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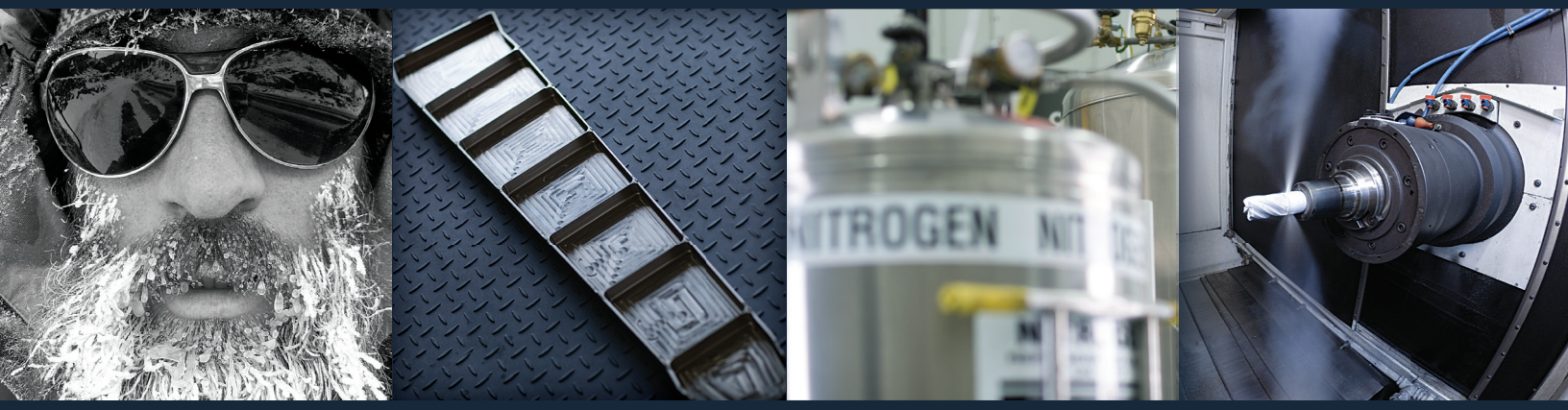
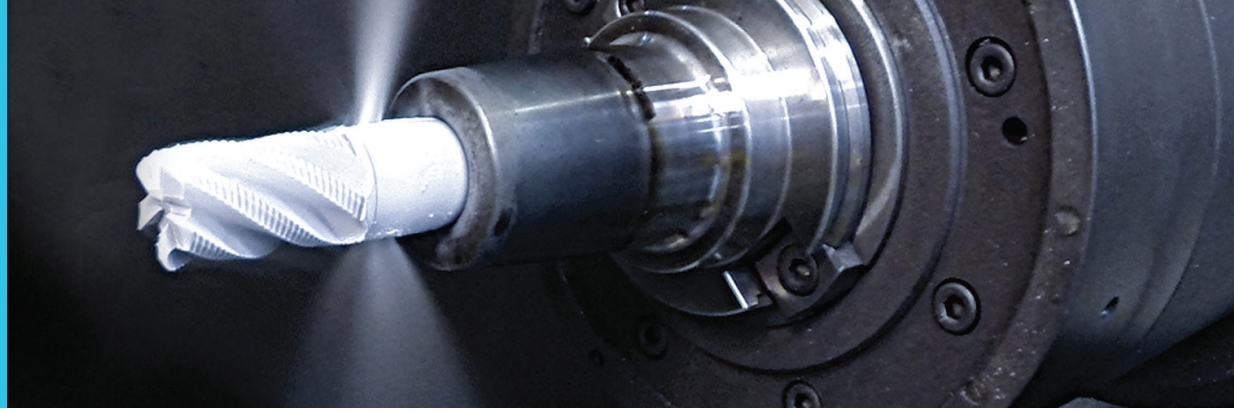


THE -321 DEGREE EDGE: 5ME'S LIQUID NITROGEN-BASED CRYOGENIC MACHINING TECHNOLOGY

A TECHNICAL GUIDE

5ME The Manufacturing Efficiency Experts



In the past, cryogenic machining was inefficient and ineffective, forcing many manufacturing facilities to stick with traditional coolants. The main problem with first generation cryogenic systems was that they utilized an external process, which allowed most of the cryogen to evaporate before reaching the cutting surface, ultimately reducing its cooling capacity.

Thanks to recent technological advances, cryogenic machining is now an affordable option with significant and measurable benefits.

In fact, the advantages of 5ME's patented liquid nitrogen-based cryogenic technology are vast – including faster processing speeds, longer tool life, and increased part quality. Additionally, this machining technology is greener, safer and easier to implement than conventional machining methods.

How it Works: Heat-absorption in Machining

Temperature plays an important role in the productivity of your shop floor. When not regulated appropriately, it is the most common cause for tool failure.

