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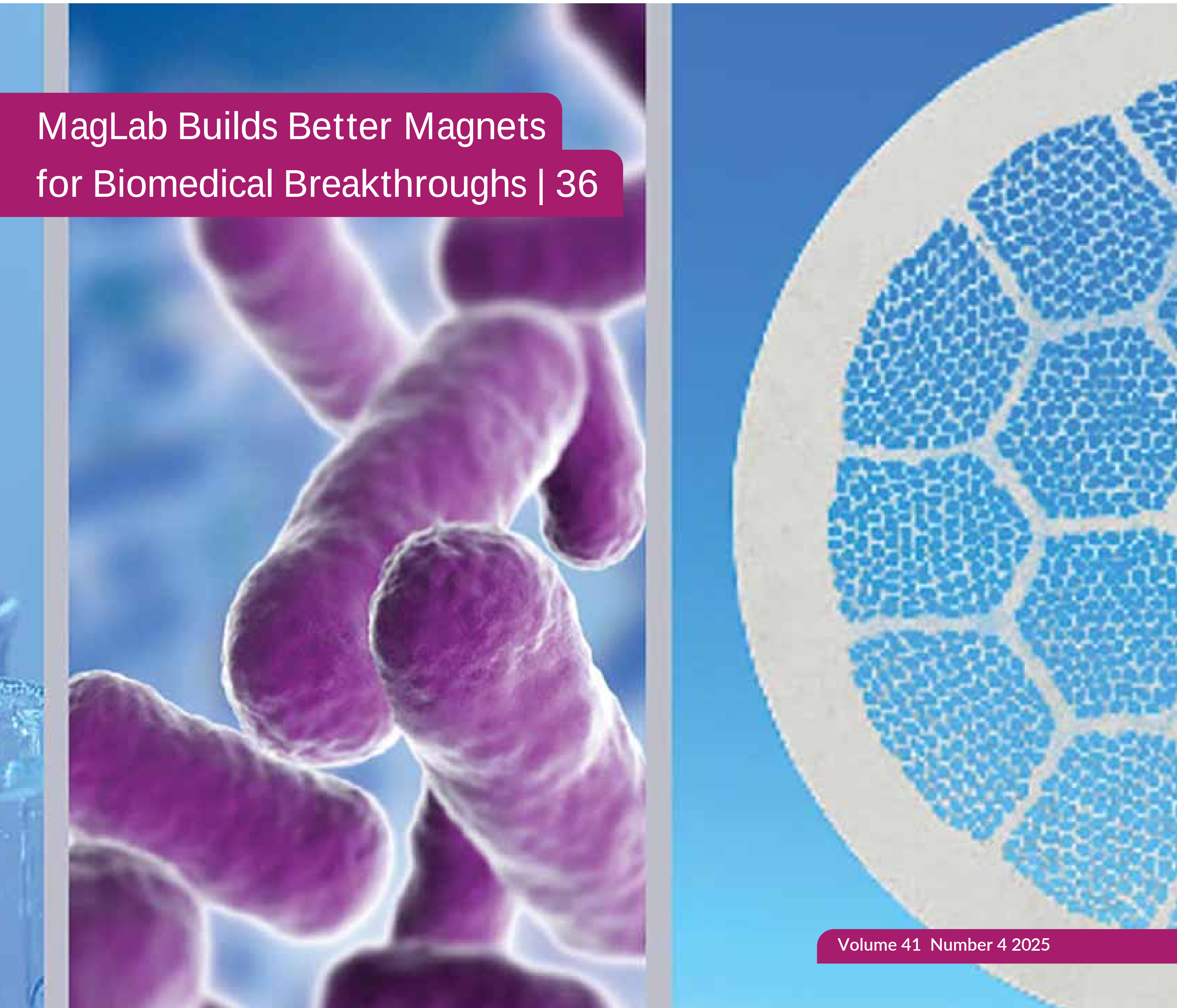

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Volume 41 Number 4 2025

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* New member since last issue

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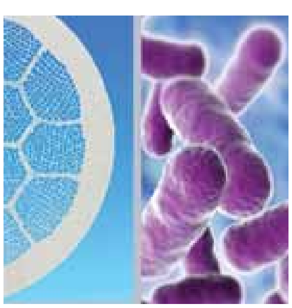

MagLab engineers will develop a new superconducting magnet for high-field nuclear magnetic resonance research.
Credit: National High Magnetic Field Laboratory

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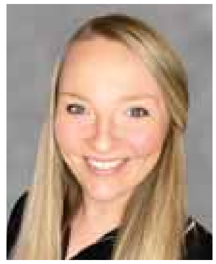
From the Executive Director



As summer draws to a close, I want to take a moment to reflect on the exciting opportunities we have had together and highlight several important initiatives now underway at the Cryogenic Society of America.

First, I would like to extend sincere thanks to everyone who participated in our most recent virtual short course, *Cool Fuel – the Science and Engineering of Cryogenic Hydrogen*, held on July 22, 2025. Our outstanding instructors, Dr. Jacob Leachman and Dr. Konstantin Matveev, provided an engaging and comprehensive overview of the science, engineering and applications of cryogenic hydrogen. If you were unable to join us live, the full course recording and all accompanying materials are now available for purchase through the CSA Online Learning Portal, which you can reach here: **https://2csa.org/learn**

Looking ahead, I am pleased to announce that the 2026 Media Guide is now available. Alongside our traditional print opportunities in *Cold Facts*, we are excited to introduce new *Cold Facts* digital advertising options. These offerings will allow companies and organizations to connect with our readership through online platforms and targeted placements, expanding visibility across both print and digital audiences. Please consider how CSA can support your outreach goals in the coming year. Check out the 2026 Media Guide here: **https://2csa.org/guide**

Another initiative I want to highlight is the Cryogenic Employment Survey currently underway. As the demand for skilled cryogenic technicians and engineers continues to rise, CSA is committed to helping the community prepare for the workforce needs of the future. This survey is designed to better understand current trends and challenges, with the goal of informing partnerships with local community colleges and universities to develop or expand cryogenics course offerings. You are not required to answer every question, and we welcome additional suggestions to ensure that the survey reflects the full scope of industry needs. All responses will remain strictly confidential, with identifying or proprietary details removed before any results are shared. A summary of findings will appear in a future issue of *Cold Facts*, and companies that complete the survey will receive an advance copy of the article. The deadline to participate was August 31, 2025. If you missed the deadline but would still like to contribute, please contact me directly at megan@cryogenicsociety.org to discuss how you can be involved.

Your active participation in the Cryogenic Society of America. Your engagement, whether through attending courses, sharing expertise or providing feedback, helps us build a stronger and more connected community. I look forward to the months ahead and to continuing our work together in advancing the science and practice of cryogenics.

Megan L Galeher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Left to right: Conner Slone, Tom Seegar, Ph.D. and Joe Maciag, Ph.D., at the Center for Advanced Structural Biology within the University of Cincinnati's College of Medicine. Credit: Conner Slone

Cryo-EM at University of Cincinnati Reveals the Invisible and Transforms Structural Biology

by Megan Burgasser, University of Cincinnati

For the first time, researchers at the University of Cincinnati have visualized the structure of two key protein partners involved in inflammation and immune signaling. This breakthrough—published in the *Proceedings of the National Academy of Sciences*—not only uncovers the structure of the ADAM17 enzyme in complex with its regulatory partner iRhom2 but also marks a milestone for UC's Center for Advanced Structural Biology (CASB), established just two years ago.

"This work provides a foundation for designing therapies targeting ADAM17-related diseases," said Tom Seegar, Ph.D., an Ohio Eminent Scholar and assistant professor in the Department of Molecular and Cellular Biosciences at UC's College of Medicine. "We're offering new strategies to address critical health conditions."

Seegar is the corresponding author on the study, the first published from his lab at UC. First authors include research scientist Joe Maciag, Ph.D. and graduate assistant Conner Slone. Their work provides a long-sought glimpse into how ADAM17 and iRhom2 interact—and how that interaction might be harnessed to better treat conditions such as rheumatoid arthritis, cancer and even Covid-19.

"If you can see something, you can figure out how it works," said Seegar. "We are figuring out what this enzyme looks like and how it's regulated."

Why Structure Matters

ADAM17 is a membrane-bound enzyme found in every cell of the human body. It plays a vital role in shedding signaling molecules that control immune response and tissue repair. But when it malfunctions or becomes overactive—as it does in several chronic inflammatory diseases—the resulting immune signaling can become pathological.

Until now, researchers had only partial views of how this protein and its regulator behaved. "We know in some cancers and rheumatoid arthritis, way too much signaling is occurring," said Maciag. "But some treatments create too many side effects, worse than the disease itself." To get a full picture, the Seegar Lab turned to a powerful new ally: cryogenic electron microscopy, or cryo-EM.

A New Microscope, A New Era

Launched in 2022, UC's Center for Advanced Structural Biology was specifically designed to accelerate breakthroughs like this one. It houses two state-of-the-art electron microscopes and specialized instrumentation for sample preparation, vitrification and data processing.

"The Center for Advanced Structural Biology is a relatively new core facility that houses two state-of-the-art electron microscopes," Seegar explained. "These high-magnification microscopes are optimized to visualize macromolecules embedded in thin layers of vitreous ice."

Cryo-EM differs significantly from more traditional structural biology techniques such as X-ray crystallography, which requires large amounts of purified protein and the formation of crystals—a time-consuming and sometimes impossible feat for complex membrane proteins. Instead, cryo-EM uses rapid freezing to preserve biological samples in a close-to-native state.

"Cryo-EM typically requires less sample and avoids crystallization altogether," Seegar noted. "The rapid freezing process preserves proteins in a near-native conformation, and when combined with single-particle analysis, can yield atomic-level resolution."

That resolution—3.4 Ångströms, or roughly the diameter of a water molecule—was critical to understanding how ADAM17 and iRhom2 communicate across the cell membrane and how disruptions in that communication may be implicated in disease.

Meeting the Challenge of Membrane Proteins

Integral membrane proteins like ADAM17 and iRhom2 are notoriously difficult to work with outside their native environments. That challenge was central to the UC team's effort.

"We needed to develop purification strategies that maintained the proteins' structural integrity outside of their native lipid context," said Seegar. Once purified, the team optimized the freezing process and used a support grid to create a thin layer of vitreous ice suitable for high-resolution imaging.

To aid particle identification, they introduced an antibody fragment called a Fab, which helped orient the particles during data processing. "The cryogenic freezing process was critical," Seegar said. "It preserved the proteins in their near-native conformations and prevented structural distortion or aggregation." The result: the first-ever detailed image of the ADAM17–iRhom2 complex and the identification of the iRhom2 "re-entry loop," a structural element that transmits signals from the cell's interior to its exterior and is required for ADAM17 to function.

On-Site Power: TEM + ARC

The team's success also hinged on infrastructure beyond the microscope itself. UC's 200 kV Thermo Fisher Glacios cryo-electron microscope and its 120 kV Talos L120C screening scope are supported by a full suite of sample preparation equipment and a staff trained in cryo-EM theory and technique. But what sets the center apart is its integration with UC's Advanced Research Computing Cluster.

"This enables users to make immediate decisions on sample quality and collection strategy," said Seegar. "Once data collection is complete, seamless transfer to the computing cluster allows for all downstream processing necessary to achieve atomic-resolution reconstructions."

In short, everything—from freezing to processing to model reconstruction—was done on campus.

Cryo-Em sample prep space. Credit: Facility Manager Desiree Benefield, PhD.

University of Cincinnati's Talos L120C transmission electron microscope, a 120 kV screening scope, is used to evaluate samples and prepare them for high-resolution cryo-EM imaging on the Glacios. Credit: Facility Manager Desiree Benefield, PhD.

Building the Future

The Seegar Lab is now planning its next steps, including deeper studies into how adapter proteins like iRhom2 regulate enzymes such as ADAM17. "These adapter proteins are not well understood," said graduate student Conner Slone. "Our research will be in understanding them and will be driven by specificity. Ideally, controlling these will allow researchers to control disease states."

Other contributors to the study included Igal Ifergan, Ph.D., assistant professor in the Department of Molecular and Cellular Biosciences; graduate student Hala Alnajjar; Medical Scientist Training Program student Maria Rich; and undergraduate Bryce Guion. The study was funded by the National Institute of General Medical Sciences and supported by a University of Cincinnati Research Innovation/Pilot Grant.

Looking ahead, Seegar says the Center for Advanced Structural Biology will evolve alongside the needs of its users. "CASB is guided by an advisory committee that evaluates user needs and helps direct future instrumentation and workflow upgrades," he said.

The cryo-EM center itself was made possible through funding from the NIH High-End Instrumentation Grant Program, the UC Office of the President and Vice President for Research and the College of Medicine.

"We are indebted to UC," Seegar said. "Our work wouldn't be possible without this research core facility."

Dr. Chang Kyu Song, second from left, and his team at the Department of Ultra-Precision Machines and Systems, KIMM. Credit: KIMM

KIMM Lab Achieves Milestone with Development of Korea's Own 'K-CNC' System for Machine Tools

by National Research Council of Science and Technology Communications

As cryogenic labs push the boundaries of low temperature research, they increasingly rely on precision machining tools and intelligent control systems. Korea's KIMM lab has taken a major step toward technological independence with the development of its own smart CNC system. While not developed exclusively for cryogenics, this system is poised to support research labs where precision, reliability and customization are critical, including those operating at cryogenic temperatures.

The Korea Institute of Machinery and Materials, affiliated with the National Research Council of Science and Technology, has successfully developed a computer numerical control system entirely with Korean technology. This milestone marks a significant step toward localizing machine tool control systems, reducing dependence on imported CNC systems and boosting the digital transformation and global competitiveness of Korea's manufacturing sector.

A research team led by principal researcher Dr. Chang Kyu Song at KIMM's Department of Ultra-precision Machines and Systems developed the smart CNC system, named K-CNC, along with 33 types of drive systems and spindles. Targeting general purpose machine tools, which make up most of the domestic market, the system was validated through joint field trials with Korean machine tool manufacturers.

The team developed core technologies including high-speed precision control, machine tool error compensation, real-time condition monitoring and AI-based fault diagnostics. The K-CNC system incorporates multi-axis control, high-speed precision machining, precise servo control, standards-based digital communication and touch-based human-machine interfaces.

Korea's machine tool makers have historically relied on imported drive systems because of high precision and reliability requirements. KIMM's development of 33 tailored drive systems fills this gap. In particular, the breakthrough in spindle motors and drives addresses a critical domestic weakness.

The system also features a flexible data exchange and processing platform, as well as a customizable HMI development kit. In collaboration with four leading Korean machine tool manufacturers, KIMM developed intuitive smart HMIs that improve equipment intelligence and operational efficiency.

To test its commercial viability, KIMM installed the K-CNC system on eight machine models across six domestic manufacturers. The trials demonstrated machining quality and cycle times on par with imported systems, proving readiness for mass production.

On June 18, a demonstration and briefing event was held at KIMM headquarters in Daejeon. About 50 machine tool manufacturers attended the morning demonstrations of complex surface machining. In the afternoon, representatives from the Ministry of Trade, Industry and Energy, KEIT, R&D partners and industry stakeholders reviewed project progress and shared feedback.

Dr. Chang Kyu Song, a principal researcher at KIMM, stated, "The successful development of the K-CNC system fulfills a long-standing aspiration of Korea's machine tool industry, marking a major step toward technological independence. It sets a solid foundation to enhance Korea's manufacturing competitiveness. We will continue striving in our R&D efforts to ensure Korea's manufacturing industry leads globally."

This research was supported by the Ministry of Trade, Industry and Energy through the project "Development of CNC System for Smart Manufacturing Equipment," as part of the Smart Controller Technology Development Program for Manufacturing Equipment Systems.

Dr. Chang Kyu Song, left, examining the K-CNC system. Credit: KIMM

50 Years of Cryogenic Magnet Technology in Biomedical Study and Use

by Quan-Sheng Shu, Ray Radebaugh, and Robert L. Fagaly

Cryogenics and superconductivity (SC) have transformed modern medicine. From noninvasive tumor treatments to the imaging power of MRI and SQUID-based diagnostics, these technologies have become essential tools across the biomedical landscape. This article traces key developments over the past 50 years and highlights how cryogenics and superconductivity are shaping the next generation of diagnostics and therapy.

