Technical Datasheet

CarTech® Free-Cut Invar "36"® Alloy

Identification

UNS Number

• K93602/K93050

Type Analysis

Single figures are nominal except where noted.

Carbon	0.05 %	**Manganese**	0.90 %
Silicon	0.35 %	**Nickel**	36.00 %
Cobalt	0.20 %	**Selenium**	0.20 %
Iron	Balance		

General Information

Description

CarTech Free-Cut Invar "36" alloy is a free-machining 36% nickel-iron alloy possessing a rate of thermal expansion approximately one-tenth that of carbon steel at temperatures up to 400°F (204°C).

Applications

This alloy has been used for machined parts whose dimensional changes due to temperature variation must be minimized such as in radio and electronic devices, aircraft controls, etc.

CarTech Free-Cut Invar "36" alloy has also been used in conjunction with high expansion alloys in applications where a motion is desired when the temperature changes, such as in rod and tube assemblies for temperature regulators.

Corrosion Resistance

Important Note: *The following 4-level rating scale is intended for comparative purposes only. Corrosion testing is recommended; factors which affect corrosion resistance include temperature, concentration, pH, impurities, aeration, velocity, crevices, deposits, metallurgical condition, stress, surface finish and dissimilar metal contact.*

Humidity	Good	

Properties

Physical Properties

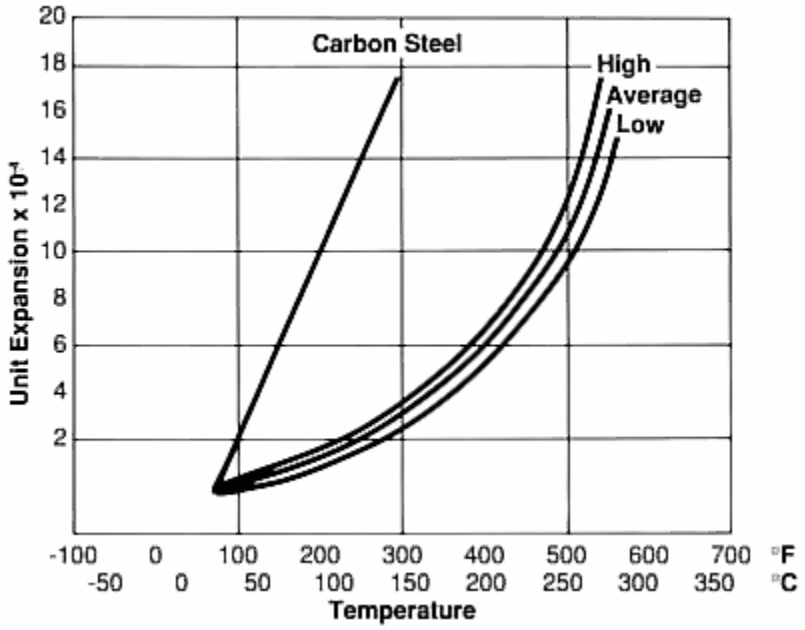
Specific Gravity	8.05	
Density	0.2910	lb/in³
Mean Specific Heat	0.1230	Btu/lb/°F
Mean CTE		
77 to 212°F	0.910	x 10 $^{-6}$ in/in/°F
77 to 302°F	1.32	x 10 $^{-6}$ in/in/°F
77 to 392°F	1.69	x 10 $^{-6}$ in/in/°F
77 to 482°F	2.34	x 10 $^{-6}$ in/in/°F
77 to 572°F	3.26	x 10 $^{-6}$ in/in/°F

Mean coefficient of thermal expansion (from R.T.)

