Technical Datasheet

CarTech® Pyrowear® 675 Stainless

Type Analysis

Single figures are nominal except where noted.

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

General Information

Description

CarTech Pyrowear 675 stainless 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 CarTech Pyrowear 675 stainless is similar to that of Type 440C stainless, while the core toughness is similar to that of AISI 9310. In addition, the alloy provides excellent hot hardness capability.

Applications

CarTech Pyrowear 675 stainless 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. Some applications for the alloy may include:

General bearings
Engine bearings
Rod end bearings
Pump bearings
Ball screws
Actuators
Cam followers
Planetary gearboxes
Well drilling equipment

Corrosion Resistance

The carburized case of Pyrowear 675 stainless possesses corrosion resistance similar to that of Type 440C stainless. Pyrowear 675 stainless resists corrosion in normal domestic environments and very mild industrial environments, including many petroleum products and organic materials.

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

Polished core and carburized case samples of Pyrowear 675 stainless 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 which 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

Properties

Physical Properties

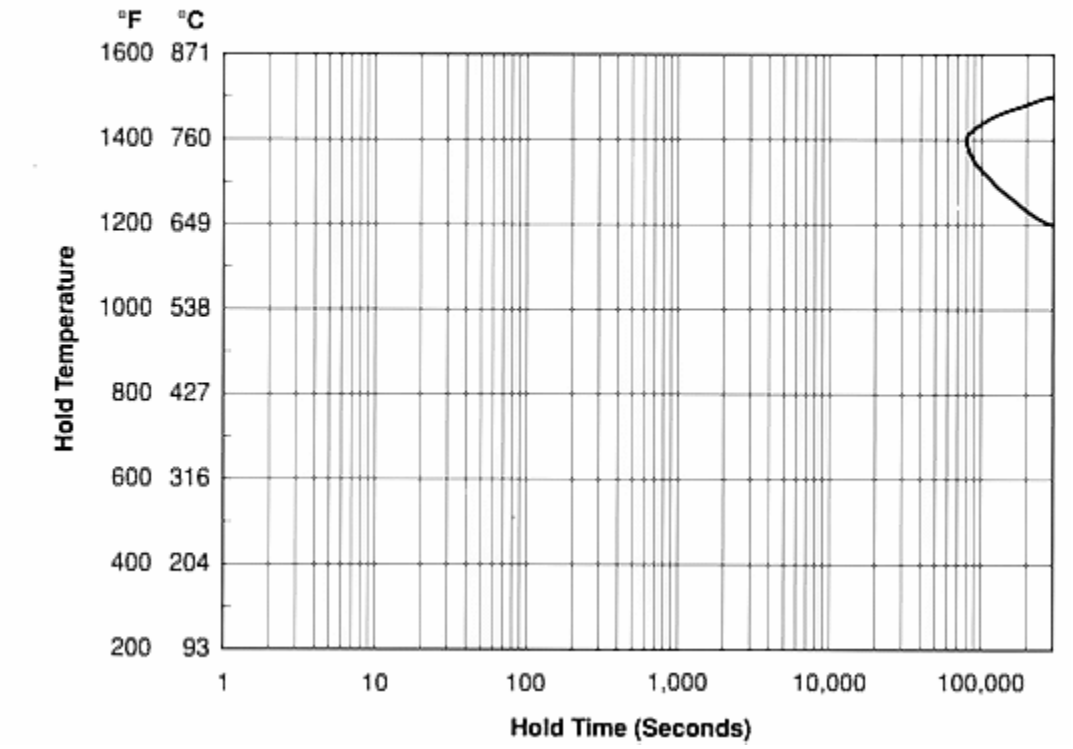
Density	0.2800	lb/in³
Mean CTE		
77 to 200°F, Annealed	5.63	x 10 -6 in/in/°F
77 to 300°F, Annealed	5.87	x 10 -6 in/in/°F
77 to 400°F, Annealed	5.98	x 10 -6 in/in/°F
77 to 500°F, Annealed	6.06	x 10 -6 in/in/°F
77 to 600°F, Annealed	6.14	x 10 -6 in/in/°F
77 to 700°F, Annealed	6.23	x 10 -6 in/in/°F
77 to 800°F, Annealed	6.32	x 10 -6 in/in/°F
77 to 900°F, Annealed	6.40	x 10 -6 in/in/°F
77 to 1000°F, Annealed	6.46	x 10 -6 in/in/°F
77 to 1100°F, Annealed	6.42	x 10 -6 in/in/°F
77 to 1200°F, Annealed	6.29	x 10 -6 in/in/°F
77 to 200°F, Hardened and Tempered	5.56	x 10 -6 in/in/°F
77 to 300°F, Hardened and Tempered	5.67	x 10 -6 in/in/°F
77 to 400°F, Hardened and Tempered	5.79	x 10 -6 in/in/°F
77 to 500°F, Hardened and Tempered	5.90	x 10 -6 in/in/°F
77 to 600°F, Hardened and Tempered	6.02	x 10 -6 in/in/°F
77 to 800°F, Hardened and Tempered	6.23	x 10 -6 in/in/°F
77 to 900°F, Hardened and Tempered	6.34	x 10 -6 in/in/°F
77 to 1000°F, Hardened and Tempered	6.42	x 10 -6 in/in/°F
77 to 1100°F, Hardened and Tempered	6.50	x 10 -6 in/in/°F
77 to 1200°F, Hardened and Tempered	6.52	x 10 -6 in/in/°F
77 to 1292°F, Hardened and Tempered	6.12	x 10 -6 in/in/°F