When the tool heats up during machining, it softens, and the cutting edge degrades severely – decreasing productivity. There are four different tool wear mechanisms, all affected by heat: Adhesion, Oxidation, Abrasion, and Diffusion. That's why an affective cooling strategy is crucial when it comes to ensuring efficient machining and extending tool life.

The Problem with Flood Coolants

Flood coolant draws heat out of the machining process; however, it does so from a distance so it's unable to effectively cool the tool directly beneath the chip, where the tool shear and friction are creating maximum heat.

Through-spindle coolant systems were created to overcome this common problem by delivering coolant closer to the cutting zone. This technological development of through-the-tool delivery provided significantly more effective cooling than external flood coolant.

When using 5ME's liquid nitrogen-based cryogenic machining versus water or oil-based coolants, you gain the advantage of delivering a super-cooled fluid directly to the tool cutting edge. While traditional coolants might be +70°F, liquid nitrogen (LN2) is -321°F. This difference of nearly 400°F causes the tool to act as a thermal sponge, absorbing the heat of machining away from the cutting edge.

The 5ME Solution

5ME's patented liquid nitrogen-based cryogenic technology allows LN2 to flow through the spindle and inside the tool just below the cutting edge, which provides optimum cooling and protection for the cutting edge.

The reduction of temperature facilitates faster cutting speeds, which makes liquid nitrogen-based cryogenic machining ideal for tough to machine materials, such as:

- **Alloy and Stainless Steels**
- **Inconel**
- **Nodular Iron and Diesel Irons**
- **Compacted Graphite Iron**
- **Titanium**
- **Carbon Fiber Composites**
- **Stacked Materials**
- **Stellite**

Cryogenic Technology is Environmentally and Work Space Friendly

Conventional "wet" machining solutions negatively impact our environment in their production, use, and disposal of often-toxic cooling fluids. 5ME cryo is a "dry" solution. When LN2 evaporates back into the atmosphere, it dissipates to – an inert, non-greenhouse gas.

The benefits are significant:

- Nitrogen is a non-contaminating natural element, which makes it ideal for machining medical components, or other bio-sensitive workpieces.
- Because it evaporates at point of use, you do not need to worry about oil mist, fumes, or slippery surfaces endangering your shop floor personnel.
- There's reduced energy usage as energy consumption is lower without coolant pumps, filter motors, and mist extraction systems..

Smarter and Safer

On your shop floor, 5ME's liquid nitrogen-based cryogenic machining reduces the risk of workplace accidents (when compared to traditional methods of machining) because there is no slippery fluid or oil mist left on the surfaces of the machine. In large-machine applications, this reduces the risk of the operator falling or injuring him/herself.

Lower Overhead with Liquid Nitrogen-based Cryogenic Machining

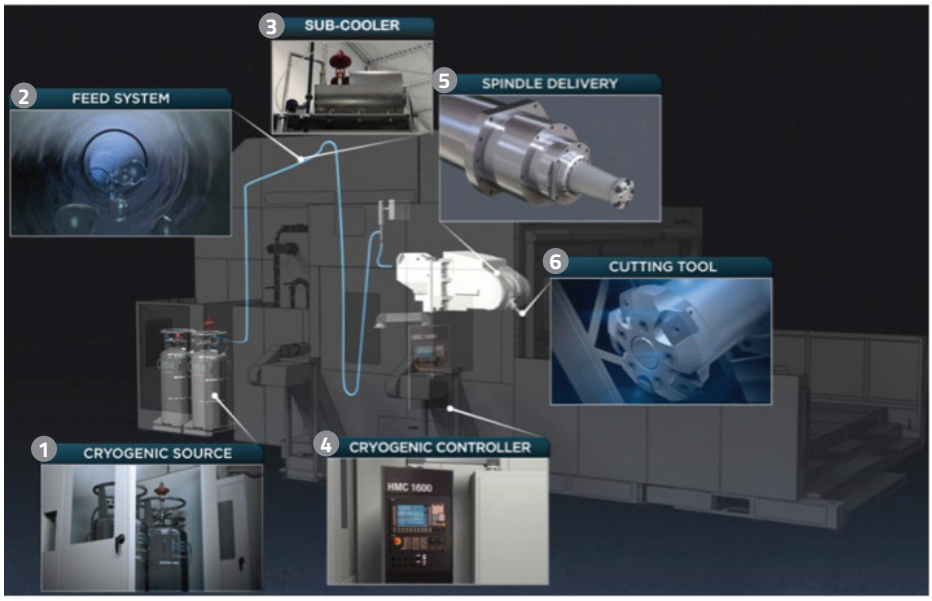
5ME's exclusive cryogenic machining technology consumes less energy than conventional coolant machining. While flood coolant requires power for pumps, mist collectors, and filters, 5ME's Cryogenic Machining system is self-pressurized, and therefore does not require any pumps or motors to induce flow.

Cleanup is also less time consuming and less costly. With flood coolants, the metal chips are wet and sticky, which complicates evacuation from the machine and typically requires draining, rinsing, and drying before reclamation. With cryogenic machining, workpieces and scrap metal are clean. This allows for more efficient production, clean up, and recycling.