Temperature		Coefficient	
77°F to	25°C to	x 10^{-6}/°F	x 10^{-6}/°C
212	100	0.91	1.64
302	150	1.32	2.38
392	200	1.69	3.04
482	250	2.34	4.21
572	300	3.26	5.87

Thermal Conductivity	72.60	BTU-in/hr/ft²/°F
Modulus of Elasticity (E)		
Annealed Bar	20.5	x 10^{3} ksi
Cold Drawn Bar	21.5	x 10^{3} ksi
Electrical Resistivity (70°F)	495.0	ohm-cir-mil/ft
Temperature Coeff of Electrical Resist (70 to 212°F)	6.00	x 10^{-4} Ohm/Ohm/°F
Curie Temperature	535	°F
Melting Range	2600	°F

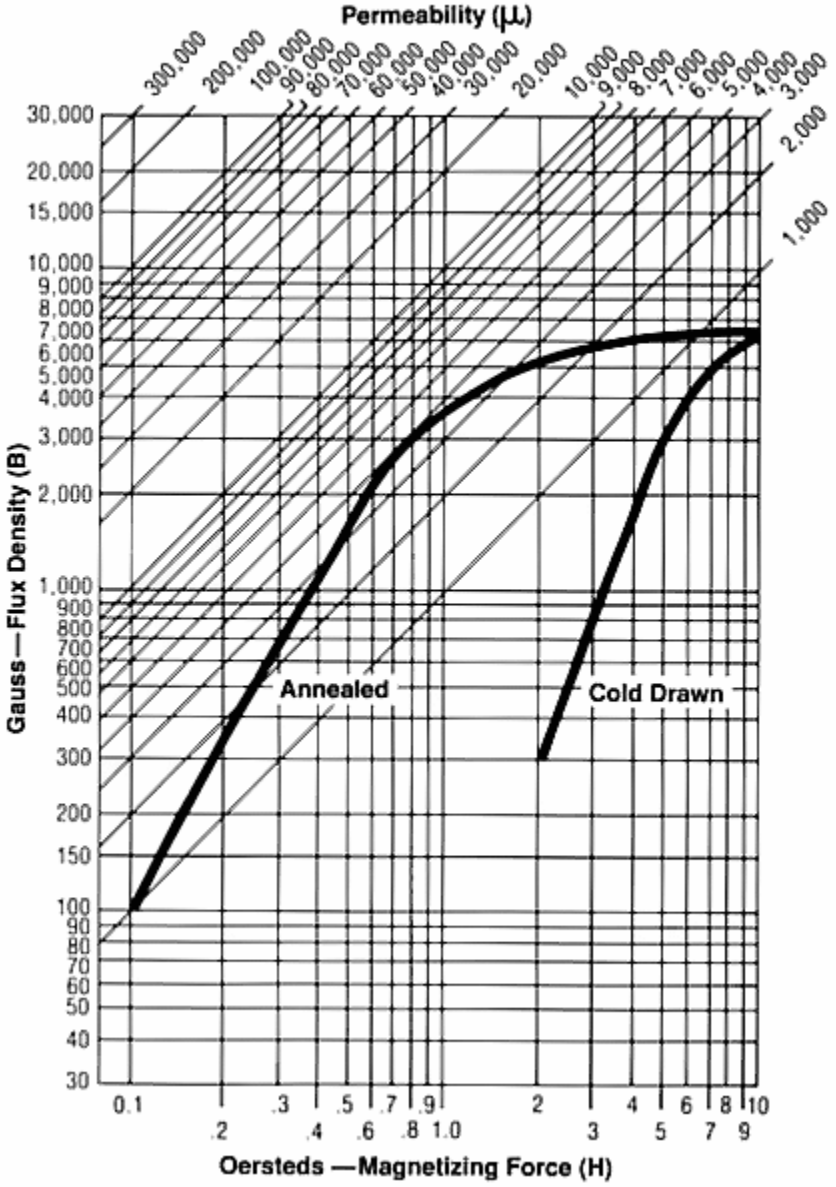
Comparative Expansion Curves - Free-Cut Invar "36" Alloy vs. Carbon Steel



