenching HRC** 60				
	Tempering °C	100	200	300	400	500	600
	HRC	60	58	56	52	48	43

Time-temperature-transformation diagram



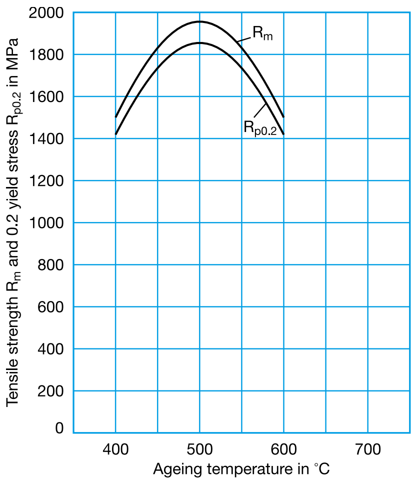
Tempering diagram



Cryodur® 2709

(X3NiCoMoTi18-9-5)	C < 0.02 Mo 5.00 Ni 18.00 Co 10.00 Ti 1.00						
Steel properties	Precipitation-hardenable grade with high yield point and tensile strength combined with good toughness.						
Standards	**AISI** 18MAR300						
Physical properties	**Coefficient of thermal expansion**						
	at °C	20 - 100	20 - 200	20 - 300	20 - 400	20 - 500	20 - 600
	10^{-6} m/(m • K)	10.3	11.0	11.2	11.5	11.8	11.6
	Thermal conductivity at °C	20	350	700			
	W/(m • K)	14.2	18.5	22.5			
Applications	Casings for cold extrusion tools, cutting and punching tools.						
Heat treatment	**Soft annealing °C**	**Cooling**			**Hardness HB**		
	820 - 850	Water			max. 340		
	Precipitation temperature °C	**Attainable hardness HRC**					
	490 / 6 h/(Air)	approx. 55					

Tempering diagram



Thermodur® 2714

55NiCrMoV7	C 0.56 Cr 1.10 Mo 0.50 Ni 1.70 V 0.10
Steel properties	Tough die steel with high tempering resistance and good through-hardening properties. This grade is usually supplied in annealed condition or quenched and tempered to a working hardness of 370 to 410 HB (round) or 355 to 400 HB (square, flat).
Standards	**AISI** ~L6 **AFNOR** 55NCDV7
Physical properties	see below
Applications	Standard steel for forging dies of all types, press dies, extrusion dies, retainer plates, armoured trim dies, hot-shear blades and tool holders.
Heat treatment	see below

Physical properties

Coefficient of thermal expansion at °C	20 - 100	20 - 200	20 - 300	20 - 400	20 - 500	20 - 600
10^{-6} m/(m • K)	12.2	13.0	13.3	13.7	14.2	14.4

Thermal conductivity at °C	20	350	700
W/(m • K)	36.0	38.0	35.0

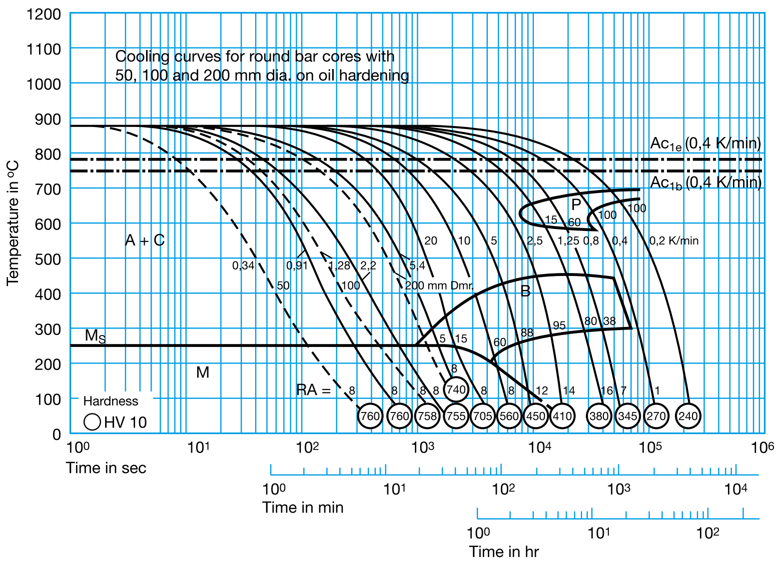
Heat treatment

Soft annealing °C	Cooling	Hardness HB
650 - 700	Furnace	max. 250

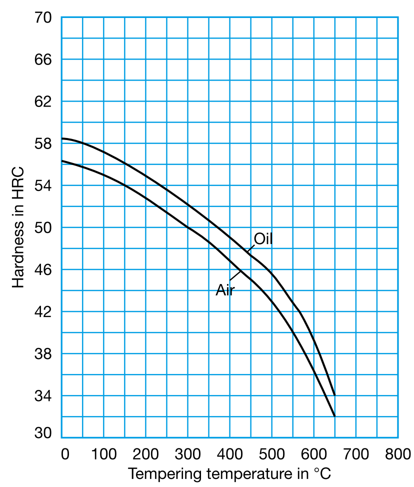
Hardening °C	Quenching	Hardness after quenching HRC
830 - 870	Oil	58
860 - 900	Air	56

Tempering °C after quenching	100	200	300	400	450	500	550	600	650
in Oil – HRC	57	54	52	49	47	46	43	38	34
in Air – HRC	55	52	50	47	45	43	40	36	32

Time-temperature-transformation diagram



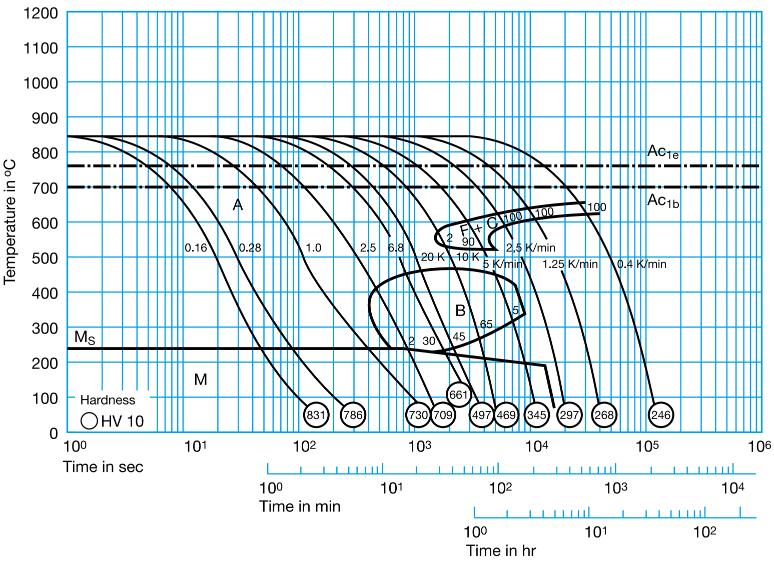
Tempering diagram



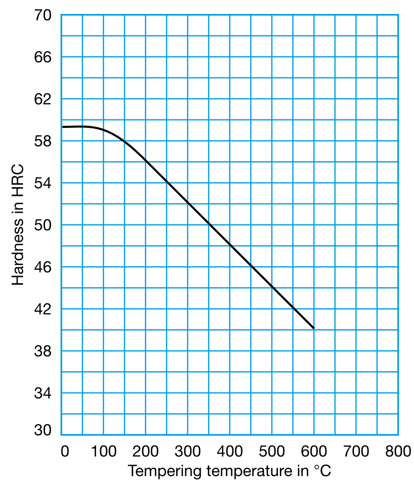
Cryodur® 2721

(50NiCr13)	C 0.55 Si 0.25 Mn 0.45 Cr 1.00 Ni 3.10					
Steel properties	Air or oil-hardenable steel with good machinability and high toughness.					
Physical properties	**Thermal conductivity at °C**	20	350	700		
	W/(m • K)	31.0	31.2	31.8		
Applications	Cold heading dies, hobbers, cutlery dies, reinforcements and pelleters.					
Heat treatment	**Soft annealing °C** 610 - 650	**Cooling** Furnace		**Hardness HB** max. 250		
	Stress-relief annealing °C approx. 600	**Cooling** Furnace				
	Hardening °C 840 - 870	**Quenching** Oil or saltbath, 180 – 220 °C		**Hardness after quenching HRC** 59		
	Tempering °C	100	200	300	400	500	600
	HRC	59	56	52	48	44	40

Time-temperature-transformation diagram



Tempering diagram

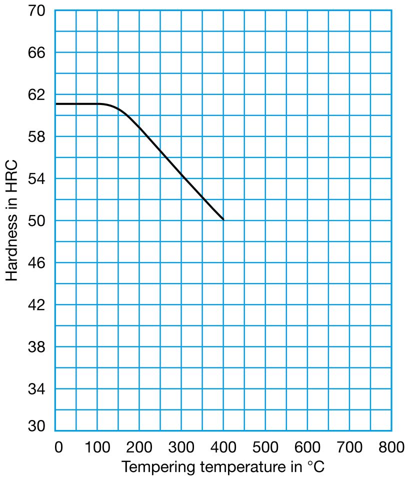


Reference numbers in brackets are not standardized in EN ISO 4957.

