Cold Facts INTERNATIONAL

The Magazine of the Cryogenic Society of America, Inc.

IceCure Redefines Cryosurgical Tumor Ablation | 8

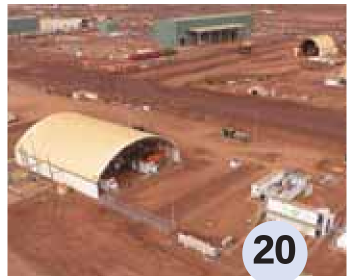
Volume 40 Number 5 2024

Join Our Growing Family of CSA Corporate Sustaining Members

Get connected to the cryogenic community worldwide.
Let your voice be heard and your contributions known.

Abbess Instruments and Systems, Inc.
Ability Engineering Technology, Inc.
Acme Cryogenics, Inc.
Ad-Vance Magnetics
Aerospace Fabrication & Materials
Air Liquide advanced Technologies
Alkegen
Alloy Valves and Control
American Magnetics, Inc.
Ampo Poyam Valves (AMPO)
Amuneal Manufacturing Corp.
Argonne National Laboratory
Atlas Technologies
Barber-Nichols LLC
Beyond Gravity GMBH
Bhiwadi Cylinders PVT
Bluefors
BRUGG Pipes
Canadian Nuclear Laboratories
CCH Equipment Company
Chart Inc.
Chase Research Cryogenics
Clark Industries, Inc.
Coax Co., LTD.
CoolCAD Electronics, LLC
Commonwealth Fusion Systems
CO2 Meter
CPC-Cryolab, an MEC Company
Creare LLC
Criotec Impianti SpA
Cryo Industries of America
Cryo Service LTDA
Cryo Technologies – A Chart Industries Company
Cryoco LLC
CryoCoax
Cryocomp
CryoEdge
Cryofab, Inc.
Cryogenic Institute of New England
Cryogenic Limited
Cryogenic Specialty Manufacturing SDN BHD
Cryoguard LLC
Cryomagnetics, Inc.
Cryomech, Inc.
Cryonova Process Systems, LLC
Cryospain
CryoSRV, LLC
CryoTechnics LLC
CryoVac GmbH
CryoWorks, Inc.
Cryoworld BV
CSIC Pride (Nanjing) Cryogenic Technology Co., Ltd.
Danaher Cryogenics
Demaco Holland BV
DMP CryoSystems, Inc.
EPSIM Corporation
Equigas, Inc.
Essex Industries
Eta Space
Fabrum Solutions
Facility for Rare Isotope Beams—Michigan State University
Fermi National Accelerator Laboratory
Fin Tube Products, Inc.
Fives Cryo
FormFactor
Gardner Cryogenics
Gas Equipment Company
GenH2
Herring Systems, Ltd.
IC Biomedical
Imtek Cryogenics
Independence Cryogenic Engineering, LLC
Iris Technology
Kelvin International Corporation
KEYCOM Corporation
kiutra GmbH
Lake Shore Cryotronics, Inc.
Lihan Cryogenics
Linde Cryogenics, Division of Linde Engineering Americas
Magnatrol Valve Corporation
Magnetic Shield Corporation
Meyer Tool & Mfg., Inc.
Micro Harmonics Corporation
Midalloy
Molecular Products, Inc
NASA Kennedy Cryogenics Test Laboratory
NASA Marshall
National High Magnetic Field Laboratory
Niowave, Inc.
Oak Ridge National Laboratory
Omega Flex, Inc.
Oxford Cryosystems
Oxford Instruments NanoScience
Penflex
Photon Spot
PHPK Technologies
Princeton CryoTech
Quantum Design, Inc.
RegO
RIX Industries
Rutherford & Titan Inc.
Scientific Instruments, Inc.
shirokuma GmbH
Sierra Lobo
Signal Microwave
SLAC-National Accelerator Laboratory
Space Dynamics Laboratory
Spaceline Technologies Inc.
SPS Cryogenics BV
STAR Cryoelectronics
Stirling Cryogenics BV
Stöhr Armaturen GmbH & Co. KG
Sumitomo (SHI) Cryogenics of America, Inc.
Sunpower, Inc.
SuperPower, Inc.
Technifab Products, Inc.
Technology Applications, Inc.
Tech4 Imaging LLC
Tempshield Cryo-Protection
The Aerospace Corporation
The Phoenix Company of Chicago
Thermal Management Technologies
Thermal Space
Thermionics Lab
Thomas Jefferson National Accelerator Facility
TRIUMF
Turbines Inc.
Vacuum Barrier Corporation
Vacuum Energy Inc.
Web Industries
WEKA AG
Wessington Cryogenics
West Coast Solutions
XMA Corporation

Inside This Issue



FEATURES

COLUMNS

ON OUR COVER

The medical world is increasingly embracing cryotherapy for tumor treatment, but not all cryoablation treatments are created equal. Liquid nitrogen cryoablation technology, the coldest of the cryogens, is taking the stage for more effective treatment and outcomes. Credit: IceCure.

SPOTLIGHTS

Lake Shore CRYOTRONICS

Lake Shore Cryotronics, Inc. was CSA's newsletter sponsor for September.

OPW | REGO | ACME CRYOGENICS

OPW was CSA's newsletter sponsor for October.

In all instances, "CSA CSM" indicates a Corporate Sustaining Member of CSA.

Cold Facts (ISSN 1085-5262) is published six times per year by the Cryogenic Society of America, Inc.

From the Executive Director

With the holiday season right around the corner, this month is a time of reflection and gratitude. I'd like to express our thanks to all of you – our readers, contributors and advertisers – who make this magazine possible. I also want to thank our amazing team here at CSA: Editor Anne DiPaola; Graphic Designer Israel Reza; Marketing Manager Jo Snyder; and Membership and Advertising Manager Jamie Luedtke. THANK YOU!

In other news, I am happy to report that registration and abstract submissions are now open for the 31st Space Cryogenics Workshop! Abstracts are solicited in all areas of cryogenics related to space applications including missions, cryostats, components, sensors, instrumentation, cryocoolers, facilities, launch vehicles and more. We particularly encourage submissions related to cryogenic in-space fluid management technologies, including the challenges, innovations and demonstration of the storage and transfer of cryogenic propellants in space.

Abstracts should be concise statements of no more than 500 words. We encourage all authors to only submit one oral session. If you have multiple abstracts to submit, please consider selecting the poster session for the additional abstracts. If you are interested in submitting an abstract, please visit **https://2csa.org/abstracts**. The deadline for abstract submissions is January 17, 2025. For full details on the Space Cryogenics Workshop, including accommodations, registration, the agenda, and more, visit **https://spacecryogenicsworkshop.org**.

I also want to remind you that CSA offers a variety of other online resources for the cryogenics community. One of the more popular resources is the CSA Job Center. This job center is your clearinghouse for cryogenic jobs, whether you are an employer looking for an employee or an individual seeking employment. CSA members receive free job postings, while non-members can post at a nominal fee. All job seekers can utilize the CSA Job Center free of charge. Visit the following link to check out the CSA Job Center: **https://cryo.mcjobboard.net/jobs.**

We've also recently re-vamped the CSA Online Buyer's Guide. Designed for cryogenic applications and provided by CSA, this product and service resource includes everything from adhesives, cryocoolers, dewars and electronic controls to greases, liquefiers, magnets, tanks, test chambers, valves and wire used in ultralow temperature applications. You can also find engineering consultants, research and test laboratories, specialty manufacturing, cryogenic treatment services, materials research and cryogenic transport services. Company profiles for leading companies in cryogenics, as well as contact information for many more suppliers, are also available. Check it out today at **https://csabg.org**.

As always, I hope you enjoy this issue of *Cold Facts*!

An interventional radiology setup showcases IceCure's state-of-the-art cryoablation technology. This setup allows physicians to precisely guide cryoprobes to targeted tissues, leveraging real-time imaging for accurate treatment with minimal invasiveness. Credit: IceCure

IceCure's Cryosurgical Tool Redefines Minimally Invasive Tumor Ablation

by Anne DiPaola, *Cold Facts* Editor and Sara Vehling, IceCure Medical Ltd.

In the ongoing battle against cancer, IceCure Medical is providing minimally invasive, lifesaving options for patients with its revolutionary cryoablation technology, particularly through its flagship product, the ProSense® System. This state-of-the-art system offers an alternative to traditional surgical methods, effectively targeting both benign and malignant tumors while significantly enhancing patient comfort and recovery. IceCure's approach is particularly timely, as the demand for less invasive treatments that improve patient outcomes and minimize the physical and emotional toll of cancer care continues to grow. Its cryoablation technology represents a groundbreaking shift in how tumors are treated.

With FDA clearance and CE marking, the ProSense System has been validated through extensive clinical experience across various cancer types. Utilizing liquid nitrogen to create ultracold temperatures that freeze and destroy tumors, it provides a novel solution that is not only effective but also well tolerated by patients. Procedures can be performed in office settings or CT rooms, offering patients quick, convenient and efficient treatment options. The ProSense System's versatility is particularly noteworthy because it treats a broad range of tumors, including those in the breast, kidney, lung, liver and musculoskeletal regions. This wide applicability exemplifies IceCure's mission to make effective, less invasive procedures accessible to more patients for a variety of tumor types or location. By focusing on patient-centered care, IceCure Medical is not just providing more choices for cancer patients—it's redefining the minimally invasive procedures altogether.

How Cryoablation Works

Cryoablation is a minimally invasive procedure that uses extreme cold to destroy benign or malignant tumors. Targeted tissues are visualized using imaging guidance such as ultrasound or computed tomography (CT). A freezing agent, typically argon or liquid nitrogen, is administered through a cryoprobe, freezing and destroying the abnormal tissue. During the procedure, one or more cryoprobes are inserted into the affected area after anesthesia or conscious sedation. Ultrasound or CT imaging guides placement to ensure proper positioning. The freezing agent circulates within the cryoprobe, creating an ice ball around the targeted tissue. CT scans verify that the ice ball covers the entire tumor and a margin of healthy tissue. Once treatment is complete, the cryoprobe is warmed and safely extracted.

Cryoablation is an effective treatment for a wide range of tumors, and its suitability depends on the tumor's type, location, size and visibility. This technique is particularly beneficial for patients unable to undergo surgical tumor removal due to age or comorbidities. It helps alleviate pain and manage symptoms of metastatic cancers. A typical percutaneous cryoablation procedure takes about 1.5 to 2 hours, although it can be shorter—between 15 and 45 minutes—when treating certain tumors. Cryoablation is generally safe, with lower risks compared to traditional surgery. While there is a small chance of complications, such as bleeding or infection, the overall risk is minimal.

In essence, cryoablation destroys tumors by freezing them, causing cellular dehydration and damage. This reduces blood flow to the tumor, and the necrotic tissue is gradually absorbed by inflammatory cells through phagocytosis. Over time, the damaged tissue is replaced by a fibrous scar. Patients typically tolerate cryoablation well, as the necrotic process is a natural response. Compared to heat-based treatments like radiofrequency ablation, cryoablation often results in less pain and quicker recovery, and the procedure can be repeated if necessary.

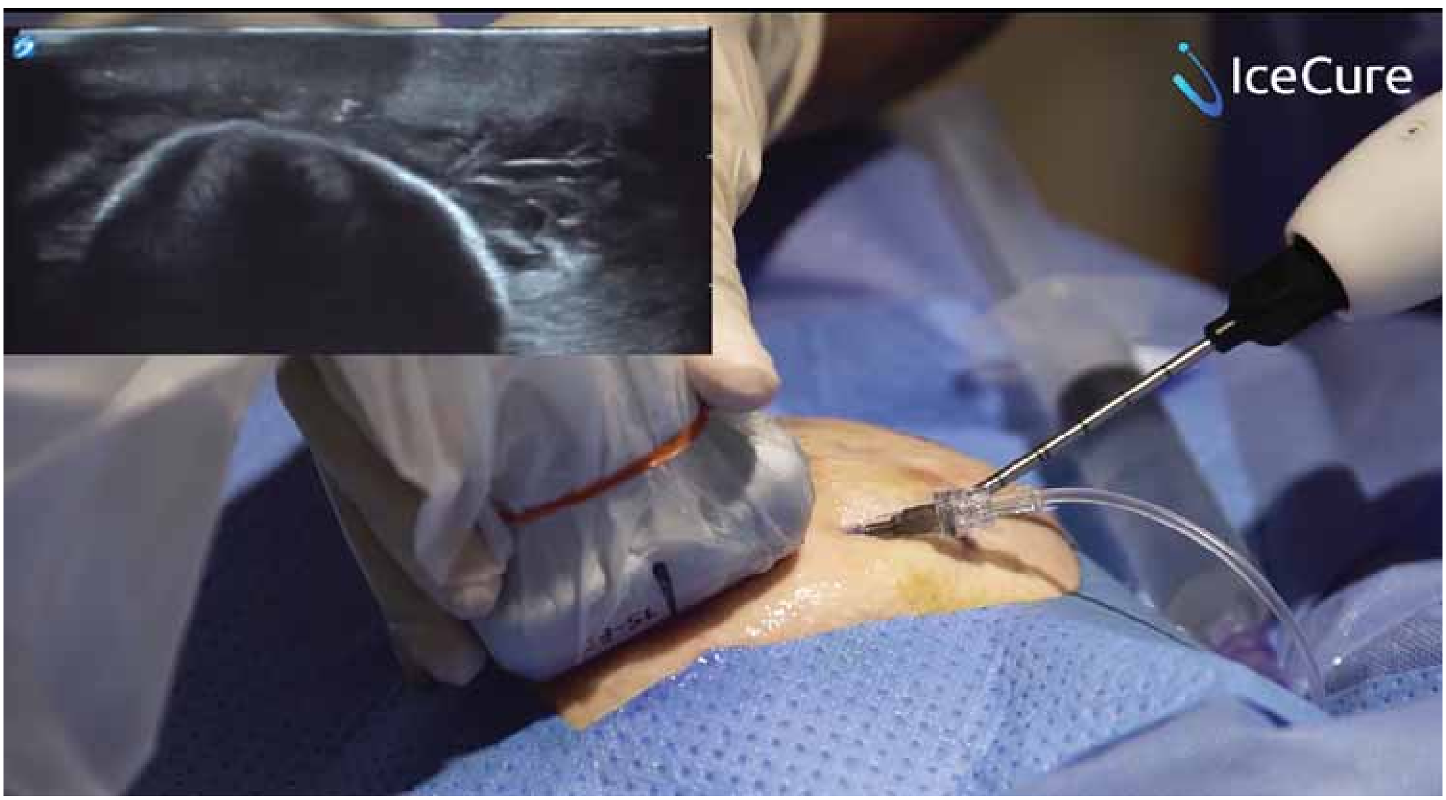
Clinical Success and Future Innovations

Cryoablation has gained traction for treating breast tumors, particularly benign ones like fibroadenomas, with FDA clearance for various indications and CE marking. Clinical trials support its effectiveness, with the American Association of Breast Surgeons recognizing it as a viable option for resolving fibroadenomas without surgical excision. In a study of 60 procedures, the ICE Crystal Study reported 93% of fibroadenoma were completely resolved at one-year post-cryoablation.

In recent years, percutaneous cryoablation has become increasingly common for early-stage lung cancer, especially in medically inoperatable patients. Studies show this technique is safe and effective, with promising long-term survival rates and minimal complications. For instance, a study involving stage I non-small-cell lung cancer patients demonstrated satisfactory local control and recurrence-free survival for tumors smaller than 1.8 cm.

Renal cell carcinoma (RCC) is a prevalent form of kidney cancer, and cryoablation is increasingly accepted as an effective

▶ *continues on page 10*



IceCure's ProSense Cryoablation System, an advanced tool for minimally invasive tumor treatment, utilizes extreme cold to ablate tumors across multiple applications, from breast and lung to kidney and liver cancers. The system's precision ensures controlled ice formation for optimal therapeutic results. Credit: IceCure

A cryoablation procedure being performed on a kidney tumor using IceCure's ProSense System. The controlled application of extreme cold creates an ice ball that ablates the tumor, offering an alternative to surgery with fewer risks and a quicker recovery time. Credit: IceCure

treatment for small renal tumors. Recent studies indicate cryoablation can achieve outcomes comparable to traditional surgical methods, with significantly fewer side effects. The ICESECRET Trial showed an 89.5% recurrence-free rate at a mean follow up of 22.2 months for a subgroup of patients with no history of cancer on the same kidney and lesions less than 3cm.

