This article looks at the science of cryogenic treating: Is it myth or fact? Research is only now beginning to unlock the secrets as to how the process works. Because the process is not technically well understood, it has not reached even a fraction of its potential.

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*Cryogenic Society of America Inc., a professional society dedicated to the study of cryogenics (Oak Park, Ill; www.cryogenicsociety.org) at temperatures below -120K (-244°F, or -153°C). An interesting article on cryogenics in general written by the National Institute of Standards and Technology (NIST) is available at http://cryogenics.nist.gov/AboutCryogenics/about%20cryogenics.htm. Notice that these temperatures preclude cold treating as practiced by heat treating companies to convert retained austenite into martensite. Cold treating is usually performed down to about -140°F. Tests and research indicate that much greater wear resistance is generated by use of cryogenic temperatures than with cold treating temperatures. Cryogenic processing, cryogenic treatment, and cryogenic tempering are all names that refer to a process where cryogenic temperatures are used to modify materials. Cryogenic processing and cryogenic treatment are the preferred names for this process.

Cryogenic tempering is a name that has become popular, but is imprecise as tempering is defined by the ASM Metals Handbook, Desk Edition as “. . . reheating hardened steel or hardened cast iron to some temperature below the eutectoid temperature for the purpose of decreasing hardness and increasing toughness.” Archaic English refers to tempering as the entire hardening process, as in “tempered steel.” Neither definition relates to the cryogenic process. This paper will stick with the term cryogenic processing. Note that we define the process as changing materials. Contrary to much popular belief, cryogenic processing works on materials other than ferrous metals.

The Cryogenic Cycle

There is a persistent idea that cryogenic processing can be accomplished...
Cryogenic Processing Research Summaries

1. Illinois Institute of Technology (Formed Thermal Processing Technology Center under Dr. Philip Nash a Study on Effect of Cryogenic Treatment on M2 Tool Steel Masters Thesis by Rajenda M. Kelkar) gives independent verification that cryogenic processing is doing something beneficial to the metal.

2. Army Aviation & Missile Command With IITRI Study of wear resistance under Hertzian contact stresses of 9310 steel: 50% extra pitting resistance, 5% more load carrying capacity, 40 to 60°F higher tempering temperature.


4. University of Trento, Trento, Italy/GKN Corp.: Effect of Deep Cryogenic Treatment of the Mechanical Properties of Tool Steels (A. Molinari, M. Pellizzari, S. Giallanella, et al. 2001 Journal of Materials Processing Technology): Studied M2 and H13; improved hardness homogeneity, led to 50% cost reduction, increased toughness on H13, no significant changes to microstructure except reduction in retained austenite; need to study the sub-microstructure for mechanism.

5. Nanostructured Copper Is Six Times Stronger, Still Ductile (Advanced Materials & Processes/January 2003; Prof. En MA, Dept. of Materials Science and Engineering, Johns Hopkins University, Baltimore, Md.) A pure nanostructured copper metal is six times stronger than conventional Cu and still retains ductility. This was achieved through a combination of cryogenic treatment, metalworking methods, and heat treatment.

6. Micro Cracks Eliminated, Carbides Modified (Deep Sub Zero Processing of Metals and Alloys – Part II Evolution of Microstructure Of AISI T42 Tool Steel, C.L.Gogete, Kumar M. Iyer-Department of Metallurgical and Materials Engineering, VNIT, Nagpur, Maharashtra, India; 2. R.K.Panetkar, R.D.Peshwe and Assab Sripad Steel Ltd., Chennai, India); There is change in the morphology of carbides, The phenomenon of merging/migration/dissolution of finer globular carbides takes place during the process leading to uniform distribution in the matrix, The microcracks present during prior to earlier processing are eliminated completely in the process, The stress-generated dislocations at the interface of the particles and the matrix causes diffusion, which is driven by the concentration gradient. The soaking time more than 8 and 16 hr leads to excessive contraction of the matrix thereby preventing any diffusion phenomenon. There is improvement in the tool life.

7. Copper Welding Electrodes Last Longer (Sub-zero Treatment of Steels Technology/Processes/Equipment, Linde AG, Linde Division/82049 Hollriegelskreuth/Germany): Increases their life by a factor 2 to 9. Both durability and conductivity were increased although the mechanisms behind the improvement are being further researched. Stress relaxation through recrystallization is responsible for the property improvement.