Cryodur® 2743

(60NiCrMoV12-4)	C 0.58 Si 0.40 Mn 0.65 Cr 1.15 Mo 0.35 Ni 2.85 V 0.10				
Steel properties	Nickel-alloyed cold-work steel with a good combination of wear resistance and toughness.				
Physical properties	**Coefficient of thermal expansion**				
	at °C	20 - 200	20 - 400		
	10^{-6} m/(m • K)	12.2	12.5		
	Thermal conductivity at °C	20	200	400	
	W/(m • K)	28.9	30.0	31.0	
Applications	Scrap-shear blades, dies and coining tools, piercing punches.				
Heat treatment	**Soft annealing °C**	**Cooling**		**Hardness HB**	
	690 - 700	Furnace		approx. 235	
	Stress-relief annealing °C	**Cooling**			
	600 - 650	Furnace			
	Hardening °C	**Quenching**		**Hardness after quenching HRC**	
	840 - 870	Oil		61	
	Tempering °C	100	200	300	400
	HRC	61	59	54	50

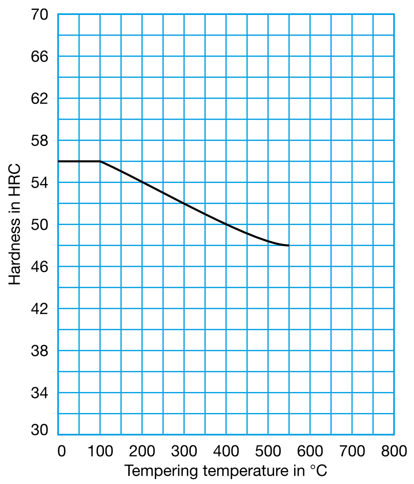
Tempering diagram



Cryodur® 2746

(45NiCrMoV16-6)	C 0.45 Si 0.25 Mn 0.70 Cr 1.50 Mo 0.80 Ni 4.00 V 0.50					
Steel properties	Air or oil-hardenable steel featuring high toughness.					
Applications	Special steel for cold-shear blades, particularly for cutting scrap. Drawing jaws, coining and bending tools.					
Heat treatment	**Soft annealing °C** 610 - 650	**Cooling** Furnace			**Hardness HB** max. 295	
	Stress-relief annealing °C approx. 600	**Cooling** Furnace				
	Hardening °C 880 - 910	**Quenching** Air, oil or saltbath, 180 – 220 °C			**Hardness after quenching HRC** 56	
	Tempering °C	100	200	300	400	500	550
	HRC	56	54	52	50	49	48

Tempering diagram

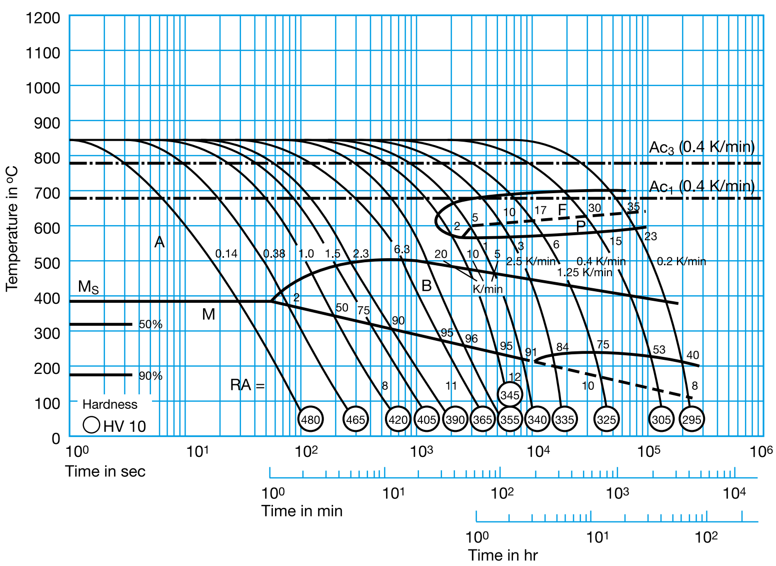


Reference numbers in brackets are not standardized in EN ISO 4957.

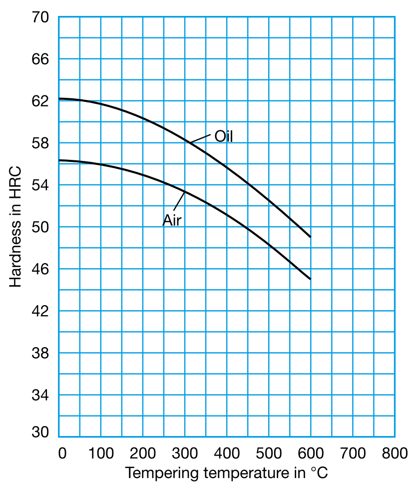
Formadur® 2764

(X19NiCrMo4)	C 0.19 Cr 1.30 Mo 0.20 Ni 4.10							
Steel properties	Case-hardening steel, high core strength, good polishability.							
Standards	**AISI** ~P21							
Physical properties	**Coefficient of thermal expansion**							
	at °C	20 - 100	20 - 200	20 - 300	20 - 400			
	10^{-6} m/(m • K)	12.1	13.0	13.1	13.5			
	Thermal conductivity at °C	20	350	700				
	W/(m • K)	33.5	32.5	32.0				
Applications	Highly stressed plastic moulds, tool holders for cutter picks.							
Heat treatment	**Soft annealing °C**	**Cooling**				**Hardness HB**		
	620 - 660	Furnace				max. 250		
	Stress-relief annealing °C	**Cooling**						
	600	Furnace						
	Carburizing °C	**Intermediat annealing °C**		**Hardening °C**		**Quenching**		**Hardness after quenching HRC**
	860 - 890	600 - 630		780 - 810		Oil or saltbath, 180 – 220 °C		62
	860 - 890	600 - 630		800 - 830		Air		56
	Tempering °C	100	200	300	400	500	600	
	after oil hardening HRC	62	60	58	56	52	49	
	after air hardening HRC	56	55	53	51	48	45	

Time-temperature-transformation diagram



Tempering diagram

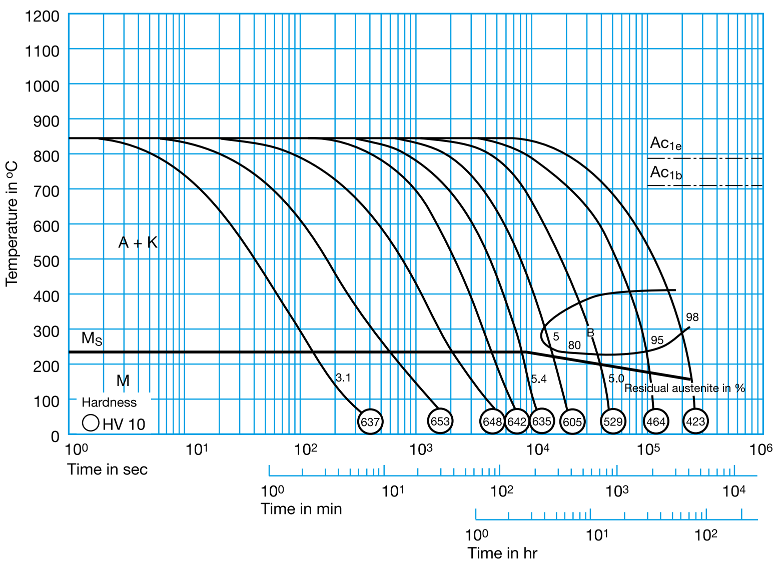


Reference numbers in brackets are not standardized in EN ISO 4957.

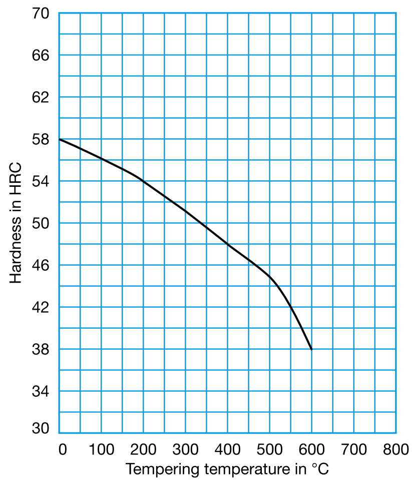
Cryodur® 2766

(35NiCrMo16)	C 0.35 Si 0.25 Mn 0.50 Cr 1.35 Ni 4.10 Mo 0.30					
Steel properties	Dimensionally stable air-hardening steel featuring maximum toughness, polishable. Also supplied with lower carbon and higher chromium content.					
Applications	Moulds, dies with deep engravings, plastic moulds und hydraulic chisels.					
Heat treatment	**Soft annealing °C** 590 - 610	**Cooling** Furnace			**Hardness HB** max. 260	
	Stress-relief annealing °C 600 - 650	**Cooling** Furnace				
	Hardening °C 820 - 840	**Quenching** Oil or saltbath, 180 – 220 °C			**Hardness after quenching HRC** approx. 58	
	Tempering °C	100	200	300	400	500	600
	HRC	56	54	51	48	45	38

Time-temperature-transformation diagram



Tempering diagram

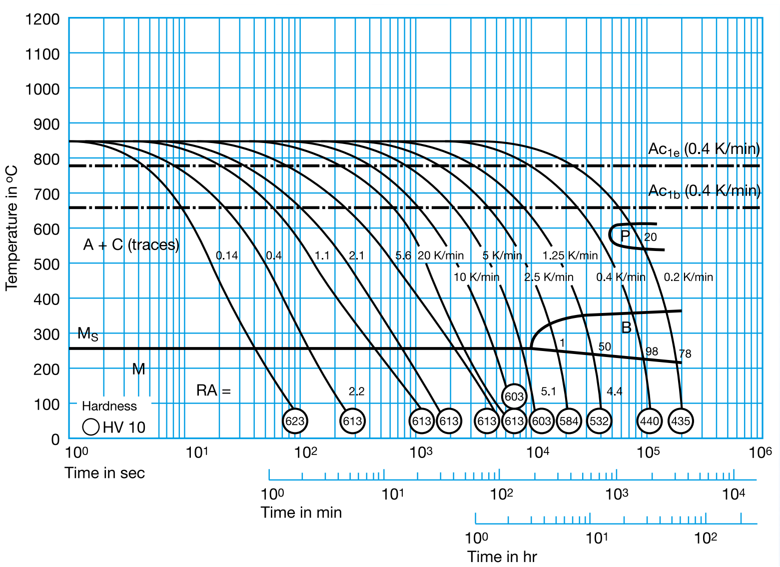


Reference numbers in brackets are not standardized in EN ISO 4957.