A technician carefully fills a liquid nitrogen container, ensuring the ProSense Cryoablation System remains fully operational. Liquid nitrogen is crucial for generating the extreme sub-zero temperatures required for effective cryoablation procedures. Credit: IceCure

For the treatment of early-stage breast cancer, IceCure's ICE3 clinical trial reported a local recurrence free rate of 96.3% for patients treated with cryoabaltion and endocrine therapy. Patients and physicans reported 100% satisifcation with the less invasive procedure which reports minimal scarring and minimal pain (thanks to the natural numbing effect of the cold).

Looking ahead, IceCure is awaiting FDA clearance for the specific indication of cryoablation for early-stage low risk breast cancer. Already available in the EU and other global regions, cryoablation for breast cancer will offer women the choice of a minimally invasive procedure with minimal scarring, minimal pain, and rapid recovery. Investigator initated trials for other types of tumors continue to demonstrate the benefits of cryoabaltion. A recent study in Italy conluded that LN_2 based cryoablation is safe across a wide range of tumor sizes and locations, with 97.7% complete tumor coverage and only minor complications observed. In lung cancer, a Japanese study showed recurrence-free rates from 77% to 100% based on tumor size, while research on musculoskeletal tumors indicated a 92.8% effiacy rate in avoiding a secondary surgery for endometriosis. Furthermore, IceCure's innovations, such as the newly FDA-cleared XSense™ cryoablation system, are expected to enhance precision and efficacy, broadening the range of treatable tumors.

Cryoimmunology—or cryoimmunotherapy—combines cryoablation with immunotherapy, creating a synergistic effect that not only destroys tumors but also boosts the patient's immune response. This approach may serve as an effective tumor vaccine, potentially eradicating visible disease, especially in metastatic patients, while also managing cancer pain with minimal side effects. This is another example of IceCure's intent to change the landscape of cancer treatment and prolong the lives of those affected by the disease. By harnessing innovation, IceCure Medical is not only advancing cancer treatment but also offering renewed hope and improved quality of life for patients facing this challenging journey. **www.icecure-medical.com**

OPW
CLEAN ENERGY SOLUTIONS

REGO

CryoMac® 4 LNG Fueling Nozzle
Maximum safety for LNG fuel technology

SAFE

"Safety Stop"
for added safety and
operator protection.

DURABILITY

Ball cage interface with receptacle adapter ring guides and locks the nozzle in place for optimum engagement and user interface to increase environmental seal life.

Patented nozzle safety feature is recognized in the market as a major failsafe advantage for the operator.

Continuing Innovations Coming Soon!
CryoMac® 5!

ACME
CRYOGENICS

Experience Innovative Excellence with our High Quality Vaporizers, Ensuring Superior Performance.

CEXI
CRYOGENIC EXPERTS

Cryogenic Experts (CEXI), builds a full line of Ambient vaporizers for both process and disposal applications. With several styles of electrically heated systems, water bath, steam, forced convection, and shell and tube designs. We design and specify vaporizers and gas heaters from 1kW gas heaters to large capacity custom-designed systems.

Ambient Vaporizers

Electric Trim Heaters

Electric Vaporizers

Specialty Vaporizers

Shell & Tube

Water Bath Vaporizers

Visit opwces.com for more information

Fellow Takes Data to Diagnosis with Cryogenic Revolution in MRI

with contributions by Lauren Otolski, Beckman Institute

Brad Sutton, Technical Director at the Beckman Institute for Advanced Science and Technology's Biomedical Imaging Center and Professor of Bioengineering at the University of Illinois Urbana-Champaign, has been named a Fellow by the International Society for Magnetic Resonance in Medicine (ISMRM) as of May 6, 2024. This honor recognizes his significant contributions to magnetic resonance imaging (MRI), particularly in developing advanced algorithms that reconstruct brain images from raw MRI data. Sutton's innovative approach transforms complex, indecipherable data into usable images, crucial for visualizing and interpreting brain structures.

By leveraging prior knowledge of brain anatomy and signal variations, Sutton's algorithms narrow the possible images from MRI data, speeding up reconstruction and enhancing accuracy. While tailored for brain imaging, the principles of his work also advance other areas of MRI research. Since joining the Beckman Institute in 2003, Sutton has committed to innovation. He leads the Biomedical Imaging Center, which features cutting-edge technology like the 7 Tesla MRI scanner—one of the first FDA-approved scanners of its kind, and the only one in Illinois. Its high magnetic field strength enables more detailed imaging, pushing the limits of MRI technology.

Cold Facts was honored to conduct the following interview with Sutton.

Brad Sutton, Technical Director at the Beckman Institute's Biomedical Imaging Center and Professor of Bioengineering at the University of Illinois Urbana-Champaign, has been named a Fellow by the International Society for Magnetic Resonance in Medicine. Credit: Beckman Institute for Advanced Science and Technology

Can you explain how cryogenics play a role in the functionality and advancements of the 7 Tesla MRI scanner used at the Beckman Institute?

High field MRI systems rely on superconducting magnets to achieve their high magnetic field strength. Typical clinical scanners are 1.5 and 3 Tesla, while the 7 Tesla magnet contains miles of wound superconductor, creating a large space for imaging and ensuring a uniform magnetic field for high-resolution imaging. The Siemens Terra 7 Tesla MRI scanner requires two cold heads for helium boiloff to keep the magnet cold. This large superconducting magnet accommodates not only scanning a person but also accommodates essential electronics, including large spatial gradient magnetic field coils and an RF coil.

What challenges do you face in developing MRI reconstruction algorithms when working with data obtained at cryogenic temperatures, and how do these challenges differ from those at standard temperatures?

Higher magnetic fields create small disruptions in the uniformity of the magnetic field, complicating the imaging process. While higher spatial resolution images are possible, deviations can distort the image and must be corrected during reconstruction. The main MRI magnet must provide a uniform magnetic field; any deviations lead to incorrect positioning of objects. Standard temperature magnets, while lower in field strength and resolution, are less dependent on a uniform magnetic field.

Another challenge is the push for faster imaging. Higher magnetic field systems allow for improved spatial resolution but are still limited by the same scan time as lower fields. Therefore, we must develop new data acquisition methods and reconstruction approaches to obtain higher resolution images in a similar timeframe.

How does the use of cryogenic materials and cooling techniques enhance the performance and accuracy of MRI technology, particularly in your research at the Biomedical Imaging Center?

Cryogenic magnet windings enable high uniform magnetic fields, facilitating high-resolution imaging and providing detailed information about brain structures. The 7 Tesla scanner allows us to identify tissue disruptions leading to epileptic seizures, map the cortex's mechanical properties, and obtain high-resolution chemical composition maps of the brain. At 3 Tesla, we conduct functional brain imaging to see network activity, but with 7 Tesla MRI, we achieve very high-resolution images, allowing us to infer the direction of information flow. We also utilize a Bruker 9.4 Tesla system for animal imaging, revealing insights into how environment and learning affect brain structures.

In your experience, what are the most significant benefits of incorporating cryogenically-cooled superconducting magnets in MRI scanners, and how have they impacted your research outcomes?

Increasing magnetic field strength through new superconducting materials not only enhances spatial resolution but also enables new imaging contrasts. This allows us to determine directionality in brain networks and to image chemical profiles. High-resolution imaging of chemical profiles helps us understand underlying processes in the brain during normal function and disease, bridging the gap between chemistry and pathology.

Could you discuss any recent breakthroughs or ongoing projects at the Beckman Institute that involve the integration of cryogenic technology with MRI imaging?

Ultrahigh field MRI has introduced new imaging contrasts. My group, in collaboration with Dr. Aaron Anderson, is investigating noninvasive methods to assess mechanical properties of brain tissue and identify areas of stiffening due to microstructural changes.

Sutton was recognized at the ISMRM's annual meeting in Singapore on May 6, 2024. Credit: Bruce Damon, Carle Foundation Hospital

The 7 Tesla MRI scanner, co-owned and -operated by the University of Illinois Urbana-Champaign and Carle Health, is the only such scanner in the state of Illinois. Credit: Beckman Institute for Advanced Science and Technology

How do you foresee the future of cryogenics influencing the field of MRI and biomedical imaging, and what potential innovations are you most excited about?

The future is promising, with cryogenics enabling MRI to achieve even higher magnetic fields in human-sized scanners. Advancements in superconductors will support larger systems, unlocking insights into brain structure and function. We aim to leverage improved signals for higher spatial resolution, create digital tissue replicas to predict individual responses to interventions, and deepen our understanding of brain function as we age.

The International Cryocooler Conference Innovates in Madison

by Professor John Pfotenhauer, University of Wisconsin- Madison

Participants of the ICC23 in the Great Hall of Memorial Union at the University of Wisconsin – Madison. Credit: ICC23

Madison, Wisconsin warmly welcomed participants to the 23rd International Cryocooler Conference, ICC23, June 3-6, 2024, and hosted the event in the stately rooms of the Memorial Union on the campus of the University of Wisconsin – Madison. Set on the shore of beautiful Lake Mendota and nestled within the thriving downtown metropolis of Wisconsin's capital city, this year's conference provided a scenic yet vibrant environment for the friendly exchange of ideas that transpired throughout the conference. Overall, 174 attendees and five guests arrived from 16 different countries and shared their progress and accomplishments via 65 oral and 18 poster presentations. The composition of attendees included 104 from industry, 31 from government and 39 from academia.

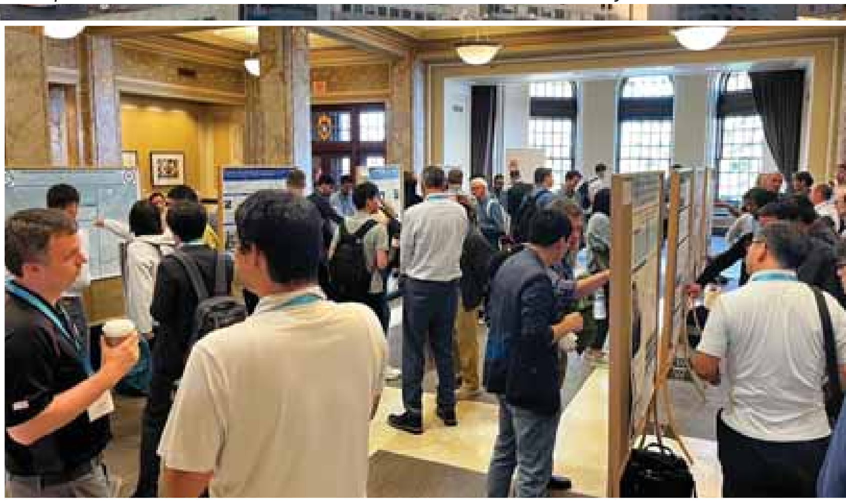
As in previous years, the conference activities were preceded by a CSA-sponsored short course on cryocoolers, taught by Ray Radebaugh and Fons DeWaele. The formal conference launched with an evening reception on Monday, followed by three days of oral and poster reports covering topics on aerospace coolers, and developments with JT, Stirling, Brayton, GM, and pulse tube coolers. Additional sessions addressed sub-kelvin cooling, regenerator and recuperator investigations, novel coolers, and integration of cryocoolers for superconductivity and other applications. Two special plenary sessions provided an extended look at the development of dilution refrigerators for quantum computing by Bluefors and an exciting report of the commercial deployment of a pulse-tube-based hydrogen liquefier at a mining site in Australia by Fabrum.

Sponsored by the UW-Madison Department of Mechanical Engineering, a parallel poster session allowed participants to leisurely peruse 18 different presentations while enjoying award-winning Babcock Hall ice cream. Prior to the poster sessions, the authors each presented a one-minute preview of their work, inviting the attendees to visit and explore their poster.

In addition to the welcome reception, social and professional interactions between attendees were enhanced by the daily on-site meals including a light breakfast served adjacent to the main meeting hall and lunch served outdoors on the balcony overlooking Lake Mendota. The conference banquet at the Vintage Brewing Company in Sauk City highlighted classic Wisconsin features such as a drive through dairy farmlands, a view overlooking a wooded riverside, and a double rainbow following a surprise downpour. An awards presentation highlighted the conference banquet with the ICC Exceptional Service Award given to Mark Zagarola of Creare and the Best Student Paper Award from the ICC22 conference going to Ali Ghavami and Alana Homa of Georgia Tech for their paper entitled "Optimizing Flow Uniformity through Regenerators of Large Cryocoolers Using CFD."

Preparations for the conference were spearheaded by the conference chair, Professor Franklin Miller (UW-Madison), the conference program chairs, Professor John Pfotenhauer (UW-Madison) and Dr. Santhosh Gandla (Sumitomo Cryogenics of America), and the program committee made up of 14 long-term contributors to the International Cryocooler Conferences. All participants received daily access to preview and/or download online versions of the presentations, access which continues to the present. (Access to the conference abstracts is also available to the public on the conference website https://cryocooler.org/.) Overall, the conference ran very smoothly and efficiently, drawing compliments from many of the attendees. The next International Cryocooler Conference, ICC24, scheduled for 2026 will be hosted by Bluefors and take place in Syracuse, New York. **www.cryocooler.org**

Participants of the ICC23 in the Great Hall of Memorial Union at the University of Wisconsin – Madison. Credit: ICC23



A poster session. Credit: ICC23

Double rainbow over the Wisconsin River. Credit: ICC23

Conference chair handoff from the 2024 chair Franklin Miller (right) to the 2026 chair Richard Dausman (left). Credit: ICC23

The Applied Superconductivity Conference Elevates in Salt Lake City

by Luisa Chiesa, Chair, ASC 2024

The Applied Superconductivity Conference (ASC 2024) took place at the Salt Palace Convention Center in Salt Lake City, Utah, September 1-6, 2024. ASC 2024, together with ELEVATE, our integrated thrust to promote educational opportunities, professional and leadership development, and outreach between our scientific community and society are the main thrusts of the Applied Superconductivity Educational Foundation (ASEF). The mission of the foundation is to promote exploration, learning, outreach and the exchange of scientific and technical ideas, breakthroughs and accomplishments, and to provide an array of educational and interactive experiences and events.

The program chairs, Tiina Salmi and Hélène Felice, together with the topical chairs and the more than 140 members of the program committee, prepared an outstanding and exciting scientific program with a wonderful lineup of plenaries and many oral and poster sessions. The participants to the conference are the ones who make the program relevant, vibrant, interesting and novel. Over 1,400 people joined ASC 2024 (including exhibitors). Student participation was solid with more than 300 students present in Salt Lake City.

The conference offered the opportunity to catch up on the latest research and developments in applied superconductivity across electronics, materials, and large-scale applications. The scientific program committee curated an outstanding agenda featuring over 400 oral presentations and 700 poster presentations, five distinguished plenary lectures and 13 special sessions. In designing the program, a special emphasis was placed on sustainability. This is a pressing topic across all fields, and it is important for the community to understand its relevance and impact on their work.

The plenary lectures covered current and future trends in key areas like electronics, with a talk on neuromorphic computing, large-scale applications, with talks on the status of fusion reactor development and magnets for future particle accelerators. On the materials front, the latest developments in iron-based superconductors and the path forward for new material development were presented.

In the frame of the ELEVATE program, for the purpose of promoting professional and leadership development, an early career plenaries event was organized. This event is one of the highlights of the conference and has been part of the program since ASC 2018. In this session, early career scientists are given the opportunity to illustrate, with short plenary talks, their achievements or vision for future directions in our field.

Special sessions covered a broad range of subjects including superconducting quantum sensing, superconducting qubits, transition edge sensors and CMB-S4, but also challenges of and opportunities for superconducting materials, protection from failures and mechanical limits of REBCO magnets, and standards in the field of applied superconductivity. Public-private partnerships in fusion reactor development were also discussed, and the Superconductivity Global Alliance reported on its most recent achievements. In addition, ASC 2024 hosted memorial sessions to honor the remarkable contributions of Harold Weinstock, Sae Woo Nam, Theodore Van Duzer and William Sampson to the field of applied superconductivity.

During ASC 2024, CSA awarded the Roger W. Boom award to Dr. Ram C. Dhuley for his pioneering work on cryocooler conduction-cooled SRF accelerator cavities and his leadership for the large-scale cryogenic distribution system for the PIP-II accelerator. Dr. Dhuley has also made noteworthy contributions to the editorial activities of the cryogenic engineering community.