Cryoablation, a technique that uses extremely low temperatures to destroy abnormal tissue, has emerged as one of the most important advances. Originally demonstrated in 1961 with vacuum-insulated cryoprobes cooled by liquid nitrogen, cryoablation now treats conditions ranging from cancer to cardiac arrhythmias. Minimally invasive techniques—like catheter-based systems or those introduced transbronchially—allow access to internal organs without open surgery. Ultrasound and MRI guide the process in real time, improving both precision and safety.[1]

The destructive impact of freezing depends on five main factors: how quickly tissue is cooled, how cold it gets, how long it stays cold, how slowly it thaws, and how many freeze/thaw cycles are used.[2] Probes reach lethal temperatures below -40°C, with an ice ball margin of 3–5 mm. Modern systems employ either liquid nitrogen (LN_2) or Joule-Thomson (JT) cooling. LN_2-based probes can reach temperatures near -150°C, while JT systems – using argon or nitrous oxide – operate through high pressure gas expansion.[3] Each system has trade-offs: LN_2 requires vacuum insulated lines, while JT systems need gas cylinders and built-in heat exchangers.

Cryoablation is FDA-approved for the treatment of tumors in the lung, prostate, liver, kidney, breast and bone, and has applications in atrial fibrillation. Some catheters use inflatable balloons to isolate and freeze targeted areas inside the heart.

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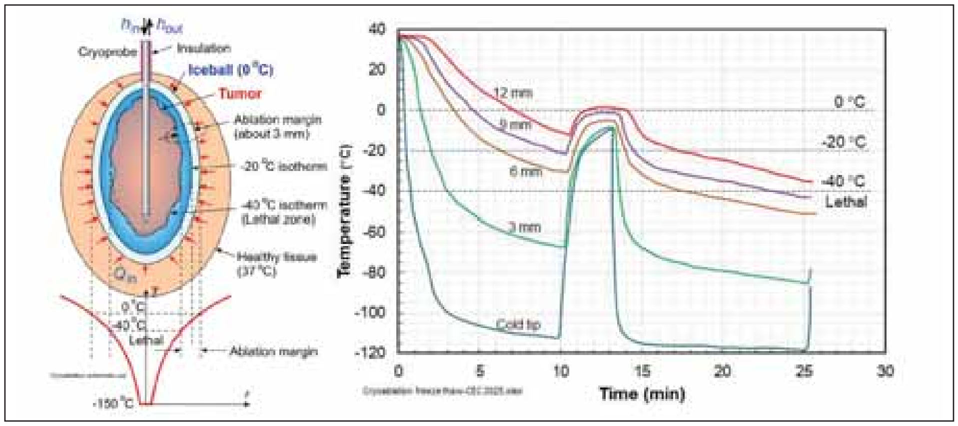

Figure 1. Left: Cryoablation isotherms showing tumor, ice ball, and margins. Right: Freeze/thaw cycle example. Credit: Quan-Sheng Shu, Ray Radebaugh, and Robert L. Fagaly

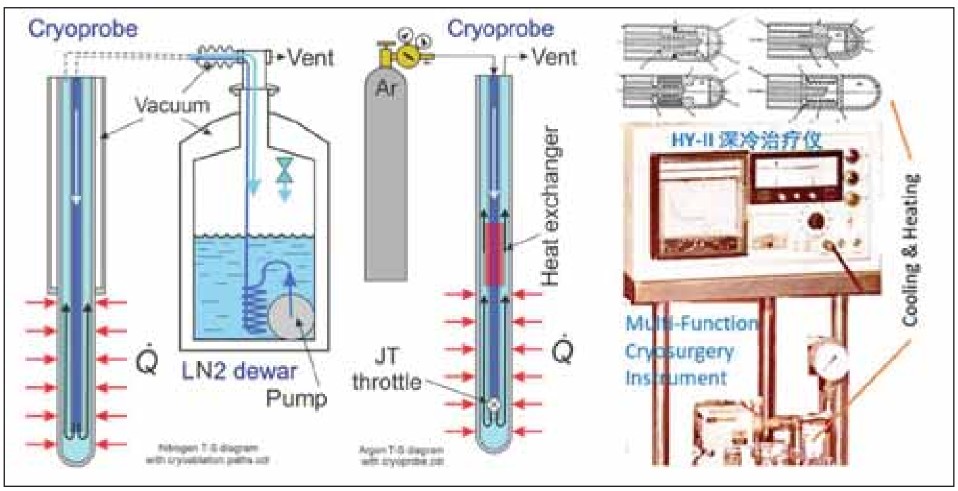

Figure 2. Left: Structure of LN_2 cryoprobe. Center: JT cryoprobe. Right: Multifunction cryosurgery instrument. Credit: Quan-Sheng Shu, Ray Radebaugh, and Robert L. Fagaly

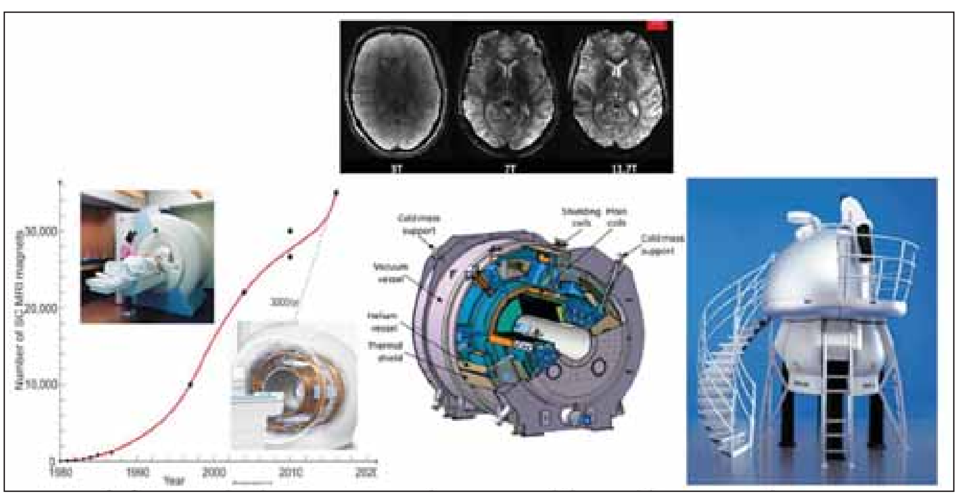

Figure 3. Left: Global superconducting MRI usage. Center: 11.7T whole-body MRI. Right: 900 MHz (21.1T) NMR. Credit: Quan-Sheng Shu, Ray Radebaugh, and Robert L. Fagaly

Cryopreservation, another cryogenic milestone, focuses on safely storing biological materials at low temperatures. To avoid lethal ice crystal formation, two strategies are used: slow cooling with cryoprotectants or rapid cooling (vitrification) at rates of 10,000°C/min in small volumes. Long-term storage below -130°C halts all biological activity, making this technique crucial for reproductive medicine, stem cell preservation and research.

MRI, based on nuclear magnetic resonance (NMR), has become the largest commercial application of superconductivity. A standard MRI machine uses superconducting NbTi magnets, first commercialized in the 1980s.[4–6] These systems provide detailed soft tissue imaging by measuring how hydrogen nuclei respond to magnetic fields. Higher magnetic field strengths (3T, 7T, and even 11.7T) improve resolution. Over 35,000 superconducting MRI systems are currently in use worldwide.

The push toward helium-free MRI systems began in 2018. These systems seal a small amount of helium inside the magnet during manufacture and rely on built-in cryocoolers, reducing helium use and operational costs. One notable example is the 11.7T whole-body MRI system reported by Boulant et al.[6] Low-field MRI systems using SQUID sensors are also being developed to operate at milli-tesla levels, reducing size and infrastructure needs. [7]

Beyond imaging, NMR spectroscopy is used for high-resolution analysis of biological macromolecules. High-field systems up to 28.2T can analyze proteins as large as 30,000 molecular weights, supporting research in cancer, Alzheimer's, Parkinson's and virology.

SQUIDs, or superconducting quantum interference devices, are the most sensitive magnetic sensors available. They detect signals from major organs, ranging from heart rhythms to brain activity, with sensitivity in the femtotesla range. Medical applications include magnetoencephalography (MEG), magnetocardiography (MCG), and liver iron concentration measurements. Coil-in-vacuum designs allow closer proximity to patients, improving resolution and reducing helium consumption. Advances in mechanical design, like adjustable tailpieces, help maintain sensor alignment despite thermal contraction.

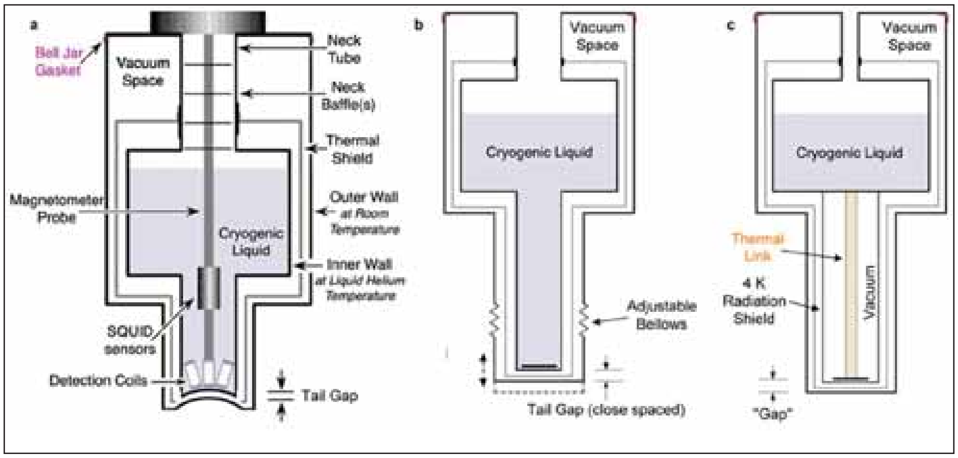

Figure 4. Dewar tail spacing methods for SQUID applications. Credit: Quan-Sheng Shu, Ray Radebaugh, and Robert L. Fagaly

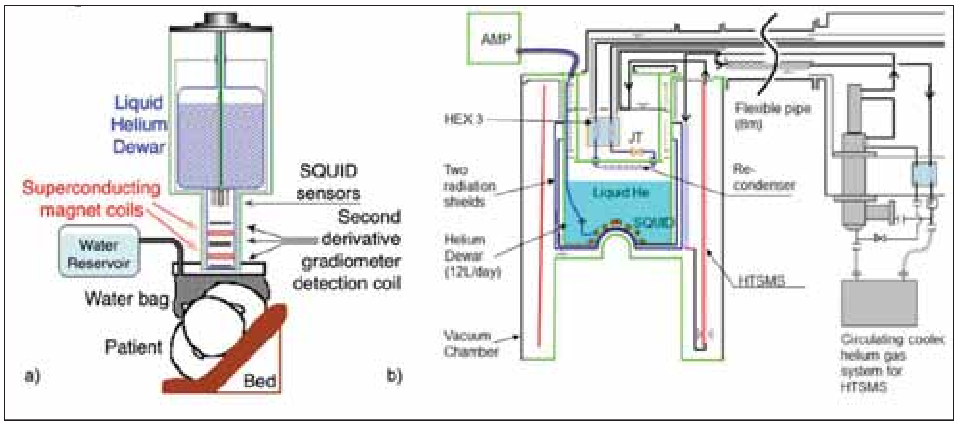

Figure 5. Left: Coil-in-vacuum system for SQUID-based liver analysis. Right: Zero boil-off MEG system. Credit: Quan-Sheng Shu, Ray Radebaugh, and Robert L. Fagaly

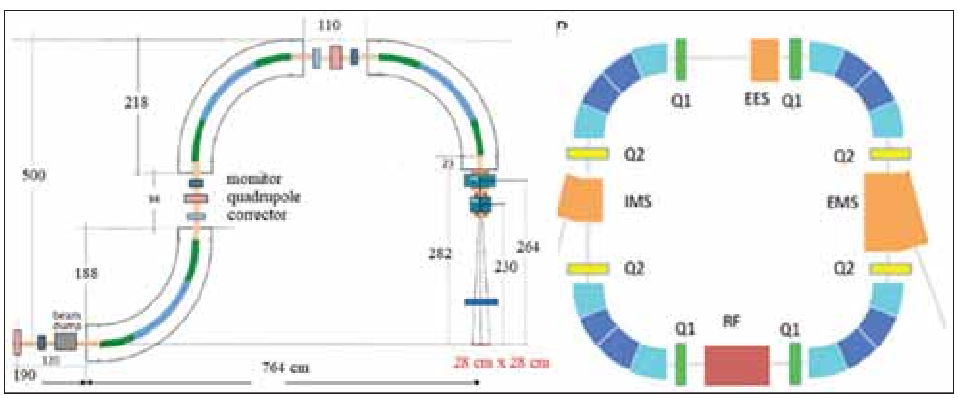

Figure 6. Left: Layout of 4-T gantry. Right: Synchrotron design. Credit: Quan-Sheng Shu, Ray Radebaugh, and Robert L. Fagaly

Innovative cryostat designs using coil-in-vacuum setups have reduced helium boiloff and enabled clinical adoption of SQUID-based devices. Figure 5 shows a setup measuring magnetic susceptibility in the liver and an MEG system using a recondensing unit for zero boiloff operation.[8, 9]

Superconductivity is also revolutionizing radiation therapy. In 2015, the world's first fully rotating superconducting gantry was installed at NIRS/HIMAC in Japan.[10] Using six combined-function magnets, it delivers carbon ion therapy with high precision.

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50 Years of Cryogenic Magnet Technology... Continued from page 14

Its ability to rotate 360° allows targeted delivery without moving the patient, enabling Intensity Modulated Particle Therapy (IMPT).

New compact gantry designs use canted cosine theta magnets, allowing smaller, lighter systems with optimized beam optics.[11] The Next Ion Medical Machine Study (NIMMS) at CERN is building on this with designs for curved superconducting magnets and synchrotrons using NbTi and high temperature superconductors.[12] These developments aim to bring down costs and size, making advanced ion therapy more accessible.

Cryogenics and superconductivity have reshaped biomedical science over the past 50 years. Their applications, from precise imaging and diagnostics to life-saving therapies, highlight the value of continued investment and collaboration in these technologies.[13]

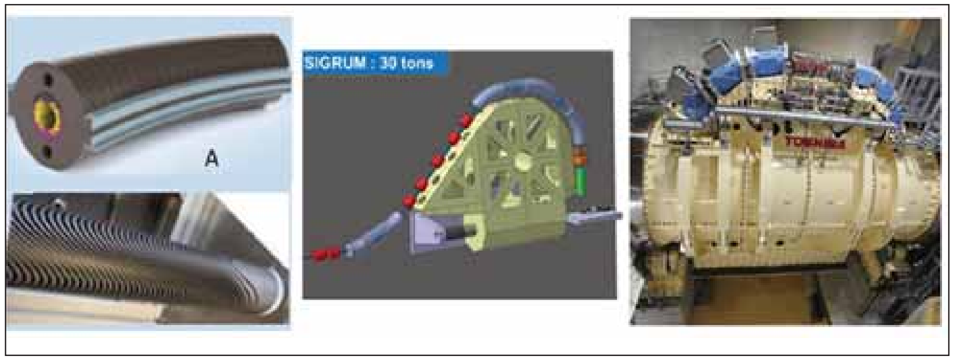

Figure 7. Left: Curved SC magnets. Center: NIMMS gantry. Right: SC gantry with 360° rotation. *Credit: Quan-Sheng Shu, Ray Radebaugh, and Robert L. Fagaly*

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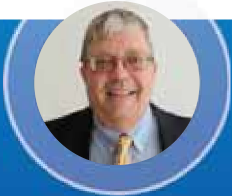


Cryo Bios

by Dr. John Weisend II, European Spallation Source ERIC, CSA Chairman, john.weisend@ess.eu, with Anne DiPaola, *Cold Facts* Editor

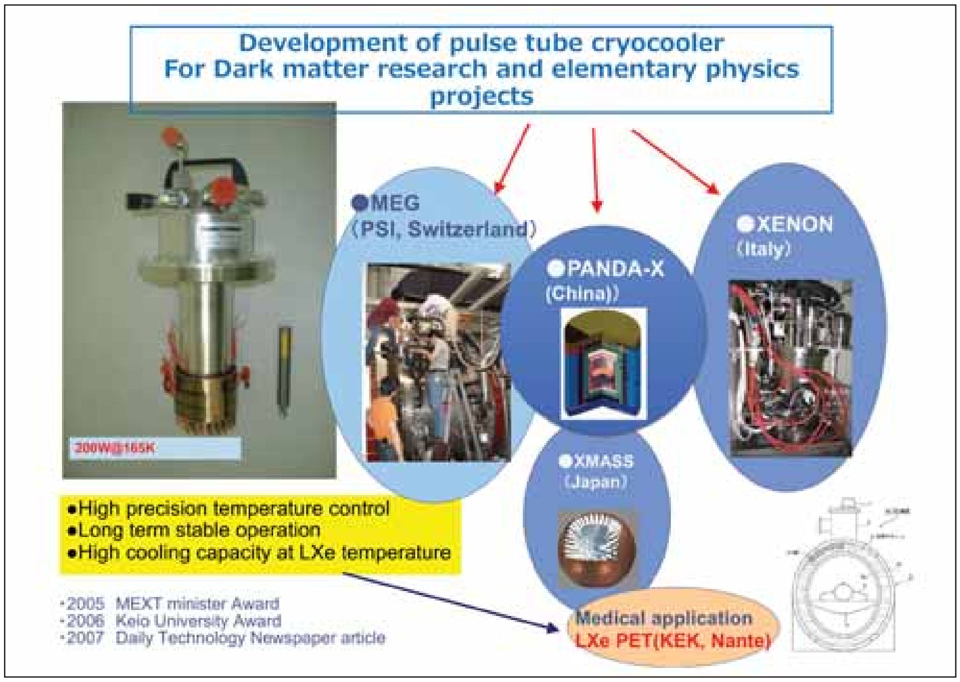
Tom Haruyama

Tom Haruyama's introduction to cryogenics came through routine lab work. As a university researcher, his first role was operating a helium liquefier, an aging ADL Collins piston type system, used to supply liquid helium for low temperature physics experiments. At the same time, he maintained a nitrogen liquefier powered by a Stirling cryocooler.

