Material bEnEFiTS at 300 BELOW

By John Koucky

For decades, cryogenic treatment has been one of metalworking's best-kept secrets. It has become mainstream in recent years, and it is now providing consistent solutions for many areas of industry. Cryogenic processing adds longer wear life and increased durability to gears, tools, and components.

Cryogenically treated tools are used to improve machining efficiencies. As a case in point, one of our customers, a major automotive manufacturer, was having trouble hobbing gears at the standard rates and had to slow the equipment because they would break off the teeth of the hobs. Reduced machining rates caused significant working overtime. Ammeters on the machines determined when the hobs were becoming dull and needed sharpening. Once the customer started using cryo-treated hobs, the breakage stopped, the speeds were increased back to the standard rates, overtime was no longer required, and more parts were run between sharpenings. In addition, there was a significant reduction in the power bill for the machining center. It was estimated by the factory that the total annual savings for treating just one type of hob was more than $600,000!

What does this mean to the gear manufacturer and end user? Large cost savings occur as a result of improved life and performance of the tools used in the manufacture of gears after cryogenic treatment. The treatment also greatly enhances the life and performance of the gears themselves.

To fully understand how cryogenic tempering can help, we will examine the process itself—what it can do, how it is performed, and where it has been successfully applied.

Cryogenic treatment is not a new technology. In fact, many historians date it back to the ancient Swiss watchmakers who learned that, by placing materials in a cave for several years—heating them in the summer, and cooling them in the winter—the properties of these materials were greatly improved.

It was the Second World War that gave the cryogenics industry a boost, however, when improved material performance was needed for the war effort. Parts were cooled in the best way that they had available. Since freezers only went down to about -20°F, cooling was done in large vats filled with alcohol into which dry ice was placed. This allowed temperatures of -100°F to be attained, resulting in improved wear properties. Large amounts of war materials were treated in this way.

During that time, some experimentation was done using the small amount of liquid nitrogen that was available. Certain materials showed some spectacular results when parts were plunged directly into the liquid nitrogen and cooled to below -300°F. But, as likely as not, many of the larger cross-sectioned pieces cracked as the outside cooled far more rapidly than the center. For this reason the process of "deep cryogenic tempering," as -300°F cooling was then called, fell into disfavor. Methods of treating, other than immersion, were developed, such as spraying liquid nitrogen (LN2) on the parts, or suspending parts over a bath of LN2. But all of these methods were expensive, the possibility of cracking still existed, and control and repeatability were lacking.