Within the Applied Superconductivity Education Foundation mission, the ELEVATE program, in its third cycle in 2024 and under the guidance of ELEVATE Chair for ASC 2024 Anna Fox, was integrated into the conference organization. It offered special events and opportunities for all participants for growth of both technical and professional skills. This program also offered numerous opportunities for students and early career scientists to network and discover what a career in applied superconductivity might be.

Among the events offered were short courses with subjects in large-scale, materials and electronic, a student welcome reception and a student/mentor trivia lunch, and student and young professional oral session moderator training. A new event was live storytelling in collaboration with the Story Collider, where some of the conference participants recounted their journeys, bringing the community together in celebration of the diversity of our community and to showcase the human side of science. In addition, outreach events were organized with the Natural History Museum of Utah and Girl Scouts of Utah.

The conference was not only a chance to talk research and science but also learn, connect and enjoy social events. Many exhibitors joined ASC 2024 and the welcome receptions and after-party karaoke events provided opportunities to network, laugh and enjoy the company of industry colleagues. **www.appliedsuperconductivity.org/asc2024**

From left: Anna Fox (ELEVATE chair), Tiina Salmi (Program Chair), Luisa Chiesa (Chair), and Hélène Felice (Program Chair). Credit: ASC 2024

Plenary session. Credit: ASC 2024

Welcome/exhibitor reception. Credit: ASC 2024

Live Storytelling Event in collaboration with The Story Collider: www.storycollider.org. Credit: ASC 2024

Danaher Cryo Releases Optimized Rodeo Control System

by Charlie Danaher, President, Danaher Cryogenics

To complement its family of sub-Kelvin cryostats, Danaher Cryogenics announces the release of its new Rodeo Control System. In an elegant, compact package, the Rodeo Control System gives the user great functionality, including system configuration and control, data collection and graphing, and system status. The Rodeo system is composed of the HorseBox Temperature Controller, Danaher's proprietary HorsePower software, a touch-screen monitor and computer.

Rodeo Control System operating on a Danaher Cryo Model DC3 Palomino Cryostat. Credit: Danaher Cryogenics

The Evolution of Control Systems

Have you ever been frustrated when all of the electronic components in your experimental setup are from different vendors, are excessively bulky and are way overkill? You know, like when the only economical power supply you could find to drive your magnet is a four-quadrant model, and all you need is a single quadrant. Or when the Resistance Bridge you are using for reading your temperatures is way fancier than what's necessary.

At Danaher Cryogenics, those days are over. The fruits of a recent development effort are a control system that's intentional and optimized for the job at hand. Instead of having a half dozen different component boxes stacked up in a 19" rack, Danaher has consolidated all the required functionality needed to control a Danaher cryostat (with a Chase cooler inside) into a single, 3U high, box. No more running cables between a temperature reader (or two), a power supply (or two), a PID controller and various other components. All of this functionality is consolidated into a single box.

HorseBox Temperature Controller

The HorseBox Temperature Controller contains the following functionality: Lock-in amplifiers for reading Ruthenium Oxide or Cernox® thermometers; diode readers for reading silicon diodes; PID modules for temperature control; heater drivers (low, high, and warmup) for powering gas gap heat switches and sorption pumps, and allowing for rapid, automated warmup.

Modularity and Expandability

One of the attractive features of the HorseBox Temperature Controller is its versatility. The system was intentionally designed to be expandable in a robust and modular fashion. The idea is to allow for convenient addition of modules to increase system sophistication, while only including necessary complexity to provide the required functionality.

In its simple state, HorseBox can be configured to run the Model DC1 Colt cryostat, which incorporates the Chase GL4 sorption cooler – a simple, single-shot ^{4}He fridge. While in its most elaborate state, HorseBox can be configured to control a Model DC6 Charger cryostat, which hosts the Chase CMD cooler – a complex continuous fridge with Qty 4 sorption pumps and a mini dilution module.

The designed-in modularity allows for easy expansion. In its most complex manifestation, HorseBox can contain as much as Qty 8 lock-in amplifiers, Qty 12 diode readers, Qty 10 low power heaters, Qty 5 high power heaters, and Qty 2 warmup heaters.

User Experience with HorsePower

Danaher's new HorsePower software makes interaction with, and control of, the cryostat a rewarding experience.

At the push of a button, the user can commence a cooldown cycle of their cryostat. Following the start command, the software then monitors vacuum levels, starts the pulse tube upon reaching a predefined pressure level and completes the system cooldown, including initiating and controlling the Chase cooler cycle. The cooldown process completes with the system beginning a

PID regulation of the cold stage at the user's desired temperature.

To help with rapid sample exchange (or experimental adjustment), the user simply clicks the button. HorsePower will then automatically end the temperature regulation process, turn off the compressor, and energize the warmup heaters until the system is ready to open.

Network connection allows the user to remotely monitor and interact with the HorsePower software. All the while, the system is collecting data and generating plots on the large touchscreen. Exporting data for analysis or archival purposes is straightforward, as in clicking on an icon.

Our goal in developing the Rodeo Control System was to make using a cryostat a more convenient and rewarding process. We hope that we've gained at least a modest level of success in that aim.

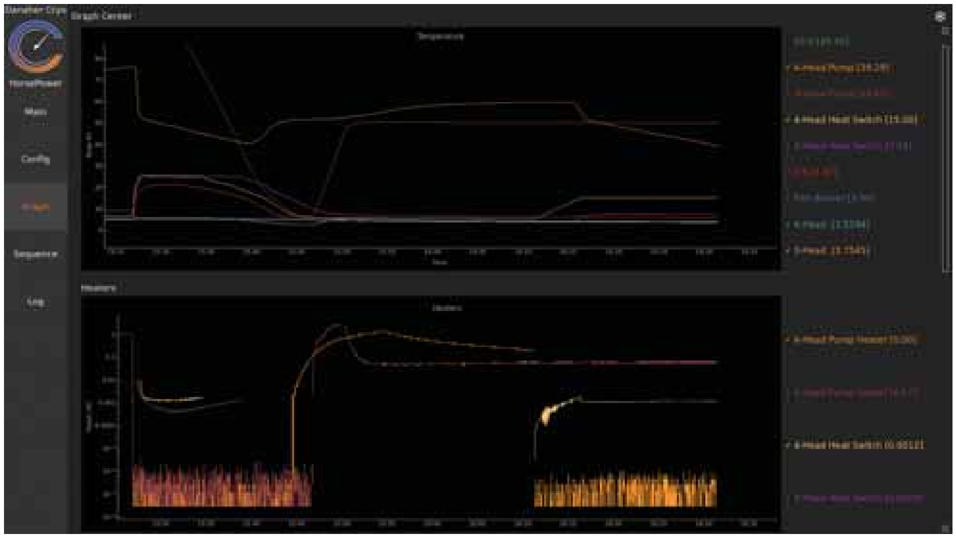
Feedback from Customers

University of Colorado, Colorado Springs Professor Dmytro Bozhko took delivery of the first Rodeo Control System, which was integrated into his new Model DC3 Palomino cryostat.

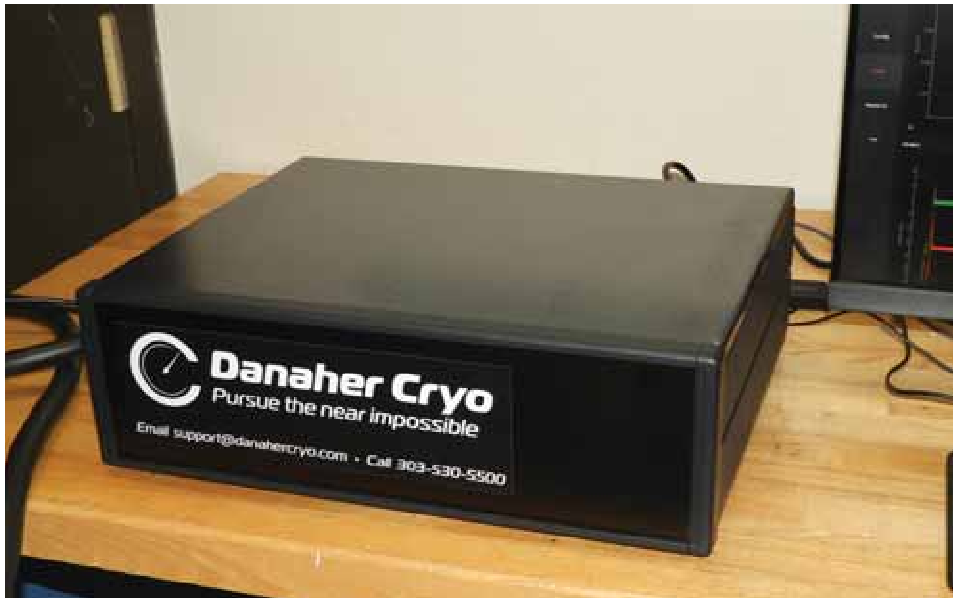
"The integrated control system provides a convenient one-push-button control of the cooldown and warmup processes as well as comprehensive logging and display of the information about all system parameters during the system's operation," states Professor Bozhko. "The well-thought-out thermal system provides for one-day cooldown to the base temperature and over a day hold time before needing to recharge the Chase cryocooler, which takes less than two hours and is fully automated. Warmup of the system is also assisted by integrated heaters allowing the system to reach room temperature overnight. Additionally, the system features a bayonet vacuum jacket fixture, which simplifies access to the cryostat and allows even single-person assembly."

Future Plans for the Palomino, Danaher Developments

The 300 mK cryostat will be used for a broad range of quantum magnetism



Screenshot of HorsePower software operating on a touchscreen monitor. Credit: Danaher Cryogenics



HorseBox Temperature Controller. Credit: Danaher Cryogenics

experiments, including the study of magnon Bose-Einstein Condensation (BEC) in the quantum limit using microwave spectroscopy as well as optical techniques like Brillouin Light Scattering (BLS) and the Time-Resolved Magneto-optical Kerr Effect (TR-MOKE). Here are a few other exciting things happening at Danaher Cryogenics.

Danaher Cryogenics is partnering with the University of Colorado and NIST laboratories in Boulder, CO to commercialize the Adaptive Cooling Technology (ACT) Pulse Tube invention. This product offers promise to the quest for more rapid and efficient cryogenic research. By speeding up system cooldown speed, and doing it without expending more energy, ACT will facilitate quantum research and development. Lastly, Danaher Cryogenics recently filed patent paperwork for its new SwiftSeal bayonet vacuum jacket fastening system. SwiftSeal makes opening and closing a cryostat a piece of cake. **www.DanaherCryo.com**.

Fabrum and Fortescue Commission Australia's Largest Liquid Hydrogen Plant on a Mine Site

by Sandra Lukey

In a landmark development for green technology, New Zealand-based Fabrum, an industry leader in zero-emission transition technologies, has successfully partnered with Australian mining giant Fortescue to design, build and commission the largest liquid hydrogen plant at a mine site in Australia. This state-of-the-art facility, unveiled in August at Fortescue's Christmas Creek mine, represents a significant step forward in the decarbonization of heavy industry and mining operations.

The facility, which includes a hydrogen liquefaction plant, storage capabilities and a liquid hydrogen refueling station, is designed to produce approximately 350 kilograms of liquid hydrogen per day, with a storage capacity of 600 kilograms. The plant's output will power Fortescue's zero-emissions mining equipment prototypes, such as the Offboard Power Unit and the hydrogen-powered haul truck. This initiative marks a bold leap toward Fortescue's commitment to achieving net-zero emissions and reinforces its leadership in the green industrial revolution.

Australia's largest liquid hydrogen plant on a mine site designed and built by Fabrum in collaboration with Fortescue is now operational at Fortescue's Green Energy Hub at Christmas Creek in Western Australia. Credit: Fabrum

Fabrum Executive Chair Christopher Boyle shared his enthusiasm for the project and emphasized the pivotal role of hydrogen in creating a sustainable future. "We're delighted to be developing world-leading hydrogen technologies for our partner, Fortescue, to help the company achieve its decarbonization goals. While others in the industry might see the decarbonization challenge as too big, Fortescue is leading the way in adopting new technologies to enable a zero emissions economy. Together, we're demonstrating that the future is here now."

Fortescue, headquartered in Western Australia, has long been at the forefront of environmental innovation. "Fortescue is moving at rapid speed to decarbonize, and the completion of our hydrogen facility, which is the largest gaseous and liquid hydrogen plant on any mine site in Australia, is testament to our commitment to leading heavy industry in decarbonizing," Fortescue Metals Chief Executive Officer Dino Otranto stated, echoing Boyle's sentiments and highlighting the significance of the new facility. Otrano also emphasized hydrogen's potential to decarbonize mining processes, from powering buses and heavy mining equipment to producing green iron.

Fabrum Chief Executive Officer Dr. Ojas Mahapatra, acknowledged the long-term potential of the collaboration with Fortescue. "This is the first project we've collaborated on with Fortescue, and it highlights the great opportunities we see to help each other be successful in the future. This project also represents our entry into the mining and minerals industry, which complements our work in heavy transport, aviation, and other sectors," he noted.

For more than two decades, Fabrum has been at the cutting edge of cryogenic and hydrogen technology. The company's cryocooler technology is integral to hydrogen liquefaction plants, refueling stations and mobility solutions across multiple industries, from aviation to heavy transport. With a focus on sustainability, Fabrum has applied its innovations to create a cleaner future for industries across the globe.

Fortescue's ambitions are no less bold. As one of the world's largest iron ore producers, the company aims to achieve net-zero terrestrial emissions (Scope 1 and 2) by 2030, driven by its portfolio of green hydrogen and ammonia projects. This partnership with Fabrum reinforces Fortescue's mission to decarbonize mining and other hard-to-abate sectors, signaling a new era for industrial-scale hydrogen adoption.

As Fabrum and Fortescue embrace a future moving toward zero emissions, this latest hydrogen plant is set to become a global benchmark for clean energy technology. By harnessing hydrogen's potential, the collaboration is helping to reshape how industries power their operations and demonstrating that decarbonization, once seen as a challenge, is now a reality. **www.fabrum.nz**

OPW's White Paper Inspires New Standard in LH_2 Refueling Operations

by Felipe Machado, OPW Clean Energy Solutions

It's a fact of life in industrial processing that in order to accomplish "good" things you must sometimes have to work with potentially "bad" things. Such is the case with liquid hydrogen, or LH_2. For example, as the industrial world continues to look for new ways to move away from the use of traditional fossil fuels to power vehicles and industrial processes, a number of alternatives have begun to rise to the fore. For the most part, this quest to expand the energy pool via "green" clean-energy alternatives is being driven by environmental, social and governance (ESG) initiatives that are aimed at reducing the high carbon footprint, greenhouse gas emissions and ozone depletion potential that are implicit in fossil fuel usage, which many argue are at the forefront of global climate change.

The HydrOMac® LH_2 nozzle is lighter than competing models, making it easier to handle during refueling. Credit: Gawda Media

While propane and liquid natural gas have traditionally been the most popular among the new wave of clean-energy fuels – with Europe, China and India at the forefront of their use – hydrogen has begun to gain additional attention and traction as another promising alternative. In fact, in 2021 the US Department of Energy announced the creation of the Regional Clean Hydrogen Hubs program, which offered $7 billion in grants to companies that would like to develop more hydrogen liquefaction plants, with many traditional oil-and-gas producers showing interest in expanding their horizons into the LH_2 universe. In late 2023, seven hub projects were selected for funding through the program, with a network of new liquefaction facilities that will eventually span the country from the mid-Atlantic to Pacific Northwest and Gulf Coast to upper midwest. Additionally, besides all the controversies around the electric vehicle market and applications, electrification alone can't solve the road to zero emissions given its interconnectivity with the grid and battery technology limitations.

The simple truth is that a clean-energy future is coming, but it can only be realized once an infrastructure is in place that makes the use of alternative fuels economically viable – and unquestionably safe to dispense. This condensed white paper focuses on the challenges that are inherent in the dispensing of LH_2 and how they must be overcome before the fuel can assume a prominent place in the world's motor fuel pool.

The Challenge

While LH_2 has the potential to power all motor vehicles, it is increasingly being viewed as a top choice for long-haul transport, including trucks, planes, and ships. However, the challenge lies in transporting the fuel in the massive quantities required. LH_2's carbon-neutral status and its clean emissions of water and air make it an attractive energy source, but its volatile nature creates difficulties in harvesting, refining, transporting and dispensing. Ensuring safety throughout its production and supply chain is essential, regardless of the quantities handled.