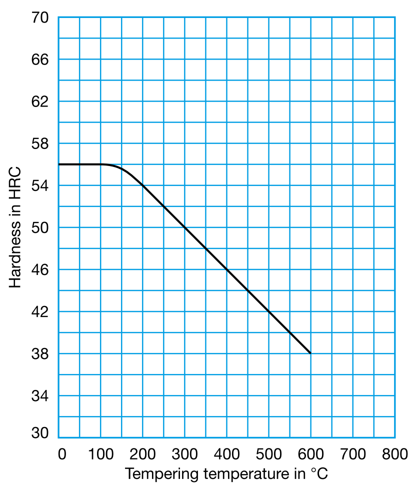
Cryodur® 2767

45NiCrMo16	C 0.45 Si 0.25 Mn 0.35 Cr 1.40 Mo 0.20 Ni 4.00
Steel properties	High hardenability and toughness, highly suitable for polishing, texturing and EDM machining. We recommend the use of Cryodur® 2767 Superclean (ESR) for extreme demands.
Standards	**AISI** 6F3
Physical properties	**Coefficient of thermal expansion**
	at °C 20 - 100, 20 - 200, 20 - 300
	10^{-6} m/(m • K) Annealed 11.7, 12.6, 13.1
	10^{-6} m/(m • K) Quenched and tempered 12.0, 12.5, 13.0
	Thermal conductivity at °C 100, 150, 200, 250, 300
	W/(m • K) Annealed 38.2, 38.6, 38.9, 39.1, 39.6
	W/(m • K) Quenched and tempered 27.7, 28.9, 29.7, 30.5, 31.0
Applications	Cutlery dies, cutting tools for thick material, billet-shear blades, drawing jaws, massive embossing and bending tools, plastic moulds, reinforcements.
Heat treatment	**Soft annealing °C** 610 - 650; **Cooling** Furnace; **Hardness HB** max. 260
	Stress-relief annealing °C approx. 600 - 650; **Cooling** Furnace
	Hardening °C 840 - 870; **Quenching** Air, oil or saltbath, 180 – 220 °C; **Hardness after quenching HRC** 56
	Tempering °C 100, 200, 300, 400, 500, 600
	HRC 56, 54, 50, 46, 42, 38

Time-temperature-transformation diagram



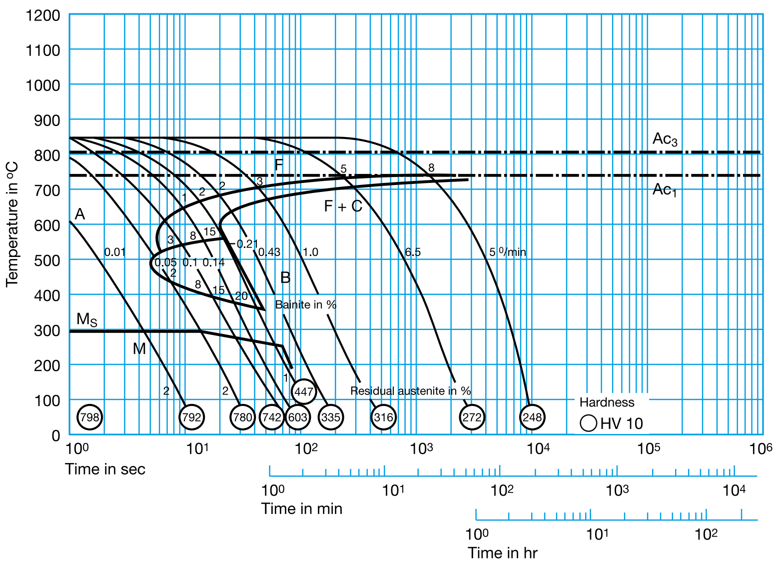
Tempering diagram



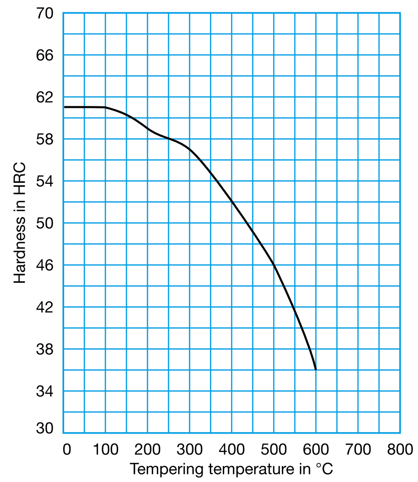
Cryodur® 2826

(60MnSiCr4)	C 0.63 Si 0.80 Mn 1.10 Cr 0.30					
Steel properties	High toughness and good resilience in tempered condition.					
Standards	**AISI** S4					
Physical properties	**Thermal conductivity at °C**	20	350	700		
	W/(m • K)	34.2	32.6	31.0		
Applications	Spring collets, shear blades and trimming dies.					
Heat treatment	**Soft annealing °C** 680 - 710	**Cooling** Furnace		**Hardness HB** max. 220		
	Stress-relief annealing °C approx. 650	**Cooling** Furnace				
	Hardening °C 820 - 860	**Quenching** Oil or saltbath, 180 – 220 °C		**Hardness after quenching HRC** 61		
	Tempering °C	100	200	300	400	500	600
	HRC	61	59	57	52	46	36

Time-temperature-transformation diagram



Tempering diagram

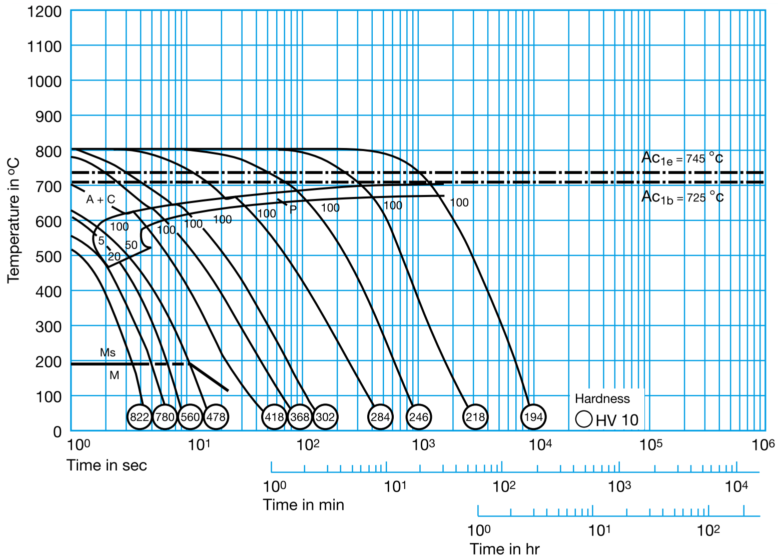


Reference numbers in brackets are not standardized in EN ISO 4957.

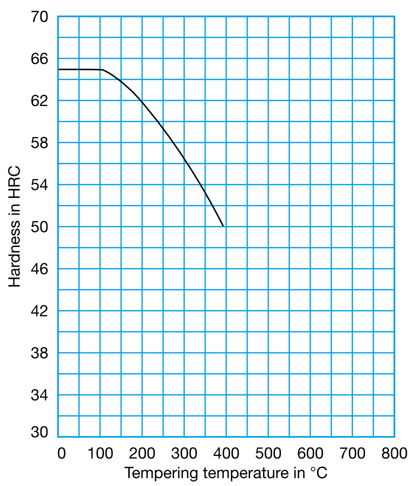
Cryodur® 2833

(100V1)	C 1.00 Si 0.20 Mn 0.20 V 0.10
Steel properties	Wear-resistant water-hardening steel with high insusceptibility to overheating.
Standards	**AISI** W210 **AFNOR** 100V2
Physical properties	**Thermal conductivity at °C** 20 350 700 **W/(m • K)** 37.6 35.2 32.6
Applications	Cold heading dies, first and finish upsetting punches, cold stamps and dies for the manufacturing of screws, rivets and bolts, compression pistons.
Heat treatment	**Soft annealing °C** 730 - 760 · **Cooling** Furnace · **Hardness HB** max. 200 **Stress-relief annealing °C** 650 - 680 · **Cooling** Furnace **Hardening °C** 780 - 820 · **Quenching** Water · **Hardness after quenching HRC** 65 **Tempering °C** 100 200 300 400 **HRC** 65 62 57 50

Time-temperature-transformation diagram



Tempering diagram

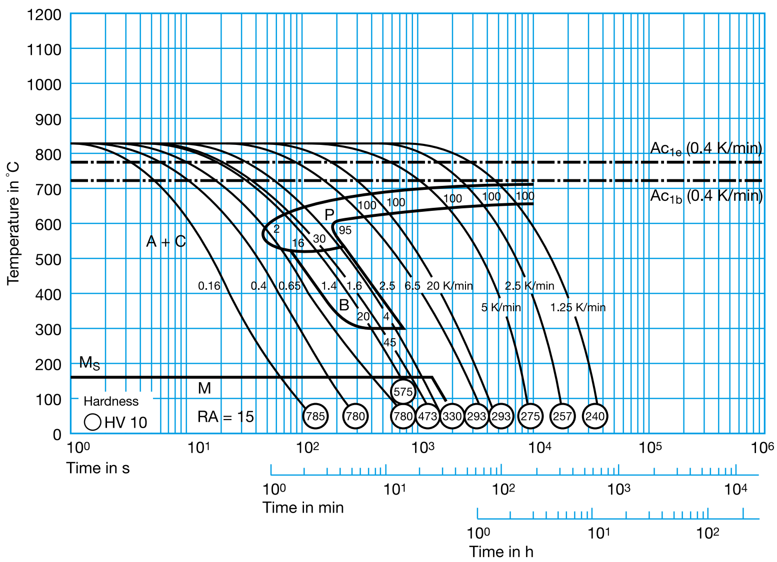


Reference numbers in brackets are not standardized in EN ISO 4957.