That hands-on foundation became the first step in what would become a decades long contribution to Japan's cryogenic development. After leaving the university lab, Haruyama joined the the Japanese High Energy Physics Laboratory (KEK), where he played a role in the TRISTAN particle accelerator project. There, he took charge of the cooling system for large superconducting magnets used in particle detectors. His work led to early research in helium two phase flow, aiming for stable operation of these powerful systems.

Haruyama's research focus gradually expanded beyond accelerator-based experiments. He became deeply involved in non-accelerator cryogenic projects that explored dark matter and rare muon decay. These areas aim to push beyond the boundaries of the Standard Model. Projects such as MEG and XMASS used large volumes of liquid xenon and carried scientific potential of the highest level.

Throughout his career, Haruyama has contributed to key advancements in cryogenic technology. He worked on the development of cryogenic particle detectors and sensors and advanced the use of superfluid helium for cooling superconducting magnets. His research on helium two phase flow supported the performance and reliability of large detector magnets used in high energy physics.



Xenon pulse tube cryocooler systems deployed globally for physics experiments including MEG in Switzerland, XMASS in Japan, Panda-X in China and XENON in Italy. Credit: Tom Haruyama

Diagram showing pulse tube cryocooler configuration for gravitational wave detection. Credit: Tom Haruyama

One of his most impactful areas of work has been liquid xenon cooling. Haruyama led the development of a pulse tube cryocooler tailored to maintain the extremely low temperatures required by xenon. He also published the world's first data on heat transfer characteristics in liquid xenon, laying the groundwork for high precision cooling techniques now used in dark matter detection and muon decay experiments.

His involvement extended to gravitational wave detection, particularly the KAGRA and CLIO projects in Japan. He helped design a low vibration cooling system using pulse tube cryocoolers and flexible wire bundles, which successfully reduced vibration levels from microns to nanometers. This improvement was crucial for mirror cooling in laser interferometers.

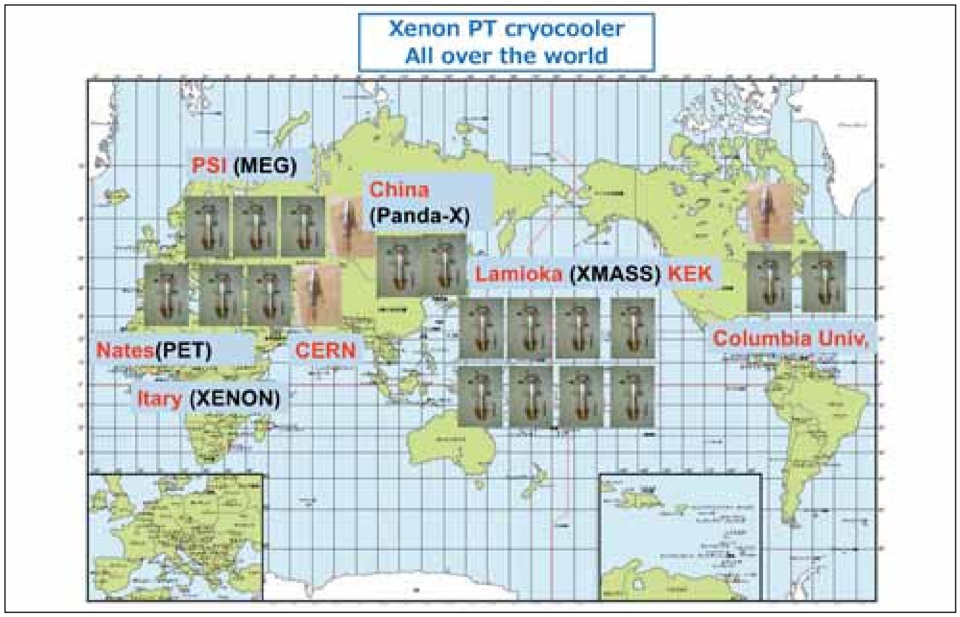
Haruyama also developed miniature sensors suited for cryogenic environments, including pressure sensors that function in helium II and temperature sensors small enough to operate effectively at cryogenic temperatures. These innovations provided researchers with real time pressure and temperature data during critical events such as magnet quenches.

His work has been central to enabling the global adoption of liquid xenon as a detection medium. Once considered impractical due to temperature challenges and xenon's physical properties, large scale xenon-based detectors are now core components of experiments such as MEG in Switzerland, XENON in Italy, XMASS in Japan and Panda-X in China. The ability to reliably cool and manage tons of xenon opened the door to a new generation of physics experiments seeking to discover phenomena beyond the Standard Model.

In the field of cryogenics, Haruyama has seen significant changes, particularly the rise of cryocoolers that simplify access to low temperatures without requiring cryogens. While this represents a practical advance, he notes that it has also led to a decline in hands-on cryogen handling experience among younger researchers.

He sees continued room for performance improvements in cryocoolers across all temperature ranges. He believes that a focused push for greater efficiency could bring further improvements in the coming years.

On the education front, Haruyama acknowledges a shift in focus. Fewer students are drawn to pure cryogenic engineering, tending instead toward superconductivity or applied physics. He sees cryocoolers as one area where cryogenic research can remain a standalone and worthwhile pursuit.



Miniature sensors developed for cryogenic use, including pressure sensors functioning at helium II temperatures. Credit: Tom Haruyama

Illustration by Tom Haruyama featured in CERN Courier. Credit: CERN Courier / Tom Haruyama

Haruyama has been deeply involved in the professional cryogenics community. He has served as chairperson and secretary of the International Cryogenic Engineering Committee and held long-term leadership roles with the Cryogenic Society of Japan. He has worked closely with members of the Cryogenic Society of America, including former president Joel Furst and longtime executive director Laurie Huget, helping to foster international collaboration through conferences and exchanges.

With over 100 peer reviewed papers and numerous conference presentations, Haruyama's influence spans both academic research and global project implementation. He also believes in the value of collaboration between physicists and cryogenic engineers. In his experience, physicists often do not fully understand cryogenic needs, while engineers may lack awareness of experimental requirements. He sees this gap as an opportunity to create new interdisciplinary research paths.

Aside from his scientific achievements, Haruyama is known for his illustrative work.

▶ *continues on page 21*

Cool Fuel

by Dr. Jacob Leachman, Professor, Washington State University, jacob.leachman@wsu.edu

It's Time for Liquid Hydrogen to Cowboy Up with Agriculture

Liquid hydrogen, produced and used on-site via innovative cooling and refueling technologies, could enable energy-independent, fuel-cost-stable farms by replacing imported fuels and fertilizers with locally generated clean energy. Credit: Andrew Botterbusch/Peak Visuals

It's harvest time here on the Palouse, and as I watch mastodon-esque combines rumble over the hills of wheat stretching as far as I can see, I am imagining a different future for the hydrogen economy. A future where we don't have to pay to construct a network of refueling stations or clean heavy-duty vehicles, and we don't need centralized hydrogen production or distribution systems. Let's take a ride through the energy-independent farm of the future, courtesy of liquid hydrogen.

Our guides on this tour are Kyle Appel and Matthew Shenton, both HYPER lab members who grew up on farms and ranches here in the Pacific Northwest (PNW). The typical family farm on the Palouse ranges from one to three thousand acres with one to three combines, one to three tractors, one to three utility trucks, one to three family members trained in engineering and one to three insurance policies covering a range of factors most of us should be thankful we avoid. Most importantly, farmers and ranchers reap what they sow – hence, they value free markets and the ability to forecast costs. Their two largest concerns are the prices of fuel and fertilizer, nearly all of which is imported into the PNW because we ran out of fossil hydrogens back in the 1960s. As a result, farmers must settle on the price they are offered for energy imports, make food from the imports and then settle again on the commodity price offered for those food products. Any farmer I know would jump at the opportunity to take more control over their energy costs: energy independence is freedom.

Kyle and Matthew understand hydrogen is key to energy independence on a farm. Small renewable energy installations allow local production of hydrogen via electrolysis. Unlike electricity going on the power grid, generating hydrogen on-site has immediate local benefits as the price of fuel increases the farther it is transported. In addition to readily available fuel, having hydrogen on-site is the first key to producing ammonia fertilizer, which is now possible on-farm due to smaller-scale systems in production from several companies. Approximately 6 acres of solar could generate enough hydrogen over the course of 4 months to produce 4,300 kg of liquid hydrogen, about what it would take to fuel a PNW farm's combines through the month-long harvest. Matthew's thermoacoustic hydrogen cooling and liquefaction research shows the potential to scale down hydrogen coolers in size while maintaining relatively high efficiencies. Such a small-scale cooler allows liquid hydrogen tanks to become liquefiers, improving transfer performance while eliminating boiloff losses. With every hydrogen tanker integrated with a liquefier/cooler, each farm could park a fuel tanker for filling throughout the year so it's ready for the sprint at harvest. Equipment could be fueled with the tanker parked, or the tanker could be driven to the equipment in a field. However, significant changes to technology and codes are required for an off-road liquid hydrogen transfer.

Current National Fire Protection Association (NFPA) hydrogen codes require liquid transfers to occur over non-flammable pavements, with significant personal protective equipment (PPE) in case liquid air and concentrated oxygen were to drip onto combustible materials (just imagine wheat straw). However, installing expensive concrete pads in fields is a non-starter for most farmers, so Kyle patented and developed a deployable fire-barrier blanket with liquid oxygen droplet prevention for uneven terrain. Transfer line purging and chill-in could be improved with a novel liquid hydrogen refueling coupler prototype developed by an undergraduate team with Reagan Dodge at HYPER. The coupler is error-proofed for public use and acts like a combination of a quick-connect and a bayonet fitting. No rules seem to preclude liquid hydrogen transfers at off-road sites; there just has never been a use case to develop the enabling technologies.

Hydrogen-fueled heavy-duty vehicles are already in development; however, most anticipate this progress slowing down with the refueling station infrastructure delays. Pivoting to agriculture allows hydrogen integration efforts to be applied to the retrofitting of existing diesel engines for hydrogen fuel, the installation of advanced fuel-cell systems for novel electric farm equipment, or the continued progress of refueling technologies and standards. Earth compaction is a significant challenge on the farm that will all but preclude battery-electric vehicles from this market. Our estimates indicate that hydrogen fuel-cell farm equipment with liquid hydrogen tanks is comparable in mass to existing equipment. Fuel cell systems would dramatically reduce the risk of engine compartment fires, which are the primary cause of fires during harvest. Although liquid hydrogen tanks are becoming available for truck applications, costs need to drop significantly to be relevant for agricultural equipment.

Significant research and development is still needed to make the hydrogen-fueled farm a reality. However, I think it's time to give it a hard look as we're getting close to the point of technological maturation where a demonstration farm could yield significant findings. Towards this end, Kyle and Matthew recently started a company, CryoCowboys LLC, to commercialize liquid hydrogen technologies for immediate and effective use in the agricultural sector and demonstrate energy independence on their own family enterprises. .

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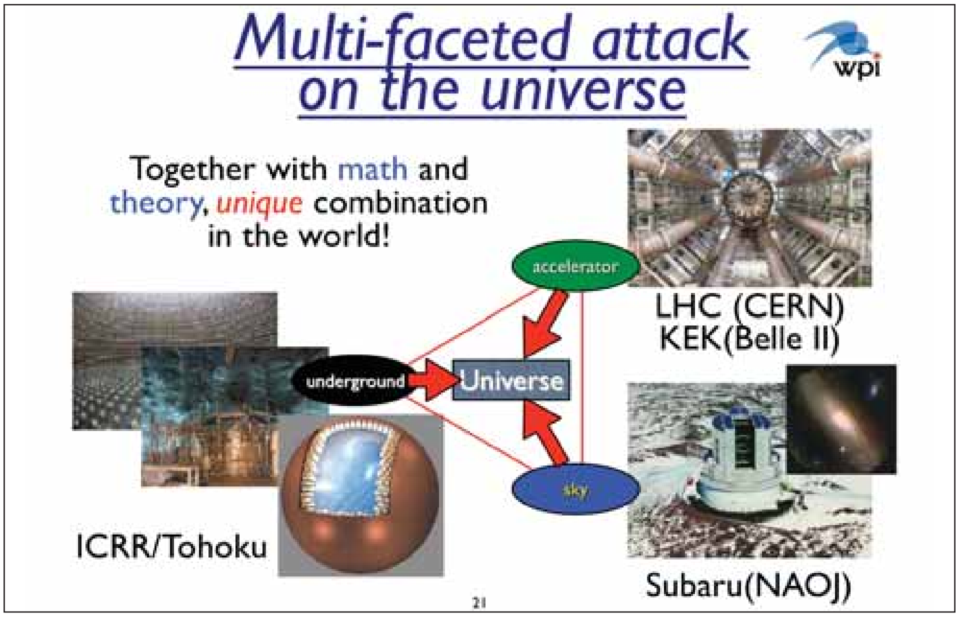
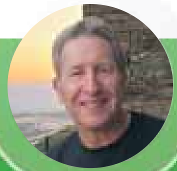
Years ago, he was profiled in CERN Courier as a cryogenics illustrator, recognized for his detailed drawings that communicate complex physics concepts through visual storytelling.

For 12 years, Tom Haruyama served as Deputy Director of Kavli IPMU at the University of Tokyo, a hub for integrated research in physics, mathematics and astronomy. His contributions continue to shape cryogenic science in Japan and internationally. Beyond his administrative roles, Haruyama is deeply involved in mentoring future scientists, fostering collaboration and promoting public engagement with complex ideas. His work balances rigorous experimentation with creative problem-solving, keeping Japan at the forefront of cryogenic and astrophysical research.



Subaru Telescope, LHC, Belle II and Kavli IPMU projects shown as part of Japan's approach to studying the universe. Credit: Kavli IPMU



Cryotreatment

by Jack Cahn, Chief Technologist, DCI, jack@deepcryogenics.com

Cryogenic Treatment Equipment

In previous columns, we explored the science behind cryogenic treatment (CT) and examined the current state of the industry. In this column, we'll take a look at who uses cryogenic treatment equipment and the types of chambers available.

CT equipment is used primarily by three groups:

1. Heat treat facilities
2. DCT service providers
3. Single industry users

Heat treaters commonly perform processes such as austenitizing and quenching, carburizing, and nitriding to improve mechanical strength and durability. Metal parts are typically processed in batches using racks or preload trays. For cryogenic treatment (CT) to be effectively integrated—aimed at reducing retained austenite and minimizing residual stress from heat treatment—it must allow for rapid, preferably automated, part transfer with minimal manual handling. Most heat treaters already use nitrogen gas as a shielding agent in ovens and maintain on-site supplies in vacuum jacketed liquid nitrogen (LN_2) dewars. As a result, the cost of implementing deep cryogenic treatment (DCT) is relatively low for these operations. Additionally, because LN_2 expands 700x when converting from liquid to gas at -320°F, it serves a dual purpose in many heat treat facilities.