One of the main challenges with LH_2 is its working temperature of -423 ºF (-253 ºC), which is close to absolute zero. This makes it one of the most demanding cryogenic gases to work with, requiring dispensing equipment to include heavy thermal insulation to prevent significant losses from evaporation. Another concern is hydrogen embrittlement, a phenomenon where exposure to hydrogen weakens metals, causing a reduction in tensile strength, ductility and fracture toughness. In extreme cases, this can lead to the catastrophic failure of components. To reduce this risk, more resistant materials, such as high-quality stainless steel, should be used in LH_2-dispensing nozzles. Additionally, the precision engineering of moving parts and seals is vital for ensuring safety. PCTFE is recommended for seals due to its high tensile strength and ability to remain stable at ultralow temperatures.

Beyond material concerns, the nozzle must be designed to prevent leaks, with the ability to immediately stop the flow if a leak occurs, to avoid dangerous situations. Automated flow control systems are also necessary to allow the operator to remain at a safe distance during refueling. Finally, LH_2

systems must address the risk of liquid air buildup, which can result in highly combustible liquid oxygen forming on the nozzle during refueling. To prevent this, the dispensing system should be jacketed and maintain an extremely high vacuum to keep outer surfaces at ambient temperature, eliminating the possibility of liquid air accumulation.

The Solution

RegO® Products, part of OPW Clean Energy Solutions, has introduced the HydrOMac® LH_2 refueling nozzle to tackle the unique challenges of LH_2 handling. This nozzle is designed to offer a safe and reliable refueling experience that mirrors the familiar process of traditional diesel fueling, ensuring ease of use for consumers.

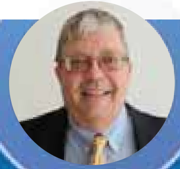
The HydrOMac nozzle reduces complexity in LH_2, dispensing with a streamlined design. It features built-in leak detection and automated fuel control, allowing operators to refuel from a safe, remote location. A three-stage, thermally isolated operation enhances both efficiency and performance, while the jacketing is engineered to meet the low temperature requirements of LH_2 and prevent the dangerous buildup of liquid air. Additionally, the nozzle is lighter than competing models, making it easier to handle during refueling.

The HydrOMac® LH_2 nozzle is meticulously designed to meet the specific demands of handling liquid hydrogen, enabling a reliable and secure transfer from storage tanks to the point of use. *Credit: OPW*

These safety-focused and user-friendly features make the HydrOMac nozzle intuitive for consumers, removing any ambiguity during operation. This ease of use helps LH_2 sellers replicate the traditional vehicle fueling experience, addressing any consumer concerns about handling an unfamiliar fuel. The HydrOMac nozzle is the latest in RegO's line of hydrogen-handling products, which includes valves, regulators and other critical components.

There's no getting around it – the clean-energy future is coming, and in order to optimize its potential from a production, supply, financial and safety aspect it must be outfitted with equipment and systems that are able to meet the unique handling characteristics of the growing roster of clean-energy fuels. In that vein, LH_2 stands poised to assume an elevated role in the nation's motor-fuel pool, especially as it relates to the fueling of large vehicles.

In order to achieve success, though, the world's producers and suppliers of LH_2 must be fully aware of the "bad" characteristics that are fundamental to its handling and dispensing in order to realize the "good" that can come from its use. RegO and OPW Clean Energy Solutions have taken a positive step forward in that quest. **www.opwglobal.com**



Cryo Bios

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

Dr. Steven Van Sciver

Dr. Steven Van Sciver's path into cryogenics was marked by a series of key experiences that ultimately led to his emergence as a leader and expert in the field. His journey began at Lehigh University, where, as an undergraduate, he was introduced to low temperature physics during a thermodynamics class. At the time, his exposure to cryogenics was brief, but it planted the seeds for what would become a lifelong passion.

It was during his graduate studies at the University of Washington (UW) in Seattle where his interest truly took shape. Under the mentorship of Oscar Vilches, an accomplished experimental low temperature physicist, Dr. Van Sciver honed his expertise. His dissertation work involved building a ^{3}He-^{4}He dilution refrigerator to cool He3 films, allowing him to measure specific heat down to 40 mK—a challenging task that prepared him for the intricacies of cryogenic engineering. Around the same time, Dr. Van Sciver became captivated by quantum fluids, particularly after reading Bill Keller's book on helium-3 and helium-4. It was these foundational experiences that solidified his place in the world of cryogenics and led him to explore applied superconductivity.

Upon completing his Ph.D., Dr. Van Sciver found himself entering a challenging job market, but a stroke of fortune led him to a position at the University of Wisconsin-Madison in 1976, where he joined the Superconducting Magnetic Energy Storage project under the leadership of Roger W. Boom and Glen McIntosh. Tasked with developing helium II technology for superconducting magnet cooling, Dr. Van Sciver embarked on a groundbreaking research path. At the time, little was known about the practical fluid dynamics and heat transfer properties of helium II, and his work helped lay the groundwork for understanding this unique fluid's behavior in cryogenic applications.

Steve Van Sciver's cryogenics group at the University of Wisconsin – Madison in the mid-1980s. Many of Steve's graduate students and postdocs have had successful careers doing cryogenics R&D in industry, government laboratories and academia. Credit: Steven Van Sciver personal collection

Dr. Van Sciver's work at Wisconsin extended beyond helium II research. He played a key role in the formation of the Applied Superconductivity Center, alongside Boom and David C. Larbalestier, where the team tackled challenges in both fusion reactor design and cryogenics for high energy physics. His research was bolstered by a National Science Foundation grant and supported by a talented group of graduate students and postdoctoral researchers, many of whom would go on to become leaders in the cryogenics field.

It was during this period that Dr. Van Sciver realized the need for a comprehensive resource on helium applications in cryogenics, leading him to write *Helium Cryogenics*, first published in 1986. This seminal text became a cornerstone for those studying and working in cryogenics, providing clear guidance on helium's role in cooling systems and its practical applications. By this time, Dr. Van Sciver had also begun to establish a reputation as an exceptional educator, developing courses on applied superconductivity and cryogenic engineering at the University of Wisconsin.

In 1991, Dr. Van Sciver accepted an opportunity that would shape the next quarter-century of his career: a position at Florida State University (FSU) and the National High Magnetic Field Laboratory (NHMFL) in Tallahassee, Florida. The NHMFL, which was newly funded by the National Science Foundation, offered a unique environment for research and development in magnet technology. As a distinguished research professor and program director, Dr. Van Sciver took the lead in designing cryogenic systems for some of the most powerful magnets in the world.

One of his team's most significant achievements was the development of the cryogenic system for the NHMFL's 45 Tesla hybrid magnet. Using a helium II cryostat design with a satellite vessel containing the superconducting magnet—made from cable-in-conduit conductors—they were able to build a system that not only allowed for higher magnetic fields but also provided easier access to the magnet bore for experiments. The 45 T hybrid magnet remains the highest field DC magnet in the world.

At NHMFL, his expertise in helium II continued to evolve. Dr. Van Sciver and his team expanded their research into the fluid dynamics and heat transfer properties of helium II, developing methods to seed neutral density particles and use laser techniques to visualize two-fluid dynamics. These advances enabled the group to record flow patterns in both counterflow and forced flow helium II, providing critical insights into the behavior of this complex fluid under various conditions. His contributions culminated in the second edition of *Helium Cryogenics* in 2012, further solidifying his authority in the field.

Throughout his time at NHMFL, Dr. Van Sciver continued to foster collaboration, working closely with graduate students, postdocs, and visiting researchers. His mentorship has been a hallmark of his career, and many of his students have gone on to make significant contributions to the cryogenics community. Beyond the lab, Dr. Van Sciver's commitment to advancing the field extended to his role as American editor for the journal *Cryogenics* from 1994 to 2014. During his tenure, he raised the journal's impact factor and established the Cryogenics Best Paper Prize, ensuring the continued dissemination of high-quality research. He is also deeply involved with professional societies, serving on the boards of the Cryogenic Engineering Conference, the Applied Superconductivity Conference, the International Cryogenic Engineering Conference, and the Cryogenic Society of America (CSA). With CSA, many of Dr. Van Sciver's publications and lecture series are available through the society's online learning portal.

Steve Van Sciver was American Editor of the journal Cryogenics for 20 years (1994-2014). In 2006 his Cryogenics Co-Editors were Asian Editor Tom Haruyama (Ret. KEK) and European Editor Luca Bottura (CERN). Credit: Steven Van Sciver personal collection

Steve Van Sciver in the Cryolab at the NHMFL-FSU spring 2015. As part of community outreach, the Magnet Lab holds an annual open house for the public with the Cryolab being one of the highlights. Credit: Steven Van Sciver personal collection

Dr. Van Sciver's career has been recognized with several prestigious awards, including a CSA Fellow in 2007, the Kurt Mendelssohn Award in 2010 and the Samuel Collins Award in 2017. His international contributions are also notable, with sabbaticals in France, Japan and New Zealand that enriched his understanding of cryogenics across borders. Since his retirement from FSU in 2016, Dr. Van Sciver has remained active in the field as a consultant, working with organizations such as Microsoft and Northrop Grumman on cutting-edge projects like superconducting data centers and helium thermosiphon systems for MRI magnets. Through his decades of research, education and collaboration, Dr. Steven Van Sciver has left an indelible mark on the world of cryogenics. His pioneering work in helium II technology, contributions to magnet cooling systems and commitment to fostering the next generation of scientists ensure his impact will continue to shape the field for years to come.

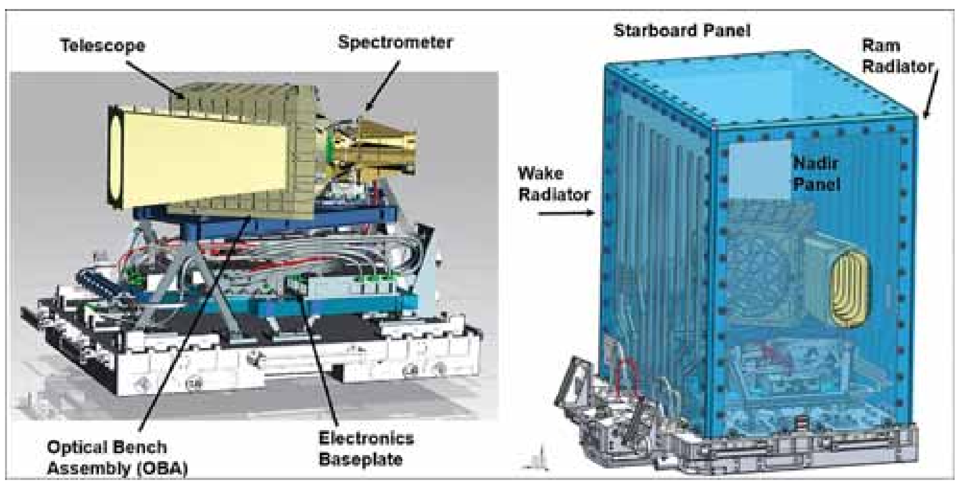
Space Cryogenics

By Ian McKinley, Perry Ramsey, Ernesto Diaz, Robert Green, Jet Propulsion Laboratory, California Institute of Technology

The EMIT Instrument after Two Years in Space

The Earth Surface Mineral Dust Source Investigation (EMIT) instrument is an imaging spectrometer that was developed at the NASA Jet Propulsion Laboratory and operates on the International Space Station (ISS). Its primary mission is to determine the mineral composition of the arid land dust source regions of Earth to advance our knowledge of the radiative forcing effect of these aerosols by measuring the visible to short wavelength infrared range of 380 nm to 2,500 nm.[1] Minerals that are dark in appearance can absorb sunlight and can warm Earth, while lighter-colored minerals can cool Earth. Prior to EMIT, uncertainties in the overall contributions of aerosols to radiative forcing in the Earth system resulted from assumptions that dust aerosol composition and optical properties were globally uniform despite variations that were documented but not measured globally.[1] The EMIT mission, at completion, has measured billions of high fidelity spectroscopic observations of Earth's arid and semi-arid mineral dust source regions.[1] In addition, EMIT has been able to detect methane and carbon dioxide and pinpoint locations where is it being released into the atmosphere.[2]

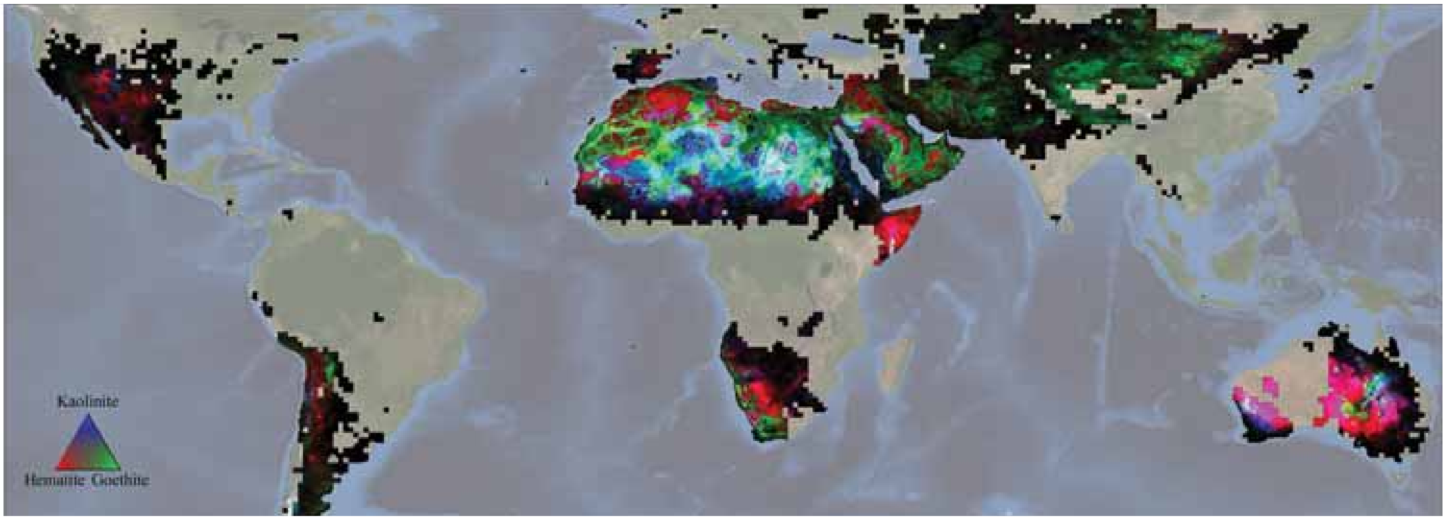
The Earth Surface Mineral Dust Source Investigation instrument attached to the International Space Station. Credit: NASA



Computer generated images of the Earth Surface Mineral Dust Source Investigation instrument. Credit: NASA

EMIT was launched on July 14, 2022, and has operated for two years in space. It was originally scheduled for a one-year science mission but has been extended through at least 2026. The instrument was transported to the ISS as unpressurized cargo aboard a SpaceX Falcon 9 rocket that launched from Cape Canaveral Air Force Station Space Launch Complex 39A. On July 16, 2022, the spacecraft successfully arrived and docked at the ISS. On July 22, EMIT was extracted from the cargo trunk and deployed at the ExPRESS Logistics Carrier 1 (ELC-1) Flight Releasable Attachment Mechanism 8 (FRAM 8).[3] On July 24, the instrument was successfully powered on and officially began its science mission.

The EMIT instrument is housed in a six-sided box that is roughly 1 meter by 1 meter by 1 meter. The bottom panel of the box is the ExPRESS Payload Adapter (ExPA) upon which the majority of the instrument components are mounted. One of the walls of the box is the nadir panel that has a baffle opening roughly 0.3 meter by 0.2 meter. Light enters the baffle and is reflected through two telescope mirrors before it passes through a slit into the Dyson spectrometer where the wavelengths are separated spatially into arrays that are then detected by the focal plane array (FPA). The instrument electronics boxes are mounted to a roughly 1 meter by 0.7-meter plate with embedded constant conductance heat pipes (CCHPs) that stands off from the ExPA by thermally isolating mounts. The optical bench assembly that includes the telescope, spectrometer and FPA is also mechanically mounted to the ExPA and sits above



The Earth Surface Mineral Dust Source Investigation instrument's first global maps of hematite, geothite, and kaolinite in Earth's dry regions. Credit: Jet Propulsion Laboratory, California Institute of Technology, NASA

the electronics mount plate. The ExPA unit is government furnished equipment that is used to make the electrical and mechanical connection to the ELC module.