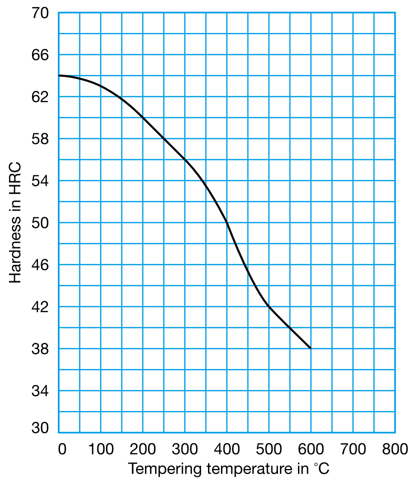
Cryodur® 2842

90MnCrV8	C 0.90 Si 0.20 Mn 2.00 Cr 0.40 V 0.10							
Steel properties	Good cutting edge retention, dimensionally stable during heat treatment.							
Standards	**AISI** O2	**AFNOR** 90MV8						
Physical properties	**Coefficient of thermal expansion**							
	at °C	20 - 100	20 - 200	20 - 300	20 - 400	20 - 500	20 - 600	20 - 700
	10^{-6} m/(m • K)	12.2	13.2	13.8	14.3	14.7	15.0	15.3
	Thermal conductivity at °C	20	350	700				
	W/(m • K)	33.0	32.0	31.3				
Applications	Tool steel for universal use, cutting and stamping tools for sheet up to 6 mm thickness, thread-cutting tools, reamers, gauges, measuring tools, plastic moulds, shear blades, guide strips and ejector pins.							
Heat treatment	**Soft annealing °C**	**Cooling**		**Hardness HB**				
	680 - 720	Furnace		max. 220				
	Stress-relief annealing °C	**Cooling**						
	approx. 650	Furnace						
	Hardening °C	**Quenching**		**Hardness after quenching HRC**				
	790 - 820	Oil or saltbath, 180 – 220 °C		64				
	Tempering °C	100	200	300	400	500	600	
	HRC	63	60	56	50	42	38	

Time-temperature-transformation diagram



Tempering diagram



Cryodur® 2990

(~X100CrMoV8-1-1)	C 1.00 Si 0.90 Cr 8.00 Mo 1.10 V 1.60
Steel properties	Newly developed ledeburitic cold-work steel with high hardness, good toughness and high tempering resistance combined with high wear resistance.
Physical properties	see below
Applications	Cutting and punching tools including precision cutting tools, threading dies and rolls, rotary shear blades, cold pilger mandrels, pressure pads and plastic moulds, cold-forming and deep-drawing dies, woodworking tools and cold rolls.
Heat treatment	see below

Physical properties

Coefficient of thermal expansion

at °C	20 - 100	20 - 150	20 - 200	20 - 250	20 - 300	20 - 350	20 - 400	20 - 450	20 - 500
10^{-6} m/(m • K)	11.4	11.6	11.7	11.9	12.0	12.1	12.3	12.4	12.6

Thermal conductivity

at °C	RT	100	150	200	300	400	500
W/(m • K)	24.0	25.9	26.8	27.1	27.4	27.2	26.8

Heat treatment

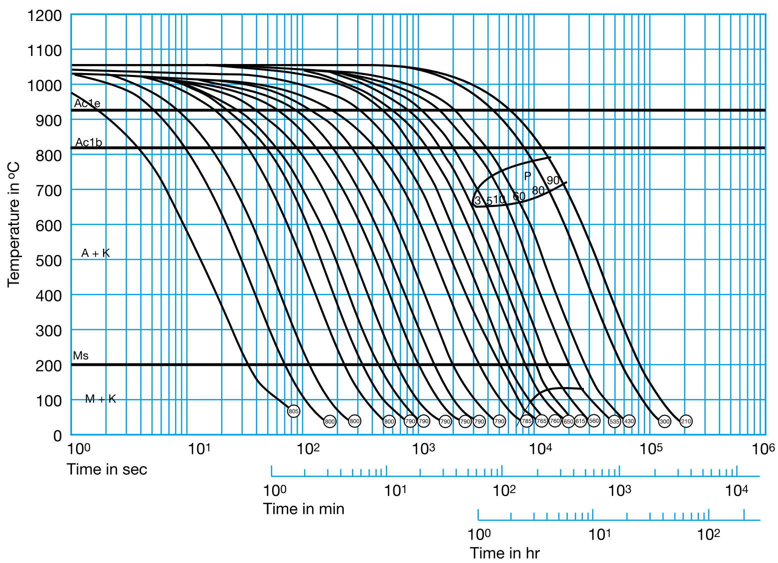
Soft annealing °C	Cooling	Hardness HB
830 - 860	Furnace	max. 250

Stress-relief annealing °C	Cooling
approx. 650	Furnace

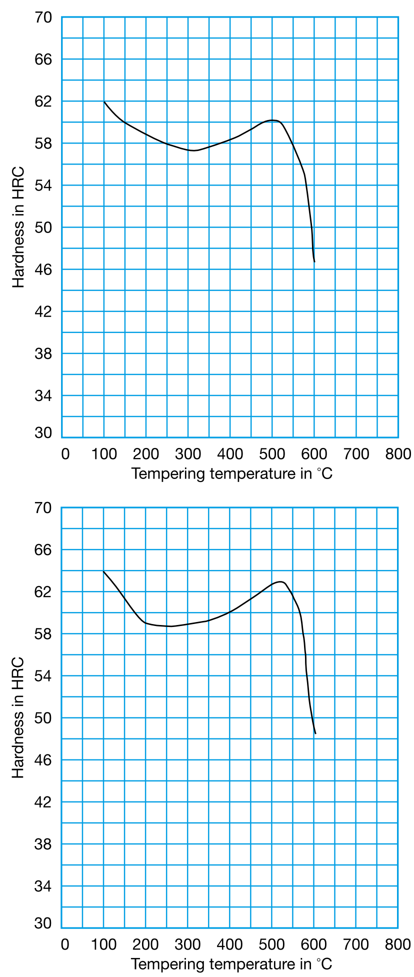
Hardening °C	Hardening °C	Hardness after quenching HRC
1030 1) - 1080 2)	Air, oil or saltbath, 500 – 550 °C	62 - 64

Tempering °C	100	200	300	400	500	525	550	575	600
1) HRC	62	59	57	58	60	60	59	55	46
2) HRC	64	59	59	60	63	63	61	57	48

Time-temperature-transformation diagram



Tempering diagram
Above: Hardening 1030 °C
Below: Hardening 1080 °C



Reference numbers in brackets are not standardized in EN ISO 4957.

Rapidur® 3202

(HS12-1-4-5)	C 1.35 Cr 4.10 Mo 0.80 V 3.80 W 12.00 Co 4.80
Steel properties	High-performance high-speed steel featuring an extremely good cutting edge retention and wear resistance due to its high vanadium content. A high cobalt content contributes to a high red hardness and tempering resistance.
Standards	**AISI** ~T15
Applications	Machining of hard materials which wear cutting edges such as highly quenched and tempered chromium-nickel grades and non-ferrous metals, mother-of-pearl, paper, hard rubber, synthetic resins, marble, slate and the like. Ideally suited for turning and finishing tools, forming tools of all kinds, heavy-duty milling cutters and automatic lathes.
Heat treatment	

Soft annealing °C	Cooling	Hardness HB
820 - 860	Furnace	max. 280

Stress-relief annealing °C	Cooling
630 - 650	Furnace

1st pre-heating °C	2nd and 3rd pre-heating °C	Hardening[1] °C	Quenching	Tempering °C	Hardness after tempering HRC
up to approx. 400 in an air-circulating furnace	a) 850 b) 850 and 1050	1190 - 1240	a) Saltbath, 550 °C b) Oil c) Air	at least three times 540 - 580	64 - 67

[1)] For cold-forming tools with a complex geometry, a hardening temperature at the lower end of the quoted range is recommended.
The stated hardening temperatures apply to saltbath hardening only. For vacuum hardening, we suggest a reduction of 10 °C to 30 °C.

Rapidur® 3207

HS10-4-3-10	C 1.23 Cr 4.10 Mo 3.50 V 3.30 W 9.50 Co 10.00
Steel properties	High-speed steel of superlative performance combining optimal cutting-edge retention, high-temperature strength and toughness on account of its composition.
Standards	**AISI** ~T42 **AFNOR** Z130WKCDV10-10-04-04-03
Applications	Universally applicable for roughing and finishing where maximum tool life is required and for automatic lathes where wear is caused by large batch production. Also for all kinds of cutting tools and milling cutters exposed to exceedingly high stresses.
Heat treatment	

Soft annealing °C	Cooling	Hardness HB
820 - 860	Furnace	max. 302

Stress-relief annealing °C	Cooling
630 - 650	Furnace

1st pre-heating °C	2nd and 3rd pre-heating °C	Hardening[1] °C	Quenching	Tempering °C	Hardness after tempering HRC
up to approx. 400 in an air-circulating furnace	a) 850 b) 850 and 1050	1190 - 1230	a) Saltbath, 550 °C b) Oil c) Air	at least three times 540 - 570	65 - 67

[1] For cold-forming tools with a complex geometry, a hardening temperature at the lower end of the quoted range is recommended.
The stated hardening temperatures apply to saltbath hardening only. For vacuum hardening, we suggest a reduction of 10 °C to 30 °C.

Rapidur® 3243

HS6-5-2-5	C 0.92 Cr 4.10 Mo 5.00 V 1.90 W 6.40 Co 4.80
Steel properties	The cobalt content in this high-performance high-speed steel results in high red hardness and tempering resistance. As a consequence, this grade is particularly suitable for conditions involving thermal stresses and discontinuous cutting. Under the name Rapidur® 3245, AISI M 35 + S and material number 1.3245, this steel grade is supplied with a higher sulphur content (S = 0.10 %).
Standards	**AISI** M35 **AFNOR** Z85WDKCV06-05-05-04-02
Applications	Heavy-duty milling cutters of all kinds, highly stressed twist drills and taps, profile knives, machining of high-strength materials, broaches.

