

PYROWEAR® 675

Applicable designation: AMS 5930

Type analysis

Single figures are nominal except where noted.

Iron	Balance	Chromium	13.00 %	Cobalt	5.40 %
Nickel	2.60 %	Molybdenum	1.80 %	Manganese	0.65 %
Vanadium	0.60 %	Silicon	0.40 %	Carbon	0.07 %

Forms manufactured

Bar-Rounds

Billet

Description

Pyrowear 675 is a carburizing, corrosion-resistant steel designed to provide a case hardness in excess of HRC 60 combined with a tough, ductile core. The corrosion resistance of carburized Pyrowear 675 is similar to that of 440C stainless, while the core toughness is similar to that of AISI 9310. In addition, the alloy provides excellent hot hardness capability. Pyrowear 675 has been used in bearing and gearing type applications. The alloy should also be considered for any application requiring parts with a hard, corrosion-resistant case and a tough, ductile core.

Key Properties:

- Case hardness
- Corrosion resistance
- Core toughness
- Hot hardness capability

Markets:

- Aerospace
- Industrial
- Energy
- Transportation

Applications:

- General, engine, rod end, and pump bearings
- Ball screws
- Actuators
- Cam followers
- Planetary gearboxes
- Well drilling equipment

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Corrosion resistance

The carburized case of Pyrowear 675 possesses corrosion resistance similar to that of 440C stainless. Pyrowear 675 resists corrosion in normal domestic environments and very mild industrial environments, including many petroleum products and organic materials. The carburized case is slightly improved with a tempering temperature of 600°F (316°C) as compared to the 950°F (510°C) tempering temperature.

The core of Pyrowear 675 possesses corrosion resistance similar to that of 410 stainless, which is generally somewhat better than that of 440C stainless.

Polished core and carburized case samples of Pyrowear 675 subjected to a humidity cabinet environment of 95°F (35°C) at 95% humidity show no signs of rusting at the conclusion of a 200-hour test.

For optimum corrosion resistance, surfaces must be free of scale, lubricants, foreign particles, and coatings applied for drawing and heading. After fabrication of parts, cleaning and/or passivation should be considered.

IMPORTANT NOTE:

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

Nitric Acid	Moderate	Sulfuric Acid	Restricted
Phosphoric Acid	Restricted	Acetic Acid	Restricted
Sodium Hydroxide	Moderate	Salt Spray (NaCl)	Restricted
Sea Water	Restricted	Humidity	Excellent

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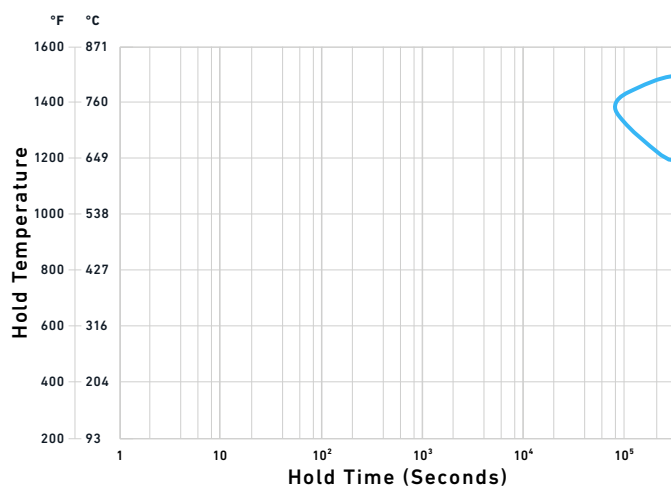
Physical properties