The thermal control system of EMIT consists of a combination of active and passive components to maintain the instrument temperatures within the allowable limits. The FPA detector and spectrometer are maintained at 155 K and 246 K, respectively, by a single Thales Cryogenics LPT9310 cryocooler.[4] The FPA is surrounded by a cold shield that is thermally coupled to the spectrometer. The cryocooler is connected to each component by a tuned flexible thermal link made of pyrolytic graphite sheets (PGS). The waste heat generated by the cryocooler and electronics is transported to the ram and wake panels of the instrument enclosure that serve as the instrument radiators and are embedded with CCHPs. The expander portion of the cryocooler is connected directly to the wake radiator by PGS thermal straps while the compressor of the cryocooler is mounted to the same plate as the electronics. The electronics mount plate is connected to each radiator via a variable conductance heat pipe (VCHP). One of the key thermal design drivers for EMIT was the requirement to survive a six-hour unpowered transfer from the SpaceX Dragon to the ELC by a robotic arm. This requirement necessitated the need for the VCHPs to passively shut off without survival heat applied to their non-condensable gas reservoirs. This critical function was successfully demonstrated in test on a prototype unit from an Orbiting Carbon Observatory flight instrument prior to the detailed design phase.

The instrument has surpassed two years of operation in space with its overall thermal performance as predicted and no changes to cryocooler performance. To date, the cryocooler has accumulated over 21 operating months. On the fifty-first day after the initial power on, an ISS power fault condition was detected and the instrument put itself into standby mode with the cooler off for 115 days. Since then, the cooler has been powered on and is operating nominally. The heat rejection system has performed as expected by maintaining all components within their allowable flight temperatures while meeting the thermal requirements.

The research was carried out at the Jet Propulsion Laboratory, California Institute of Technology, under a contract with the National Aeronautics and Space Administration (80NM0018D0004).

References

[1] R.O Green et al., "The Earth Surface Mineral Dust Source Investigation: An Earth Science Imaging Spectroscopy Mission," 2020 IEEE Aerospace Conference, Big Sky, MT USA, 2020, pp 1-15, doi:10.1109/AERO47225.2020.9172731.

[2] https://earth.jpl.nasa.gov/emit/news/23/methane-super-emitters-mapped-by-nasas-new-earth-space-mission/

[3] J.S Cha et al., "Thermal Design of the Earth Surface Mineral Dust Source Investigation (EMIT)," Cryocoolers 21, International Cryocooler Conference, Inc., Boulder CO, 2021, pp 15-22.

[4] D.L. Johnson et al., "Characterization testing of the Thales LPT9310 pulse tube cooler," Cryocoolers 18, ICC Press, Boulder CO, 2015, pp. 125-133.

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

Superconducting Magnets for Current and Future Accelerators (I)

Particle accelerators represent the most extensive scientific projects globally, both in size and budget. Specifically, they garner significant interest within the cryogenic community due to being at the forefront of utilizing superconducting (SC) materials and magnet-cryomodules, often requiring a large helium liquefier/refrigerator. For the stats of the art, SC accelerators utilize thousands of SC magnets, each weighing several tons. These magnets are responsible for steering and reshaping the particle beams along beamlines spanning to tens of kilometers. Furthermore, several cutting-edge future SC accelerators have been proposed worldwide.[1-4] These proposals present numerous challenges and benefits to the cryogenics communities. These SC accelerators have various applications in high energy physics, nuclear science, materials science, astrophysics and medicine. The successful operation of existing and forthcoming SC accelerators would be impossible without the crucial contributions made by the SC magnets.

Various Functions of SC Magnets for Accelerators

An accelerator can be a ring (a circular accelerator), or a straight line (a linear accelerator). Particle beams in accelerators consist of numerous bunches of particles, such as protons, electrons, or heavy ions, moving at close to the speed of light. In an accelerator, there are various types of SC magnets, which create and control the magnetic fields needed for focusing/defocusing and compressing/decompressing, shaping the bunches like specific bullets. As illustrated in Figure 1, when a bunch of particles sized about several ns to ps moves vertically through the magnetic fields generated by a quadruple magnet, the Lorentz forces F are applied to the bunch. These bunches are functioning as microprobes that either collide with a target or other particles in the opposite direction, or generate light/laser.

Innovative Superconducting Dipole Magnets

Dipole magnets provide the primary magnetic fields to bend the trajectory of charged particles, ensuring they follow a circular or elliptical path. In the past, large SC accelerator magnets, such as those in Tevatron, RHIC, HERA, KEK, all utilized NbTi alloy operating with supercritical liquid helium (LHe) at ~ 4.5 K, generating magnetic fields of up to 5 tesla (5 T).[1-4] Figure 2 (left) shows a HERA dipole magnet, which has two layers of SC coils, laminated Al-collars in the vacuum container. Its cold mass supported by glass fiber structures with MLI on the thermal shields.

To optimize construction cost and accelerator size, the Large Hadron Collider (LHC) determined to advance to ~ 8T dipole magnets, which operate with subcooled helium II (superfluid) at 1.9 K.[5] The LHC ring accommodates 1,232 main dipoles. Figure 2 (right) illustrates the LHC dipole cryomodule, featuring two beam tubes, each housing its own paranal SC magnet coils within a shared yoke. The two-in-one design (or "twin-bore") enhances cost-effectiveness and optimizes space utilization. The cold mass is ~28,000 kg with an external diameter of 0.6 m and length ~15 m. The dipole inner coils have a Cu/SC ratio of 1.7, and the outer layer is 1.9. The SC filament diameters of the cable are 6-7 µm. The operation current is about 11.8-12.8 kA at 1.8 K. When the particles are accelerated from 450 GeV to 7 TeV, the dipole field will be increased from 0.54 to 8.3 T to keep the particle bunches in the same trajectory.

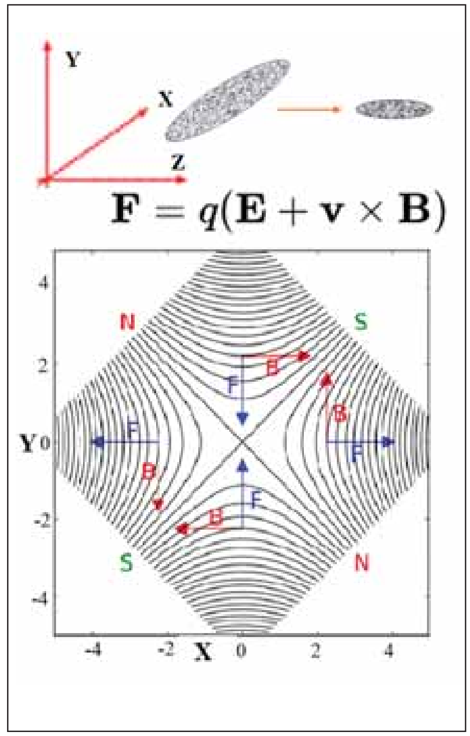


Figure 1. Cartoon of particle bunch, Lorentz force to particles, and magnetic fields by quadruple magnets. Credit: Shu and Demko

Advanced Superconducting Quadruple, Sextuple, Octuple and Others

Quadruple magnets have a specific configuration of magnetic field B gradients to focus/defocus and compress/decompress the beam and helps to keep the beam tightly collimated and for precise control over the bunch's dimensions as show in Figure 1 and Figure 3 left. The LHC main quadruple also utilizes the two-in-one design with two SC magnets sharing the common yoke in one cryomodule, operated at 1.9 K. The main quadruple magnets have the following key parameters at 7 TeV operation: nominal B gradient 223 T/m, peak field in SC conductor 6.85 T, I = 11.8 kA, L = 5.3m, total mass 6500 kg.

Sextuple magnets are used to correct higher-order aberrations in the magnetic field, addressing the beam nonlinear effects. Figure 3 (right) shows a KEK design model of the QC1P quadruple magnet and sextuple leak field cancel magnet.[2] Other correcting magnets are utilized, including Octuple, skew magnets and solenoid magnets (for focusing and collimating beams).

Glorious Achievements and Challenges to Future Accelerators

The SC accelerators have contributed to several groundbreaking discoveries in particle physics and glorious achievements in many other areas. Beginning with the Tevatron in 1983, followed by HERA in 1991, RHIC in 2000, and finally the LHC in 2008, all large-scale accelerators have been constructed with NbTi magnets.

Encouraged by these remarkable achievements, several ambitious accelerator projects have been proposed globally. These projects are not limited to, include (Figure 4): HL-LHC (High-Luminosity LHC) and FCC (Future Circular Collider) at CERN; the Muon Accelerator at Fermilab and EIC at BNL; Super-KEKB and ILC (International Linear Collider) in Japan; and SPPC (Super Proton-Proton Collider) in China.[1,3,6-10]

All these proposed projects face two categories of challenges. Firstly, each requires a financial budget of billions of US dollars. Secondly, the yet-to-be-approved projects and studies for future accelerators all rely on crucially higher-performing SC cables and advanced magnets capable of generating much greater magnetic fields surpassing those for the LHC with 8.5 T. Dr. Shoji Asai, the new director of KEK, expressed concern: “I am afraid that our next major project has become too large and will cost more than one country can afford, which is why we need the ILC to be a global project.”

Future Superconducting Cable Development for Large Accelerators

All present accelerator magnets have used for decades the NbTi SC Rutherford cables. These accelerator magnets are

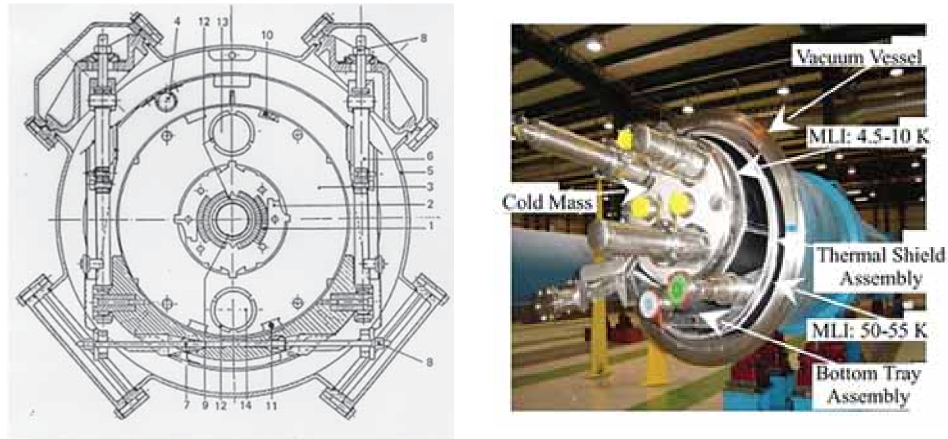


Figure 2. Left: Cross-section of HERA dipole magnet, Credit: DESY. Right: LHC dipole cryomodule assembly. Credit: P. Védrine CERN

Figure 3. Left: Cross-section of LHC embedded.[5] Credit: P. Vedrine. Right: Model of the KEK QCIP quadruple and sextuple magnets.[2] Credit: N. Ohuchi

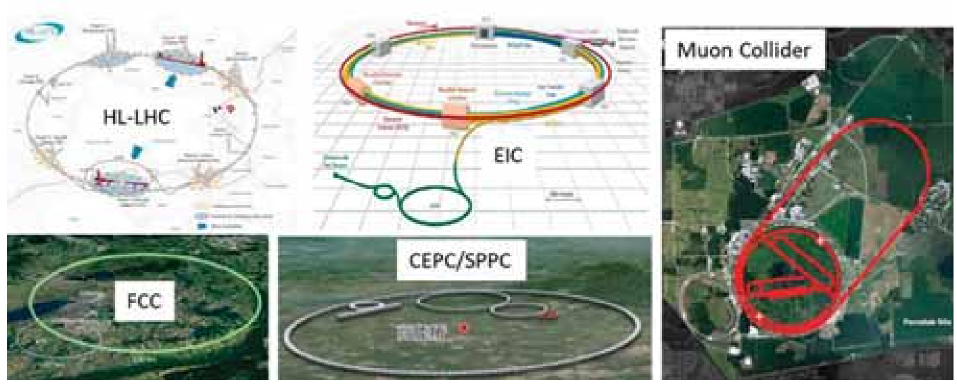


Figure 4. Proposed layouts of the future accelerators: HL-LHC (CERN), EIC (BNL), FCC (CERN), SPPC (China) and Muon Collider (Fermilab).[9] Credit: L. Bottura et al

successfully reached to, but is also limited by 8–9 T. In the short term (~ next 5 years), the HL-LHC at CERN will require an 11 T field. The inspiring magnetic fields by next-generation accelerator magnets shall be up to 15–16 T.[1,9-11] For further significant increase in the cost efficiency and compact accelerator, 30 T magnetic fields are on the table for discussion.

Such fields require new SC materials. The first logical candidate is Nb_3Sn, which has a critical field of about 30 T and a critical T of about 18 K, outperforming NbTi by a factor of two.[11] Nb_3Sn has not yet been utilized for large accelerator magnets due to its inherent brittleness, making it unable to withstand significant stress and strain without special precautions. R&D based on Nb_3Sn with operation fields up to 15-16 T has shown good progress.[1,11] These R&D Nb_3Sn accelerator magnets consist of winding the magnet coil with glass-fiber insulated cables made of multifilamentary wires that contain Nb and Sn precursors in a Cu matrix

▶ continues on page 30

 Continued from page 29

(Figure 5). However, A field of 16 T seems to be the upper limit with a Nb_3Sn accelerator magnet.

Critical magnetic fields of HTS materials are about 10 times higher than that of NbTi. Initial trials for accelerator-class HTS magnets have been started by several institutes globally. [1,7,11] It is still too early to count on its practical applications.

Future Superconducting Magnet Development for Large Accelerators

To increase the LHC integrated luminosity at ATLAS and CMS by a factor of 10, the HL-LHC requires very large-aperture quadruple, with fields at the coil about 12 T. Nb_3Sn technology of 12 T magnets is sufficiently mature to meet this requirement, which are considered as a springboard to the future accelerator magnets. Figure 6A is one of the 11 T Nb_3Sn dipoles for the HL-LHC, currently being built and tested at CERN and Fermilab as a fruits of the collaboration. [1,9]

For future circular colliders, the target dipole field has been set at 16 T for FCC-hh, allowing proton–proton collisions at an energy of 100 TeV, while China's SPPC aims at a 12 T dipole, to be followed by a 20 T dipole. Great efforts have been focused on the development of a series of short Nb_3Sn magnets (> 1 m) to demonstrate the technology with "racetrack style coils." Figure 6b presents a successful roadmap of record fields attained with various Nb_3Sn dipole magnets:[1] at liquid He (4.2K, red) or superfluid He II (1.9K, blue). Solid symbols are short (> 1 m) demonstrator with no bore, while open symbols are short models (> 1 m) and long magnets with bore. For comparison, past and present SC colliders are shown as triangles. Besides, IHEP-CAS etc. are carrying out R&D of HTS accelerator magnets potentially for SPPC.