Heat treatment

Soft annealing °C	Cooling	Hardness HB
820 - 860	Furnace	max. 269

Stress-relief annealing °C	Cooling
630 - 650	Furnace

1st pre-heating °C	2nd and 3rd pre-heating °C	Hardening[1] °C	Quenching	Tempering °C	Hardness after tempering HRC
up to approx. 400 in an air-circulating furnace	a) 850 b) 850 and 1050	1190 - 1230	a) Saltbath, 550 °C b) Oil c) Air	at least three times 540 - 570	64 - 67

[1] For cold-forming tools with a complex geometry, a hardening temperature at the lower end of the quoted range is recommended.
The stated hardening temperatures apply to saltbath hardening only. For vacuum hardening, we suggest a reduction of 10 °C to 30 °C.

Rapidur® 3247

HS2-9-1-8	C 1.08 Cr 4.10 Mo 9.50 V 1.20 W 1.50 Co 8.00
Steel properties	High-carbon, high-speed steel based on molybdenum. Characterized by high wear resistance, red hardness and toughness. As a result of its low vanadium content, this grade exhibits good grindability.
Standards	**AISI** M42 **AFNOR** Z110DKCWV
Applications	For tools subject to severe mechanical wear (e.g. in case of small cross-section cuts at high cutting speeds). Particularly suitable for die-sinking cutters, milling cutters and engraving machines including gravers as well as for tool bits in automatic lathes. Also suitable for non-cutting shaping (e.g. cold extrusion rams and tools employed in machining materials for the aviation industry such as titanium alloys).

Heat treatment

Soft annealing °C	**Cooling**	**Hardness HB**
820 - 860	Furnace	max. 277

Stress-relief annealing °C	**Cooling**
630 - 650	Furnace

1st pre-heating °C	**2nd and 3rd pre-heating °C**	**Hardening[1] °C**	**Quenching**	**Tempering °C**	**Hardness after tempering HRC**
up to approx. 400 in an air-circulating furnace	a) 850 b) 850 and 1050	1160 - 1190	a) Saltbath, 550 °C b) Oil c) Air	at least three times 530 - 560	66 - 69

[1] For cold-forming tools with a complex geometry, a hardening temperature at the lower end of the quoted range is recommended.

The stated hardening temperatures apply to saltbath hardening only. For vacuum hardening, we suggest a reduction of 10 °C to 30 °C.

Rapidur® 3333

HS3-3-2	C 1.00 Cr 4.00 Mo 2.60 V 2.30 W 3.00
Steel properties	High-speed steel with economic use of alloys, universally applicable at medium performance. Suitable for series tooling.
Applications	Twist drills, circular saws, hacksaws, reamers and milling cutters.
Applications	

Soft annealing °C	**Cooling**	**Hardness HB**
770 - 840	Furnace	max. 255

Stress-relief annealing °C	**Cooling**
630 - 650	Furnace

1st pre-heating °C	**2nd and 3rd pre-heating °C**	**Hardening[1] °C**	**Quenching**	**Tempering °C**	**Hardness after tempering HRC**
up to approx. 400 in an air-circulating furnace	a) 850 b) 850 und 1050	1180 - 1220	a) Saltbath, 550 °C b) Oil c) Air	at least twice 540 - 560	62 - 64

Tempering °C	100	200	300	400	500	525	550	575	600
HRC	63	61	60	58	62	63	64	63	62

[1] For cold-forming tools with a complex geometry, a hardening temperature at the lower end of the quoted range is recommended.
The stated hardening temperatures apply to saltbath hardening only. For vacuum hardening, we suggest a reduction of 10 °C to 30 °C.

Rapidur® 3343

HS6-5-2C	C 0.90 Si 0.30 Mn 0.30 Cr 4.10 Mo 5.00 V 1.90 W 6.40
Steel properties	Standard high-speed steel grade. Its well-balanced alloy composition forms the basis of its high toughness and good cutting edge retention, rendering it suitable for a large variety of applications.
Standards	**AISI** M2 **AFNOR** Z85WDCV06-05-04-02
Physical properties	**Thermal conductivity** **at °C**: 20 / 350 / 700 **W/(m • K)**: 32.8 / 23.5 / 25.5
Applications	For all metal-cutting tools for roughing or finishing such as twist drills, diverse milling cutters, thread dies, broaches, reamers, countersinks, thread chasers, circular saw segments, shaping tools and woodworking tools. Also highly suitable for cold-forming tools such as cold extrusion rams and dies, as well as cutting and precision cutting tools, plastic moulds with elevated wear resistance and screws.

Heat treatment

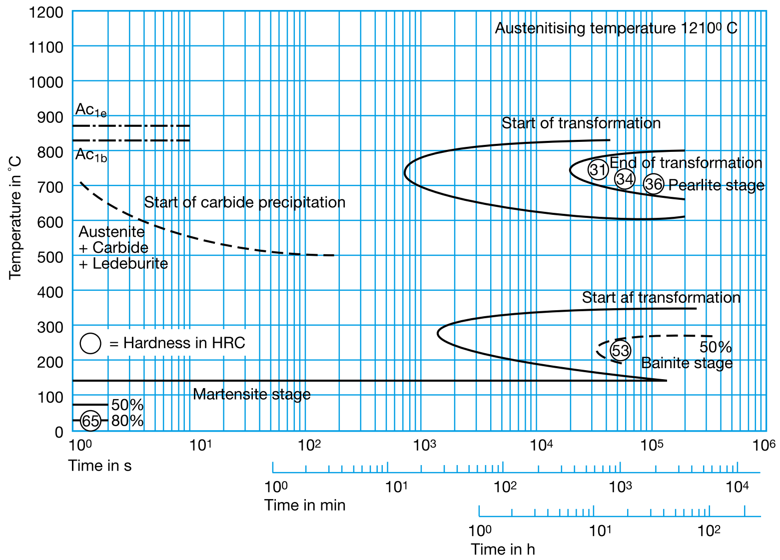
Soft annealing °C	Cooling	Hardness HB
770 - 860	Furnace	max. 269

Stress-relief annealing °C	Cooling
630 - 650	Furnace

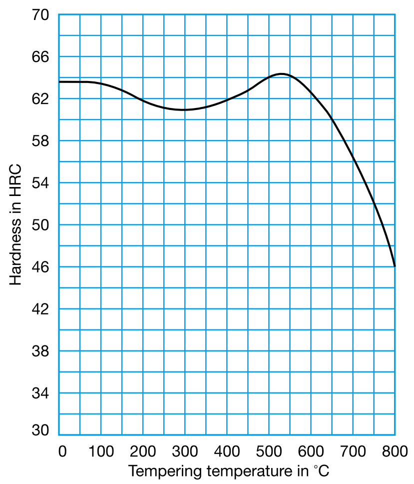
1st pre-heating °C	2nd and 3rd pre-heating °C	Hardening[1] °C	Quenching	Tempering °C	Hardness after tempering HRC
up to approx. 400 in an air-circulating furnace	a) 850 b) 850 and 1050	1190 - 1230	a) Saltbath, 550 °C b) Oil c) Air	at least three times 530 - 560	64 - 66

[1] For cold-forming tools with a complex geometry, a hardening temperature at the lower end of the quoted range is recommended.
The stated hardening temperatures apply to saltbath hardening only. For vacuum hardening, we suggest a reduction of 10 °C to 30 °C.

Isothermal time-temperature-transformation diagram



Tempering diagram



Rapidur® 3344

HS6-5-3	C 1.22 Cr 4.10 Mo 5.00 V 2.90 W 6.40
Steel properties	Very similar composition to Rapidur® 3343, but with substantially higher V and C content, resulting in combined maximum wear resistance and cutting edge retention with good toughness.
Standards	**AISI** M3 Typ 2 **AFNOR** Z120WDCV06-05-04-03
Applications	Taps, reamers, heavy-duty milling cutters, dies, rotary gear shaping and shaving cutters for the processing of hard materials, hexagon socket punches and piercing dies for the nut production.
Heat treatment	see below

Heat treatment

Soft annealing °C	Cooling	Hardness HB
820 - 860	Furnace	max. 269

Stress-relief annealing °C	Cooling
630 - 650	Furnace

1st pre-heating °C	2nd and 3rd pre-heating °C	Hardening[1] °C	Quenching	Tempering °C	Hardness after tempering HRC
up to approx. 400 in an air-circulating furnace	a) 850 b) 850 and 1050	1190 - 1230	a) Saltbath, 550 °C b) Oil c) Air	at least three times 540 - 570	64 - 66

[1] For cold-forming tools with a complex geometry, a hardening temperature at the lower end of the quoted range is recommended.
The stated hardening temperatures apply to saltbath hardening only. For vacuum hardening, we suggest a reduction of 10 °C to 30 °C.

Notes on processing

The cost-efficiency of the manufacture of industrial products is determined by, among other things, the performance of the tools used. This is greatly influenced by:

design conditions (planning)
» material selection
» design
» shape

production technology
» heat treatment and/or
» surface treatment
» machining
» assembly

errors in operational use
» operating errors
» temperature control, cooling
» maintenance errors

errors during necessary repairs
» incorrect welding

As high costs are generally incurred at a very early stage in the course of tool production (design, material, machining, etc.), errors usually entail major financial losses. Either tools of this kind are never put to use at all (production delays, contractual penalties), or the service life is seriously impaired as a result (repairs).

Design

It has long been known that sharp edges and large changes of cross-section should be avoided when designing tools, as peak stresses that can be several times higher than the creep limit develop at these points. Nevertheless, this old design rule is still broken surprisingly often today.

The following factors can promote cracking and fracturing:
» incorrect dimensioning
» abrupt changes of cross-section
» sharp notches (e.g. turning or grinding scores, scriber marks, punched numbers, etc.)

The notch sensitivity increases with the strength of the tools: the higher the hardness selected, the more care must be taken when machining the surfaces and the cross-section transitions. Consequently, the largest possible radii should be provided and these should also be polished if at all possible.