Heat treaters often use rectangular "coffin-style" modified deep freezers for cryogenic treatment, tailored to fit their operational needs. They typically prefer to perform post-cryogenic tempering in their existing heat treat ovens. This approach provides redundancy in capacity while ensuring compliance with AMS 2750—a standard that governs the control, testing, quality and processing of heat-treated metal components in the aerospace industry. However, many cryogenic treatment chambers, including their electrical systems and manufactured components, do not meet UL/CSA safety certifications or the AMS pyrometry equipment standards. Currently, there are no industry-wide AMS- or SME-recognized quality standards or certification requirements specifically for cryogenic treatment.

Rectangular cryogenic treatment chamber. Credit: Jack Cahn

DCT service providers typically offer cryogenic treatment as a supplementary service rather than as part of a full heat treatment operation. They cater to individuals or organizations specifically seeking local cryogenic processing. Because post-DCT tempering is essential to completing the treatment cycle, and these providers often lack dedicated tempering ovens, they tend to favor DCT chambers capable of performing both cryogenic and tempering functions. This minimizes part handling and allows for unattended operation. Most service providers purchase bulk LN_2 on a per-cycle basis, making low LN_2 consumption crucial to maintaining competitive pricing. Due to limited material handling infrastructure, they also generally prefer manual loading of smaller parts.

Single-industry users are specialized manufacturers who have identified substantial performance gains from cryogenic treatment and use it to gain a competitive advantage. This group includes knife makers, brake rotor and gear manufacturers, machine shop tooling OEMs, firearms producers, motorsport engine builders and audiophiles. They typically invest in cryogenic chambers that accommodate dense loading of their specific part geometries, such as knife blanks, brake rotors or gun barrels, while prioritizing ease of use and operational efficiency.

The two most common designs of cryogenic treatment chambers are rectangular and round.

1. Rectangular machines

A variety of rectangular chamber options are available for shallow and deep cryogenic treatment, commonly used in motorsport, tool and die, machine shop, firearm and audio applications. Readers can find suppliers listed in the cryogenic treatment category of the CSA Online Buyer's Guide. These units are not designed to temper parts and require an additional tempering oven to complete the full DCT cycle.

DMP CryoSystems manufactures both square and rectangular chambers that can heat treat up to 1,200°F and perform DCT down to -300°F. Most machines monitor internal chamber temperature using one or more type T thermocouples. High-quality systems use a PLC connected to an onboard proportional-integral-derivative (PID) or fuzzy logic controller to adjust LN_2 flow in real time, compensating for minor temperature variations with precision.

Most rectangular cryogenic machines are insulated with polyurethane blocks or foam, operated via a PLC and powered by 110/220V single-phase electricity. They are engineered to deliver convective heat exchange at a controlled rate of up to 1.5°F per minute, cooling from ambient temperature down to approximately -300°F. These machines can accommodate payloads up to 2,500 pounds and are typically loaded manually with an automotive hoist or via an overhead gantry. Because heat treaters primarily use rectangular machines to reduce retained austenite in ferrous materials—a process that occurs above -120°F—this design allows for efficient LN_2 usage while achieving the desired goal.

Deep Cryogenics International specializes in manufacturing large, industrial-scale rectangular DCT chambers designed for heavy-duty applications in mining, road construction and energy sectors. These chambers are built to handle payloads ranging from 10,000 to 30,000 pounds, with a volumetric capacity of 8 feet by 8 feet by 20 feet. Parts are loaded via forklift onto fixed rollers, offering a setup comparable to the car bottom furnaces used by industrial heat treaters. Tempering is provided by propane or electric auxiliary heaters. The chambers are insulated with six layers of polyisocyanurate, separated by vapor barriers, and operate across a thermal range of -280°F to 250°F. They comply with CSA, UL, EU and OSHA standards, feature external nitrogen gas venting for safety and are third-party inspected and certified.

2. Round machines

Round CT chambers are truly in a class of their own. Their cylindrical shape allows for even distribution of pressure and compressive forces across all surfaces—since curved surfaces act like segments of

▶ *continues on page 24*

12,000-lb payload inside the Deep Cryogenics 36 K industrial DCT chamber. *Credit: Jack Cahn*

Forklift loading parts into the Deep Cryogenics 36 K industrial DCT chamber. Credit: University of Alberta

Cryotreatment... Continued from page 23

spheres—making them structurally very strong. The double-walled, vacuum-insulated units require no foam or urethane insulation. They are 10 to 25 times more effective at reducing heat transfer compared to non-vacuum insulated polyurethane machines, making them the most LN_2-efficient CT chamber design available.

Constructed from stainless steel, round chambers feature a hinged foam lid over the loading zone, which serves as the only thermal bridge. They offer in-situ tempering powered by a 220V electric heater, operate via a straightforward PLC/PID control system and come in three sizes. The upside of high-quality construction without insulation degradation is balanced by the need for material handling in the large size machine, which is simply too tall and deep to manually load without a support structure and gantry or preload cages. Applied Cryogenics Inc. is the only known manufacturer of round, vacuum-insulated chambers in the world, with sales, leasing and distribution handled by Deep Cryogenics International. Both the rectangular and round machines are mounted on wheels for easy mobility on the shop floor.

ACI round CT chambers (CP200 and CP1200). *Credit: Jack Cahn*

Limited awareness and adoption of cryogenic treatment remain the main barriers to equipment cost reduction and availability. Nearly all machines are handcrafted, with no economies of scale, resulting in delivery times ranging from 10 weeks to 6 months. Smaller DCT machines typically cost between $40,000 and $120,000, while industrial-scale units range from $620,000 to $740,000. Unlike heat treat ovens—which begin to degrade from heat exposure after their first use—cryogenic treatment chambers have a lifespan of 10 to 30 years, due to both their lack of moving parts and the absence of high temperatures that can damage insulation and compromise safety.

In our next column, we will explore the major challenge hindering widespread adoption of cryogenic treatment across industries: the lack of standardized testing, certification and acceptance protocols.

1,500 lb payload in the CP-1200. *Credit: Jack Cahn*

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Zero Resistance Zone

by Quan-Sheng Shu, cryospc.com, and Jonathan Demko, Le Tourneau University

Toward Optimal Cryogenic MLI System (II): Mapping Temperature Profile and Local Effective Thermal Conductivity

Multilayer insulation (MLI) systems are extensively used in cryogenic and superconducting applications across various fields such as physics, fusion energy, space and biomedicine due to their ability to minimize heat transfer under high vacuum conditions, typically below 1×10^{-5} torr (Figure 1). These systems employ multiple reflective shields to suppress thermal radiation, yet real-world applications often experience degraded thermal performance compared to ideal conditions. In practice, several factors remain uncertain, including the actual radiation behavior across complex multilayer structures, the geometry and contact characteristics of solid layers and the true vacuum level between layers during operation as extensively studied by Shu, James, Johnson and Demko et al.[1-4]

To gain deeper insight into these mechanisms, this column introduces the temperature distribution across MLI layers and the local effective thermal conductivity between the hot and cold boundaries (Th to Tc) through section to section. By analyzing the T-distribution and effective thermal conductivity and comparing it against predictions based on the four ideal heat transfer mechanisms, the findings will enhance understanding of MLI thermal behavior and mechanism in real applications, guide more accurate thermal modeling and support the design of efficient cryogenic insulation systems.

Heat Transfer in Ideal MLI Blanket

Key thermal transport processes in a MLI system are illustrated in Figure 2, including radiation, gas conduction, solid

Figure 1. James Webb Space Telescope being prepared for vacuum chamber test. Credit: NASA (CHM)

conduction and solid contact occurring between adjacent reflective layers.

Thermal radiative transfer: Thermal radiation is exchanged across the vacuum gaps between reflective surfaces. Each layer reflects infrared radiation back, with emissivity carefully controlled to reduce net radiative heat transfer. Engineering design often includes low emissivity coatings and optimization of layer spacing to limit view factors. Equation 1 quantifies the thermal radiation heat transfer through NMLI shields, reaching the cold surface per unit area. T1 is higher temperature (K), T2 is lower temperature (K), ε is surface emissivity, σ = 5.6703×10-8 (W/m^2K4) is the Stefan-Boltzmann constant and A is the area of the emitting body (m^2).

$$Q/A = q = \sigma(T_1^4 - T_2^4)/\left(\frac{1}{\varepsilon 1} + \frac{1}{\varepsilon 2} - (1+N)\,(2/\varepsilon s - 1)\right) \qquad (1)$$

Gas conduction: Gas conduction depends on pressure, composition and mean free path. The mean free path, λ, is defined as the average distance travelled by molecules between collisions. The distance between the two surfaces across which heat is transferred is denoted as d. The dimensionless Knudsen number, Kn = λ/d. For high vacuum, the mean free path is much larger than the distance (Kn≫1), which is called the free molecular flow regime. For coaxial cylinders, concentric spheres or parallel plane walls, Q can be calculated by equation 2,

$$Q1 = \alpha((\gamma + 1)/(\gamma - 1))\ \sqrt{(R / 8\pi)} * p / \sqrt{MT} * (T2 - T1) \quad (2)$$

The overall accommodation coefficient, α, depends on the accommodation coefficients for the inner surface (equation 3), α1 and the outer surface, α2, and the area of the inner surface A1 and the outer surface A2, and γ = Cp / Cv.

$$\alpha = (\alpha 1\ \alpha 2) / (\alpha 2 + \alpha 1(1 - \alpha 2)\ A1 / A2) \quad (3)$$

R is the universal gas constant, T1 is the inner surface temperature and T2 is the outer surface temperature. The molecular weight of the gas is M. The value of the pressure, p, corresponds to the temperature, T, at which a value would be measured.

Solid conduction and thermal contact conductance (TCC): Heat is conducted through the contact points of mechanical spacers – typically polymeric meshes or silk netting – not shown in the figure. These spacers maintain layer separation but introduce unavoidable solid conduction paths. To minimize this effect, materials with low thermal conductivity are selected and the contact area is kept minimal. Thermal conductivity integral, mean thermal conductivity and heat transferred Q are presented as equations 4-5.

$$\bar{k} = \int_{T_C}^{T_H} k(T)dT \,/ (T_H - T_C) \quad (4)$$

$$Q = (\bar{k}_t A(Th - Tc))/L \quad (5)$$

Thermal contact conductivity (TCC) is a measure of how well heat transfers across the interface between two solid surfaces in contact, which is the inverse of thermal contact resistance. TCC is a crucial parameter in an MLI blanket where efficient heat transfer is vital. It's caused by surface roughness and microscopic air gaps at the interface, hindering heat transfer. The formula for calculating TCR is R = ΔT / Q, where R or 1/hc is the thermal contact resistance (m^2K/W), ΔT is the temperature difference across the interface (K) and q is the heat flow rate per unit area (W/m^2) (found as equation 6). Ka and Kb are solid conductivity, A is contact area and thermal contact resistance is 1/hc.

$$Q = (T_1 - T_3) \,/\, [XA/(KaA + 1/(heA) + Xb/KbA)] \quad (6)$$

Heat Transfer in Applied MLI Blankets

In practice, MLI thermal behavior departs significantly from ideal models due to multiple uncontrolled factors. Layers are often misaligned or unevenly spaced, affecting radiative and conductive paths. Contact points between layers are numerous and irregularly distributed, complicating heat transfer modeling. Unknown and elevated internal vacuum levels introduce uncertainty in gas conduction and outgassing. Localized, unmeasurable contact pressures further impact thermal contact resistance. These non-idealities challenge accurate performance prediction and model validation, as illustrated in figure 3, making the design of effective insulation strategies under real-world mechanical and environmental conditions complex for engineers and researchers.

Experimental Investigation of Heat Transfer Mechanisms in Practical MLI Configuration

Beyond heat flux measurements, temperature distribution and local effective

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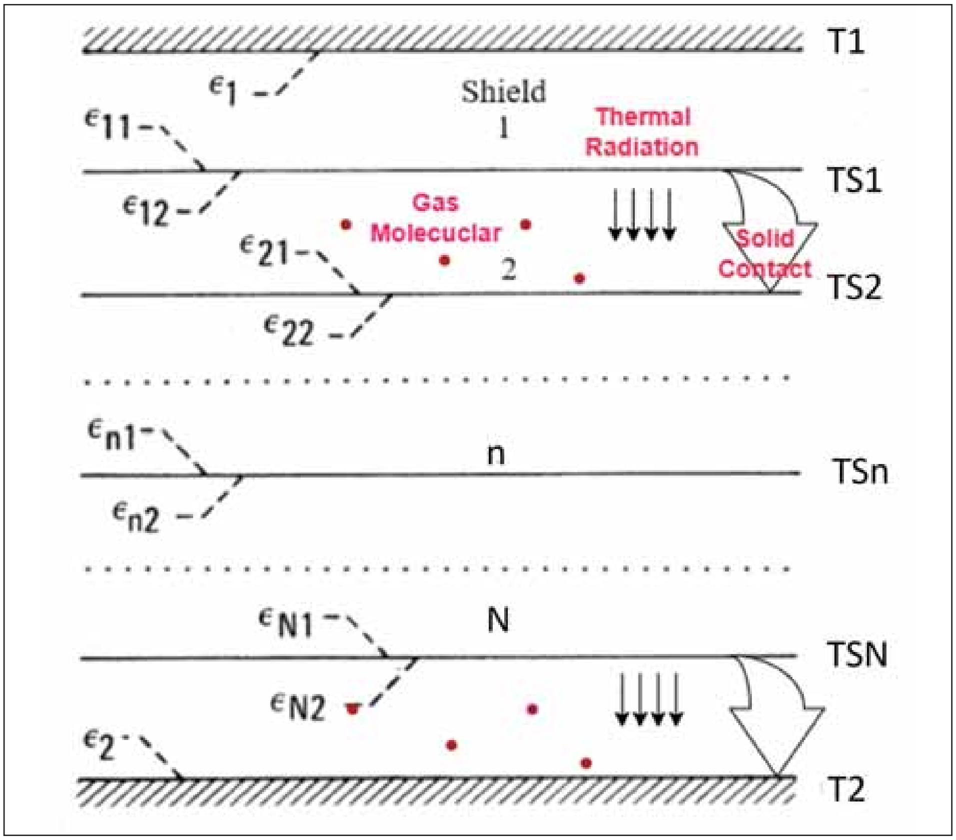

Figure 2. Heat transfer in a multilayer insulation system, illustrating heat transfer by radiation, gas conduction, solid conduction and solid contact between adjacent reflective layers (thin insulation spacers not shown). Credit: Shu and Demko

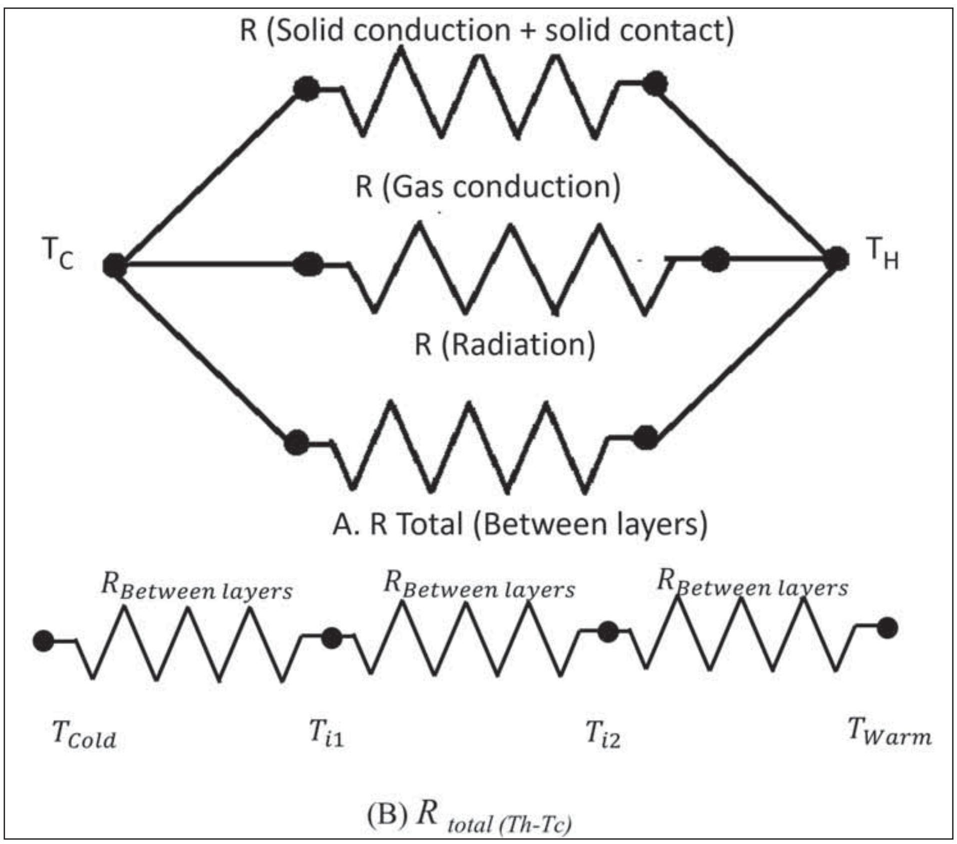

Figure 3. Thermal resistances: (A) three heat transfer mechanisms in parallel through adjacent reflective layers of multilayer superinsulation; (B) total heat resistance in series through the multilayer superinsulation. Credit: Shu and Demko