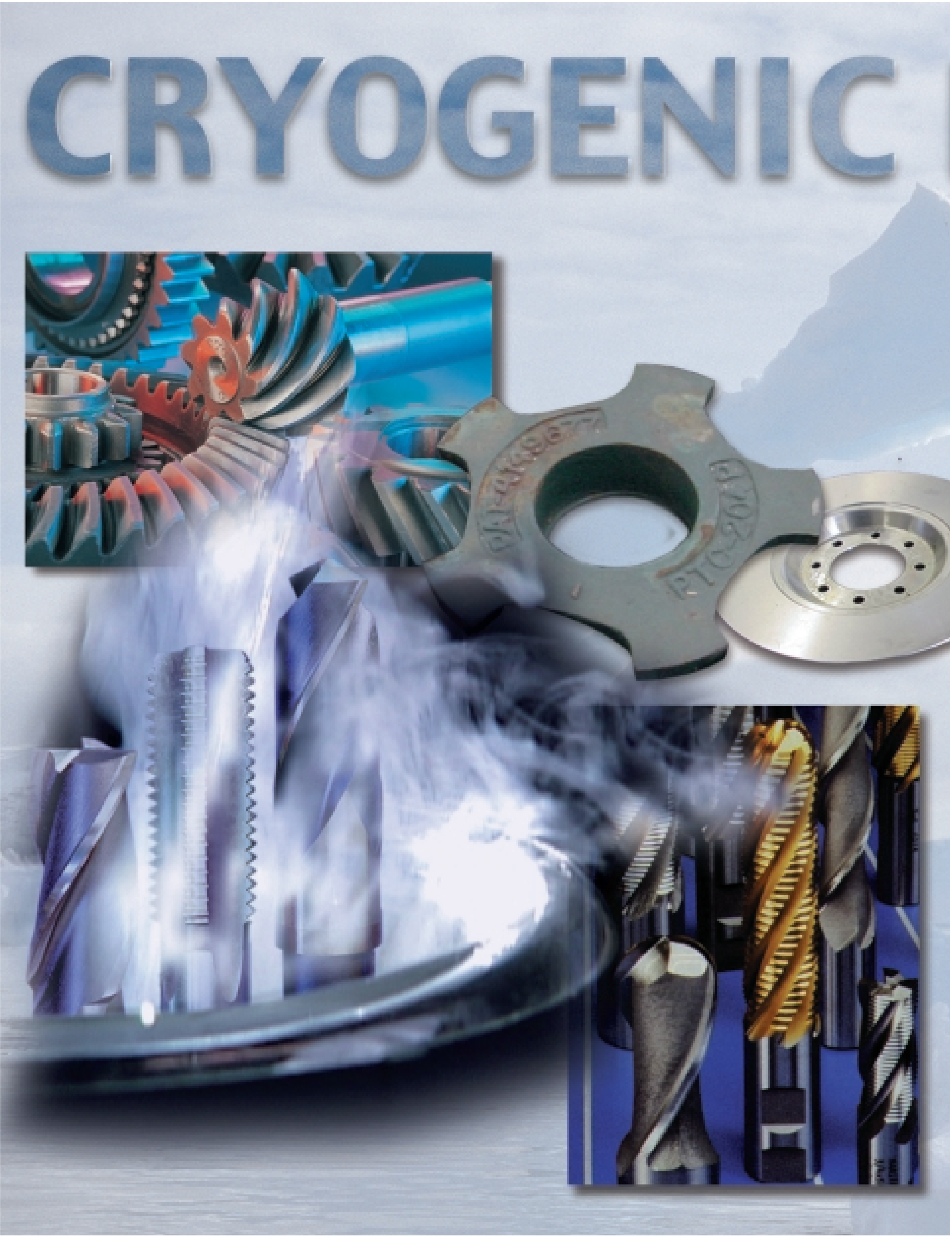
During 1966, Ed Busch founded a company named Cryo-Tech, which was located in Detroit, Michigan. He was the industry founder, developing the Commercial Deep Cryogenic Processor. Busch also built the first "dry" cryogenic processor. Instead of plunging the parts into a bath of LN2, he cooled the parts by using the dry vapors of LN2, thus controlling the temperature as it was ramped down, held for a long period of time, and then returned slowly to room temperature. The new controlled cryogenic treatment utilized slow cooling and eliminated the problem of cracking. It also proved to be a more economical process. He solved one set of problems, but encountered others—few had ever heard of cryogenics, for one, and there was no scientific data available.

In 1973, Busch contacted Dr. Randall Barron of Louisiana Tech University and commissioned him on a fee basis to develop data regarding the process. At that time, Barron was the most noted academic authority on cryo treatment. Working together, they started to develop some of the basic information used for establishing the standard treatment cycles for tool steels. Barron took five common tool steels, treated samples at both -110°F and -310°F, and then performed a pin abrasion test. In all the original samples treated at -310°F, a marked improvement in wear resistance was shown. With this data in hand, Busch slowly started to develop the tooling market. Additional materials were tested. The figure at right shows a more-complete list, beyond the original five materials, showing some materials that improved when treated and others that did not.

During 1989, Peter Paulin—the current CEO of 300 Below, Inc.—heard of Busch's work and called on him. Busch had tried unsuccessfully to develop joint ventures in Phoenix and California. Busch sent Paulin out to inspect the handful of newly minted imitators, and exhorted Paulin to marry his core technology to computerization. Paulin developed a "process controlled" deep cryogenic processor using electrical means to cool to -100°F, at which point the dry liquid nitrogen vapors were used to cool the remaining cycle.