Road to the Future

It is crucial to maintain an energetic plan from now on. With critical decisions looming regarding future accelerators, the core technology must be ready for imminent requirements. Due to the lengthy development cycle, relying on the private sector to

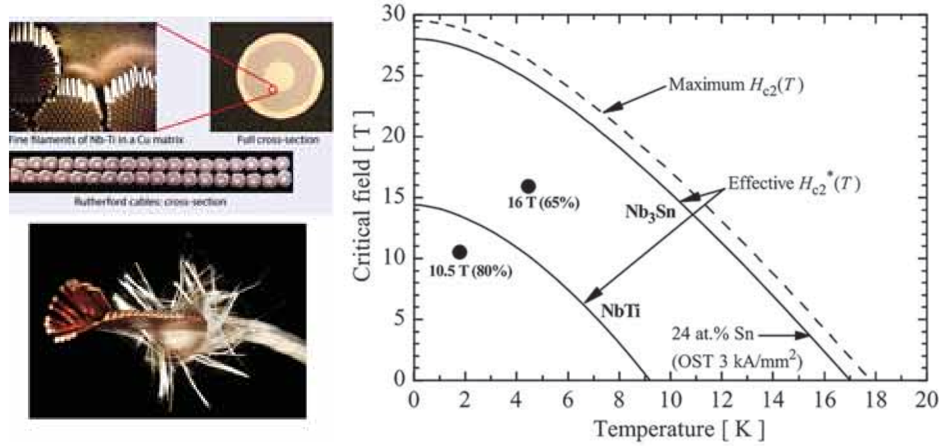


Figure 5. Upper left: NbTi cable. Lower left: Nb_3Sn cable for future colliders.[1] Credit: L. Bottura and M. Brice, CERN. ***At right: The phase diagram of T vs. critical magnetic field with record magnet-fields for NbTi and Nb3Sn.***[11] Credit: A. Godeke

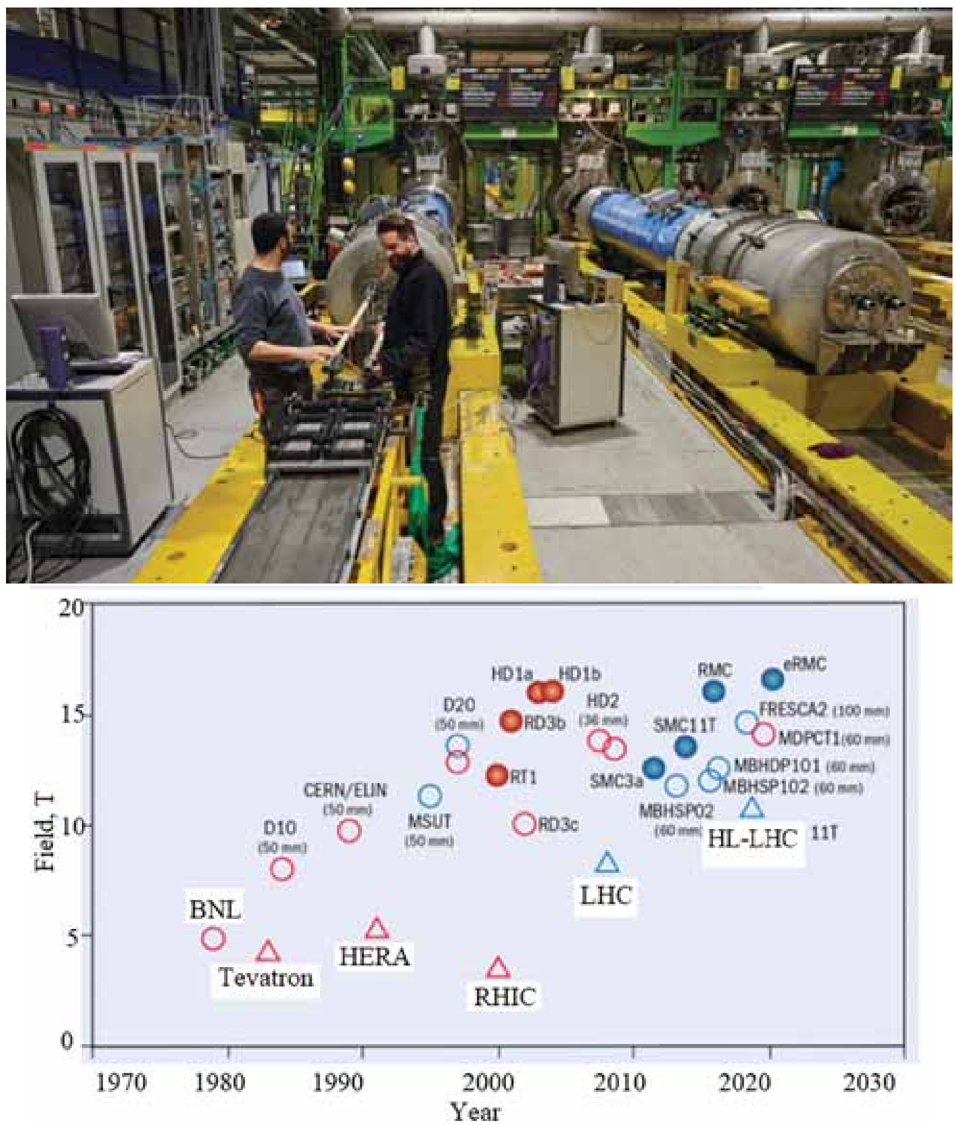


Figure 6. Upper: Nb3Sn 11 T dipoles for the HL-LHC, CERN-PHOTO-202002-038-5. Lower: Summary of recorded exist and future SC magnets for accelerator,[1] Credit: L. Bottura

advance and sustain the plan of high field magnets for accelerators is not realistic. Therefore, ensuring critical technical know-how and infrastructure in this field with international collaborations is essential for future success. High-energy physics and accelerators are crucial, yet proposed accelerators are becoming larger and costlier. Professor Chen-Ning Yang, a Nobel laureate has a suggestion: People might prioritize seeking more cost-efficient technologies of particle acceleration and collider.

References:

[1] Bottura, L. (2019). "Accelerating Magnet Technology." CERN. Retrieved from www.cerncourier.com, September 2019.

[2] Ohuchi, N., et al. (2022). "SuperKEKB Beam Final Focus Superconducting Magnet System." *Nuclear Instruments & Methods in Physics Research A*, 1021, 165930.

[3] Gourlay, S. (2023). "Technology Demands of a Muon Collider and Its Relation to Other HEP Projects." Presented at EUCAS, Italy, September 2023.

[4] Wolff, S. (1986). "Superconducting Magnets for HERA." Presented at the 13th International Conference on High-Energy Accelerators, Novosibirsk, 1986.

[5] Védrine, P. (2014). "Large Superconducting Magnet Systems." *Proceedings of the CAS-CERN Accelerator School*, CERN-2014-005.

[6] Shu, Q.-S., Green, G., Neuffer, D., Summers, S., Simrock, S., & Willen, E. (1998). "Superconducting RF Cavities and Magnets for a 4-TeV Energy Muon Collider." *Advances in Cryogenic Engineering*, 43.

[7] Wang, F.-L., & Li, Y.-H. (2022). "IHEP Makes the Case for Accelerator R&D." CERN. Retrieved from www.cerncourier.com, December 2022.

[8] Asai, S. (2023). "The Future Is International." CERN. Retrieved from www.cerncourier.com, November 2023.

[9] Bottura, L., Prestemon, S., Rossi, L., Alexander, R., & Zlobin, V. (2022). "Superconducting Magnets and Technologies for Future Colliders." *Frontiers in Physics*, 10.

[10] Demko, J., Fesmire, J., & Shu, Q.-S. (2022). *Cryogenic Heat Management: Technology and Applications*. CRC Press, Taylor & Francis Group.

[11] Godeke, A., et al. (2006). "Limits of NbTi and Nb_3Sn, and Development of W&R Bi-2212 High Field Accelerator Magnets." Presented at ASC 2006.


Cryobiology

by Dr. Iqra Azam and Dr. James Benson, University of Saskatchewan

New *Cold Facts* Column Addresses the Hopes and Challenges of Cryobiology

What if we could pause life by freezing it? Is a frozen cell alive? These intriguing questions are at the core of cryobiology, a rapidly evolving field dedicated to understanding how low temperatures affect living organisms and systems. Cryobiology investigates life processes at subphysiological temperatures across a wide spectrum, from individual proteins and cells to more complex systems like tissues, organs, plants and even entire organisms. This includes a broad range of phenomena, from hypothermia and hibernation in animals to the survival of microorganisms in extreme cold, lyophilization (freeze-drying) of biological pharmaceuticals and even cryosurgery, which uses freezing to destroy unhealthy tissues in a minimally invasive manner.

Since the dawn of human civilization, low temperatures have been a tool for preservation. Early humans used caves or carved ice to store food, preventing spoilage and extending the utility of resources. Five thousand years ago, ancient Egyptians used low temperatures in medical procedures. Two hundred and fifty years ago, Italian researcher and Catholic priest Lazzaro Spallanzani used a microscope and some snow to investigate the effects of cold on the motion of sperm, questioning whether those that had stopped movement and then recovered upon warming were alive in their frozen state. Basile Luyet, another Catholic priest and one of the most influential founders of modern cryobiology, was intrigued by the dichotomy and precarious balance of “life and death at low temperatures.” Today, biologists have harnessed the cold in ways that ancient civilizations could never have imagined—enabling everything from biobanking of plant and animal germplasm, cell therapy and blood products to organ transplants and in vitro fertilization (IVF). But as technology evolves, what other possibilities could the cold offer for the future?

Cryovials containing biological samples stored in liquid nitrogen, essential for long-term preservation in cryobiology research. Credit: Muhammad Kaleem Sarwar

The potential is enormous. One of the most impactful applications of cryobiology is cryopreservation—the process of freezing biological materials at ultralow temperatures to halt all biological activity, effectively "pausing" life, or as Giwa, et al. put it, “stop biological time.” In cryopreservation, we have successfully frozen and thawed thousands of unique cell lines, creating a vast reserve of biological resources for future research and therapeutic use. This technology is crucial for regenerative medicine, providing stable, long-term storage for cell-based therapies. Biobanks now play an essential role in personalized medicine by storing patient-derived cells for future diagnostics and treatments. With the global biobank market estimated at USD 76.74 billion in 2023, the demand for genetic and cell-based therapies is on the rise, especially following the global pandemic where biobanking proved critical in diagnostics and vaccine development. Cryopreservation also plays a significant role in fertility treatments, enabling the freezing of human sperm, eggs and embryos, which has been a cornerstone of IVF, with the market valued at USD 25.3 billion in 2023. Beyond individual cells, some organized tissues—such as heart valves, blood vessels and skin—can now be cryopreserved and successfully transplanted, driving advancements in industries like skin grafting, projected to reach USD 7.36 billion by 2032.

This is not to say that all “single cell” cryopreservation is solved. Many cell types including those being generated for biobanking require bespoke preservation protocols that do not translate directly from the industry standard “10% dimethyl sulfoxide (DMSO) at 1 °C/min.” There is a continual push to reduce the use of DMSO in transfusion, and some cell types are more sensitive to cold or cryoprotectant chemicals. Moreover, while the cryopreservation of many cells and small biological samples has become routine, preserving more complex structures like tissues and organs presents significant challenges. Since the first organ transplant, reviving organs from a deep freeze without injury and restoring full functionality has been the dream cryopreservation research. Although there have been some successes—such as freezing dog intestines in liquid nitrogen or achieving partial recovery of organs like livers and kidneys—the damage caused by freezing often necessitates extensive regeneration. Dog spleens and ureters have survived freezing for transplantation, and more recently, scientists have successfully thawed and transplanted rat organs, marking a breakthrough that could revolutionize transplant medicine. Imagine a future where cryopreserved hearts, livers and kidneys are readily available for transplant, removing the urgent need for matching donors within a narrow time frame. This would save millions of lives and reduce the strain on organ waiting lists. However, significant challenges remain in achieving reliable cryopreservation for complex tissues and organs.

In recent years, sustainability has emerged as a key focus in global health, with the world's growing population and climate change making food security a pressing concern. Advances in cryopreservation have potential applications not only in medicine but also in agriculture. New techniques are being developed to preserve the genetic material of animal agriculture and vital crops ensuring long-term availability and distribution of ever-improving genetics and improving cold storage methods for post-harvest food products to reduce waste. Cryobiology also holds promise for preserving whole plants, rare species and complex tissue cultures, with global seed banks playing a pivotal role in safeguarding biodiversity. The Global Seed Vault in Norway, for instance, stores more than 930,000 varieties of crops as a protective measure for future generations. Such developments could enhance food security and contribute to the preservation of endangered plant species amid an uncertain environmental future.

The principal challenge in cryopreserving complex tissues and organs lies in controlling the formation of ice. When tissues are frozen, water inside and outside cells forms ice crystals, which can puncture cell membranes and disrupt capillaries, causing irreversible damage. Even organisms that survive extreme cold, like certain frogs and fish, employ specialized mechanisms to prevent ice formation inside their cells. Inspired by nature, cryobiologists use chemical additives known as cryoprotective agents (CPAs) to inhibit ice formation during freezing. CPAs, such as dimethyl sulfoxide and glycerol, work by lowering the freezing point of water, neutralizing the harmful effects of high salt concentrations and encouraging the formation of stable glass instead of deleterious ice crystals. However, using CPAs presents its own challenges: at high concentrations, these agents can be toxic to cells. Striking the balance between protection and toxicity remains a complex task, and there is a growing need to identify novel CPAs, antifreeze proteins and ice inhibitors.

Dr. James Benson (left) and Dr. Iqra Azam (right) safely storing cryopreserved cells in a liquid nitrogen container. Credit: University of Saskatchewan

Beyond freezing, the process of delivering CPAs to relatively impermeable biologics like seeds or insects or larger tissues and organs is also challenging. Different cell types have varying levels of permeability to CPAs, and organs have intricate vascular systems that must be preserved during freezing and thawing. Uneven distribution of CPAs can lead to ice formation or damaging toxicity, causing structural and functional damage that results in organ failure. Progress has been made in developing perfusion systems to circulate CPAs evenly throughout organs, but removing CPAs and achieving safe, uniform rewarming remains critical. Tissues and organs must be thawed quickly and evenly to prevent ice recrystallization, which can occur during warming when small ice crystals expand and cause further damage. Traditional methods of thawing often lead to uneven heating, resulting in thermal stress. However, promising techniques like electromagnetic warming and nanowarming, where nanoparticles generate heat internally, are being explored for more uniform and faster rewarming, though these methods are still in experimental stages.

Despite the formidable challenges, the future of cryobiology is filled with immense promise. As researchers continue to push the boundaries of what can be cryopreserved, we are moving closer to breakthroughs that could make the long-term storage of complex animal and plant tissues a reality. The steady progress in cryopreservation techniques—whether through the successful preservation of organs, the protection of global food sources, or the preservation of biodiversity—brings us ever closer to transformative solutions. Cryobiology is a critical technology that enables the addressing of pressing challenges in health, agriculture and conservation, and its future is brimming with hope.

Frozen mountain ash berries in Saskatoon, showcasing natural ice formation. Credit: University of Saskatchewan

In the next issue of *Cold Facts*, we will further explore the unique challenges and breakthroughs in cryobiology.

Clean Energy Future

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

Advanced Thermal Insulation Systems for Low-Temperature Applications, Part 2 (materials data)

Do we need better insulation materials for the cryogenic clean energy transition? Not really, but these are important in the optimization of future products. What we do need is a combination of great design, manufacturing and execution of total systems, including structural materials, in their operational situations. That is, an intersection of lowest CAPEX and OPEX for optimum thermoeconomic efficiency, safety and reliability. Definitions and examples of cryogenic thermal insulation systems, along with heat transmission calculations, testing methodologies and test cryostats, were given in Part 1 of this series as well as previous columns with a focus on liquid hydrogen (LH_2) systems.[1-2]

Data in terms of ke for a variety of insulation materials and systems tested under representative and similar conditions are presented as a variation CVP in Figure 1.[3] Included are two MLI systems, one with 80 layers of aluminum foil and microfiberglass paper and another with 20 layers of double-aluminized Mylar (DAM) and polyester netting. Two different Layered Composite Insulation (LCI) systems are given: LCI with a fumed silica and DAM and LCI with aerogel paper (0.7-mm) and DAM. Data for an aerogel blanket material (Cryogel® by Aspen Aerogels) is presented. Two bulk-fill materials are given: aerogel particles (white 1-mm diameter) material by Cabot Corp. and glass bubbles (Type K1) material by 3M. For general comparison, the data for "vacuum only" and a polyisocyanurate foam (BX-265) by NCFI and are also given. The boundary temperatures are 293 K (WBT) and 78 K (CBT) in all cases. The physical parameters of thickness, number of layers and bulk density are also provided in the legend.