Mean coefficient of thermal expansion

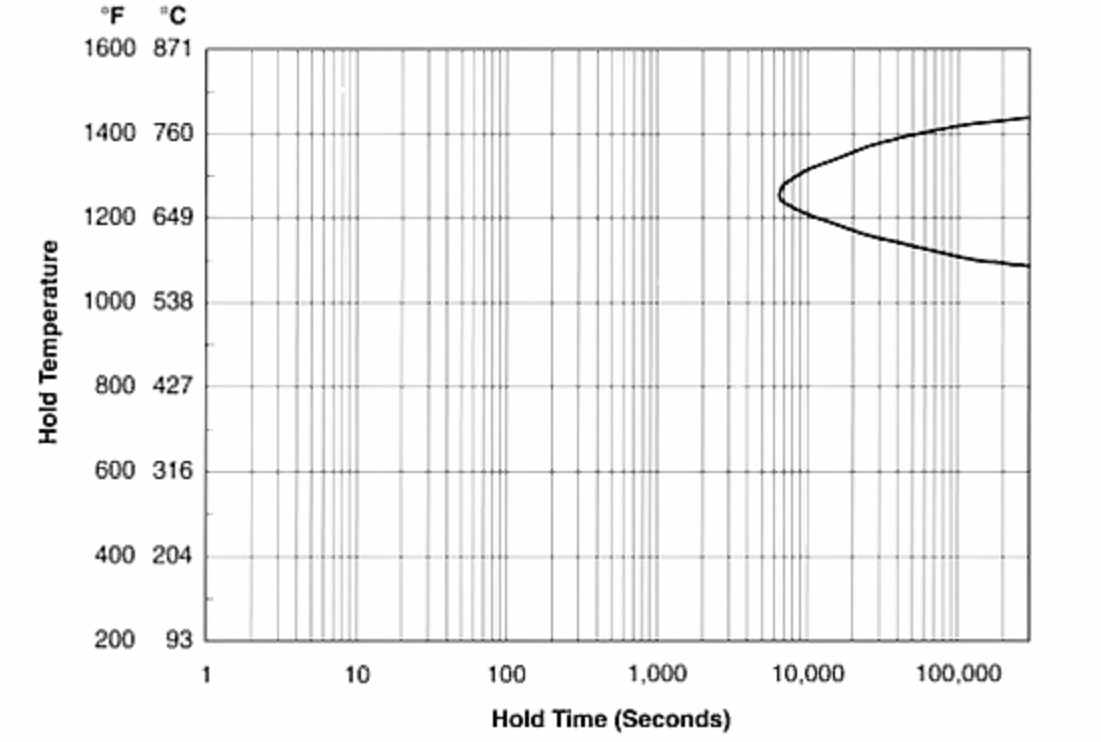
Temperature Range		Coefficient			
		Annealed		Hardened and Tempered	
77°F to	25°C to	in/in/°F x 10^{-6}	mm/mm/°C x 10^{-6}	in/in/°F x 10^{-6}	mm/mm/°C x 10^{-6}
200	93	5.63	10.13	5.56	10.01
300	149	5.87	10.57	5.67	10.21
400	204	5.98	10.76	5.79	10.42
500	260	6.06	10.91	5.90	10.62
600	316	6.14	11.05	6.02	10.84
700	371	6.23	11.21	6.12	11.02
800	427	6.32	11.38	6.23	11.21
900	482	6.40	11.52	6.34	11.41
1000	538	6.46	11.63	6.42	11.56
1100	593	6.42	11.56	6.50	11.70
1200	649	6.29	11.32	6.52	11.74

Modulus of Elasticity (E)	29.6	x 10 3 ksi

Isothermal Transformation (I-T) Diagram—Pyrowear 675 Stainless (0.07% C core) Austenitized at 1900°F (1038°C) for 15 minutes, quenched to I-T temperature, held for indicated time, then oil quenched to room temperature.