10. Classical Superconductors Absolute-Zero Phase Diagrams (Publication: Thermodynamics and Phase Diagram of High Temperature Superconductors; Reference: Ph. Curt, H. Beck Phys. Rev. Lett. 91, 257002 (2003) cond-mat/0401124): Superconductivity is present only below $T_c$ (see Fig. 2).
gist’s understanding of what happens at cryogenic temperatures is somewhat limited by several factors. There are thousands of years of experience with heating metals above ambient temperatures, but cryogenic temperatures have only been achievable since the late 1800s when the first ASUs (air separation unit) were produced. University courses for metallurgical engineering only explore phase diagrams from 0°C up. However, we know that there are definite changes at very low temperatures due to well-known phenomena such as superconductivity (see summary 5).

Most metallurgical engineering courses start with a description of crystal structures. In the book entitled *Structure-Property Relations in Non-Ferrous Metals*, the authors write: “In fact, the principal task of the metallurgical engineer could be described concisely as crystal defect engineering.” They continue, “For all temperatures above 0K (-273°C) [italics added], there is a thermodynamically stable concentration of vacancies and interstitial atoms. Introducing a point defect into a crystal increases its internal energy vis-à-vis a perfect crystal.”

Part of what we believe is the answer to what is happening is that the point defects in the crystal structure are being modified by the reduction in temperature as the crystal structure thermodynamically stabilizes to the low temperature. We also theorize that changes in solubility of the alloying elements in the crystal structure redistribute those elements.

Another theory is that the atom-to-atom spacing in the crystal structure becomes more uniform due to the removal of energy from the lattice structure. We invite those with more intimate knowledge of these factors to discuss them with us. We also invite experimentation and wish to cooperate with researchers into these subjects.

Organizational Support of Cryogenic Processing

Both ASM Cryogenic Processing Subcommittee and the Cryogenic Society of America are working to encourage research of cryogenic processing. Both ASM and CSA have published papers and data on the process, and have taken an active interest in the issues regarding the process.

Cryogenic Research Database

As a result of cooperation between the ASM Cryogenic Processing Sub-
Wherever possible, CSA has acquired publications rights for papers and the entire paper is available on the web site. In some cases, important research articles are owned by publications that restrict access to visitors to their own sites, or by publishers who charge for access to the research. In those cases, we have included abstracts where available, along with information about the online location of the article or publisher.

The database is open for submission of articles and research papers. They should be mailed to:

Cryogenic Society of America
Cryogenic Treatment Database Article Submission
218 Lake St.
Oak Park, IL 60302-2609
USA

Articles and papers also can be submitted electronically via the database web site. Submitted articles are reviewed by a committee of three persons who vote on whether the article should be included in the database. Currently on this review committee are Dr. Randall Barron, Dr. Tom Siewert, and Frederick Diekman.

Conclusions
Cryogenic processing uses cold temperatures (liquid nitrogen, or in some cases helium) to make changes in materials properties. Most metals respond to cryogenic processing, and we are just beginning to understand why cryogenic processing works. The process can be used to improve performance, and it can give a company or race car enterprise a competitive advantage.

Future Work
Controlled Thermal Processing Inc. and Air Liquide U.S. LP work together in developing demonstration tests on different materials and industry applications that will continue to validate the previous work and benefits of cryogenic treating. Cryogenic processing holds huge promise to reduce production costs and increase product durability, which offers companies that use the process a means to hold a competitive edge in their markets. Cryogenic processing has proven itself with improved performance for many products including strength and wear life of all types of vehicle components, castings, cutting tools, etc. Other benefits include reduced maintenance, repairs, and replacement of tools and components, reduced vibrations, rapid and more uniform heat dissipation, and improved conductivity. A big advantage of the process is that it can often be added to components with no other engineering design changes. Research is only now beginning to unlock the secrets as to how the process works. Because the process is not technically well understood, it has not reached even a fraction of its potential.

References
1. Numerous tests performed for Precision Fleet Brakes, Inc. by Greening Laboratories and Link Laboratories to SAE 2707 JUL 2004 METHOD B.

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