PROPERTY		At or From	English Units	Metric Units
DENSITY		—	0.2800 lb/in ³	—
MEAN COEFFICIENT OF THERMAL EXPANSION (CTE)	ANNEALED	77 to 200°F (25 to 93°C)	5.63 x 10 ⁻⁶ in/in/°F	10.13 x 10 ⁻⁶ mm/mm/°C
		77 to 300°F (25 to 149°C)	5.87 x 10 ⁻⁶ in/in/°F	10.57 x 10 ⁻⁶ mm/mm/°C
		77 to 400°F (25 to 204°C)	5.98 x 10 ⁻⁶ in/in/°F	10.76 x 10 ⁻⁶ mm/mm/°C
		77 to 500°F (25 to 260°C)	6.06 x 10 ⁻⁶ in/in/°F	10.91 x 10 ⁻⁶ mm/mm/°C
		77 to 600°F (25 to 316°C)	6.14 x 10 ⁻⁶ in/in/°F	11.05 x 10 ⁻⁶ mm/mm/°C
		77 to 700°F (25 to 371°C)	6.23 x 10 ⁻⁶ in/in/°F	11.21 x 10 ⁻⁶ mm/mm/°C
		77 to 800°F (25 to 427°C)	6.32 x 10 ⁻⁶ in/in/°F	11.38 x 10 ⁻⁶ mm/mm/°C
		77 to 900°F (25 to 482°C)	6.40 x 10 ⁻⁶ in/in/°F	11.52 x 10 ⁻⁶ mm/mm/°C
		77 to 1000°F (25 to 538°C)	6.46 x 10 ⁻⁶ in/in/°F	11.63 x 10 ⁻⁶ mm/mm/°C
		77 to 1100°F (25 to 593°C)	6.42 x 10 ⁻⁶ in/in/°F	11.56 x 10 ⁻⁶ mm/mm/°C
		77 to 1200°F (25 to 649°C)	6.29 x 10 ⁻⁶ in/in/°F	11.32 x 10 ⁻⁶ mm/mm/°C
	HARDENED AND TEMPERED	77 to 200°F (25 to 93°C)	5.56 x 10 ⁻⁶ in/in/°F	10.01 x 10 ⁻⁶ mm/mm/°C
		77 to 300°F (25 to 149°C)	5.67 x 10 ⁻⁶ in/in/°F	10.21 x 10 ⁻⁶ mm/mm/°C
		77 to 400°F (25 to 204°C)	5.79 x 10 ⁻⁶ in/in/°F	10.42 x 10 ⁻⁶ mm/mm/°C
		77 to 500°F (25 to 260°C)	5.90 x 10 ⁻⁶ in/in/°F	10.62 x 10 ⁻⁶ mm/mm/°C
		77 to 600°F (25 to 316°C)	6.02 x 10 ⁻⁶ in/in/°F	10.84 x 10 ⁻⁶ mm/mm/°C
		77 to 700°F (25 to 371°C)	6.12 x 10 ⁻⁶ in/in/°F	11.02 x 10 ⁻⁶ mm/mm/°C
		77 to 800°F (25 to 427°C)	6.23 x 10 ⁻⁶ in/in/°F	11.21 x 10 ⁻⁶ mm/mm/°C
		77 to 900°F (25 to 482°C)	6.34 x 10 ⁻⁶ in/in/°F	11.41 x 10 ⁻⁶ mm/mm/°C
		77 to 1000°F (25 to 538°C)	6.42 x 10 ⁻⁶ in/in/°F	11.56 x 10 ⁻⁶ mm/mm/°C
		77 to 1100°F (25 to 593°C)	6.50 x 10 ⁻⁶ in/in/°F	11.70 x 10 ⁻⁶ mm/mm/°C
		77 to 1200°F (25 to 649°C)	6.52 x 10 ⁻⁶ in/in/°F	11.74 x 10 ⁻⁶ mm/mm/°C
ELASTIC MODULUS (E)		—	29.6 x 10 ³ ksi	—
CRITICAL TEMPERATURE (AC1)		1112°F (600°C)		
CRITICAL TEMPERATURE (AC3)		1500°F (816°C)		

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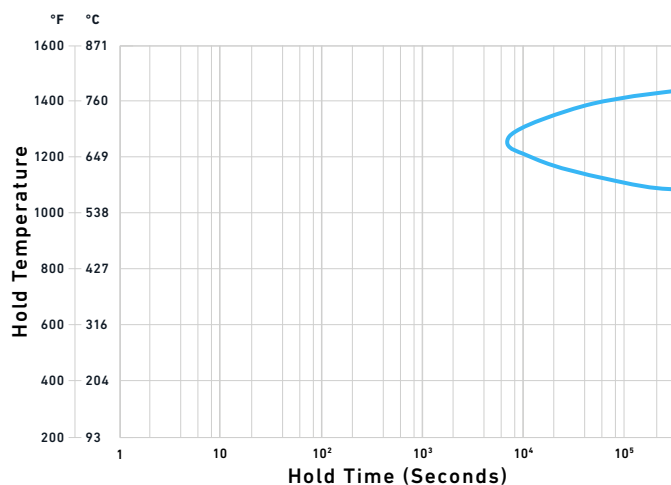
ISOTHERMAL TRANSFORMATION (I-T) — 0.07% C CORE