Isothermal Transformation (I-T) Diagram—Pyrowear 675 Stainless (1.5% C case) Preoxidized at 1700°F (927°C) for 1h, pack carburized at 1650°F (899°C) 48h, 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.



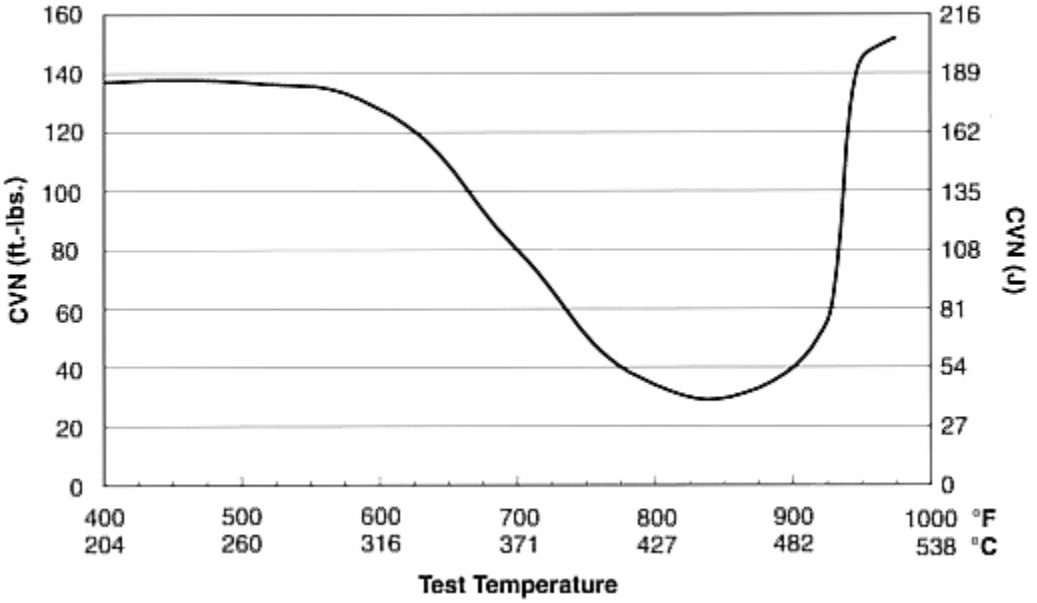
Critical Temperature (AC1)	1112 °F

Critical Temperature (AC3)	1500 °F

Typical Mechanical Properties

All samples pseudocarburized at 1650°F (899°C) for 48h, oil quenched, annealed at 1200°F (649°C), double normalized at 1900°F (1038°C) 1/2h, 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) 1h, tempered as indicated for 2h + 2h.

Charpy V-Notch vs. Tempering Temperature—Pyrowear 675 Stainless
Longitudinal samples.



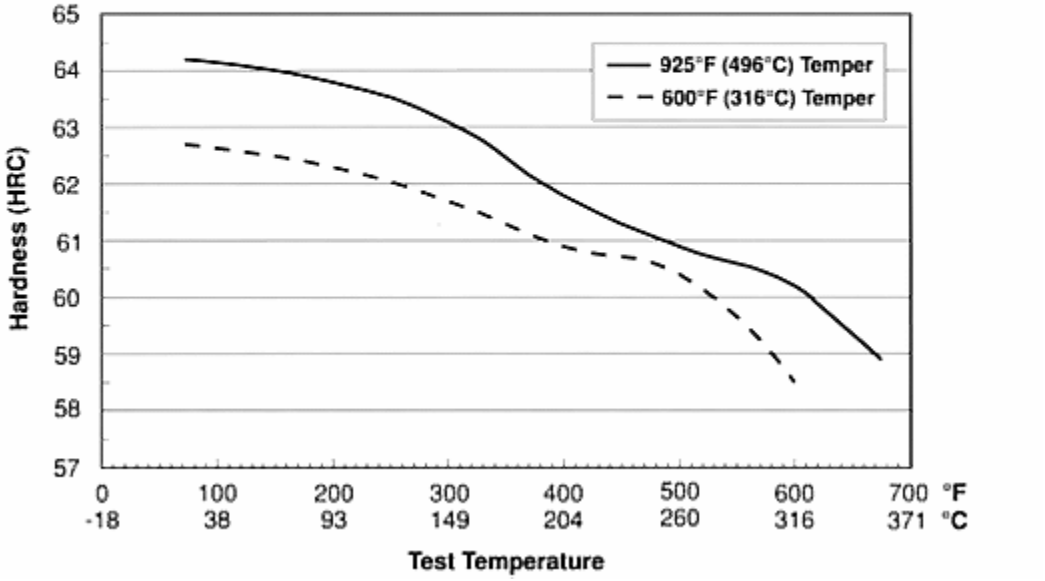
Core Fracture Toughness—Pyrowear 675 Stainless