5ME's Liquid Nitrogen-based Cryogenic Machining Can Be Implemented Quickly

5ME's multi-patented Cryogenic Machining System can be utilized for either individual machines or large-scale usage. Specially designed delivery system kit, tooling, and tool holders make retrofitting machines easy, which minimizes downtime and eliminates the need to invest in new machines.

5ME's Liquid Nitrogen-based Cryogenic Machining System Has Six Separate Components:



1 The Source – Cryogenic Cooling Fluid Storage

Liquid nitrogen is stored in a central storage location and then fed into the Cryogenic Machining System. The system is self-pressurizing; eliminating the need for pumps and other additional power consuming assets. There are three options for storage of the liquid nitrogen:

- Individual machine storage in a vacuum jacketed container (or "dewar") that allows for insulated storage of the liquid nitrogen to minimize evaporation.
- Cell-based storage with a micro-bulk vessel and feed "drops" to each machine via vacuum jacketed feed lines. For small cells of two to six machines, a cellular storage and supply system is recommended.
- Central/External storage and feed "drops" to each machine – for large-scale installations, a centralized external storage system with "drops" to individual machines is recommended.

2 The Feed – Cryogenic Machining Insulated Fluid Transfer

The feed system consists of vacuum jacketed insulated lines that run from the machine source system to the Sub-Cooler, and then to the spindle, or turret, depending on the machine type. The LN2 feed system seals out ambient heat and feeds the super- cooled (-321° F) liquid to its point of use. The feed system also starts and stops the flow of liquid nitrogen, which is delivered at a prescribed pressure and flow rate for the specific tool and/or application.

3 The Sub-Cooler – Cryogenic Machining Temperature Management

The patent pending 5ME Sub-Cooler removes "pressure generated" heat out of the system which returns the liquid nitrogen flow back to -321° F and condenses dual phase liquid nitrogen (liquid and gas) back to 100% liquid. This critical process helps prevent the formation of gases from downstream heat leaks and pressure drops. It also allows accurate liquid metering for the flow control valves, ensuring the right amount of liquid nitrogen is delivered to the cutting edge, which is critical for optimum heat extraction and extreme performance gains.

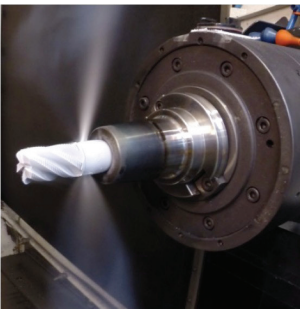
4 The Cryo Controller – Programmable Flow Control

This programmable system allows operators to program the LN2 flow rate to match the requirements of the application. The Cryo Controller is also interlocked with the CNC's EStop circuitry.

5 The Spindle – Retrofit Cryogenic Machining to Various Machines

The patented 5ME Cryogenic Machining System can easily be retrofitted to almost any OEM spindle or turret. A vacuum insulated tube called a "Lance" is installed through the ID of the drawbar and interfaces with the tool holder. A wide variety of interfaces are available including CAT 40, CAT 50, HSK 63A, HSK 100A, and HSK 125A.

The fully insulated system allows Cryogen to be transferred through the spindle, or turret, without affecting the functional temperatures of these critical machine components. The spindle has excellent reliability and maintenance with long seal life, no thermal cycling issues, and no adverse effect on spindle bearings (based on over three years of continuous testing).



6 The Tool – Delivering Cryogen Directly to the Tool Cutting Edge

5ME's patent pending Cryogenic Tooling is specifically designed to interface with the Cryogenic System and is required for proper functionality and safety. Our current tooling suite includes tool holders, turning tools, solid carbide mills, drills, reamers, and thread mills. Indexable Tooling includes face mills, hi-feed mills, drills, and boring tools with cryogenic inserts of various grades and coatings developed for cryogenic machining.

All 5ME Cryogenic Tooling is specifically designed and insulated to accept liquid nitrogen in the liquid state and keep it liquid up until the cutting edge. This ensures the most efficient use of the liquid nitrogen and optimal cooling at the point of cut.

If you're interested in learning more about 5ME's exclusive cryogenic machining technology, download our free **11 Essential Facts guide** or contact one of our cryogenic experts.

GET THE FACTS AT 5ME.COM/CRYOGENIC-EDGE

About 5ME

5ME brings a proven suite of capabilities to industry, solely focused on increasing manufacturing efficiency as a means of building profitable, competitive and sustainable businesses. Today, that mission is more critical than ever. Manufacturers are under increasing pressure from agile competitors, capacity constraints, material cost increases, and skilled labor shortages; but there are still significant opportunities to improve existing operations and return lost profit to the bottom line. 5ME addresses five critical components – the five "M's" of Man, Material, Machines, Methods and Money – to improve a manufacturing enterprise's efficiency (the "E").