Austenitized at 1900°F (1038°C) 15 minutes, quenched to I-T temperature, held for indicated time, then oil quenched to room temperature.



ISOTHERMAL TRANSFORMATION (I-T) — 1.5% C CASE

Preoxidized at 1700°F (927°C) 1 hour, pack carburized at 1650°F (899°C) 48 hours, oil quenched, annealed at 1200°F (649°C), austenitized at 1900°F (1038°C) 15 minutes, quenched to I-T temperature, held for indicated time, then oil quenched to room temperature.

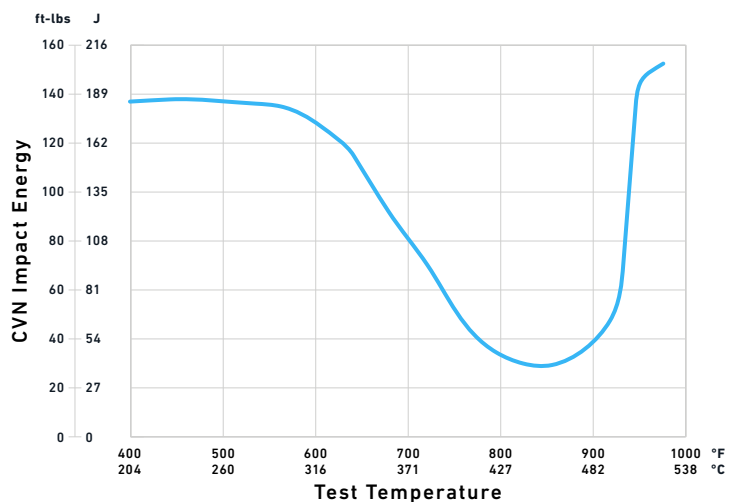


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Typical mechanical properties

All samples pseudocarburized at 1650°F (899°C) 48 hours, oil quenched, annealed at 1200°F (649°C), double normalized at 1900°F (1038°C) 0.5 hour, air cooled (2 cycles), annealed at 1200°F (649°C), austenitized 15 minutes in salt at 1900°F (1038°C), oil quenched, refrigerated at -100°F (-73°C) 1 hour, tempered as indicated for 2 hours + 2 hours.

CHARPY V-NOTCH VS. TEMPERING TEMPERATURE — LONGITUDINAL SAMPLES



CORE FRACTURE TOUGHNESS

ORIENTATION	TEMPERING TEMPERATURE		HARDNESS	K ₀	
	°F	°C	HRC	ksi./in	MPa./m
Longitudinal	600	316	41.0	150	165
Transverse				140	154
Longitudinal	950	510	41.0	125	138
Transverse				78	86

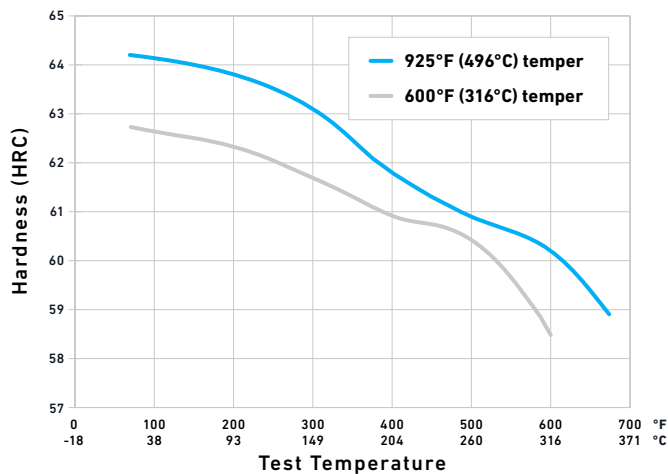
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CORE TENSILE PROPERTIES