In ambient pressure applications, an alternative to closed-cell foam is the layered composite extreme (LCX) system. The LCX system is an MLI system but for open-air environments. Its various combinations of aerogel blanket and compressible barrier layers provide unique performance benefits where complex shapes, weathering, moisture and mechanical damage are problematic. This breathable (non-sealed) type insulation system has been proven at 20 K on operational LH_2 systems based on the characteristic of the aerogel as a hydrophobic, nano-porous and amorphous (non-cellular) composite that does not cryopump, beyond initial cooldown, even as low as 4 K.[4]

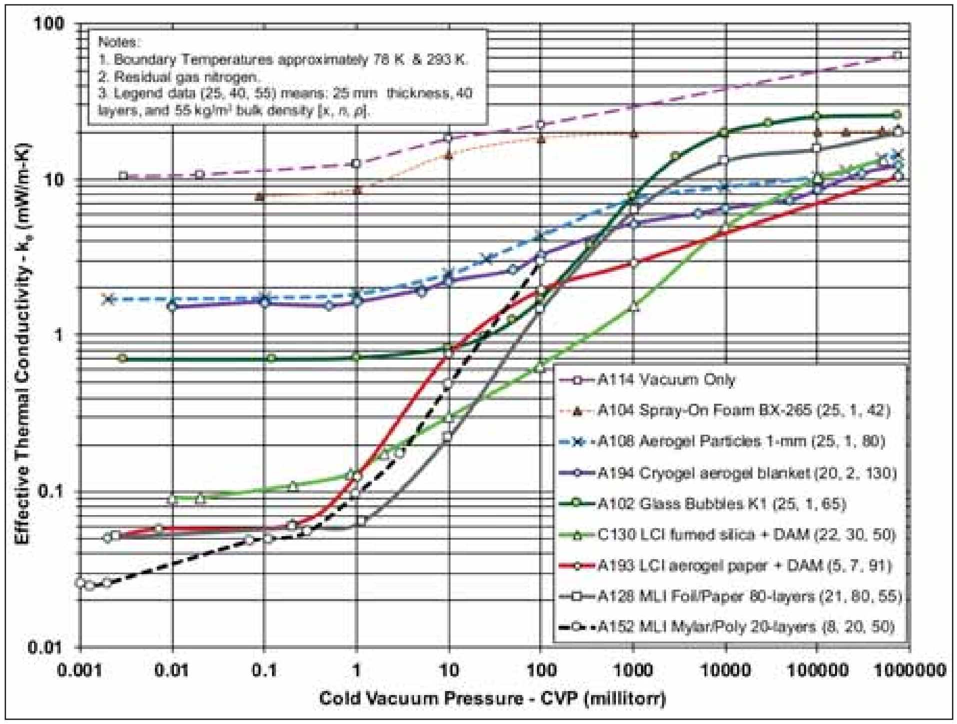


Figure 1. Cryostat test data for thermal insulation systems tested at 293 K / 78 K (1 millitorr = 0.0013 mb). Credit: James Fesmire

Table 1. Thermophysical data for structural-thermal materials used in cryogenic systems

Material	†σ	ρ	*k_e	F_{ST}
	MPa	*kg/m³*	*mW/m-K*	*K-m-s/g*
G-10 (transverse direction)	448	1,939	467	495
Ultem® 2300 Glass Filled PEI	221	1500	212	695
Teflon™ PTFE	24.1	2,120	253	45
Rohacell® WF-300 PMI Foam (2 psi)	17.8	324	42.1	1,305
Balsa Wood (transverse direction)	7.0	166	45.9	919
AeroZero® polyimide aerogel	1.6	150	28.1	380
Foamglas® Cellular Glass Foam	0.8	118	32.3	210
Divinycell® H45 PVC Foam (2 psi)	0.6	50	23.8	504
Spray Foam Polyiso BX-265 (2 psi)	0.4	37	22.6	483

†At ambient temperature *Boundary temperatures 293 K / 78 K; compressive load 5 psi or as noted.

Thermophysical data for a range of different structural-thermal materials used in cryogenic systems data are given in Table 1. Included are polyimide aerogel AeroZero®, Ultem®, Foamglas, Divinycell® and Rohacell®. Also included are G10 composite, Teflon™, balsa wood and polyiso spray foam for general reference. These k_e data were produced using the Macroflash instrument, per ASTM C1774 Annex A4, for boundary temperatures of 78 K (CBT) and 293 K (WBT) and under a compressive load of 34 kPa. The structural-thermal figure-of-merit (F_{ST}) is calculated as given in Eq. (2).

$$F_{ST} = \frac{\sigma}{\rho k_e} \text{ x } 10^6 \quad \left[\frac{\text{K} \cdot \text{m} \cdot \text{s}}{\text{g}}\right] \quad \text{Eq. (2)}$$

Where ρ is the bulk density in kg/m^3, k_e is the effective thermal conductivity in mW/m-K (with the prescribed CBT and WBT), and σ is the compressive strength in MPa (at ambient temperature).

Newer materials developed in the last decade include AeroFoam, AeroPlastic and AeroFiber composites.[5] These structural-thermal composites composed of hybrid combinations of aerogels, polyimides, and other engineering polymers further demonstrate the possibilities for tailoring systems to achieve specific combinations of light weight, low thermal conductivity and high strength, along with excellent fire properties.

Cold Triangle Design

A practical methodology for designing cryogenic thermal insulation systems is based on a "cold triangle" approach of insulation, supports and piping as well as the insulation quality factor (IQF).[6] The total heat leak of the end product is what matters, but to minimize this heat leak in the most cost-effective way, the calculations, testing, and materials data must be covered and the thermal performance understood as a summation of its parts. A crucial part of the Qtotal for a cryogenic system is the additional heat leak due to the insulation quality factor (IQF). The IQF is a means of capturing the combined degradation of the insulation's thermal performance due to practical limitations of its installation and also the negative effects of supports and piping. In the basic cases presented here, a single IQF is applied for the entire cryogenic assembly as a separate heat leak element of Q_{total} as given in Eq. (2).

$$Q_{total} = Q_i + Q_s + Q_p + Q_{IQF} \quad \text{[W]} \quad \text{Eq. (2)}$$

Where Q_i is the heat leak for the insulation, Q_s is the heat leak attributed to the supports, and Q_p is the heat leak due to the piping penetrations, and the additional Q_{IQF} is the heat leak associated with the IQF.

In the conclusion (Part 3) of this series, we will examine engineered systems examples of different LH_2 tanks and piping, including the breakdown of the parts of the total heat transmission.

References:

[1] "Misconceptions in Cryogenic Heat Management." *Cold Facts.* Vol. 37, No. 1.

[2] "Liquid Hydrogen (and Tank Insulation) to Electrify the World." *Cold Facts.* Vol 36. No 6.

[3] Fesmire, J. and Swanger, A. "Advanced Cryogenic Insulation Systems." 25th IIR International Congress of Refrigeration. Montreal, Canada. IIR No. 1732, 2019.

[4] Fesmire, J. and Sass, J. 2008 "Aerogel Insulation Applications for Liquid Hydrogen Launch Vehicle Tanks." *Cryogenics.* Vol. 48, pp. 223-231.

[5] Williams, M. and Fesmire, J. "Aerogel Hybrid Composite Materials: Designs and Testing for Multifunctional Applications." NASA Tech Briefs Webinar. April 2016.

[6] "Thermal Insulation Systems for Liquid Hydrogen Storage." *Cold Facts.* Vol 37. No1.

From Home Garage to Industry, Fluoramics Innovates Safety and Performance

by Patti Reick, Fluoramics

It was in the late 1960s when Frank Reick, who at the time was working for the International Telephone and Telegraph Corporation, identified a significant gap in sealing systems for oxygen services used in welding and steelmaking. To address this, he developed a pipe sealant known as Formula-8, suitable for both gaseous and liquid oxygen applications. This innovation caught the attention of the military, leading to its NSN designation for use by the US Navy in 1968, along with LOX-8 Paste, which was originally named OXY-8. Both products were initially supplied to Linde, marking the start of Fluoramics' contributions to the cryogenics industry.

Frank Reick in the Fluoramics home lab in the 1970s. Credit: Fluoramics

By the end of the 1970s, inspired by environmental concerns over vehicle pollution, Frank patented Tufoil Technology, which effectively suspends PTFE particles in oil to enhance engine efficiency. This breakthrough resulted in the creation of Tufoil Engine Treatment and a comprehensive line of lubricants and greases designed to reduce friction, lower temperatures and minimize wear on equipment. In the late 1990s, after experiencing corrosion issues with his car's brake lines, Frank developed HinderRUST, a line of effective corrosion inhibitors that emerged as a solvent-free solution for rust prevention. The business initially operated as a family venture, with Frank's wife managing office tasks and their three sons assisting in various roles. Notably, the middle child, Gregg, who graduated with a degree in Chemical Engineering from Rutgers University, eventually took a leadership role as president and chief chemical engineer in 2015, guiding the company's growth from a home garage to industrial facilities.

Ensuring Safety in Harsh Environments

The company's trajectory reflects a continuous commitment to innovation in response to industry challenges. With the introduction of LOX-8 Thread Sealant, Fluoramics not only addressed safety concerns but also set new standards in performance for sealing systems in harsh environments.

LOX-8 Thread Sealant. Credit: Fluoramics

LOX-8 Thread Sealant is a specialized thread sealant highly recommended for use in environments where oxygen and harsh chemicals, such as chlorine and powerful oxidizers, are present. This product excels in applications that prioritize critical safety and resistance to aggressive chemicals, making it the preferred choice in high pressure and extreme temperature situations. Its superior performance as both a sealant and anti-galling agent ensures reliable operation under severe conditions.

Designed for versatility, LOX-8 is effective in both wet and dry applications, featuring a high density formulation that withstands significant pressures. The sealant is odorless, noncorrosive, waterproof, non-migrating, and nonflammable, with certification for oxygen service. Additionally, it is NSF-approved for use in food processing facilities, reinforcing its safety and efficacy in a variety of harsh chemical environments, including those involving extreme acids and powerful oxidizers.

Key benefits of LOX-8 include its stability at temperatures up to +287° C (+550° F) and its resistance to corrosive substances like chlorines and hypochlorites. By allowing users to standardize on one sealant, LOX-8 eliminates plumbing errors and simplifies inventory management. Its anti-galling, anti-seize and anti-corrosive properties make it an essential tool in various industries, including aerospace, automotive and water treatment.

LOX-8 Thread Sealant has a wide range of applications, including water treatment systems where it resists harsh chemicals, aerospace use with gases like argon and helium, and sealing fittings in the welding and bottled gas industries. Its compatibility with a diverse array of materials—metal, plastic, PVC—further enhances its utility in numerous environments, from chemical processing to offshore drilling and medical equipment. The sealant is also effective in cryogenic applications, ensuring its relevance in cutting-edge fields such as gas storage and transportation.

Fluoramics continues to innovate and remains a reliable partner in the most challenging conditions. **www.fluoramics.com**

Pioneering High Strength Austenitic Stainless Steels for Cryogenic Applications

by Philip Roscoe, N'GENIUS Materials

Furniss & White, a British steel foundry specializing in high integrity stainless steel castings, has announced its groundbreaking achievement as the first company in the world to manufacture castings using a novel series of high strength austenitic stainless steels. These advanced materials, part of the N'GENIUS Series, offer exceptional performance across a wide range of temperatures, including ambient, sub-zero and cryogenic environments.

The Sheffield-based firm, known for its extensive experience in fabrications, precision machining and casting production, has entered into a long-term agreement to produce its castings using the high performance alloys of the N'GENIUS Series under license. This collaboration marks a significant milestone in the foundry's history, positioning it at the forefront of metallurgical innovation.

The N'GENIUS Series, patented in 30 countries, represents a complete reinvention of conventional austenitic stainless steels, commonly referred to as the 300 Series. "Furniss & White is a company that shares our own passion and drive for innovation, and we are absolutely delighted to be collaborating with them on what is destined to be an industry-changing technology," said Dr. Ces Roscoe, CEO of N'GENIUS Materials Technology and inventor of the N'GENIUS Series, expressed his enthusiasm for the partnership.

This image demonstrates how the N'GENIUS alloy is prepared for forms compatible with cryogenic conditions, showing precision in shaping blocks designed to withstand low temperatures. Credit: Foundries Ltd

This image emphasizes the flexibility in casting complex, cryogenic-compatible shapes, a critical feature for components exposed to varying cryogenic applications. Credit: Foundries Ltd.

As part of its commitment to this new venture, Furniss & White has successfully completed a range of manufacturing procedure qualification tests across various grades from the N'GENIUS Series at its facilities. The foundry will now supply castings made from these advanced materials to its customers in industries such as oil and gas, chemical, petrochemical, mining, marine, defense, power generation and, notably, cryogenics. The high strength, ductility and toughness of these materials at cryogenic temperatures make them ideal for use in components that must perform reliably under extreme conditions, such as those found in cryogenics where materials are subjected to extremely low temperatures. The series exhibits not only the typical benefits of conventional austenitic stainless steels, such as excellent ductility and toughness, but also vastly superior strength and corrosion resistance, which are critical for ensuring the reliability and safety of cryogenic systems.

The N'GENIUS Series can be manufactured in both cast and wrought product forms, offering a complete family of grades that provide a wide range of high performance, high strength austenitic stainless steels. These materials, including cost-effective alternatives to certain nickel alloys, are suitable for all products, service conditions and even the harshest of process media environments. Their applicability in cryogenic technology positions N'GENIUS as a total system material that could revolutionize the field.

The N'GENIUS Series offers higher allowable design stresses and superior resistance to various forms of corrosion and fatigue. Additionally, each alloy type in the

▶ *continues on page 40*


GARDNER CRYOGENICS

 Continued from page 38

series has distinct minimum pitting resistance equivalent values, ensuring tailored corrosion protection for different applications.

Sam Scholes, managing director at Furniss & White, expressed his pride in the company's pioneering role: "For more than 44 years, we have built a strong reputation as a high quality British manufacturer of high integrity castings made in our modern foundry in the UK. Now, as an approved licensed N'GENIUS manufacturer, we are writing an exciting new chapter in our history, and to be the first foundry in the world to have this capability makes us extremely proud."

This transition of molten metal at high temperatures illustrates how the N'GENIUS alloy withstands initial heat stress before adapting to ultra-low temperatures, a unique requirement for cryogenic materials. Credit: Foundries Ltd.

Established in 1980, Furniss & White employs has built a strong reputation as a high quality British manufacturer of integrity castings, with products ranging from 0.5 kg to 2,600 kg in finished weight. The firm's modern foundry in the UK has become a trusted supplier to various industries, and the adoption of N'GENIUS materials is expected to further enhance its market position. "With a long history of steelmaking, Sheffield is widely regarded as the birthplace of stainless steel, and it seems befitting that it will essentially be 'reborn' in the same city more than a century later," Dr. Roscoe added.

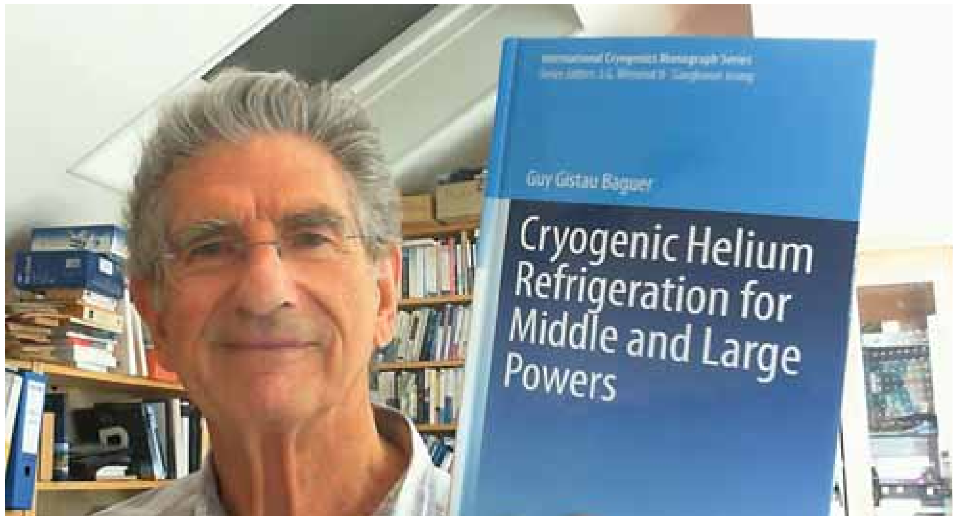
Scholes concluded, "We expect these game-changing N'GENIUS materials to be extremely popular with our existing customers and help open up new opportunities in other markets, including the US and Canada and in clean energy industries such as hydrogen." **www.furnisswhite.com**.

≈In Memoriam≈

Guy Gistau-Baguer, 1940-2024

By Pascale Dauguet

Guy Gistau-Baguer, an iconic figure in the field of cryogenics, passed away August 25, 2024, leaving behind a significant scientific and technical legacy. Born on June 22, 1940, in Génos, France, he graduated from the École Nationale Supérieure des Arts et Métiers in 1963. His career was marked by an unwavering passion for innovation and research, making him a pioneer in cryogenics, particularly in the refrigeration and liquefaction of helium.