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thermal conductivity within MLI layers reveal key heat transfer mechanisms. These insights aid both theory and engineering practice—for example, diagnosing thermal integrity, equilibrium and internal vacuum states. In 14 experiments, fine thermocouples (∅0.07 mm Cu-Constantan or Au-Fe) were placed between every fifth layer from 300 K to 77 K (or 40–4 K), with leads wire-sunk to LN_2 temperature or ambient surfaces. After cryogen fill and 24 hours equilibration, heat load and temperatures were recorded across vacuum levels. Each step reached thermal equilibrium before data collection.[1, 5-7]

Temperature Profile in MLI Blankets: 30-, 60- and 90-Layer Cases

During testing, the cold plate was held at 77 K and the outer box at 277.2 K (±0.25 K variation). Under a vacuum of 1×10^{-5} torr, the boil-off heat flux for a 60–90-layer MLI blanket measured ~0.55 W/m². Temperature profile across the MLI blankets of 30-, 60- and 90-layer configurations reveal dominant radiative, gas conduction and solid conduction effects (figure 4). In the crack-free 90-layer setup, the stack was divided into three regions: 0–10 layers (N/ΔT = 0.15), 10–60 layers (0.48) and 60–90 layers (0.67), yielding K(outer) > K(intermediate) > K(inner). This highlights higher outer-layer heat transfer driven by radiation and gas conduction. Temperature profiles show the 2nd, 8th and 15th layers in the 30-, 60- and 90-layer systems each reach 158 K. These results reflect layered impact of solid conduction and contact pressure. More graphics and tables illustrating the thermal transfer mechanism are discussed in references.[5-6]

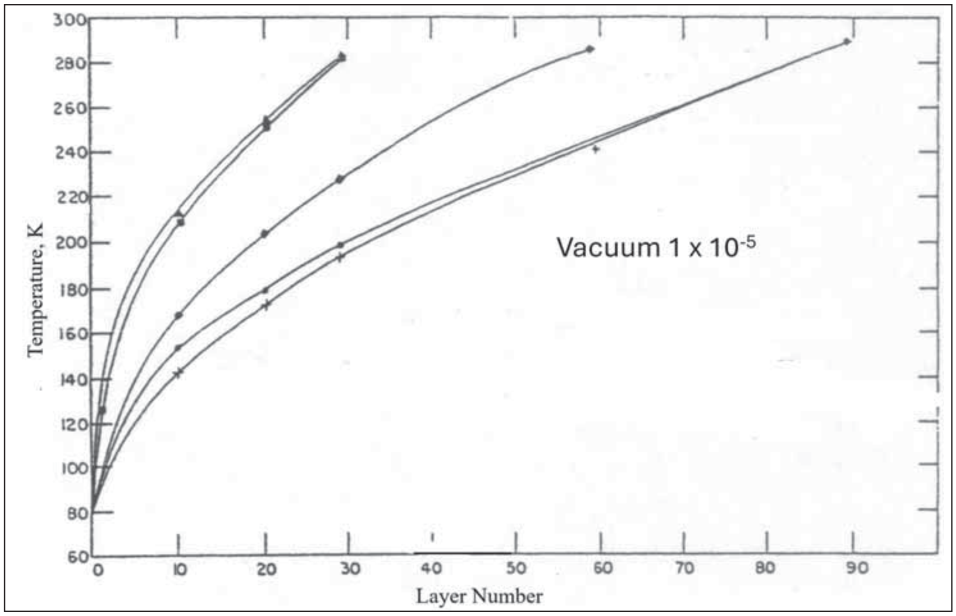

Figure 4. Temperature profiles across 30-, 60- and 90-layer multilayer insulation blankets at 1×10^{-5} torr, showing the effects of radiative, gas, solid conduction – solid contact. Credit: Shu and Demko [5]

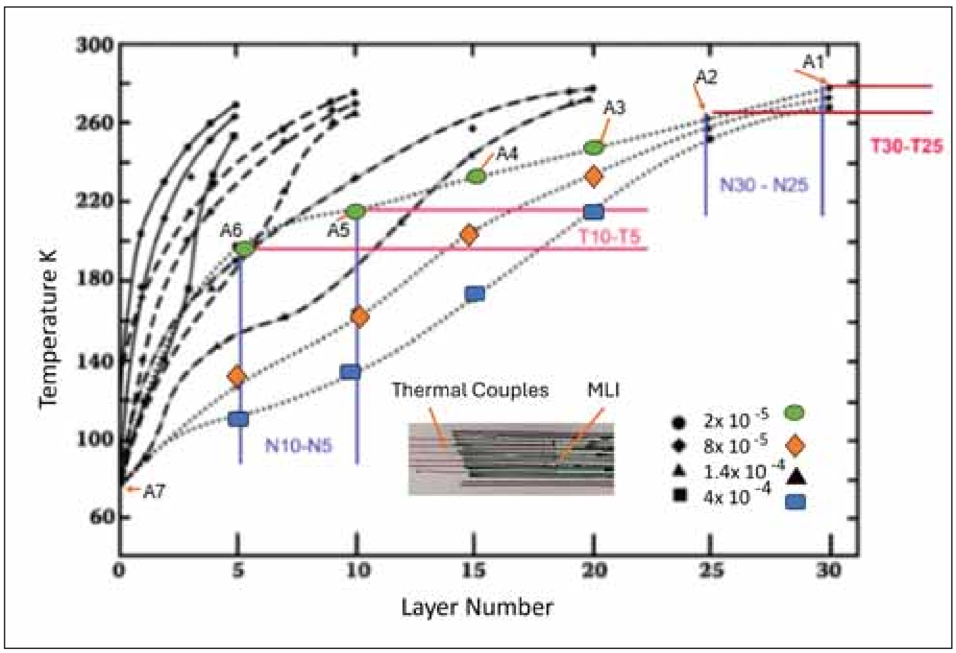

Figure 5. Temperature profiles of the multilayer insulation blanket at four distinct vacuum levels: ● = 2×10^{-5} torr; ◆ = 8×10^{-5} torr; ▲ = 1.4×10^{-4} torr; ■ = 4×10^{-4} torr. Credit: Shu and Demko [6]

Layer-Wise Temperature Response of MLI Blankets to Vacuum Variation

This study examines the thermal performance of MLI systems under varying vacuum conditions, using four blankets composed of 5, 10, 25 and 30 total layers. Temperature distributions, mapped against layer depth and vacuum pressure, reveal that intermediate layer temperatures decline significantly with worsening vacuum (figure 5). For example, in a 30-layer system, the first layer temperature dropped from 128.5 K at 1.5×10^{-5} Torr to 83.4 K at 9.5×10^{-4} Torr, while the fifteenth layer fell from 230 K to 175 K over the same pressure range. Heat flux measurements show that systems with fewer layers (e.g., 5–10) exhibit strong dependence on vacuum level due to pronounced gas conduction, whereas systems with more than 10 layers maintain nearly constant flux below 5×10^{-5} Torr. Above this threshold, flux increases sharply, approaching that of non-MLI conduction. Surface condition further affects thermal behavior; to maintain a heat flux below 0.5 W/m², approximately 60 layers are needed over a black-painted surface but only 30 layers over a taped surface, with observed flux ratios of black: polished: taped = 1: 0.56: 0.19. These findings underscore the importance of layer count, surface treatment and vacuum control in optimizing MLI performance for cryogenic applications.[6-8]

Local Effective Thermal Conductivity in MLI Systems: Calculation and Comparison

The effective thermal conductivity within an MLI blanket is not uniform—it varies with depth due to the combined effects of radiation, gas conduction and solid conduction. These temperature gradients mean that each region within the blanket exhibits a different level of thermal resistance. All of the effects influencing the temperature distribution in MLI blankets will cause the effective thermal conductivity to be a function of depth in the MLI blanket. The total effective thermal conductivity can be defined as:

Defining Kij as the effective thermal conductivity between the Ith and Jth layer

Heat transfer area (m²), D(N) is total layer density for N layer system (m^{-1}), Dij is layer density between layer i and layer j (m^{-1}), K(N) is effective thermal conductivity of N layer system ($W\ m^{-1}\ K^{-1}$), K'(N) = K(N) D(N) ($W\ m^{-2}\ K^{-1}$), Kij is effective thermal conductivity between layer i and j ($W\ m^{-1}\ K^{-1}$).

$$K(N) = \frac{Q(N)}{D(N)} \frac{N}{\Delta T(N)} \qquad (7)$$

In condition to thermal stability balance, the Qij = Q(N).

As simplifying, the Q(N) and Qij should be a constant value for each test case. Therefore, the local effective thermal conductivity Kij depends on the ΔTij (proportional reversely). This relationship offers a practical way to evaluate how insulation quality changes from one zone of the blanket to another. For instance, a smaller temperature drop between adjacent layers (smaller ΔTij) implies higher local conductivity – often due to increased gas conduction or contact pressure.

$$K_{ij} = \frac{Q_{ij}}{D_{ij} A} \frac{N_{ij}}{\Delta T_{ij}} \qquad (8)$$

Recommendations Inferred from Partial Experimental Data

MLI is often manufactured from thin plastic films metallized with aluminum, such as polyester or polyimide. Spacers made of netting or scrim are added to maintain separation between the radiation shields. It is generally accepted that MLI can reduce heat flux by more than two orders of magnitude under high vacuum, but for flight hardware or commercial systems, the exact performance is almost always unknown before system integration. Because the contribution from the vacuum shell is small in most MLI-insulated cryostats, the dominant heat leak is through the MLI. These systems typically operate at high vacuum, and conduction through residual gas is minimal. Similarly, conduction through MLI spacers and supports is minimal. In this case, the net heat leak through the MLI is primarily due to radiation.

There are empirical models of heat transfer through MLI, such as the Keller model, but they require fitting coefficients that are difficult to obtain without access to a cryostat. One way to approximate heat leak through MLI is to back out an effective emissivity or apparent ε from steady-state temperature measurements. The basic premise is that you can isolate the contribution from the MLI if the other heat transfer paths are known or negligible. If a radiative enclosure is instrumented with heaters and temperature sensors, one can set up a thermal balance on the inner wall to estimate how much heat is leaking out through the MLI to the outer shell. This leads to a reasonable estimate of heat flux and an effective ε. The estimate can then be used to model the effect of adding or removing layers.

Although effective ε or thermal conductivity k cannot be directly mapped to physical properties, such as number of layers or packing density, they are useful engineering approximations that can be used to optimize MLI design. These inferred quantities are only as good as the assumptions used in their calculation. They also average over the entire surface, so local variations such as seams, feedthroughs or penetrations are smeared out. Still, effective ε and k provide a practical approach to predict heat leak in geometries or configurations where more direct measurements are not available.

The inferred values of effective ε or k allow quick parametric modeling. This is especially helpful in early design when decisions must be made before all components are available for thermal testing.

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Clean Energy Future

by James E. Fesmire, President, Energy Evolution LLC, james@321energy.us

Making Liquid Hydrogen Flow Like Water Part 3 – Controlled Storage and Transfer

In Part 3, we address the most energy-efficient way to prevent losses and a practical means for making liquid hydrogen (LH_2) flow like water, on demand, as needed for the more sporadic on/off operations required for transportation industry applications from aviation to long-haul trucking, marine and shipping, warehousing and logistics, and the extreme energy demands of data centers and AI processing. Previously, in Part 2, we looked at the benefits and limitations of reliquefaction, and in Part 1 we examined the utilization of "boiloff" gas for electrical power or other uses.

From the ambient environment, there is a continuous heat flow into the liquid. With a refrigeration system employed, there is a heat lift out of the liquid. In the usual case, there is only heat flow in (with the corresponding pressure buildup), resulting in positive boiloff. If the heat flow in equals the heat lift out, there is zero boiloff. But if the heat flow into the liquid is less than the heat lift-out, there is negative boiloff. Negative boiloff is a good thing, providing utility to make LH_2 flow like water. The thermodynamic term for negative boiloff is called enthalpy margin, or the ability for the liquid to absorb heat. Liquid densification, or conditioning the liquid below its normal boiling point, is another example of enthalpy margin.

A liquid, even liquid hydrogen, will not boil if it can absorb heat. The heat-lift refrigeration system integral with the storage tank provides the capability for controlled storage and transfer of liquid hydrogen, making the LH_2 pathway practical and effective for end-use applications. Demonstrations of modern methods of refrigeration, storage, and transfer of liquid hydrogen are ongoing at the GenH2 Corp. facilities in Titusville, Florida, as shown in Figure 1. These facilities comprise a simulation test platform (STP) that includes the LS20 hydrogen liquefier with controlled (refrigerated) storage, a controlled transfer system for conditioned LH_2 operations, and the Cryostat CS900 for multipurpose real-world testing and simulation performance of mobile tanks, thermal insulation systems, instrumentation and sensors, and advanced components, materials, and devices (see Figure 2).

Figure 1. Simulation test platform including hydrogen liquefier and controlled (refrigerated) storage and transfer system for LH_2 operations. Credit: J. Fesmire, GenH2 Corp.

Just as SpaceX uses the enthalpy margin created by densification to load liquid oxygen and liquid methane quickly and safely onto its rockets right before liftoff, the liquid hydrogen operations of the STP include zero-loss transfer from the LS20 system to the CS900 system. Other operations of the STP include gas recovery and reliquefaction from the CS900 system back to the LS20 system. Future expansion plans to cover long-duration mobile tank testing include a hydrogen electric cell ("fuel cell") driven by a hydrogen vent stream to power a base load portion of the liquefaction process.

Conditioning the liquid with an enthalpy margin makes it possible to transfer that liquid with zero loss (not including initial cooldown loss). The greater the enthalpy margin, the more heat can be absorbed as the liquid moves from the supply tank to the receiving tank. For example, if LH_2 at 1 bara is pressurized to 8 bara, there is, at the start of the process, a 141 kJ/kg enthalpy margin to work with, as shown in Figure 3. This margin diminishes quickly, and the operation only works for that one instance. To

Figure 2. Hydrogen liquefier and controlled (refrigerated) LH_2 storage and transfer system, Liquefier LS20, left, and LH_2 simulation test platform, Cryostat CS900, right. Credit: J. Fesmire, GenH2 Corp.

start again, the storage tank must be vented back to 1 bara. This circa-1965 method of transfer is still the customary method today but is problematic due to excessive hydrogen gas losses and its inability to meet the newer requirements of sporadic duty cycles and much lower losses.

A modern methodology is required for putting LH_2 to work for the range of emerging end-use applications. Integral servicing system architectures for liquid and gas flow streams are needed for both safety and cost-effectiveness in the key drivers of loss mitigation and operational efficiency. Modern circa-2025 controlled storage and transfer systems, enabled by heat-lift refrigeration systems like the RS1500 of GenH2, provide quick and effective supply and servicing of vehicles and power units at their many points of use.