Machining

The tool-making methods and the associated influence on the material can impair the tool service life. In addition to cutting methods (milling, planing, drilling, turning, grinding), electrical discharge machining has gained increasing attention in toolmaking in recent years.

Damage analyses indicate that errors made in these machining processes take a top position in the rankings, at about 20 %.

Electrical discharge machining

The essential advantages of electrical discharge machining compared to conventional machining methods lie in the production of extremely complex geometrical shapes in a single operation and in the possibility of machining materials that are hard to cut. However, it is very often forgotten in this context that the tool surfaces are severely affected during the erosion process, mainly due to the heat involved, particularly when working at high removal rates in order to boost output. Changes in the microstructure as a result of carburization and the development of internal tensile stresses (temperature stresses) impair the toughness.

Particularly in the case of hard (brittle) materials, the additive effect of heat-treatment stresses can lead to fracturing, either directly or in later use. Possible remedies first of all lie in electrical discharge treatment that is more suitable for the material, i.e. an appropriate power reduction in the individual stages of the process. In the finishing stage, for instance, this can help to reduce the damage caused during roughing.
An inadequate finishing operation can only improve the appearance of the surface and set the required roughness – it cannot eliminate the surface damage. Further improvements can be achieved by subsequent twofold annealing or mechanical reworking. In addition to the impaired toughness, attention must equally be paid to the changed chemical composition of the surface, as a uniform etching pattern, such as is required in many plastics moulds, cannot be achieved.
Again, it can be seen that striation, for example, is dependent on the removal rate set. Particularly serious damage occurs if the electrode comes into contact with the tool during the machining process.

Grinding

The surface is again exposed to very high thermal stresses during grinding. This is particularly the case if the contact pressure is too high or there is insufficient cooling due to the use of unsuitable (blunt) grinding wheels. In this case, the surface temperature can exceed the hardening temperature of the material and thus cause local new hardening. As a result of the tensile stresses developing in the process, the typical network of grinding cracks often occurs.

Heat treatment

Only if the heat treatment is adapted to the steel composition, the intended application and the size of the part, will the potential of the tool steel used be exploited to the full. Inappropriate heat treatment can jeopardize the functions and characteristics of the tool. Errors can occur in the form of incorrect time and temperature specifications, unsuitable atmospheres or incorrect heating and cooling conditions.

Stress relief annealing

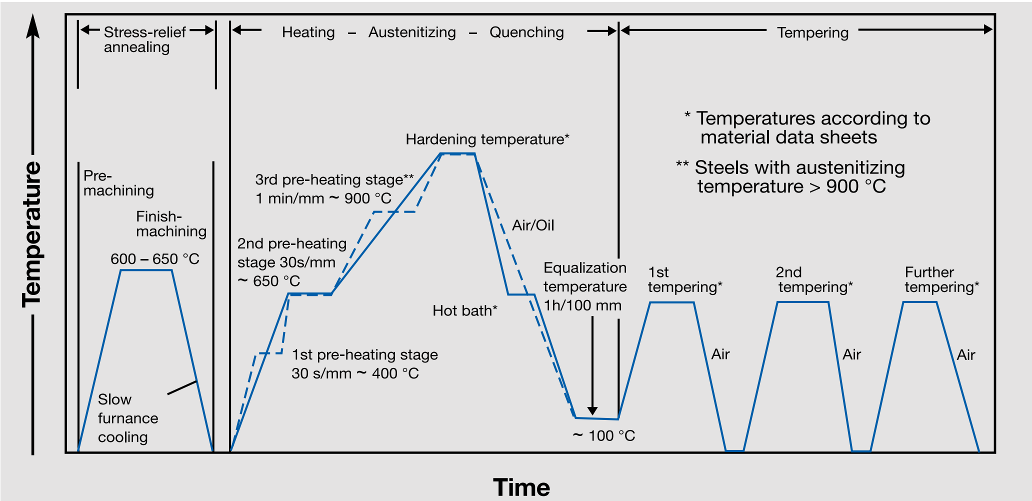
Stress relief annealing before hardening proves to be favourable, as this reduces any internal stresses that may have arisen during the preceding machining process. In the course of subsequent heat treatment, internal stresses can lead to distortion and, under certain circumstances, to expensive reworking.

Particularly with tools of complex shape, stress relief annealing at a temperature of 600 °C to 650 °C should be carried out after pre-machining. The holding time at this temperature should be a minimum of two hours, or at least one hour per 50 mm wall thickness in the case of fairly large tools. This must be followed by slow cooling in the furnace.

Heating

When heating to forming or hardening temperature, the surface and core zones reach the specified treatment temperature at different speeds. The larger the tool and the higher the heating rate, the greater the temperature difference becomes. This difference in temperature leads to tensile stresses in the core, meaning that there is a risk of cracking owing to the decrease in tensile strength that accompanies the temperature increase. Large tools of complicated shape and made of fairly high-alloy steel grades are particularly at risk due to their lower thermal conductivity. Cracking of this kind can largely be avoided by pre-heating in several stages. The holding time at the respective temperature is 30 seconds per 50 mm wall thickness at both the first and second stage. In the case of high-alloy tool steels with a hardening temperature in excess of 900 °C, the third pre-heating stage at roughly 850 °C serves not only the above-mentioned purposes, but also to dissolve some of the carbides. The holding time at this temperature is thus twice as long as for the second pre-heating stage.

Heat treatment



Time-temperature sequence diagram for the special heat treatment of Cryodur® 2379.

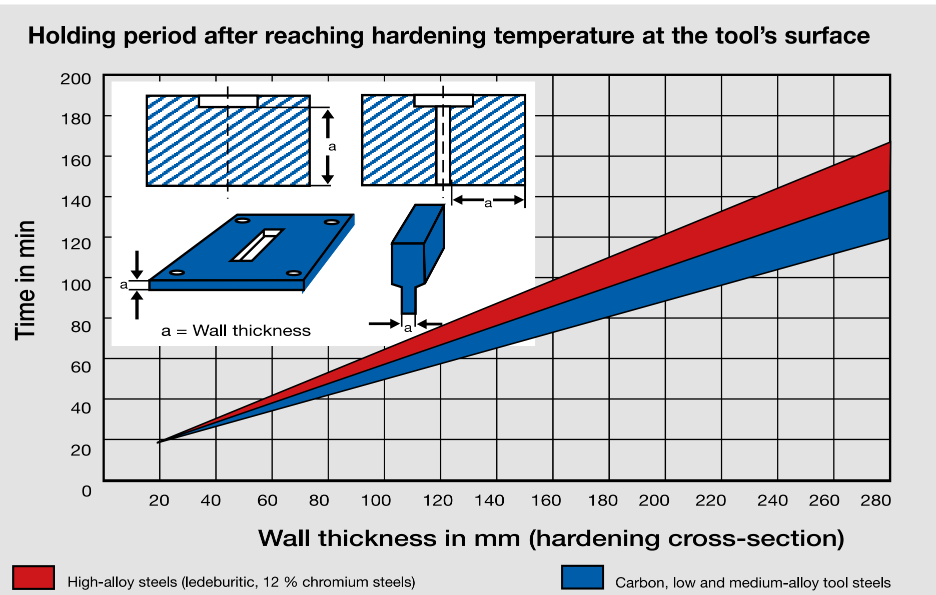
Austenitizing

Depending on the material used, every heat treatment operation requires a certain temperature and holding time during austenitization, so that the required transformations can take place. Typical errors arise if the selected hardening temperature is too high or the holding time too long. The results can be grain growth and the associated loss of toughness, as well as partial melting. Hardening temperatures that are too low and holding times that are too short result in only partial austenitization.

Stresses caused by different constituents in the microstructure can occur in this context, as can problems with setting the required hardness. The diagram provides standard values for the holding time at hardening temperature once the hardening temperature has been reached on the surface of the tool. The immersion times in the salt bath can also be determined with the help of the diagram.

Hardening behaviour

The time-temperature transformation diagrams for continuous cooling are shown in the material data sheets in order to facilitate understanding of the transformation processes taking place during hardening. By following the various cooling curves, which begin at hardening temperature and run to room temperature, it can be seen from these diagrams which microstructure constituents (in %) are formed at a given cooling rate. The respective cooling rate is stated on the cooling curves, either in °C/min. or, in the case of very rapid cooling, as a parameter (Cooling parameter = Time to cool from 800 °C to 500 °C in s divided by 100). In order to avoid tool failures due to incorrect heat treatment whenever possible, precise heat treatment instructions are given for the individual steel grades in the material data sheets. In this context, reference must be made to the following fundamental circumstance, which applies to the heat treatment of all tool steels: given the correct heat treatment of tool steel, there is no way of shortening the times or substantially changing the temperatures. The overall procedure must be adhered to without fail. The hardness achieved by the individual steel grades depends not only on the carbon content, but also very much on the cross-section. The hardness values after quenching/annealing stated in the material data sheets refer to a 30 mm square cross section. The diagram above shows the depth of hardening as a function of the workpiece diameter for a minimum hardness of 64, 62, 60 and 58 HRC.



Quenching

The quenching of the tools is the most critical phase of the heat treatment process. On the one hand, quenching operations must reach the material-dependent critical cooling rates for hardening. On the other hand, however, they must proceed as slowly as possible, in order to minimize the risk of distortion and stress cracking (re-work).