Fig 1 — Test Results [% Wear Increase after Cryogenic Tempering]

		(-110°F)	(-310°F)
AISI#	**Description**	**Improvement**	
D-2	High carbon/chromium die	316%	817%
A-2	Chromium cold work die	204%	560%
S-7	Silicon tool steel	241%	503%
52100	Bearing steel	195%	420%
0-1	Oil hardening cold work die	221%	418%
A-10	Graphite tool steel	230%	264%
M-I	Molybdenum high speed	145%	225%
H-13	Chromium/moly hot die	164%	209%
M-2	Tungsten/moly high speed	117%	203%
T-1	Tungsten high speed	141%	176%
CPM-10V	Alloy steel	94%	131%
P-20	Mold steel	123%	130%
440	Martensitic stainless	128%	121%
430	Ferritic stainless	116%	119%
303	Austenitic Stainless	105%	110%
8620	Nickel-chromium-Moly steel	112%	104%
C1020	Carbon steel	97%	98%
AQS	Graphitic Cast Iron	96%	97%
A-6	Manganese air cold work die	73%	97%
T-2	Tungsten high speed steel	72%	92%


CRYOGENIC

PROCESSING

CRYO-what?

What we do.

Treat metal tools and wear parts with our "CRYO-TECH" process that improves the wear resistance and durability of metal. As temperatures are progressively and systematically lowered to -300°F in our computer-controlled processor, the microstructure of metal parts is altered, increasing toughness, stability and resistance to wear.

How it benefits your business.

As you know, to become more profitable, you either produce and sell more OR cut expenses. We help you do both. Tooling that undergoes cryogenic processing lasts from twice as long to 50 times longer than untreated tools and parts, and saves on repairs and replacements. For every $10 you invest in processing, it's possible to receive thousands in savings that goes directly to your bottom line. This one-time process has a 72-hour turn around time and is 100% guaranteed. If you don't see the benefit, you don't pay the bill.

Q. What kinds of industries can benefit from the process?

A. Almost any process using any form of metal tools, dies or wear parts. We've worked with machine shops, die shops, paper mills, textile firms, metalworking and welding shops, and many more.

Q. What kinds of things do you "freeze"?

A. Alloy steel, tool steels, stainless steels, gray iron, copper alloys, aluminum or magnesium. Including but certainly not limited to: Mill cutters, drills, punches, dies, knives, pistons, engines, cylinder heads, gun barrels, bearings, welding electrodes. Or ask us to run tests on your particular need.

Q. How will it improve my profitability?

A. The one-time Cryo-Tech deep cryogenic treatment changes the very structure of metals, making them stronger and wear resistant. Users gain 50% to 300% longer wear, on average. That means parts and tools last longer with fewer change outs and less downtime. Every $10 in processing can save you thousands of dollars in tool costs.

Q. Is sharpening or other maintenance more difficult after Cryo-Tech?

A. Thankfully, no. The substructure changes affect the strength and durability of the metal, not the hardness.

We'll prove it to you.

Call 217-423-3070 today and we'll send you proof in the form of a cryogenically treated razor. Try it out and see how long the razor keeps giving a close shave. After 4 weeks of clean shaves we're sure you'll be convinced. Offer expires 12/31/02.

Again... call 217-423-3070 today!

300° Below, Inc. ▪ Decatur, Illinois

www.300below.com

300° BELOW

CRYOGENIC TEMPERING SERVICES, INC.

300° Below, Inc./Cryo-Tech founded commercial cryogenic processing in 1966.
This year, 300° Below, Inc. will process over a million pounds of steel and carbide tooling.

The system reduced nitrogen usage by 50 percent, and opened many new markets due to the resulting cost efficiency.