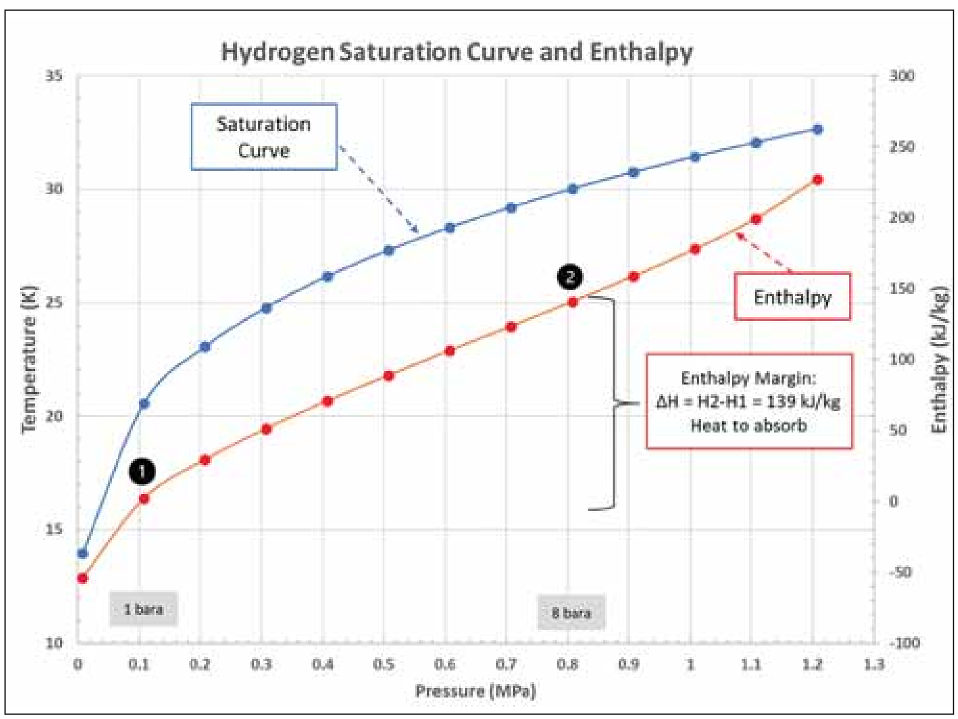

Figure 3. The hydrogen saturation curve and an example enthalpy margin needed for the effective transfer of liquid hydrogen with zero loss: a liquid will not boil if it can absorb heat. Credit: J. Fesmire, GenH2 Corp.

SPOTLIGHT ON A CORPORATE SUSTAINING MEMBER (CSA CSM): Fabrum

Fabrum Pioneers the Future of Clean Energy

by Fabrum Communications Team

In a world increasingly focused on the pathway to decarbonization, hydrogen and natural gas are critical components in the global transition towards clean fuels. The technology associated with this transition is a major catalyst for driving change and delivering the sustainability outcomes that are required to make this change a reality. The most efficient way to store these fuels is in liquid form at cryogenic temperatures. Fabrum's patented cryocooler technology is at the forefront of this sector, providing innovative solutions to establish and validate these clean fuel supply chains.

For 20 years, Fabrum's patented cryogenic technologies have been part of the global movement toward a clean energy transition. Distilled down to fundamentals, our technology has the ability to make gasses cold (through liquefaction systems) and keep that liquid cold (via super-insulated composite storage infrastructure).

Delivering solutions that support a zero-emission future, Fabrum leads the market in hydrogen liquefiers and boiloff-gas-management systems (reliquefiers). With a vision to leverage New Zealand's high-tech manufacturing capability and provide a pathway for emerging Kiwi talent, Fabrum continues to develop world-leading technologies that are adopted globally, enabling humanity to tread lightly and live sustainably.

Fabrum's patented pulse tube cryocooler. Credit: Olivia Ross

Liquefaction Systems

Fabrum's expertise in cryogenic systems lies in small-scale containerized hydrogen liquefiers. The current range includes daily liquid hydrogen capacity of 10 kg, 30 kg, 75 kg and 400 kg. In addition to producing liquid hydrogen, Fabrum's range of cryocooler-based products are also capable of producing liquid nitrogen, liquid oxygen and support cryogenic comingled gas separation. Our systems are modular by design, intended to be relocatable, scalable and easily integrated into diverse operational environments – from mining sites to academic institutions and everything in between.

Fabrum's expertise in liquefaction systems has resulted in patented solutions with highly desirable benefits, including rapid startup and turn-down, no requirement for liquid nitrogen precooling and built-in reliquefying capability (i.e. zero loss). Our systems are based on an industrialized high efficiency pulse tube cryocooler with a history spanning a decade of deployment into many different and challenging environments across the globe.

Beyond the technical strengths, Fabrum's cryocoolers and systems are well placed to be integrated into broader systems and end-user solutions. For example, our liquid hydrogen boiloff-gas-management solutions can be retrofitted into existing liquid hydrogen refuelling stations (HRS), whilst our PTCs can be integrated into electrolyzer technology or vertically integrated liquid production infrastructure. Fabrum's hydrogen liquefiers have multisector use cases and have been adopted globally across industries including aerospace, mining, heavy transport, marine and research, demonstrating their versatility and reliability in demanding environments.

Boiloff-Gas Management

Fabrum's expertise in liquefiers became a catalyst for the development of its boiloff-gas-management systems, addressing the widely acknowledged challenge of storing and handling liquid hydrogen. Effective boiloff-gas management (BOGM) is a critical aspect of the liquid hydrogen supply chain. Uncontrolled boiloff gas leads to product loss and increases operational costs, as evaporated hydrogen must either be vented, re-liquefied, or compressed for reuse. Vented hydrogen also has an environmental impact as it is recognized as a greenhouse gas.

Efficient boiloff-gas-management systems not only ensure the safe containment of hydrogen but also enhance economic viability and environmental sustainability by minimizing waste and optimizing energy use. Fabrum's hydrogen reliquefier includes pressure management systems for optimized liquid transfer and storage and is retrofittable to existing infrastructure, eliminating boiloff losses and extending asset life.

Fabrum's technology can also be adopted for liquid natural gas (LNG)-based applications, reinforcing its role in supporting clean energy solutions across multiple fuel types. Being retrofittable to LNG stations provides genuine versatility in ensuring the elimination of harmful gaseous emissions.

Fabrum's boiloff-gas-management systems are retrofittable to existing liquid hydrogen storage tanks, as well as being incorporated into new-build fuel station infrastructure. All our systems are containerized or can be built on transportable skids, providing the ability to redeploy. By capturing valuable boiloff gases, it not only delivers a proven return on investment but also contributes significantly to global sustainability efforts.

Case Study: First Hydrogen Liquefier at a Mine Site

One of the world's largest iron ore producers, Fortescue, developed and deployed a liquid hydrogen production and refuelling facility at its Green Energy Hub in the Pilbara region of Western Australia, to support the testing of prototype hydrogen-powered mining equipment. To deliver the project, Fortescue partnered with Fabrum to design, manufacture and commission a containerized 400-kilogram-per-day liquid hydrogen plant, along with mobile-refuelling infrastructure and onboard storage systems. It is currently the largest liquid hydrogen plant operating on a mine site in Australia.

The facility enables on-site production, storage and dispensing of liquid hydrogen to power prototype heavy mining equipment, supporting the use of hydrogen as a viable, zero emissions alternative to diesel.

Insights from the project are helping inform Fortescue's broader goal to decarbonize its Pilbara iron ore operations by 2030.

With the combination of kiwi ingenuity and the vision to help humanity tread lightly, Fabrum is continuing to push boundaries and technology capabilities all around the world. **https://fabrum.nz**

Fortescue's liquid hydrogen plant at their Green Energy Hub in Western Australia. Credit: Fortescue

Fabrum's boiloff-gas-management system successfully completed testing. Credit: Olivia Ross

A closer look into Fabrum's 400-kg/day hydrogen liquefier. Credit: Olivia Ross

Lake Shore Reduces Helium Costs to Maximize Research Efficiency

By Rachael Floyd, Director of Product Management for Cryogenic Systems, Lake Shore Cryotronics

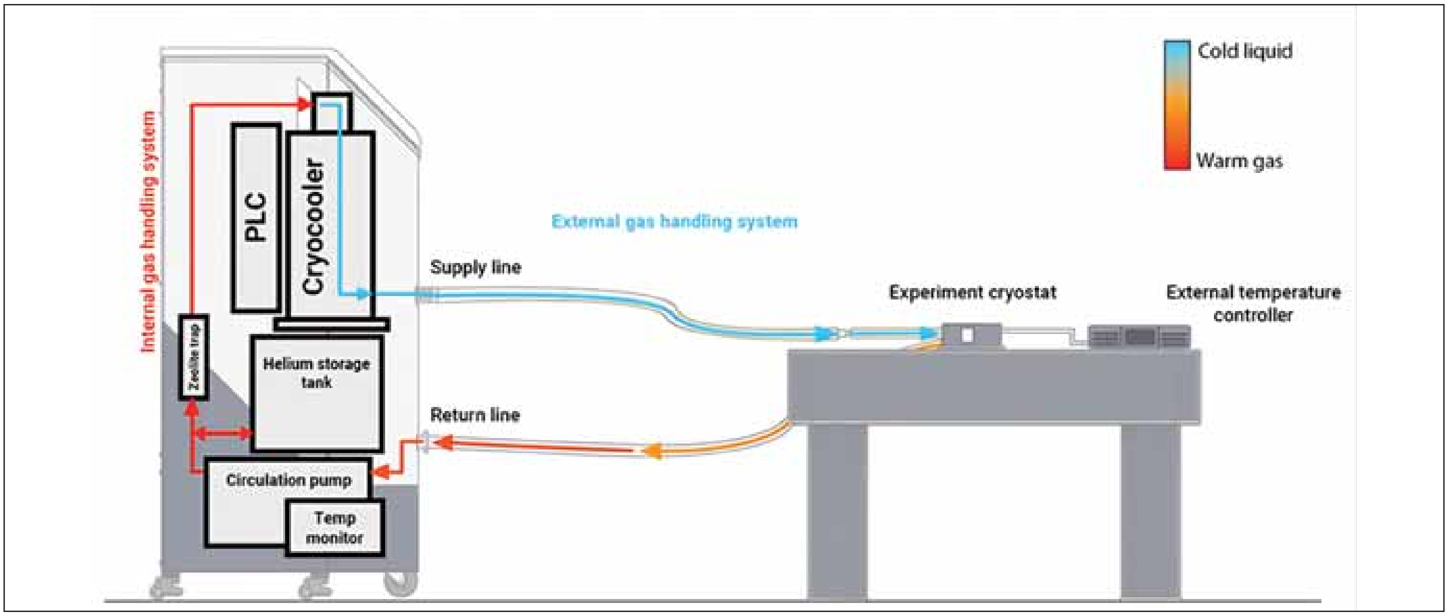

Figure 2: Infinite Helium flow path and heat diagram. Credit: Lake Shore Cryotronics

At a time when the price of helium is rising and funding is tightening, laboratory managers should investigate ways to minimize helium consumption.

The Rising Price of Helium

Helium is a nonrenewable resource that is increasingly difficult to obtain reliably. Once released into the atmosphere, it is irretrievable. Limited availability and few sources of production are driving helium prices upward. Add in growing demand for helium in semiconductor manufacturing, magnetic resonance imaging, data storage and low temperature research, and the result is clear: helium prices have doubled since 2021.[1]

Currently, prices for liquid helium range from $30/liter for large quantity purchases to $60/liter for small quantity purchases. Consider an example of a cryostat that requires 1 liter to cool down to base temperature and 1 liter per hour to maintain it. If the cryostat is used for six hours a day, four days a week, the weekly cost for research using the best available helium pricing is:

$30/L × (1 L + 1 L/hr × 6 hr/day) × 4 days/week = $840/week

For a month, that adds up to $3,360—a painful fixed cost. If the price per liter is $60, the monthly cost doubles to $6,720.

Options for Reducing Helium Consumption

Fortunately, there are strategies to manage helium expenditures. One option is a helium reclamation system, which captures and recycles used helium gas. However, these systems typically come with significant capital and infrastructure costs. For smaller labs, startups and teaching institutions, reclamation systems are often out of reach.

A second option is a closed-cycle refrigerator cryostat. The cold head is connected to the cryostat to form an integrated assembly. Unlike continuous flow cryostats, these do not require helium during operation. Disadvantages include higher initial cost, increased vibration due to the cold head being directly coupled to the cryostat, challenges in achieving ultrahigh vacuum, and a larger, heavier assembly that is less maneuverable.

A third option is a system that uses recirculating gas cooling technology, allowing researchers to operate a continuous flow cryostat as a closed-loop system. Rather than consuming and venting helium, a recirculating gas system uses a fixed amount of helium circulated through a closed loop, cooling the sample chamber without helium loss. One example is the Infinite Helium recirculating gas cooler from Lake Shore Cryotronics (see Figure 1).

How a Recirculating Gas Cooling System Works

Figure 2 shows a system using the Infinite Helium recirculating gas cooler. In this setup, a continuous flow cryostat on an optical table receives liquid helium from a cryocooler. A flexible, vacuum-insulated transfer line connects the cryocooler to the cryostat. Helium cools the cryostat and then evaporates. A circulation pump draws the warmed gas back into the system through a return line and feeds it into the cryocooler. The cryocooler reliquefies the gas and returns it to the cryostat, completing the loop.

When idle, the system compresses and stores helium gas in a holding tank. The Infinite Helium system incorporates programmable logic controller (PLC) technology for automated operation.

Research Efficiently, Safely and Cost-Effectively with Infinite Helium

In addition to significant helium cost savings, the Infinite Helium system offers numerous benefits:

- Automated operation – No more time wasted manually adjusting valves. Infinite Helium determines optimal settings for cooldown and base temperature maintenance.
- Greater setup flexibility – The cryostat can be oriented in any position to accommodate detection and measurement equipment.
- Compatibility with existing cryostats – The system works with many current continuous flow cryostats, reducing the need for new hardware or experimental redesign.
- Low vibration – Vibration isolation and physical distance from the cryostat allow sensitive research like microscopy to proceed undisturbed.
- Long-term continuous operation – The system can run for up to six months, enabling uninterrupted experimentation and eliminating mid-project maintenance.
- Enhanced thermal stability – Through controlled cooldown cycles, temperature setpoints and gas flow management, the system ensures a stable experimental environment with minimal thermal drift.
- Multi-lab utility – Designed with mobility in mind, Infinite Helium can be shared across labs, increasing ROI and supporting collaborative research.
- Enhanced safety – Built-in monitoring prevents fault conditions and reduces operator error that could cause downtime or equipment damage.
- Ease of use – Minimal training is required. For example, initiating cooldown is as simple as pressing one button on the touchscreen panel.

Figure 1: Infinite Helium. Credit: Lake Shore Cryotronics

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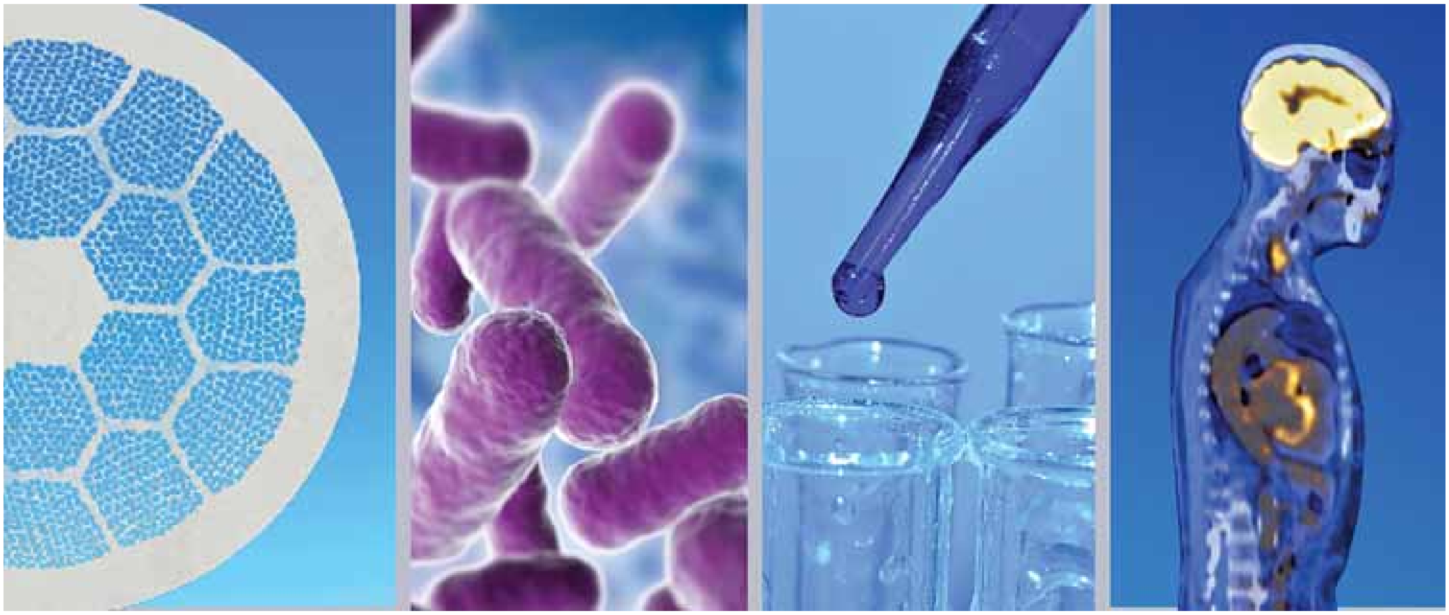
MagLab Is Building Better Magnets for Biomedical Breakthroughs

by Dr. Ulf Trociewitz, National High Magnetic Field Laboratory

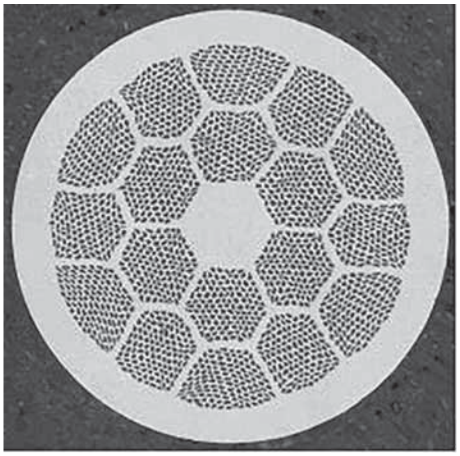


MagLab engineers will develop a new superconducting magnet for high-field nuclear magnetic resonance research. Credit: National High Magnetic Field Laboratory

The National High Magnetic Field Laboratory is developing new magnet technology aimed at enabling the next generation of groundbreaking biomedical research. With a new $2.4 million grant from the National Institutes of Health, the lab's Applied Superconductivity Center will demonstrate that a cutting-edge high temperature superconducting material can be used to build a nuclear magnetic resonance, or NMR, magnet.