Temepering Temperature		Hardness HRC	Orientation	K_Q	
°F	°C			ksi√in.	MPa√m
600	316	41.0	L	150	165
			T	140	154
950	510	41.0	L	125	138
			T	78	86

Core Tensile Properties—Pyrowear 675 Stainless

Tempering Temperature		Hardness HRC	Orientation	0.2% Yield Strength		Ultimate Tensile Strength		% Elongation in 4D	% Reduction of Area
°F	°C			ksi	MPa	ksi	MPa		
600	316	40.0	L	143	986	185	1276	20	73
			T	143	986	185	1276	19	70
950	510	39.0	L	154	1062	185	1276	20	75
			T	154	1062	185	1276	18.5	70

Hot Hardness—Pyrowear 675 Stainless (Carburized Case)
Samples preoxidized at 1900°F (1038°C) 1h, gas carburized at 1600°F (871°C) 48h, oil quenched, double normalized at 1900°F (1038°C) 1/2h, 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) 1h, tempered at 600°F (316°C) or 925°F (496°C) for 2h + 2h.



Heat Treatment

Decarburization

Carburized Pyrowear 675 stainless, like all high carbon steels, is subject to decarburization during thermal processing. Means of preventing decarburization are well known. Modern furnaces which 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 stainless 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

I Preoxidizing

Pyrowear 675 stainless 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 stainless preoxidizing temperatures on the lower side of the range will produce a better case structure following carburizing.

II Carburizing Temperature

The recommended carburizing temperature range for Pyrowear 675 stainless 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 stainless.

III Carbon Potential

In general a carbon potential of 0.65/1.0 percent 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.

IV 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" (0.51mm) and an HRC 50 depth of 0.045" (1.14mm).

V Post Carburizing Quench

Following carburizing, parts with diameters greater than about 1" (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.

VI 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 1/2 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 stainless has a high case carbon level, proper control of furnace atmosphere to prevent decarburization during subsequent heat treatment is very important.

Hardening

Pyrowear 675 stainless 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 2h + 2h.

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—Pyrowear 675 Stainless

Hardness measurements are averages rounded to the nearest 0.5 HRC.
Heat Treatment: Preoxidized at 1750°F (954°C) for 1h, pack carburized at 1600°F (871°C) for 48h, oil quenched, annealed at 1200°F (649°C), double normalized at 1900°F (1038°C) 1/2h, 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) 1h, tempered at indicated temperature for 2h + 2h.

Tempering Temperature		Carburized Case HRC	Core HRC
°F	°C		
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 stainless should not be tempered in the range 700/900°F (371/482°C) as decreased case and core toughness and ductility will result.

Workability

Forging

Heat to 1950/2000°F (1066/1093°C) for forging. Even though Pyrowear 675 stainless 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 stainless machines similar to Types 410 and 420 stainless. Tools should be sharp and ground to a fine finish. Tool holders must be rigid.

Following are typical feeds and speeds for Pyrowear 675 stainless.

Machining

Pyrowear 675 stainless machines similar to Types 410 and 420 stainless. Tools should be sharp and ground to a fine finish. Tool holders must be rigid.

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 (SFPM)	Feed (IPR)
Turning	85-115	0.001-0.0015
Drilling	35-75	0.005-0.010
Milling (Depth of cut 0.050")	70-105	0.001-0.004
Reaming	20-60	0.002-0.008

Additional Machinability Notes

Cutting speeds of 200 surface speed feet/minute (SFPM) and 400 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.

Other Information

Wear Resistance

The wear characteristics within the hyperlink entitled "Dry Sand/Rubber Wheel Abrasion Test" 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. The 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. It should be noted therefore that a lower number indicates better wear resistance.

Dry Sand/Rubber Wheel Abrasion Test—Pyrowear 675 Stainless
Pyrowear 675 stainless samples carburized and heat treated using standard cycle for elevated service temperatures.

All other alloys given standard hardening/tempering treatment for the grade.

Alloy	Hardness (HRC)	Average ASTM Volume Loss (mm^3)
Pyrowear 675	64.0	33.0
440C	60.0	29.0
M50 NiL	62.5	56.3
M50	61.0	22.5

Applicable Specifications

- AMS 5930

Forms Manufactured

- Bar-Rounds
- Billet

Technical Articles

- A Guide to Etching Specialty Alloys for Microstructural Evaluation
- How to Passivate Stainless Steel Parts
- New Torrington Airframe Control Bearings Offer Improved Corrosion Resistance and Longer Dynamic Life
- Passivating and Electropolishing Stainless Steel Parts

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