Hardness Testing. Lower than expected HRC values may indicate excessive retained austenite. Significant increases in hardness readings following cold treatment indicate conversions from austenite to martensite.

Precipitation-Hardening Steels. Specifications for these steels may include a mandatory deep freeze after solution treatment and prior to aging.

Shrink Fits. This result can be obtained by cooling the inner member of a complex part. Care is advised to avoid brittle cracking when the inner member is made of heat treated steel containing large amounts of retained austenite, which converts to martensite in subzero cooling.

Stress Relief. Cold treating is beneficial in stress relieving castings and machined parts of even or nonuniform cross section. Features of the treatment include:

- Transformation of all layers is accomplished when the material reaches −84 °C (−120 °F)
- The increase in volume of the outer martensite is somewhat counteracted by the initial contraction due to chilling
- Rewarm time is more easily controlled than cooling time, allowing equipment flexibility
- The expansion of the inner core due to transformation is somewhat balanced by the expansion of the outer shell
- The chilled parts are more easily handled
- The surface is unaffected by low temperature
- Parts that contain various alloying elements and that are of different sizes and weights can be chilled simultaneously

Advantages of Cold Treating

Success depends only on reaching the minimum low temperature, and there is no penalty for a lower temperature. As long as −80 °C (−115 °F) is reached transformation takes place. Reversal is not caused by additional chilling. Also, materials with different compositions and different configurations can be chilled at the same time, even though each may have a different high temperature transformation point.

Cryogenic Treatment

A typical treatment consists of a slow cool-down rate (2.5 °C/min equivalent to 4.5 °F/min) from ambient temperature to the temperature of liquid nitrogen. When the material reaches approximately 80 K (−315 °F), it is soaked for an appropriate time (generally 24 h). Then the part is removed from the liquid nitrogen and allowed to warm to room temperature in ambient air. The temperature-time plot for this treatment is shown in the adjoining Figure. By using gaseous nitrogen in the cool-down cycle, temperatures can be controlled accurately, to avoid thermal shock.

Single cycle tempering usually is the next step—to improve impact resistance, although double or triple tempering cycles are sometimes used for the same reason.

Kinetics of Cryogenic Treatment

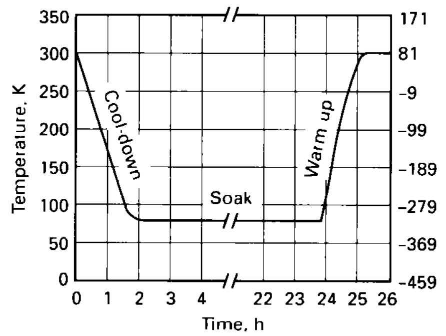
According to one theory with this treatment, transformation of retained austenite is nearly complete—a conclusion that has been verified by x-ray diffraction measurements. Another theory is based on strengthening a material via the precipitation of submicroscopic carbides. An added benefit is said to be a reduction in internal stresses in the martensite developed during carbide precipitation. Lower interior stresses may also reduce tendencies to microcrack.

Wear Resistance as a Function of Cryogenic Soak Temperature for Five High-Carbon Steels

	Wear resistance, R_W(a)		
		Soaked	
Alloy	Untreated	−84 °C (−120 °F)	−190 °C (−310 °F)
52100	25.2	49.3	135
D2	224	308	878
A2	85.6	174.9	565
M2	1961	2308	3993
O1	237	382	996

(a) $R_w = FV/WH_v$, where F is the normal force in newtons, N, pressing the surfaces together; V is the sliding velocity in mm/s; W is the wear rate in mm^3/s; and H_v is the Vickers hardness in MPa. R_w is dimensionless. Source: Ref 3

Plot of temperature vs. time for the cryogenic treatment process. Source: Ref 2



References

1. *ASM Metals Handbook*, Heat Treating, Vol 4, 10th ed., ASM International
2. R.F. Barron and R.H. Thompson, Effect of Cryogenic Treatment on Corrosion Resistance, in *Advances in Cryogenic Engineering*, Vol 36, Plenum Press, 1990, p 1375-1379
3. R.F. Barron, "How Cryogenic Treatment Controls Wear," 21st Inter-Plant Tool and Gage Conference, Western Electric Company, Shreveport, LA, 1982

Representative Applications of Heat Treating Furnaces

Representative applications of 36 different types of heat treating furnaces, reported by suppliers of equipment, are listed in this section. Ref 1.

Soaking Pit Furnaces

Normalizing
Stress relieving
Reheating

Batch or In-and-Out Furnaces

Normalizing
Annealing
Aging