NMR is the technology behind magnetic resonance imaging, or MRI, which uses strong magnets to see inside the human body. At much higher magnetic fields, the technique can be used to closely examine biological processes, including the structure, dynamics and interactions of proteins. Higher-field NMR is opening new frontiers in biomedical research and helping scientists develop new ways to treat disease.

The new NIH grant aims to demonstrate a powerful NMR magnet that could become the basis for more commercially viable systems available outside large national research labs, expanding high-field NMR research.



A cross-section of Bismuth-2212 superconducting wire. The dark dots are the filaments that carry current with zero resistance. Credit: MagLab

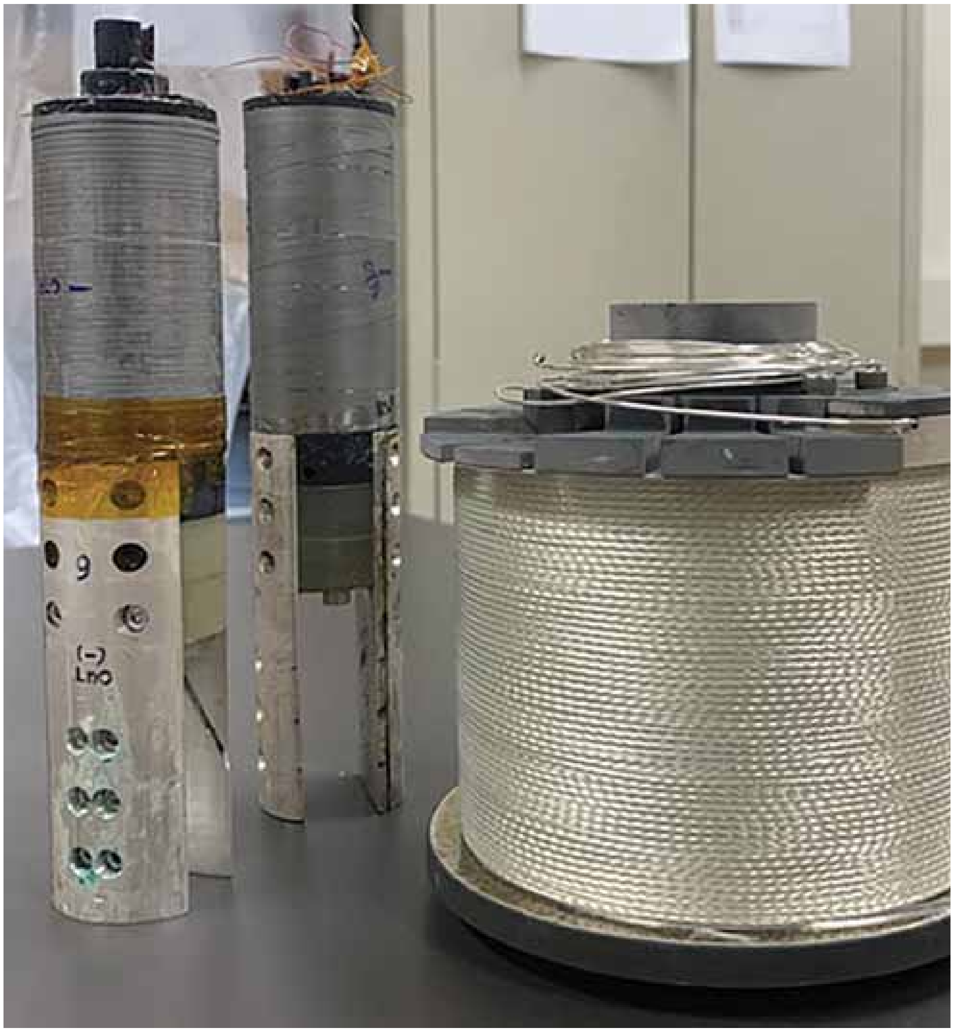
The heart of the new magnet will use a high temperature superconducting wire known as Bismuth-2212, or Bi-2212. First discovered in 1988, Bi-2212 can carry electricity with near-zero resistance at temperatures below minus 307 degrees Fahrenheit. It has become one of the most popular conductors for high-field magnet technology because it can be made in lengths of more than a kilometer and consistently carries very high currents. Several kilometers of wire with high current density must be tightly wound into coils to create a powerful electromagnet.

In this project, several of those coils will be stacked together and nested inside a low temperature superconducting magnet made by Oxford Instruments. This will allow the combined magnets to reach fields of up to 30 tesla, much more powerful than a standard hospital MRI at 1.5 tesla.

The work will tap into the "broad expertise of NHMFL scientists and engineers in building high field magnets and magnetic resonance equipment for biological and biomedical applications," according to Dr. Ulf Trociewitz, the principal investigator on the project.

"It will also involve students and postdocs as a commitment to educating and training the next generation of magnet researchers," Trociewitz said.

One big challenge will be ensuring the mechanical strength of the magnet, which must be able to endure enormous forces



Two high-field magnet test coils (left) made of Bismuth-2212 alongside a spool of the superconducting wire. Credit: MagLab

pulling on it during operation. Another hurdle will be achieving the very high homogeneity, or stability, needed for NMR operation. While Bi-2212 shows great promise of producing a uniform field, there is still a lot to learn from coils wound with it, Trociewitz says.

The MagLab has long spearheaded high-field magnet development, including for MRI and NMR. The lab's 21 tesla (900 MHz) all-superconducting magnet has been the world's strongest MRI system since 2004. The lab also built a 36 tesla magnet that has provided a world-record field for NMR since 2017. The 36 tesla system, however, combines a superconducting magnet and a power-hungry resistive magnet, which requires the MagLab's unique infrastructure to operate.

A commercially viable high-field NMR magnet would need to achieve its high fields without the massive power infrastructures available exclusively at national research labs. The ASC is partnering with magnet industry leaders like Cryomagnetics and Oxford Instruments to advance these goals as well. There is a strong desire for high-field systems at various locations across the United States.

"That makes this R and D work very timely," Trociewitz says. **https://nationalmaglab.org**

Who's New in the **Cold Facts Buyer's Guide?**

The Cold Facts Buyer's Guide is the place to find suppliers in every area of cryogenics and superconductivity. These are our new Corporate Sustaining Members and suppliers added to the Buyer's Guide since the last issue of the magazine. Find it online at *csabg.org*.

*Celeroton AG

Manufacturer of oil-free, vibration-free cold and warm gas compressors and turboexpanders designed to perform at cryogenic temperatures. Its proprietary technology uses process gas itself as a lubricant, ensuring no contamination of the cryogenic environment.

ConScience AB

Experts in nanofabrication, microfabrication and cleanroom work, ConScience designs and fabricates micro- and nanostructures for academia and industry. Streamlined processes and expert customization allow for cost-effective, high-quality solutions.

CryoR

A research-driven cryogenic engineering company based in Israel, serving clients worldwide with advanced thermal management solutions and specializing in the design and development of compact, high-reliability cryocoolers tailored to clients' specific requirements.

Hesse Mechatronics

Hesse Mechatronics is a wire bonder manufacturer. The company also makes ultrasonic welders and laser welders. Hesse Customer Solutions is the division that provides wire bonding services for companies.

OPW Clean Energy Solutions

OPW Clean Energy Solutions unites Acme Cryogenics, CPC-Cryolab, Demaco, RegO® Products and SPS Cryogenics BV to deliver global cryogenic solutions: valves, piping, fueling systems and flow control for hydrogen, helium, LNG and other industrial gases.

***CSA CSM**

Ratermann Keeps Valves and Industry Confidence Flowing

by Lance Looper, Ratermann Manufacturing

For companies working with cryogenic and industrial gas systems, valve failure isn't just a maintenance issue; it's a safety risk. Pressure relief valves must operate with precision under intense thermal and mechanical stress. That's why Ratermann Manufacturing has made valve recertification a central part of its operation, helping customers meet industry guidelines, avoid unnecessary downtime and stay within ASME standards.

Now operating a full in-house valve service center in Houston, Ratermann provides certified testing, oxygen cleaning and turnaround repairs for brands including Herose, Kunkle, Anderson-Greenwood and Cash. The company has paired its large product inventory with a growing service division, further positioning itself as a resource for both parts and performance.

"Valve reliability isn't optional, it's essential," said Joel Rodriguez, service manager at Ratermann. "That's why we've made it easier to get valves inspected, recertified and back in the field without compromising safety or compliance."

Recertification and retesting performed across trusted valve brands in the industry. Credit: Ratermann Manufacturing

The dedicated service department at Ratermann. Credit: Ratermann Manufacturing

Why Recertification Matters

Industry guidelines call for pressure relief valves to be recertified every five years, and for good reason. These valves are critical to preventing overpressure events in cryogenic tanks, piping systems and gas delivery infrastructure. Over time, mechanical fatigue can impact performance. Without regular testing, there's no guarantee a valve will work when it's needed.

Ratermann's ASME-certified test bench allows for full pressure testing and restamping in line with National Board requirements. For customers, this reduces the likelihood of compliance issues or preventable failures and may help extend the life of valves already in service.

If a valve fails in the field, Ratermann's team can often bring it back into spec through repair and recertification. When timing is tight, multiple service tiers are available, from standard (6 to 10 business days) to rush (under 24 hours). For teams managing production schedules or time-sensitive cryogenic systems, this kind of flexibility can be essential.

Built for Cryogenic and Industrial Gas Needs

The valve service division works on the same high performance components

Ratermann stocks: trusted names like Herose, which offers global certifications and temperature ratings down to -425°F. Their technicians are certified for valve repair (VR), test only (TO) and assembler (UV), qualifying them to perform ASME work entirely in-house.

The company also provides oxygen cleaning in a controlled environment, a key step for any valve used in oxygen service. Contamination can result in ignition hazards, and Ratermann's process supports the cleanliness standards necessary for safe operation.

By combining product access with in-house technical support, Ratermann provides continuity throughout the valve's lifecycle. Customers can source parts, consult on installation and get the same team to handle maintenance, testing and repairs.

Staying Ahead of Downtime

Fast turnaround has long been part of Ratermann's approach. The company was built to serve time-sensitive markets such as cryogenic distributors, medical gas suppliers and industrial gas firms. Whether overseeing an oxygen system at a hospital or managing a microbulk fleet, customers rely on systems that work without delay.

Keeping valve services in-house minimizes third-party delays and gives Ratermann tighter quality control. For pressurized systems at ultralow temperatures, that control can make a difference.

"Our commitment to quality and speed helps customers minimize downtime and maximize confidence," Rodriguez said.

Beyond the Parts

The Houston facility operates alongside other sites in California, Tennessee and North Carolina. With expanded support hours and technical resources online, the company is aiming to improve access and help users stay informed about valve selection, maintenance and certification. The goal is more than supplying products. With its mix of technical expertise, service infrastructure and inventory, Ratermann works to help customers prevent issues before they disrupt operations.

As cryogenic technologies develop and demand for gases like oxygen, nitrogen and hydrogen increases, the infrastructure behind them will need to become more dependable. Valves may be small, but their performance shapes the reliability of the systems they support. With its in-house valve recertification services, Ratermann is contributing to that reliability by helping the industry stay compliant, reduce downtime and maintain safer operations over time. **www.cryoorder.com**

CEC/ICMC 2025 Highlights Cryogenics at the Crossroads of Science and Industry

This May, the cryogenics community once again gathered in force for the 2025 Cryogenic Engineering Conference and International Cryogenic Materials Conference (CEC/ICMC), held at the Peppermill Resort in Reno, Nevada. From May 18 to 22, over 800 attendees from around the globe came together to share technical breakthroughs, discuss critical infrastructure needs, and chart the future of cryogenic technologies across a rapidly evolving industrial landscape.

The joint conference continues to serve as the field's premier platform for the integration of engineering and materials science. It attracts leading researchers, engineers, students and industry professionals from diverse sectors. This year's event showcased both the enduring value of foundational research and the urgency of addressing real-world challenges. Topics ranged from securing helium supplies to enabling hydrogen-powered aircraft and advancing superconducting power systems.

A Conference Framed by Visionary Plenaries

Four plenary presentations throughout the week reflected the broad and growing impact of cryogenics across science, technology and industry.

The conference opened Monday morning with John Davis, professor of physics at the University of Alberta and CTO of Zero Point Cryogenics. In his talk titled "Novel Sub-Kelvin Cryogen-free Refrigeration at Zero Point Cryogenics," Davis introduced advancements in dilution refrigerator technology and shared insights into commercializing ultralow temperature systems for research and quantum applications. His dual perspective as both academic and entrepreneur resonated with attendees navigating the boundary between laboratory innovation and scalable technology.

Dr. Ralph Longsworth was the recipient of CEC's Samuel C. Collins Award, a well-deserved honor for his lifetime of contributions to the cryogenic community. Credit: SHI Cryogenics Group

On Tuesday, Dr. Laura Greene of the National High Magnetic Field Laboratory delivered a thought-provoking talk on unsolved mysteries in unconventional superconductors. Drawing from decades of experience and global leadership in science diplomacy and policy, Greene emphasized how quantum materials, still not fully understood, remain central to the performance of high-field magnets and emerging quantum technologies.

Wednesday's plenary highlighted the intersection of cryogenics with aerospace electrification. Dr. Parag Kshirsagar of the RTX Technology Research Center discussed cryogenically cooled power distribution systems, motors and drives. These technologies are becoming essential for compact, high-performance electric aircraft and defense platforms, underscoring the strategic role cryogenics plays in advancing flight technology.

The final plenary on Thursday featured Brad Cage of Pulsar Helium, who addressed the growing urgency of securing a domestic helium supply. Cage outlined Pulsar's work on the Topaz Project and detailed how the company is applying oil and gas expertise to helium exploration. With helium remaining a critical and limited resource, his insights were timely and well received.

Special Sessions, Specialized Focus

A standout feature of CEC/ICMC 2025 was the inclusion of targeted special sessions designed to spotlight fast-moving or emerging areas of interest. These included discussions on liquid hydrogen testing for aviation, NASA's latest cryogenic propulsion developments, materials for high-field magnets, and system-level cryogenic applications in transportation.

The emphasis on transportation, spread across multiple sessions, reflected a growing trend: the integration of cryogenics into large-scale mobility platforms. From superconducting motors for electric aircraft to cryocooled electronics for space and defense, the sessions demonstrated that cryogenics is no longer confined to laboratory or stationary applications. It is increasingly a core enabler for mobile, high-efficiency, and high-reliability systems.

A Program as Broad as It Is Deep

The technical program offered numerous parallel tracks across both the CEC and

Chad Thomas, Ana Perez and Ronald Dekker from OPW Clean Energy Solutions and Demaco enjoyed the opportunity to converse with fellow industry members around topics like hydrogen applications, superconductivity and cryogenic systems. Credit: Demaco

Students from the joint college of FAMU FSU College of Engineering presented their research at the CEC/ICMC25, contributing to discussions on cryogenic materials science and thermal management systems. Credit: FAMU FSU College of Engineering

The team from INOXCVA with CSA Board Chairman John Weisend II. Credit: INOXCVA

CSA CSM Bluefors presents cryogenic innovation in the exhibitors' hall at CEC/ICMC25. Credit: Bluefors

ICMC sides of the conference, reflecting the richness and diversity of the cryogenics field.