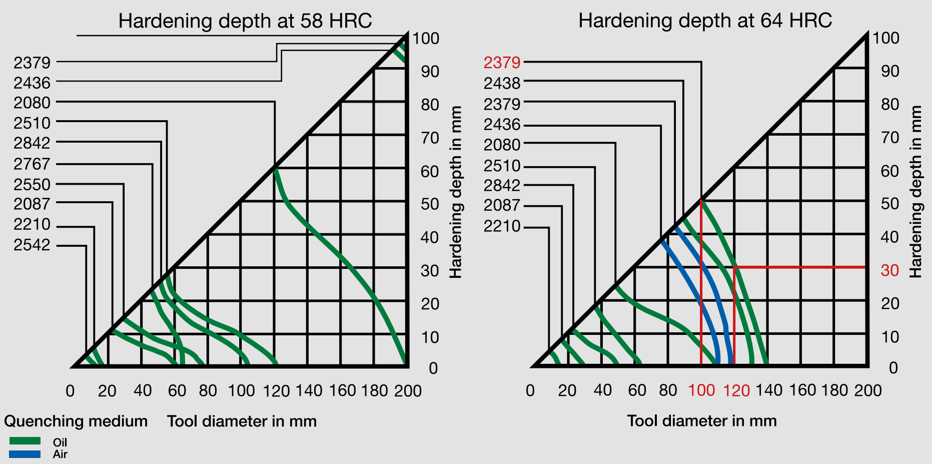
As when heating, the risk is greatest when dealing with tools of complicated shape. This is particularly true if other faults are additionally present. Typical problems in this context are cracking following overheated hardening, as temperature and transformation stresses are then joined by stresses resulting from the different microstructural constituents. Cooling to room temperature is a particular disadvantage, owing to the risk of stress cracking. The tools are expediently only cooled to approx. 80 °C before being soaked and then directly tempered. Soaking is important in order to obtain complete martensite transformation over the entire cross-section, as cracking during cooling after tempering is otherwise possible.

Step quenching is advisable in critical cases in order to avoid the risk of cracking. This extensively reduces temperature stresses and achieves almost simultaneous transformation of case and core.

Tempering

Tempering operations are necessary in order to set the correct combination of strength and toughness in tools. This both reduces the stresses in the hardening structure and eliminates the internal stresses resulting from quenching (temperature stresses). Insufficient tempering (time, temperature, frequency) can thus favour later failure. Particularly critical are steel grades which contain residual austenite after hardening that could be transformed under the effects of stress in use. In order to avoid mistakes, the information in the material data sheets concerning the correct tempering treatment for the material should be observed and no attempt made to save lost time here of all things. The holding time at tempering temperature is one hour per 20 mm wall thickness, but not less than two hours. The tools are subsequently cooled in air and their hardness is then tested.

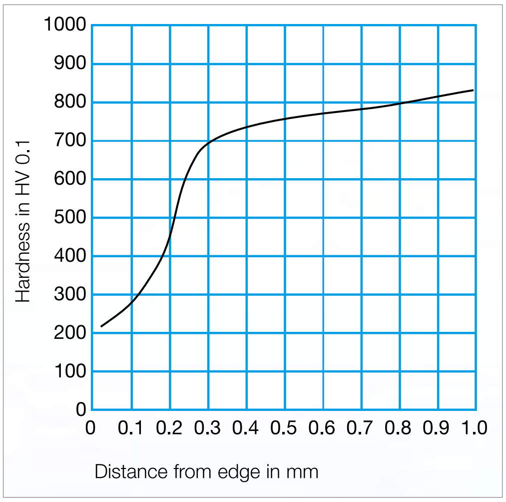
Effect of hardening depth on the diameter of the workpiece for cold work tool steels Cryodur



The depth of hardening for a tool of 120 mm dia. made of Cryodur® 2379 is to be determined for a hardness of 64 HRC and oil hardening. In the top left diagram, the intersection of the vertical line for 120 mm dia. with the curve for Cryodur® 2379 indicates a depth of hardening of 30 mm for oil hardening (to be read off the right- hand axis). The intersection of the Cryodur® 2379 curve with the straight line at an angle of 45° yields the diameter to be through-hardened, which can be seen from the bottom axis: 100 mm dia.

Furnace atmospheres

In customary heat treatment operations (hardening and tempering), it is generally assumed that the furnace atmosphere is adjusted in such a way that no surface decarburization or carburization occurs. Nonetheless, practical experience shows that unintentional carburization or decarburization repeatedly occurs in the event of process malfunctions. In medium-alloyed steel, surface decarburization results in a mixed microstructure. During hardening, this leads to internal stresses and frequently to cracking, owing to the different microstructure constituents. More highly alloyed steel often only displays carbon depletion, resulting in impaired performance in use. In extreme cases, however, complete decarburization is also possible here. In regions close to the surface, unwanted carburization results in other microstructural states (incorrect heat treatment) and thus involves an additional risk of cracking. To avoid this, the material to be hardened should be packed for protection when using a batch furnace. In controlled-atmosphere systems, a C level must be set in the gas that corresponds to the C content of the batch to be treated. The same applies to salt baths. Only in vacuum systems do problems of this kind not occur.



Surface treatment

Carburization

Where carburization processes are intended, the aim is generally to combine a tough core with a more wear-resistant surface. The carbon accumulations in the surface require a corresponding reduction of the hardening temperature, as high residual austenite contents must otherwise be expected, even after proper tempering. This can increase the risk of cracking or reduce the service life. High residual austenite contents give rise to an additional problem when polishing tools, owing to the tendency to develop the orange-peel effect. On the other hand, if too much carbon is supplied, it is preferentially precipitated at the austenite grain boundaries. This results in an increased risk of cracking and substantial embrittlement of the material. Process control appropriate to the material is the remedy in this case. This involves controlling not only the carbon level, but also the time/temperature profile.

Nitriding

As in carburization, the purpose of nitriding is to produce a hard surface layer, the main purpose of which in tools is to afford protection against wear. The reduction in toughness that occurs, even in the event of optimum nitriding, is usually not taken into consideration. The result is often spalling of the surface zone in use. Prior to nitriding, the tools must first be cleaned and degreased. Nitriding can be carried out in a salt bath, in gas or in plasma. Depending on the composition of the steel, the hardness of nitrided surfaces is up to 1100 HV.

Another major mistake that can be made is that of combining tempering and nitriding in order to save time and money. This must be expected to result in dimensional changes and distortion, which is then virtually impossible to correct because of the hard surface layer that is subsequently present.

Repair welding

Owing to the nature of the alloys used, tool steel belongs to those steel grades where welding involves a certain degree of risk. During the cooling of the weld, thermal and microstructural transformation stresses occur which can lead to cracking. However, design changes, natural wear or tool failures due to breakage or cracking often make repair by electric welding unavoidable.

The following basic rules should be observed for repair welding:

» clean the surfaces thoroughly, grind out the crack in U shape

» preheat thoroughly using a preheating temperature above the martensite transformation temperature (Ms line, see TTT diagram in material data sheet) to avoid microstructural transformations during welding

» high-alloyed steel: heat to hardening temperature (austenitization), cool to above martensite temperature

» welding (possibly with intermediate reheating)

» use electrodes corresponding to the parent material

» TIG welding offers the advantage of producing a finer microstructure, as the temperatures are lower and the cooling rate higher than when using fluxed electrodes in order to minimize distortion, larger areas to be built up should be welded in separate

» sections that are subsequently joined (the bead should be hammered in order to reduce contraction stresses)

» cooling of the tools to approx. 80 °C to 100 °C after the welding operation and tempering to installation hardness immediately afterwards.

Tool steel weight comparisons in kg / m

Dimensions in mm	square	round	hexagonal	octagonal
5	0.196	0.154	0.170	0.163
6	0.283	0.222	0.245	0.234
7	0.385	0.302	0.333	0.319
8	0.502	0.395	0.435	0.416
9	0.636	0.499	0.551	0.527
10	0.785	0.617	0.680	0.650
11	0.950	0.746	0.823	0.789
12	1.130	0.888	0.979	0.936
13	1.327	1.042	1.149	1.099
14	1.539	1.208	1.332	1.275
15	1.766	1.387	1.530	1.463
16	2.010	1.578	1.740	1.665
17	2.269	1.782	1.965	1.879
18	2.543	1.998	2.203	2.107
19	2.834	2.226	2.454	2.348
20	3.140	2.466	2.719	2.601
21	3.462	2.719	2.998	2.868
22	3.799	2.984	3.290	3.148
23	4.153	3.261	3.596	3.440
24	4.522	3.551	3.916	3.746
25	4.906	3.853	4.249	4.065
26	5.307	4.168	4.596	4.396
27	5.723	4.495	4.956	4.741
28	6.154	4.834	5.330	5.099
29	6.602	5.185	5.717	5.469
30	7.055	5.549	6.118	5.853
31	7.544	5.925	6.533	6.250
32	8.038	6.313	6.961	6.659
33	8.549	6.714	7.403	7.082
34	9.075	7.127	7.859	7.518
35	9.616	7.553	8.328	7.966
36	10.714	7.990	8.811	8.428
37	10.747	8.440	9.307	8.903
38	11.335	8.903	9.817	9.391
39	11.940	9.378	10.340	9.891

Dimensions in mm	square	round	hexagonal	octagonal
40	12.560	9.865	11.877	10.405
41	13.196	10.364	11.428	10.932
42	13.847	10.876	11.992	11.472
43	14.515	11.400	12.570	12.024
44	15.198	11.936	13.162	12.590
45	15.896	12.485	13.767	13.169
46	16.611	13.046	14.385	13.761
47	17.341	13.619	15.017	14.336
48	18.086	14.205	15.663	14.983
49	18.848	14.803	16.323	15.614
50	19.625	15.414	16.996	16.258
51	20.418	16.036	17.682	16.915
52	21.226	16.671	18.383	17.585
53	22.051	17.319	19.096	18.267
54	22.891	17.978	19.824	18.963
55	23.745	18.750	20.595	19.772
56	24.618	19.335	21.319	20.394
57	25.505	20.031	22.088	21.129
58	26.407	20.740	22.869	21.887
59	27.326	21.462	23.665	22.638
60	28.260	22.195	24.474	23.412
61	29.210	22.941	25.296	24.198
62	30.175	23.700	26.133	24.998
63	31.157	24.470	26.982	25.881
64	32.154	25.263	27.846	26.637
65	33.170	26.050	28.720	27.480
66	34.200	26.860	29.610	28.330
67	35.24	27.68	30.52	29.19
68	36.30	28.51	31.44	30.07
69	37.37	29.35	32.37	30.96
70	38.46	30.21	33.31	31.87
71	39.57	31.08	34.27	32.78
72	40.69	31.96	35.24	33.71
73	41.83	32.86	36.23	34.66
74	42.99	33.76	37.23	35.61