ORIENTATION	TEMPERING TEMPERATURE		HARDNESS	0.2% YIELD STRENGTH		ULTIMATE TENSILE STRENGTH		ELONGATION IN 4D	REDUCTION OF AREA
	°F	°C	HRC	ksi	MPa	ksi	MPa	%	%
Longitudinal	600	316	40.0	143	986	185	1276	20	73
Transverse				143	986	185	1276	19	70
Longitudinal	950	510	39.0	154	1062	185	1276	20	75
Transverse				154	1062	185	1276	18.5	70

HOT HARDNESS

Samples preoxidized at 1900°F (1038°C) 1 hour, gas carburized at 1600°F (871°C) 48 hours, oil quenched, double normalized at 1900°F (1038°C) 0.5 hour, air cooled (2 cycles), annealed at 1200°F (649°C), austenitized 15 minutes in salt at 1900°F (1038°C), oil quenched, refrigerated at -100°F (-73°C) 1 hour, tempered at 600°F (316°C) or 925°F (496°C) for 2 hours + 2 hours.



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Heat treatment

Decarburization	Carburized Pyrowear 675, like all high-carbon steels, is subject to decarburization during thermal processing. Means of preventing decarburization are well known. Modern furnaces that employ protective environments, such as a protective atmosphere, salt pots, fluidized bed furnaces, and vacuum furnaces, should present no difficulty with decarburization of this alloy.
Annealing	Pyrowear 675 should be annealed at 1150/1200°F (621/649°C) for a minimum of 4 hours, followed by air cooling. This should produce a maximum hardness of Brinell 320. An annealed hardness as low as Brinell 280 can be obtained by holding parts at 1200°F (649°C) for 12 hours, followed by air cooling. Annealing for times longer than 12 hours will not result in any additional significant softening.
Carburizing	Preoxidizing: Pyrowear 675 must be preoxidized prior to carburizing. This can be accomplished by heating clean parts to a temperature between 1650 and 1900°F (899 and 1038°C) for a minimum of 1 hour in an air furnace followed by an air cool, or by allowing the part to be exposed to an air atmosphere in the carburizing furnace prior to introducing the carburizing gas. It should be noted that Pyrowear 675 preoxidizing temperatures on the lower side of the range will produce a better case structure following carburizing. Carburizing temperature: The recommended carburizing temperature range for Pyrowear 675 is 1600/1650°F (871/899°C). In general, the 1700°F (927°C) temperature used for other carburizing grades is too high a temperature for Pyrowear 675. Carbon potential: In general, a carbon potential of 0.65/1.0% is adequate for most applications. The actual surface carbon content following carburizing at this carbon potential will result in sufficient carbon in the case to achieve a surface hardness of HRC 60 minimum during final heat treatment. Carburizing time: As in most carburizing operations, carburizing time is directly related to case depth for this alloy. Samples carburized for 24 hours provided a fully heat treated HRC 60 depth of 0.020 in. (0.51 mm) and an HRC 50 depth of 0.045 in. (1.14 mm). Post-carburizing quench: Following carburizing, parts with diameters greater than about 1 in. (25.4 mm) should be oil quenched. Smaller parts may be oil quenched or air cooled. Once the parts have reached room temperature, they should be given a stress relief anneal at 1150/1200°F (621/649°C) for 4 hours minimum. Post-carburizing normalize and stress relief (optional): To ensure the best case microstructure, a double normalizing cycle may be employed following carburizing. Parts should be heated to 1900°F (1038°C), held 0.5 hour, and air cooled. This should be done for 2 cycles. Parts should then be stress relief annealed at 1150/1200°F (621/649°C) for 4 hours minimum and air cooled. Double normalizing may also slightly increase carburized case depth. Because carburized Pyrowear 675 has a high case carbon level, proper control of furnace atmosphere to prevent decarburization during subsequent heat treatment is very important.

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Hardening

Pyrowear 675 should be heat treated using proper precautions to prevent decarburization. Parts should be austenitized for 15/30 minutes and either oil quenched to room temperature or quenched into salt at 400°F (204°C), equalized, and air cooled to room temperature. After reaching room temperature, parts should be refrigerated at -100°F (-73°C) for 1 hour and air warmed in order to obtain maximum case hardness.