On the CEC side, presentations ranged from large-scale refrigeration and liquefaction systems to aerospace applications, cryocooler development, cryofuels, and safety standards. Sessions addressed superconducting system integration, medical cryogenics, and a growing number of quantum system applications. This area continues to draw attention as quantum computing and sensing move toward commercial deployment.

The ICMC program provided equally rich content on the materials front. Tracks included superconducting wire and cable technologies, mechanical and thermal properties of materials at cryogenic temperatures, and new directions in cryogenic power electronics and hydrogen-compatible materials. As decarbonization and electrification gain momentum, sessions also explored cryogenic solutions for power, mobility, and space systems. These talks helped connect materials advances directly to emerging system needs.

Across both conferences, a significant number of talks emphasized applied research and development. Presenters from industry, national laboratories, and government agencies offered insights into the real-world challenges of bringing cryogenic systems from concept to deployment. Many sessions included invited talks designed to provide context and synthesis. This approach allowed attendees to see not just what is being developed, but why it matters and how it will be used.

Student Involvement and Community Connection

CEC/ICMC 2025 continued its strong tradition of supporting early-career professionals, with robust student participation throughout the week. Poster sessions, student paper awards, and numerous networking opportunities helped integrate the next generation of cryogenic scientists and engineers into the broader professional community. These interactions remain one of the most vital parts of the conference. They ensure the sustainability of the field while infusing it with new ideas and energy.

The exhibit hall provided additional value, with vendors showcasing the latest in cryogenic instrumentation, cryocoolers, materials and testing equipment. For many attendees, it was a chance to see firsthand the products and tools that support their work while engaging with the engineers and developers behind them.

Looking Ahead

As cryogenics continues to expand into fields as varied as energy storage, space exploration, medical imaging and transportation, CEC/ICMC remains an essential venue for collaboration across disciplines. The 2025 event in Reno made it clear that the challenges ahead, whether technical, economic or environmental, will require innovation at every level. This includes everything from fundamental materials science to large-scale systems engineering.

Just as importantly, these efforts will require community. CEC/ICMC offers that community a place to convene, to learn, and to inspire one another.

Save the date! CEC/ICMC 2027 is scheduled to take place on June 13-17, 2027 in Knoxville, Tennessee.

31st Space Cryogenics Workshop Sparks Collaboration Across Continents

Scientists and engineers from across the world gathered in Lake Tahoe for the 2025 Space Cryogenics Workshop. Credit: CSA

by Wesley Johnson and Dan Hauser, NASA

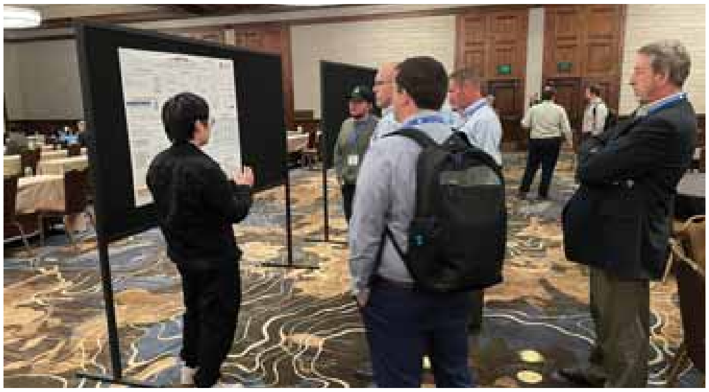
The 31st Space Cryogenics Workshop (SCW) was held at the Hyatt Regency Lake Tahoe in Incline Village, Nevada, from May 13 to 15, 2025, chaired by Wesley Johnson and Daniel Hauser. More than 60 scientists and engineers from around the world convened to discuss space applications for cryogenics, renew acquaintances and connect with new practitioners in the field. As is typical, the workshop was held the week before the Cryogenic Engineering Conference.

Attendees enjoyed two full days of abstract presentations. Credit: CSA

The technical program featured 35 papers and posters presented in a single-track format across eight oral and two poster sessions. Day one included mission overviews of the Black Hole Explorer, Titan Submarine and LOXSat; a session on multiple analysis methodologies and the verification of computational fluid dynamics and nodal codes for long-duration storage and pressure control of in-space propellants; a session on cryogenic chilldown testing and analysis; a session on heat transfer coefficient testing for boiling and subcooling cryogenic fluids; and an overview of sunshield developments. The first day's poster session highlighted hydrogen heat pipes and the on-orbit performance of the XRISM dewar.

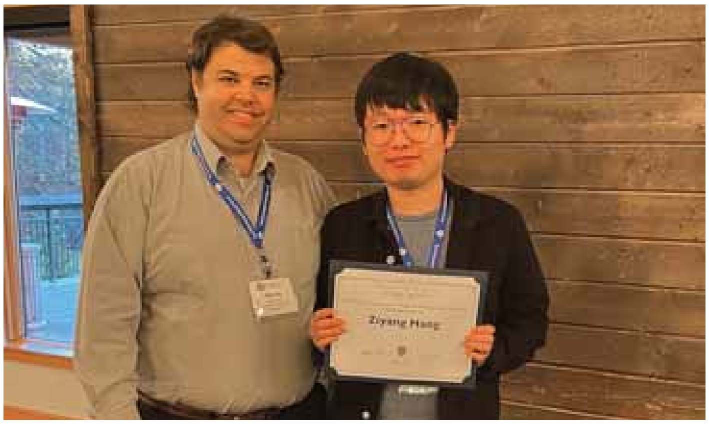
The second day was equally broad, featuring sessions on more experimental works, cryocoolers under lifetime testing, analytical modeling of aerospace cryogenic fluid systems and cryogenic long-duration propellant storage missions. A cryogenic propellant transfer test conducted aboard SpaceX's Starship vehicle was also presented, detailing the transfer of cryogenic liquid oxygen between tanks under low-gravity conditions. Also included were presentations on the Cryogenic Active Cooling for Human Exploration (CACHE) acquisition and liquid hydrogen boiloff loss recovery systems. The second day's poster session included presentations on a Turbo-Brayton cryocooler, a sub-kelvin adiabatic demagnetization refrigerator and a feasibility study of a mechanical cooler system for LiteBIRD. It was interesting to observe the combination of component testing and analysis as they fit into the bigger picture of several planned and proposed missions.

The SCW awards banquet was held at the Chateau, where attendees enjoyed mountain scenery and social interaction.



Poster sessions were held both days. Credit: CSA

Attendees enjoyed the scenery during the Awards Banquet at The Chateau. Credit: CSA



SCW Co-chair Wesley Johnson presented the T.H.K. Frederking Space Cryogenics Workshop Student Scholarship to Ziyang Hang of the University of Wisconsin-Madison. Credit: CSA

SCW Co-chair Dan Hauser presented the Best Paper Award to Jinwook Kim, Kyoung Joong Kim, Junhyuk Bae, and Sangkwon Jeong for their paper "Experimental and Numerical Investigation of Cryogenic No-Vent Fill (NVF) Process Using Adsorption on Activated Carbon. Credit: CSA

Ample networking time was provided throughout the event. Credit: CSA

Attendees enjoying the scenery of the Sierra Nevada Mountains. Credit: CSA

The best paper award for the 2025 workshop was presented to Jinwook Kim, Kyoung Joong Kim, Junhyuk Bae and Sangkwon Jeong, of the Korea Advanced Institute of Science and Technology, for their paper entitled "Experimental and Numerical Investigation of Cryogenic No-Vent Fill (NVF) Process Using Adsorption on Activated Carbon." The T.H.K. Frederking Space Cryogenics Workshop Student Scholarship was awarded to Ziyang Hang, a Ph.D. student at the University of Wisconsin. Michael Meyer, recently retired from NASA, and Wei Dai, of the Chinese Academy of Sciences, were recognized as Fellows of the Cryogenic Society of America for their contributions to space cryogenics and their demonstration of professional excellence and service.

The papers from the SCW have been submitted to *Cryogenics* for publication in a special edition.

The authors thank the Diamond sponsors (OPW Clean Energy Solutions and Omega Flex), Gold sponsor (Alloy Valves and Control), Silver sponsors (Spaceline Technologies and Quest Thermal Group), and the session chairs and presenters for their patience with last-minute changes.

The 31st Space Cryogenics Workshop once again demonstrated the vibrant and collaborative nature of the space cryogenics community. Attendees left with new insights, strengthened professional connections and a renewed sense of purpose for advancing cryogenic technologies in future space missions.

Product Showcase

This Product Showcase is open to all companies and related manufacturers offering new or improved products for cryogenic applications. We invite companies to send us short releases (150 words or fewer) with high-resolution JPEGs of their products to editor@cryogenicsociety.org.

Edwards GV80 Dry Vacuum Pump

Edwards Vacuum

Edwards Vacuum highlights its GV80 dry vacuum pump as a key solution for effective thermal management in AI-enabled data centers, where increasing computing power and data throughput generate significant heat loads. The GV80 is an oil-free claw pump engineered to handle vapors and particles with precision, forming the backbone of energy-efficient cooling systems that include heat pipes, vapor chambers and liquid cooling solutions. Designed for reliability and environmental sustainability, the GV80 maintains high vacuum levels, stabilizes performance and extends the lifespan of electronic components. Edwards emphasizes that behind every high performance cooling system is a dependable vacuum solution like the GV80, which helps ensure safe, efficient and long-term operation in demanding digital environments. **www.edwardsvacuum.com**

Mobile Cryogenic Supply System

Spaceline Technologies Inc.

Spaceline Technologies has successfully engineered and is producing a new system for NASA's Armstrong Flight Research Center, a mobile cryogenic trailer that can store and output both liquid cryogen and temperature-controlled purge gas. The system includes a liquid storage tank, vaporizer system, electric heater, power generation and PLC panel for automated controls. The user can control liquid and gaseous flowrate as well as gas temperature with the onboard Human Machine Interface. The system is designed for versatile operations in remote environments. The Spaceline Technologies team brings decades of experience designing, fabricating and activating complex cryogenic fluid systems. **www.spacelinetech.com**

CH-160D3 Single-Stage Cryocooler Series

SHI Cryogenics

The SHI Cryogenics Group has unveiled its highest-capacity single-stage GM cryocoolers to date: the CH-160D3LT for 20 K applications and the CH-160D3 for applications at 77 K. The CH-160D3LT delivers up to 100 W at 20 K, while the CH-160D3 achieves up to 725 W at 77 K, setting new benchmarks in cooling performance. Engineered for high-demand applications such as liquid hydrogen and nitrogen production, clean energy systems and high temperature superconductivity, the series combines the best design elements from the company's CH and RDK product lines with innovations like Whisper® technology for quiet operation and Displex® drive for reduced wear. A new gas-balanced valve, stem drive and heat exchanger further improve efficiency, durability and maintenance intervals. Each cryocooler is paired with two F-70 water-cooled compressors, which provide oil-free, high pressure helium delivery. CE compliant and backed by SHI's global support network, the CH-160D3 series delivers powerful performance and long-term value. **www.shicryogenics.com**

Dry-Compressing Screw Vacuum Pumps for Vacuum-Assisted Casting

Leybold GmbH

Leybold presents its line of dry-compressing screw vacuum pumps as an optimal solution for vacuum-assisted casting applications in automotive, aerospace and rail manufacturing. These pumps eliminate oil contamination by using a frictionless, oil-free compression mechanism, which reduces energy consumption, minimizes maintenance and improves sustainability. Unlike oil-lubricated systems that require frequent servicing due to dust and debris buildup, dry vacuum pumps efficiently evacuate molds while maintaining performance and durability. Equipped with smart features like frequency-controlled operation and energy savers, Leybold's dry pumps offer advanced process control, reduced operating costs and reliable performance in harsh environments. As manufacturers seek cleaner, more efficient casting technologies, Leybold's dry-compressing systems meet the demand with lower emissions and longer lifespans. **www.leybold.com**

People & Companies in Cryogenics

At its 2025 "Optimism Engineered" gala in New York, the **American Society of Mechanical Engineers** (ASME) Foundation honored prominent leaders in engineering and STEM education while rallying support for programs that empower the next generation of innovators. Hosted by Emmy-winning engineer and entertainer Loni Love, the event featured the presentation of three major awards: the Hoover Medal to **The Honorable Dr. Aprille J. Ericsson**, former U.S. Assistant Secretary of Defense for Science and Technology, for her distinguished career at NASA and the Department of Defense; the Excellence in Industry Award to **Dr. Ajei Gopal, President and CEO of Ansys**, for expanding STEM access through simulation software and partnerships; and the Next Gen Award to **Jay Flores**, STEM education champion, for inspiring millions of students through bilingual science programming. More than 250 attendees, including donors and industry leaders, gathered to celebrate the achievements of these honorees and support the ASME Foundation's initiatives in education, workforce development, and global access to engineering opportunities.

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Bernhard, a national leader in Energy-as-a-Service (EaaS), has rebranded as **ENFRA** to better reflect its focus on energy infrastructure and its continued growth in the evolving energy sector. The name change marks a new chapter for the New Orleans-based company, which has experienced significant expansion – particularly in its EaaS segment, now accounting for approximately 50% of revenue. ENFRA serves not-for-profit institutions in health care and higher education, delivering measurable impacts such as substantial energy savings, emissions reductions and cost efficiencies. Despite the rebrand, leadership and operations remain unchanged and clients can expect uninterrupted service as the company updates its branding across platforms.

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Bluefors (CSA CSM) has announced that **Kim Povlsen** will become its new CEO by October 1, 2025, bringing leadership experience from Universal Robots and Schneider Electric. He will guide the 700-employee global team in advancing Bluefors' industry-leading cryogenic systems for quantum technology and low temperature physics. Board Chair Kimmo Alkio praised Povlsen's strategic vision and customer focus, aligning with Bluefors' collaborative, innovation-driven approach. Povlsen succeeds interim CEO and founder Rob Blaauwgeers, following the departure of Jonas Geust.

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On May 16, Chile signed an agreement to become an Associate Member State of **CERN**, marking a major milestone in its scientific development. The new status, pending ratification, will deepen Chile's participation in CERN's research programs and expand opportunities for collaboration, education and industry engagement. Chilean institutions have been involved in CERN experiments since 2007, and this formal association reflects the country's growing contributions to particle physics and technological innovation.

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Angel Wileman, manager of the Thermofluids Section at **Southwest Research Institute** (SwRI), has been named one of the 2025 "Women in Hydrogen 50" by the Women's Global Leadership Conference (WGLC) in Energy. Recognized for her leadership in advancing hydrogen technology, Wileman spearheads projects involving hydrogen-natural gas blends, hydrogen refueling systems and custom flow facilities. She also leads SwRI's H_2HD REFUEL consortium, focused on developing hydrogen infrastructure for heavy-duty vehicles. Beyond her technical achievements, Wileman mentors students and advocates for women in STEM—efforts that earned her the 2019 Empowering Women in Industry Award and a 2023 San Antonio Business Journal "40 Under 40" honor.

Image: Angel Wileman. *Credit: SwRI*

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GenH2 Corp. (CSA CSM) has received an Honorable Mention in NASA's prestigious Commercial Invention of the Year Award for its Cryostat CS500, a simulation test platform originally developed at Kennedy Space Center by co-inventor **James Fesmire** (*Cold Facts* columnist). The technology, licensed from NASA, is now driving global adoption in cryogenic materials testing and clean energy applications, with collaborations spanning universities, research labs, and industry leaders worldwide.

Meetings & Events

European Conference on Applied Superconductivity (EUCAS)
September 21, 2025
Porto, Portugal
https://eucas2025.esas.org

European Cryogenic Days & Cryogenic Heat and Mass Transfer Workshop 2025
October 27-30, 2025
Twente, Netherlands
https://www.ecd-chmt.com

24th International Cryocooler Conference
June 15-18, 2026
Syracuse, NY
https://cryocooler.org

ICEC 30/ICMC 2026
June 22-26, 2026
Daejeon, Korea
https://icec30-icmc2026.org/

Cryogenic Engineering and Safety Annual
5-Day Course
August 3-7, 2026
Golden, CO
https://cryocourses.com/

Applied Superconductivity Conference (ASC)
September 6-11, 2026
Pittsburgh, PA
https://www.appliedsuperconductivity.org/asc2026/

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