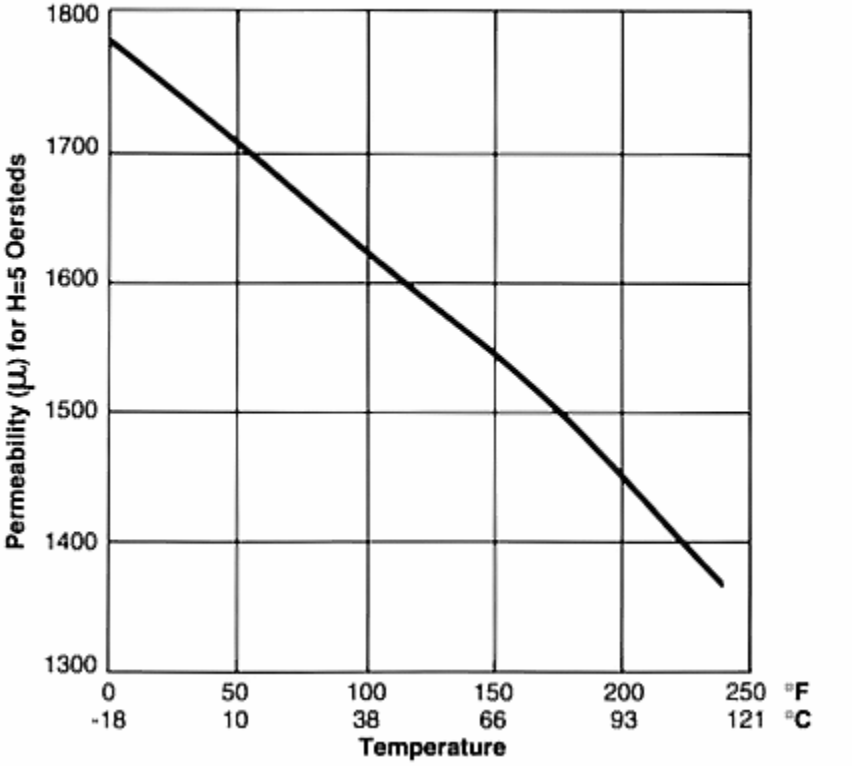
Magnetic Properties

DC Magnetization Permeability Curves - Free-Cut Invar "36" Alloy

Results for material in both the annealed and cold drawn conditions.



Permeability (Gauss/Oersted) vs. Temperature Characteristics - Free-Cut Invar "36" Alloy
Material in annealed condition. H = 5 Oersteds.



Typical Mechanical Properties

Typical Mechanical Properties - Free-Cut Invar "36" Alloy

Tensile Strength		Yield Strength		% Reduction in Area	% Elongation in 2" (50.8 mm)	Hardness Rockwell B
ksi	MPa	ksi	MPa			
Cold Drawn Bars						
90	621	70	483	60	20	90
Annealed Bars						
65	448	40	276	65	35	70

Heat Treatment

Heat Treatment for Optimal Dimensional Stability:

The presence of stress causes very slight changes in dimensional stability with respect to time and temperature. This change can be detected only with exceedingly sensitive devices. To assure the best dimensional stability use the following heat treatment.

Heat to 1500°F (815°C) and hold at heat for 30 minutes per inch of thickness followed by water quenching. Reheat to 600°F (315°C) and hold for one hour, cool in air.

Annealing

Heat to 1450°F (790°C) and hold at heat 30 minutes per inch of thickness, air cool.

Heating to temperatures above 1000°F (540°C) relieves the presence of cold work stresses. The higher the temperature, the lower the annealed hardness as illustrated in the hyperlink entitled "Effect of Annealing on Hardness".

Effect of Annealing on Hardness - Free-Cut Invar "36" Alloy
Specimen held 5 minutes at indicated temperature.

Temperature Air Treat		Rockwell B Hardness
°F	°C	
1200	650	87/88
1500	815	77/78
1800	980	70/71
1900	1040	66/68

Holding at heat for longer periods will result in even lower hardnesses.