For service temperatures 400°F (204°C) and below, austenitize at 1900°F (1038°C) 15 minutes, quench to room temperature. For service temperatures above 400°F (204°C), austenitize at 1900/1925°F (1038/1052°C) 15 minutes, quench to room temperature.

Tempering

Parts should be tempered immediately upon completion of refrigeration. All tempering cycles should be for 2 hours + 2 hours.

For service temperatures 400°F (204°C) and below, temper in the range 400/600°F (204/316°C). For service temperatures above 400°F (204°C), temper in the range 925/975°F (496/524°C).

EFFECT OF TEMPERING TEMPERATURE ON CASE AND CORE HARDNESS

Heat treatment: Preoxidized at 1750°F (954°C) 1 hour, pack carburized at 1600°F (871°C) 48 hours, oil quenched, annealed at 1200°F (649°C), double normalized at 1900°F (1038°C) 0.5 hour, air cooled (2 cycles), annealed at 1200°F (649°C), austenitized 30 minutes at 1900°F (1038°C), oil quenched, refrigerated at -100°F (-73°C) 1 hour, tempered at indicated temperature for 2 hours + 2 hours.

HARDNESS AVERAGES ROUNDED TO THE NEAREST 0.5 HRC

TEMPERING TEMPERATURE		CASE	CORE
°F	°C	HRC	HRC
As-hardened		63.0	40.0
400	204	62.5	39.5
500	260	62.0	39.0
600	316	62.0	39.0
700	371	62.5	40.0
800	427	63.5	41.0
875	468	64.5	42.5
925	496	64.0	40.0
950	510	63.0	39.0
975	524	59.0	38.0

Note: Pyrowear 675 should not be tempered in the range 700/900°F (371/482°C), as decreased case and core toughness and ductility will result.

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Workability

Forging	Heat to 1950/2000°F (1066/1093°C) for forging. Even though Pyrowear 675 is a low-carbon steel, it can lose carbon from the surface if exposed without a protective atmosphere at forging temperatures for extended periods. Do not forge below 1700°F (927°C), and reheat as often as necessary. Forgings can be either air or furnace cooled to room temperature and should be annealed as soon as possible following cooling from forging.
Machinability	Pyrowear 675 machines similar to 410 and 420 stainless. Tools should be sharp and ground to a fine finish. Tool holders must be rigid.
Additional machinability notes	Cutting speeds of 200 and 400 surface speed feet/minute (sfpm) can be used for roughing and finishing with carbide-tipped single-point turning tools. Figures used for all metal removal operations covered 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 and feeds should be increased or decreased in small steps. Various cutting oils are used for cooling and lubricating. If parts are to be carburized after machining, they should be thoroughly degreased to allow for optimum carburization.

Typical feeds and speeds

Turning tools: Rake angle—8 to 15°

Drills: Point angle—140°

Threading tools: Back rake angle—10 to 15°

With cobalt high-speed tools, use the following cutting speeds as a guide:

OPERATION	SPEED, FPM	FEED, IPR
Turning	85–115	0.001–0.0015
Drilling	35–75	0.005–0.010
Milling (depth of cut 0.050 in)	70–105	0.001–0.004
Reaming	20–60	0.002–0.008

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Wear resistance

DRY SAND/RUBBER WHEEL ABRASION TEST

The wear characteristics below were generated using the ASTM standard practice for conducting dry sand/rubber wheel abrasion tests. Its ASTM designation is G65 and Procedure "B", which calls for a 10-minute test, was used rather than the standard 30-minute test due to the relatively thin carburized case on some of the test samples. The data are presented as volume loss, as required by the ASTM standard; a lower number indicates better wear resistance.

Pyrowear 675 samples were carburized and heat treated using the standard cycle for elevated service temperatures. All other alloys were given standard hardening/tempering treatments for the grade.

ALLOY	HARDNESS	AVERAGE ASTM VOLUME LOSS
	HRC	mm ³
Pyrowear 675	64.0	33.0
440C	60.0	29.0
M50 NiL	62.5	56.3
M50	61.0	22.5

**For additional information, please
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