With the implementation of exact process control and repeatability of the computer, work rapidly advanced, finding new materials to treat and developing cycles which maximize the properties of the cryo-treated parts. Paulin moved his business to the local business incubator, and soon thereafter purchased his own factory as the market developed. A few years later, Busch chose 300 Below to acquire Cryo-Tech. The marriage propelled 300 Below not only to the largest, but now the oldest of the commercial cryogenic processors. A business that had started treating cutting tools was soon treating more than a million pounds of many other things each year, such as: musical instruments, to improve their tonal quality; racing engines and components, to improve their performance and durability; gun barrels, to improve accuracy; softball bats, to stop their denting and improve performance; golf clubs, to improve their performance and accuracy, and; disc brake rotors, to improve life and stop warping and cracking. Treating industrial tools still remains the largest use for the cryogenic treatment. Imitators came and went, but 300 Below has flourished. As of 2003, the company had started more than 156 operations and joint ventures worldwide, with customers including NASA, the U.S. Army and Navy, Boeing, General Motors, Ford, Chrysler, and a host of others.

What is cryogenic treatment? Simply put, it is a process of freezing parts and tools to -300°F to improve their properties—particularly the wear properties. It is a "dry" process, during which the parts are never put in contact with the liquid nitrogen. The parts are cooled very slowly and then held at a temperature of about -300°F for anywhere from 24 to 36 hours, and then brought very slowly back to room temperature. Different materials and cross sections require different cycles. It is a "one time" treatment meaning that, once treated, it will not be necessary to repeat the treatment, as the properties will remain for the life of the part. It is also a "through" treatment; one that, unlike a surface treatment or coating, alters the microstructure all the way through the part, thus lengthening the life of your twist drill each time the drill is sharpened—as long as there is a stub left to sharpen.

What's happening to the tools? During the cryogenic treatment of ferrous materials, the process modifies the carbon that's present in the material. Three major changes occur. First, the microstructure of the material is changed to structures that

Cryogenic treatment results in greater dimensional stability and improved fatigue resistance.

have increased wear properties. The retained austenite in the structure is changed to martensite. Retained austenite is relatively soft and unstable, and it does not have adequate wear properties. Martensite, on the other hand, is hard and fairly brittle until tempered. Therefore, parts must be tempered following the cryo treatment. This develops a structure of "tempered martensite," which is the desired structure for tooling, with its good wear characteristics and toughness.

Second, during the treatment, small complex carbide particles called "eta" carbides are formed. This process is known as "carbide precipitation," and these carbides form from alloying elements that are present in the steel. The microfine carbides fill the interstitial boundary areas and the microvoids in the structure, creating a more coherent crystalline structure. These carbides have a marked effect on the wear properties of the material.

The third benefit is the reduction of random residual compressive and tensile stresses that may have resulted from heat treating or machining. These random stresses are significantly diminished by the changes in the microstructure, and from the uniform expansion and contraction created by thermo-mechanical cycling. The result is greater dimensional stability and improved fatigue resistance.

What are the benefits? Deep cryogenic tempering creates significant increases in abrasive wear resistance and durability. These improvements may be accompanied by increases in tensile strength, toughness, and stability, coupled with the release of internal residual stresses. While cryogenic treatment is primarily used to improve the wear properties of the material, it can also provide stress relief, reductions in stress-relief cracking, improved surface finish, and improved machinability.

Fig. 2 — Field Test Results

Increased: Useful Life, Stress Relief, Stabilization, Machinability
Reduced: Abrasive Wear, Corrosive Wear, Erosive Wear, Distortion

Tool Type	Tool Material	Results	Tool Cost Reduction
Drills	M42 M-7 C2	300%	-67%
Milling Cutter	M-7	250%	-60%
Deburring	Inconel	400%	-75%
Gear Cutter	TIN Coated	350%	-71%
Broach	Carbide	300%	-67%
Punch	M-7	600%	-83%
End Mill	M42	450%	-78%
Hob	M-2 M-7	300%	-67%
Face Mill	C2 Carbide	400%	-75%
Key Cutter	M2 M-7	250%	-60%
Slicer	M7	600%	-83%
Chipper Knives	Carbide	500%	-80%
Shredder	M7	400%	-75%
Tap	C2 Carbide	600%	-83%
Die	Hi Nickel	300%	-67%
Dentist	400 Stainless	500%	-80%
Broach	Hi Nickel	250%	-60%
Logging	Hi Nickel	400%	-75%
Milling	347 Stainless	375%	-73%
Woodcutting	HSS	500%	-80%
Stamp Die	D-2	1000%	-90%
Corrosion	S7 M2 4142 316	less corrosion	
Machining	Aluminum Castings	50% less time	
Electrode	Welding	600%	-83%