Workability

Forging

The principal precaution to observe in forging is to heat quickly and to avoid soaking in the forge furnace. Long soaking may result in a checked surface due to absorption of sulfur from the furnace atmosphere. A forging temperature of 2150/2200°F (1180/1200°C) is desirable.

Cold Heading

Free-Cut Invar "36" alloy may be swaged or cold upset.

Machinability

Free-Cut Invar "36" alloy machines easily with a brittle chip. In turning operations, speeds of 85/120 sfm (0.43/0.61 m/s) can be used. Moderate cold working slightly increases the machinability.

Following are typical feeds and speeds for Free-Cut Invar "36" alloy.

Turning—Single Point and Box Tools

Depth of Cut, in.	High-Speed Tools			Carbide			
	Speed, fpm	Feed, ipr	Tool Material	Speed, fpm		Feed, ipr	Tool Material
				Brazed	Throw Away		
.150	80	.015	M-33	275	300	.015	C-2
.025	100	.007	M-41-47	320	365	.007	C-3

Turning—Cut-Off and Form Tools

Speed, fpm	Feed, ipr							Tool Material
	Cut-Off Tool Width, Inches			Form Tool Width, Inches				
	1/16	1/8	1/4	1/2	1	1-1/2	2	
65	.001	.0015	.002	.002	.0015	.001	.001	M-2
220	.004	.0055	.007	.005	.004	.0035	.0035	C-2

Drilling

Speed, fpm	Feed, ipr								Tool Material
	Nominal Hole Diameter, Inches								
	1/16	1/8	1/4	1/2	3/4	1	1-1/2	2	
50	.001	.002	.004	.007	.010	.012	.015	.018	M-1; M-10

Tapping

Speed, fpm	Tool Material
10-15	M-1; M-7; M-10

Die Threading

Speed, fpm				Tool Material
7 or Less	8 to 15	16 to 24	25 and up, T.P.I.	
10-20	15-25	20-35	25-40	M-1; M-2; M-7; M-10

Milling—End Peripheral

Depth of Cut In.	High-Speed Tools						Carbide Tools					
	Speed, fpm	Feed—Inches per Tooth				Tool Material	Speed, fpm	Feed—Inches per Tooth				Tool Material
		Cutter Diameter, inches						Cutter Diameter, inches				
		1/4	1/2	3/4	1-2			1/4	1/2	3/4	1-2	
.050	85	.001	.002	.003	.004	M-42	280	.001	.002	.004	.005	C-2

Additional Machinability Notes

Figures used for all metal removal operations are average. On certain work, the nature of the part may require adjustment of speeds and feeds. Each job has to be developed for best production results with optimum tool life. Speeds or feeds should be increased or decreased in small steps.

Grinding and Polishing

A silicon carbide wheel is desirable, preferably a soft wheel which will wear without loading. For finish grinding, a satisfactory grade to start with is No. 80 grit.

Weldability

Free-Cut Invar "36" alloy can be welded by the conventional methods. Caution must be taken not to overheat the molten metal. This will avoid spattering of the molten metal and pits in the welded area. When filler rod is required, Invarod has been used.

Brazing

Silver and zinc-free alloys have been used for brazing Free-Cut Invar "36" alloy. Free-Cut Invar should be annealed prior to brazing. Joints should be designed to avoid placing this material in tension during brazing.

Plating

Free-Cut Invar "36" alloy can be chromium, cadmium and nickel plated or zinc coated by the usual methods for ferrous alloys.

Other Information

Applicable Specifications

- ASTM F1684

Forms Manufactured

- Bar-Flats
- Bar-Squares
- Billet
- Wire

Technical Articles

- After 100 Years, the Uses for Invar Continue to Multiply
- Invar Alloy-There's Profit to be Made in Machining This Popular, High Tech Material
- Selecting Controlled Expansion Alloys

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