Dimensions in mm	square	round	hexagonal	octagonal
75	44.16	34.68	38.24	36.58
76	45.34	35.61	39.27	37.56
77	46.54	36.56	40.31	38.56
78	47.76	37.51	41.36	39.56
79	48.99	38.48	42.43	40.59
80	50.24	39.46	43.51	41.62
81	51.50	40.45	44.50	42.67
82	52.78	41.46	45.71	43.73
83	54.08	42.47	46.83	44.80
84	55.39	43.50	47.97	45.89
85	56.72	44.55	49.12	46.99
86	58.06	45.60	50.28	48.10
87	59.42	46.67	51.46	49.22
88	60.79	47.75	52.65	50.36
89	62.18	48.84	53.85	51.51
90	63.58	49.91	55.07	52.68
91	65.01	51.06	56.30	53.85
92	66.44	52.18	57.54	55.04
93	67.90	53.32	58.80	56.25
94	69.36	54.48	60.07	57.46
95	70.85	55.61	61.36	58.69
96	72.35	56.82	62.65	59.93
97	73.86	58.01	63.96	61.19
98	75.39	59.21	65.29	62.46
99	76.94	60.34	66.63	63.74
100	78.50	61.65	67.98	65.03
102	81.67	64.15	70.73	67.66
104	84.91	66.68	73.53	70.34
106	88.20	69.27	76.39	73.07
108	91.56	71.91	79.30	75.85
110	94.98	74.60	82.26	78.69
112	98.47	77.34	85.28	81.58
114	102.02	80.13	88.35	84.52
116	105.63	82.96	91.48	87.51
118	109.30	85.85	94.66	90.55

Dimensions in mm	square	round	hexagonal	octagonal
120	113.04	88.78	97.90	93.65
122	116.84	91.77	101.19	96.79
124	120.70	94.80	104.53	99.99
126	124.63	97.88	107.93	103.25
128	128.61	101.01	111.38	106.55
130	132.66	104.20	114.89	109.90
135	142.50	112.35	123.60	118.40
140	153.86	120.84	133.25	127.46
145	164.20	129.10	142.96	136.70
150	176.60	138.70	153.00	146.30
160	201.00	157.80	174.00	165.50
170	225.90	178.20	196.50	187.90
180	254.30	199.80	220.30	210.70
190	283.4	222.6	245.4	234.8
200	314.0	246.6	271.9	260.1
220	379.9	298.4	329.0	314.8
240	452.2	355.1	391.6	374.6
260	530.7	416.8	459.6	439.5
280	615.4	483.4	533.0	509.9
300	706.5	554.9	611.8	585.3
320	803.8	631.3	696.1	665.9
340	907.5	712.7	785.9	751.8
360	1071.0	799.0	881.0	842.0
380	1133.0	890.0	982.0	939.0
400	1256.0	986.0	1088.0	1040.0
450	1589.0	1248.0	1377.0	1317.0
500	1962.0	1541.0	1699.0	1626.0
600	2826.0	2219.0	2447.0	2341.0
700	3846.0	3021.0	3331.0	3187.0
800	5024.0	3926.0	4351.0	4162.0
900	6358.0	4994.0	5507.0	5268.0
1000	7850.0	6165.0	6798.0	6503.0

	Width in mm								
Thickness in mm	**10**	**15**	**20**	**25**	**30**	**35**	**40**	**45**	**50**
4	0,312	0,467	0,623	0,779	0,935	1,091	1,249	1,402	1,558
5	0,390	0,584	0,789	0,974	1,169	1,363	1,558	1,753	1,948
6	0,467	0,701	0,935	1,169	1,402	1,636	1,870	2,103	2,337
7	0,545	0,818	1,091	1,363	1,636	1,909	2,181	2,454	2,727
8	0,623	0,935	1,246	1,558	1,870	2,181	2,493	2,804	3,116
9	0,701	1,051	1,402	1,753	2,103	2,454	2,804	3,155	3,506
10	0,779	1,169	1,558	1,948	2,337	2,727	3,116	3,506	3,895
11	0,857	1,285	1,714	2,142	2,571	2,999	3,428	3,856	4,285
12	0,935	1,402	1,870	2,337	2,804	3,272	3,739	4,207	4,674
13	1,013	1,519	2,025	2,532	3,038	3,544	4,057	4,557	5,064
14	1,061	1,639	2,181	2,727	3,270	3,817	4,362	4,908	5,453
15	1,169	1,753	2,337	2,921	3,506	4,090	4,674	5,258	5,843
16	1,246	1,870	2,493	3,116	3,739	4,362	4,986	5,509	6,232
17	1,324	1,986	2,649	3,311	3,973	4,635	5,297	5,959	6,622
18	1,402	2,103	2,804	3,506	4,207	4,908	5,609	6,310	7,011
19	1,480	2,220	2,960	3,700	4,440	5,180	5,920	6,660	7,401
20	1,558	2,337	3,116	3,895	4,674	5,453	6,232	7,011	7,790
21	1,636	2,454	3,272	4,090	4,907	5,726	6,544	7,362	8,180
22	1,714	2,571	3,428	4,285	4,141	5,998	6,855	7,712	8,569
23	1,792	2,688	3,585	4,479	5,375	6,271	7,167	8,063	8,959
24	1,870	2,804	3,739	4,674	5,609	6,544	7,478	8,413	9,348
25	1,948	2,921	3,895	4,869	5,843	6,816	7,790	8,764	9,738
26	2,025	3,038	4,051	5,064	6,076	7,069	8,102	9,114	10,13
27	2,103	3,155	4,207	5,258	6,310	7,362	8,413	9,465	10,52
28	2,181	3,272	4,422	5,453	6,544	7,534	8,725	9,815	10,91
29	2,259	3,389	4,581	5,648	6,777	7,907	9,036	10,17	11,30
30	2,337	3,506	4,674	5,843	7,011	8,180	9,348	10,52	11,69
35	2,727	4,090	5,453	6,816	8,180	9,543	10,91	12,27	13,63
40	3,116	4,674	6,232	7,790	9,343	10,91	12,46	14,02	15,58
45	3,506	5,258	7,011	8,764	10,52	12,27	14,02	15,77	17,53
50	3,895	5,843	7,790	9,738	12,69	13,63	15,58	17,53	19,48

	Width in mm									
Thickness in mm	55	60	65	70	76	80	85	90	95	100
4	1,714	1,870	2,025	2,181	2,337	2,493	2,649	2,804	2,960	3,116
5	2,142	2,337	2,503	2,727	2,921	3,116	3,311	3,506	3,700	3,895
6	2,571	2,804	3,038	3,272	3,506	3,739	3,973	4,207	4,440	4,675
7	2,999	3,272	3,544	3,817	4,090	4,362	4,635	4,908	5,180	5,453
8	3,428	3,739	4,051	4,362	4,674	4,986	5,297	5,609	5,920	6,232
9	3,856	4,207	4,557	4,908	5,258	5,609	5,959	6,310	6,660	7,011
10	4,285	4,674	5,064	5,453	5,843	6,232	6,622	7,001	7,401	7,790
11	4,713	5,141	5,570	5,998	6,427	6,855	7,248	7,712	8,141	8,569
12	5,141	5,609	6,076	6,511	7,011	7,478	7,916	8,413	8,881	9,318
13	5,570	6,076	6,583	7,089	7,595	8,102	8,608	9,114	9,621	10,13
14	5,998	6,544	7,089	7,634	8,180	8,725	9,270	9,815	10,36	10,91
15	6,420	7,011	7,595	8,180	8,761	9,318	9,932	10,52	11,10	11,69
16	6,855	7,478	8,102	8,725	9,348	9,971	10,59	11,22	11,84	12,46
17	7,284	7,946	8,608	9,270	9,932	10,59	11,26	11,92	12,58	13,24
18	7,712	8,414	9,114	9,815	10,52	11,22	11,92	12,62	13,32	14,02
19	8,141	8,880	9,620	10,36	11,10	11,84	12,58	13,32	14,06	14,80
20	8,569	9,350	10,13	10,91	11,69	12,46	13,24	14,02	14,80	15,58
21	8,997	9,820	10,63	11,45	12,27	13,09	13,91	14,72	15,54	16,36
22	9,426	10,28	11,14	12,00	12,85	13,71	14,57	15,42	16,28	17,14
23	9,854	10,75	11,65	12,54	13,44	14,33	15,23	16,13	17,02	17,92
24	10,28	11,22	12,15	13,09	14,02	14,96	15,89	16,83	17,76	18,70
25	10,71	11,69	12,66	13,63	14,61	15,58	16,55	17,53	18,50	19,48
26	11,14	12,15	13,17	14,18	15,19	16,20	17,22	18,23	19,24	20,25
27	11,57	12,62	13,67	14,72	15,77	16,83	17,88	18,93	19,98	21,03
28	12,00	13,09	14,18	15,27	16,36	17,45	18,54	19,63	20,72	21,81
29	12,43	13,55	14,68	15,81	16,94	18,07	19,20	20,33	21,46	22,59
30	12,85	14,02	15,19	16,36	17,53	18,70	19,86	21,03	22,20	23,37
35	14,90	16,36	17,72	19,09	20,45	21,81	23,17	24,54	25,90	27,27
40	17,14	18,70	20,25	21,81	23,37	24,93	26,49	28,04	29,60	31,16
45	19,28	21,03	22,78	24,54	26,29	28,04	29,80	31,55	33,30	35,06
50	21,42	23,37	25,32	27,27	29,21	31,16	33,11	35,06	37,00	38,95

General note (liability): *All statements regarding the properties or utilization of the materials or products mentioned are for the purpose of description only. Guarantees regarding the existence of certain properties or a certain utilization are only ever valid if agreed upon in writing. No responsibility is taken for the correctness of this information*

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