Guy Gistau-Baguer with his book, *Cryogenic Helium Refrigeration for Middle and Large Powers. Credit: Cryoguy.com*

During his career at Air Liquide, Gistau-Baguer played a central role in developing technologies for very low-temperature helium refrigeration. From 1975 to 2000, he served as the technical manager of the Helium Refrigeration activity within the Advanced Technology Division in Grenoble. He oversaw the design and development of the first automatic helium refrigerator/liquefier, the HELIAL, in 1980. He also led the design, construction, and commissioning of several major refrigeration installations, including those used by CERN and the CEBAF project. These achievements set new standards in the field, with advances such as the integration of cryogenic centrifugal compressors.

Guy Gistau lecturing to a room of students. Credit: FRM II / TUM

Gistau-Baguer was a member of the International Cryogenic Engineering Committee (ICEC) for over two decades and served as its president from 1998 to 2008. He contributed significantly to the dissemination of knowledge as an advisory editor for the journal *Cryogenics* and authored numerous technical publications, including his reference work on helium refrigeration, which became an essential guide for professionals in the field.

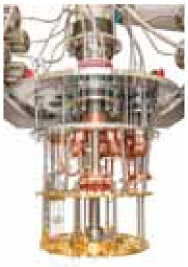
His nine patents, some of which remain in use, stood as a testament to his innovative spirit. The advances he introduced significantly improved the efficiency of cryogenic refrigeration systems, leaving a lasting influence on industry practices.

Even after his retirement in 2000, Gistau-Baguer continued to share his knowledge, leading over 80 cryogenics training sessions worldwide, mentoring young scientists and inspiring countless students. His passing left a huge void in the scientific community, but his legacy lives on through his indelible contributions to cryogenics.

In recognition of his lifelong commitment to Cryogenic Engineering, Gistau-Baguer was awarded the International Cryogenic Engineering Committee (ICEC) Mendelssohn Award in 2020. His work continues to inspire future generations of scientists and engineers. To his wife, Anne, and to his relatives and friends, the community expresses its deepest condolences.

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) and one high-resolution JPEG of the product using the form at **www.cryogenicsociety.org/submit-a-product-showcase**.



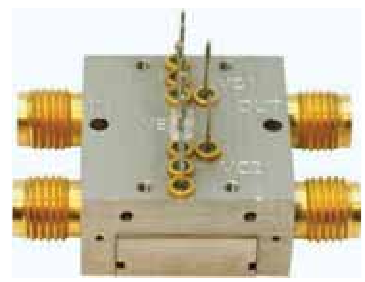
XLDHe High Power System

Bluefors

Bluefors presents the XLDHe High Power System, a cryogen-free, helium-4 powered measurement system for experiments in the 1 K range. It offers high cooling power between 200 and 700 mW at 1–1.2 K, and features a large 540 mm experimental flange for greater flexibility and scalability. A version with integrated superconducting magnets and extra payload space is also available. Standard systems reach a base temperature of <900 mK in 12–16 hours, with an optional LN_2 Pre-Cooling Loop reducing cooldown to 9 hours. Ideal for spin qubit and photon detector applications. **www.bluefors.com**

CMTDA1 Cryogenic Differential Amplifier

Cosmic Microwave Technology, Inc.



Cosmic Microwave Technology's cryogenic differential amplifiers enhance the performance of superconducting nanowire single photon detectors (SNSPDs). These amplifiers reduce timing jitter and improve data rates and image resolution. Two versions are available: an AC-coupled, self-biasing model with single supply voltage and a DC-coupled model for high data rates, which eliminates DC offset but requires additional biasing. Both models are crucial for advancing SNSPD technology. **www.cosmicmicrowavetechnology.com**

DF Series

Wessington Cryogenics

The DF Series of vacuum insulated dewars from Wessington Cryogenics are made entirely from stainless steel and are designed for use with liquid nitrogen in various laboratory and industrial applications. These dewars are known for their strength and performance, making them ideal for immersion applications and cold trap operations. The series features a loss-reducing plug cap and includes options such as intermediate and larger sizes, roller bases for the DF-50, and bespoke top flange designs. Larger capacity dewars, such as those with bottom outlet ports or valves on models like the DF-10 and above, are also available. Additionally, the series offers 100+ liter capacity dewars with skirt bases and wheels for enhanced mobility. **www.wessingtoncryogenics.com**

Superconducting Magnet Dewars CSM/CVSM Series

Cryofab

Cryofab's stainless steel superconducting magnet dewars are designed for research with magnet coils. Customizable to specific dimensions and shielding needs, they are available with either LN_2 or vapor shielding. Vapor shielding reduces maintenance costs, though it may have higher helium loss rates. Configurations range from straight bore to reservoir types, with diameters from 2 to 96 inches and depths up to 14 feet. Includes a one-year vacuum warranty. **www.cryofab.com**

People & Companies in Cryogenics

The US Department of Energy (DOE) has awarded **Washington State University** (WSU) $4.8 million in grant funding for hydrogen fuel research, including a $3 million Hydrogen Properties for Energy Research (HYPER)-Flow grant led by professors **Jacob Leachman** and **Konstantin Matveev** to create the world's first continuous liquid hydrogen flow loop for visualizing and characterizing multiphase hydrogen flow in pipes. WSU will also receive $1.8 million as part of a $10 million HYPER-Fuel grant, in partnership with Plug Power, aimed at improving hydrogen refueling stations for medium- and heavy-duty vehicles. This project includes the construction of a heavy-duty

Jacob Leachman. *Credit: WSU*

hydrogen fueling station on WSU's Pullman campus, which will support research and community vehicle fueling by 2026. The DOE's $62 million in grants for hydrogen fuel projects across the US, including these at WSU, are intended to drive research, training and infrastructure development to support widespread hydrogen fuel use. Hydrogen-fueled vehicles, touted as a solution to reducing greenhouse gases, face challenges like fuel venting loss, but the HYPER-Fuel project will address this by developing technology to reliquefy hydrogen that turns to gas, allowing for longer on-site storage. The $3 million HYPER-Flow grant will enable continuous testing of liquid hydrogen fueling components.

……………………………………

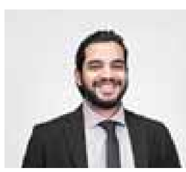
Biocair has won the **Best Cryogenic Supplier Award** at the Asia Pacific Cell and Gene Therapy Excellence Awards 2024, a recognition voted by thousands from the biopharma community. The award, presented in Singapore on September 10, highlights

Kevin Xu and Nicholas Jayaselan accept the honor.
Credit: Biocair

Biocair's significant contributions to cell and gene therapy logistics, particularly in cryogenic storage and packaging. Biocair APAC General Manager Kevin Xu and APAC Operations Manager Nicholas Jayaselan attended the event, which celebrated leaders driving advancements in therapies and manufacturing. Founded in 1987, Biocair continues to be a global leader in time-sensitive, temperature-controlled logistics services.

……………………………………

Rohith Prakash, a Ph.D. student from Chennai, is conducting groundbreaking research at **Monash University's Department of Civil Engineering** after being selected for the Australian government-funded Maitri Scholars Program. His research focuses on the safe transport and storage of liquid hydrogen, particularly the sloshing effects in tanks and their impact on boiloff rates, a critical issue for the future of clean energy.



Rohith Prakash.
Credit: Monash University

……………………………………

Horizon Aircraft, an advanced aerospace engineering company and developer of hybrid electric vertical takeoff and landing (eVTOL) aircraft, has appointed **Tom Brassington** as chief technology officer. Brassington, formerly head of system design engineering at Lilium, brings 17 years of aerospace systems engineering experience to Horizon as it continues development of its piloted seven-seat hybrid eVTOL, the Cavorite X7. His expertise in eVTOL development and certification is expected to enhance Horizon's engineering capabilities, drive innovation and streamline the company's production and testing processes. Horizon is currently testing a 50%-scale version of the Cavorite X7, which is designed to fly like a traditional aircraft for most of its mission, offering greater safety and easier certification. With a gross weight of 5,500 pounds and a projected range of over 500 miles, the aircraft is intended to support various sectors, including medevac, business aviation and commercial cargo.

Tom Brassington.
Credit: Horizon Aircraft

……………………………………

Nominations are open for the **2025 Olli V. Lounasmaa Memorial Prize**, which recognizes significant contributions to low temperature physics and related fields. Established in 2004 to honor **Olli V. Lounasmaa**, the prize is awarded every

Olli V. Lounasmaa in Argonne in 1962. *Credit: Aalto University*

three years and supported by funds from the Finnish Society of Sciences and Letters, as well as Bluefors (CSA CSM), which spun off from Lounasmaa's Low Temperature Laboratory. Nominations, including supporting letters, should be sent to Professor Mika Sillanpää by January 15, 2025. The award will be presented at the 30th International Conference on Low Temperature Physics in Bilbao, Spain.

……………………………………

The **Cryogenic Engineering Conference (CEC)** will award two distinguished scholarships at the upcoming 2025 CEC/ICMC: the **Donna Jung Memorial Scholarship Award** and the **Klaus and Jean Timmerhaus Scholarship Award**. Supporting excellence and inclusivity in the cryogenics community, these awards are part of the CEC's ongoing efforts to encourage the next generation of engineers and scientists in cryogenics, funded by the Cryogenic Engineering

Credit: CEC

Conference, Inc., along with contributions from industrial and private sponsors. The Donna Jung Memorial Scholarship, introduced in 2013, promotes the participation of women in cryogenic studies, honoring the legacy of former International Cryogenics president Donna Jung, a long-time CSA member and supporter. The Klaus and Jean Timmerhaus Scholarship, established in 2005, commemorates Dr. Klaus Timmerhaus, a pivotal figure in cryogenics and is awarded to full-time graduate students in engineering or scientific disciplines related to cryogenic technology. Both scholarships are open to graduate students enrolled in U.S. universities, with recipients announced at the 2025 CEC/ICMC. The deadline for the scholarships is December 20, 2024.

....

The **Alliance for Renewable Clean Hydrogen Energy Systems (ARCHES)**, joined by California Governor Gavin Newsom, US Under Secretary of Infrastructure David Crane, Senator Alex Padilla and other leaders, celebrated a significant $12.6 billion agreement in Oakland to enhance clean energy infrastructure across California. The half-day event highlighted innovative hydrogen-powered transportation initiatives, including a journey on the hydrogen-powered Sea Change Ferry and demonstrations of hydrogen fuel cell electric buses and trucks. The ARCHES hub aims to create over 220,000 jobs, improve air quality and cut carbon emissions significantly. As part of its efforts, ARCHES will continue to announce projects that encompass the full hydrogen lifecycle, contributing to California's goal of achieving a carbon-neutral economy by 2045.

California Gov. Newsom celebrates the launch of nation's first hydrogen hub alongside federal, state and local leaders in Oakland on August 30. *Credit: Office of Governor Gavin Newsom*

....

On October 8, 2024, **attocube systems AG** received the Quantum Effects Award from the Quantum Effects Conference for its groundbreaking attoCMC system, recognized in the "Quantum Communication & Networks" category. The attoCMC system addresses a key challenge in photon-based quantum technologies—the need for scalable cryogenic cooling—by offering the first ultra-compact, autonomous 19" cryostat system, operating at just 1 kW and a base temperature of 2.3 K without cooling water or additional infrastructure. CEO Peter Kraemer said the award affirms attocube's ability to accelerate innovation and commercialization in the quantum industry.

Credit: Attocube

....

Airbus UpNext, a subsidiary of **Airbus**, and **Toshiba Energy Systems and Solutions Corporation** have partnered to develop superconducting technologies for future hydrogen-powered aircraft. Hydrogen-powered planes are key to decarbonizing aviation by 2050 and superconducting technology, cooled by -253 °C liquid hydrogen, could significantly enhance energy efficiency in electric propulsion systems. This collaboration aims to create a two-megawatt superconducting motor, pushing beyond the limits of current motors to unlock new design possibilities. The agreement was signed at Japan Aerospace 2024, marking the first achievement of Airbus Tech Hub Japan's initiative to drive next-gen aerospace innovation.

Credit: Airbus

Meetings & Events

The CERN Accelerator School – CAS Advanced Accelerator Physics
November 10-22, 2024
Spa, Belgium
https://indico.cern.ch/event/1380440/

CCA 2025: International Workshop on Coated Conductors for Applications
March 11-13, 2025
Geneva, Switzerland
https://indico.cern.ch/event/1347361/

31st Space Cryogenics Workshop
May 13-15, 2025
Incline Village, Nevada
https://spacecryogenicsworkshop.org

CEC/ICMC 2025
May 18-22, 2025
Reno
www.cec-icmc.org/2025

30th International Conference on Low Temperature Physics
August 7-13, 2025
Bilbao, Spain
www.lt30.es

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

Index of Advertisers

Join CSA and start receiving ***Cold Facts***!

Rates: circle $ amount

In US: Individual $85 • Student or retiree: $40

Outside US: Individual $130 • Student or retiree $80

Corporate, in US, number of employees:
1-10, $495 • 11-25, $695 • 16-50, $915 • 51-100, $1,355
101-500, $2,460 • 501-1,000, $5,515 • 1,000+, $7,720

Corporate, outside of US, number of employees:
1-10, $555 • 11-25, $765 • 16-50, $990 • 51-100, $1,400
101-500, $2,580 • 501-1,000, $5,725 • 1,000+, $8,000

Government/Non-profit: $475

Outside the US, please remit in US $ on US bank. No bank transfers.

Charge your membership

__Discovery __Visa __MasterCard __AmEx

Account number Expiration Security code

Signature

Please print

Name Title

Company

Address

City State/Country Zip + 4

Email Website

Phone Fax

Send to:

New Memberships • Cryogenic Society of America
800 Roosevelt Rd. Suite 312-C • Glen Ellyn, IL 60137
Fax: 630-790-3095

Join CSA online!

www.cryogenicsociety.org/membership

***Cold Facts* is the official technical magazine of The Cryogenic Society of America, Inc.** 800 Roosevelt Rd. Suite 312-C • Glen Ellyn, IL 60137
Phone: 630-858-7337 Ext. 8765 • Fax: 630-790-3095
Email: membership@cryogenicsociety.org • Web: cryogenicsociety.org
A non-profit technical society serving all those interested in any phase of cryogenics
SSN 1085-5262 • November 2024
Printed in USA


Connecting Customers With Solutions
Dewars
Containers
Tanks
Cryostats
Transfer Systems
Vacuum Components
Vacuum Jacketed Valves
VJ Manifolds
CRYOFAB
1-800-426-2186 | cryofab.com


Linde
Partner you can count on
For over nine decades, we have been enabling ground-breaking discoveries that challenge the boundaries of physics. As the world's leading cryogenic engineering company, we have the technologies, experience and skills to keep cool – while you unravel the secrets of science.
Linde – your trusted partner.
Linde Engineering Americas
945 Keystone Avenue, Catoosa, Oklahoma, 74015 USA
Phone +1 918 266-5700, linde-engineering.com
Linde Kryotechnik AG
Daettlikonerstrasse 5, 8422 Pfungen, Switzerland
Phone +41 52 304-0555, linde-kryotechnik.ch, info@linde-kryotechnik.ch
Making our world more productive

OmegaFlex®

Cryogenic / Vacuum Jacketed Hose Assemblies

Keep Cryogenic Liquids Cold • Safety Containment

Cryogenic and Vacuum Jacketed Assemblies are oven dried and purged with argon to a moisture content of 2 PPM and verified with a moisture analyzer. Assemblies are helium leak checked to 1 x 10-9 std. cc/sec.; and can be charged with helium to maintain dryness during shipping and storage.

OmegaFlex welders and OmegaFlex welding procedures are qualified to Section IX of the ASME Boiler and Pressure Vessel Code. OmegaFlex hose assemblies are tested in accordance with ISO- 10380:2012.

Omegaflex Cryogenic / Vacuum Jacketed Hose Assemblies

- Superior insulation properties
- Multi-layer insulation creates a low heat transfer rate
- Minimizes cryogenic liquid boil-off
- Containment of the media in case of inner hose rupture
- Bayonet connections available for quick, leak-resistant installations

Metal Hose

- Allows for the transfer of liquids or gases, usually at high pressure and high or cryogenic temperature

Cryogenics Applications

- Nitrogen
- Hydrogen
- Oxygen
- Carbon Dioxide
- Helium
- Argon
- Other Natural Gases

Contact OmegaFlex with your specification and we will engineer a custom jacketed hose assembly for you.

omegaflex.com

OmegaFlex®

Omega Flex, Inc.
451 Creamery Way
Exton, PA 19341
1-800-671-8622
ISO 9001 Registered Company
IND-673 Rev 1223