What materials show favorable results when treated? Not all materials respond to cryogenic treatment. Here is a partial list of materials which do respond: Higher carbon, higher steel alloys, tool steels, martensitic stainless steels, cast stainless steels, gray cast iron, some white irons, some manganese steels, aluminum, brass, and tungsten carbide.

What types of parts can be treated? The figure above shows some examples of the typical types of tools that were processed and the results that we might expect. The results are dependant on which material is used to produce the tool, rather than what the tool actually is.

A federal government-sponsored study is under way by the name of INFAC—Instrumented Factory for Gears. Helicopter gears are critical components. Under this program, helicopter gears were manufactured using the very best techniques of gear production available. The selected test gears were carburized and then cryo treated. The final report has been delayed by 9/11, but the last progress report showed 50 percent extra pitting resistance life and 5 percent more load carrying capacity when cryo treated. They also listed as potential benefits that; gears will last longer; maintenance costs will be reduced; gears can carry higher loads; transmissions can be smaller and lighter; operating temperatures can be increased, and; longer life in "oil-out" situations.

Many of the early gear applications using cryogenics were in the racing industry. These motorsports applications have served as an ideal, severe test bed for cryo-treated engines, turbochargers, gears, shafts, and bearings. With the high horsepower produced today in tractor pulling and drag racing, improvements in those areas are a great indicator of improvements gained by cryogenics in less-severe applications.

The late Tom Nixon, a top tractor puller in the multiple-turbocharged Super Stock class, turned his non-treated ring and pinions so hard that they had to be replaced every two seasons. Following cryogenic treatment, he found virtually no wear after that same period of time.

Gardner Stone, the owner/driver of "The General"—the well-known modified pulling tractor with four Chinook helicopter turbines for a total of 12,000 horsepower—was having trouble with his non cryo-treated gears. He and crew chief Jeff Carter learned that "Top Gun" and "Money Pit," two twin-Allison 1710 cubic inch aircraft-powered modified tractors, were using cryo-treated engines, transmissions, and rear ends, and had never had a failure. Stone chose to have his gears cryo-treated, and he now replaces them every two years instead of at mid-season, as he'd done in the past.

Why hasn't cryogenics been more readily adopted? The customer or end user is learning about the potential of cryogenics, and is now demanding its use. One would think that the tool producer would search for new ways to improve their tools. However, when cryo processors say that they are going to increase the life of those tools by 200 to 300 percent, the manufacturer is thinking "and cut my sales by two thirds." The manufacturer is therefore reticent to adopt the process.

Savvy tooling operations implement cryogenic treatment because they recognize that the process offers a significant competitive advantage for their product. In many cases the current product is undifferentiated today. As an example let's analyze a simple twist drill. It is a commodity item, and the metallurgy is basically the same with all manufacturers. The geometry and functionality are the same. The last item to fall is price, and the profits have been squeezed to a low of 5 percent.

A premium tool line of cryogenic-treated twist drills offers a significant competitive advantage. The customer is willing to pay a 50-percent premium for 200 percent longer life.

The drill manufacturer loses the next sale at a 5-percent profit, but has a 50 percent profit premium to pocket today. The math is easy: The customer wins, the manufacturer wins, and the distributor wins by garnering additional market share from competitors who have no premium-product options.

Increased safety, increased reliability, high cost effectiveness, longer life, and improved performance are all measurable benefits of this high-tech process. It would be foolhardy to pass up a program that can easily save a company millions of dollars, especially when implementation is as simple as mailing a box.

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