Can LH_2 Save Antarctica? 11
Emissions-Free Flight 12
LCLS-II's 'First Light' 14
Cryo-Engineering for SRF 78
Revolutionizing Cryogenics Connectivity 84
Innovating Cryogenic Horizons 86

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for Cryogenic and Superconductivity Applications Worldwide

Volume 39 Number 6 2023


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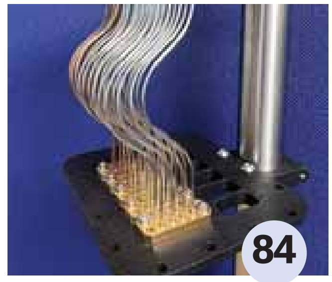
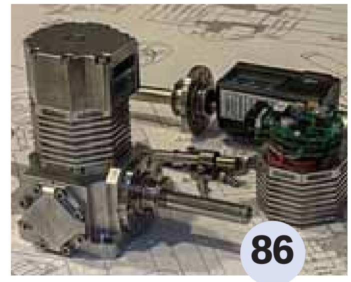
Inside This Issue





2023 BUYER'S GUIDE

25 **Products and Services**

42 **Alphabetical Listing**

56 **Supplier Profiles**

FEATURES

8 Commonwealth Fusion Cryo Team's Just-in-Time Engineering

11 Can LH_2 Preserve Our Last Clean Continent?

12 H2FLY Pioneers Emissions-Free Flight with Successful Liquid-Hydrogen-Powered Aircraft

14 LCLS-II's 'First Light' Revolutionizes X-ray Science

16 Elevating Pipe Support Systems with "Lift-Off" Innovation

20 Cryogenics Drives Advancements in Aerospace Welding

COLUMNS

6 Executive Director's Letter

41 Look who's NEW in the Cold Facts Buyer's Guide

78 Zero Resistance Zone: Cryo-Engineering for SRF

SPOTLIGHTS

82 White Paper Explores Gas Monitoring in Food Storage Safety

84 CryoCoax Revolutionizes Cryogenic Connectivity

86 HeLIUM Cryogenics Redefines Cryogenic Technology

88 Advances in Manufacturing Yield a Clean ID Hose

90 **PRODUCT SHOWCASE**

92 **PEOPLE & COMPANIES**

92 **CALENDAR**

ON OUR COVER

The Commonwealth Fusion System's (CFS) team is working on a high temperature superconducting magnet for SPARC, the CFS commercial fusion demonstration facility.
Credit: Commonwealth Fusion Systems

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

Steven Van Sciver, Florida State University

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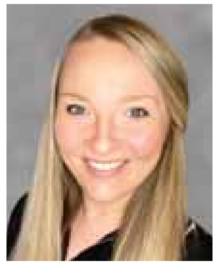
From the Executive Director



It's that time of year again! We are proud to present to you our 2024 edition of the printed Buyer's Guide – a resource of products and services designed for cryogenic applications. We hope you find this year's edition to be a useful tool for you to use throughout 2024 and beyond. As a reminder, you can always access the online version of our Buyer's Guide, which is updated regularly at www.csabg.org.

With 2023 coming to a close, I enjoy reflecting on the successes CSA has experienced in the last year. The year began with a great issue of *Cold Facts*, published in February, spotlighting the next generation in cryogenics and superconductivity through our Young Professionals feature. We had a record turnout of submissions and were able to spotlight nine young professionals in total.

In July, we jetted off to Honolulu, Hawaii, to attend CEC/ICMC'23 and to host numerous CSA short courses which took place the day prior to the conference. These courses provided a comprehensive understanding of different aspects of cryogenics and were an excellent opportunity for students and researchers to enhance their knowledge and skills in the field.

During CEC/ICMC'23, CSA was able to host an exhibit table where we got to meet and visit with many of you! It's always a pleasure to chat with our readers and members to see how we can continue to improve our offerings. Also during CEC/ICMC'23, CSA presented two awards – the Vance Award and the Mullholland Award. The Vance Award was presented to Rich Dausman to recognize his long-term support of the Cryogenic Society of America. The Mullholland Award was presented to Shrikant Pattalwar for his leadership in both the cryogenics and systems integration for the Daresbury Vertical Test Facility.

After CEC/ICMC'23, we hopped over to Kailua-Kona, Hawaii, for the 30th Space Cryogenics Workshop (SCW). SCW was a major success with more than 100 people in attendance. The event took place at the stunning Outrigger Kona Resort, which is an oceanfront resort on the Kona Coast overlooking Keauhou Bay. The workshop offered two days of oral and poster sessions. Attendees raved about the quality of session content and ample networking opportunities with industry colleagues. We look forward to hosting the 31st Space Cryogenics Workshop in the spring of 2025. More details coming soon!

Looking forward to 2024, I have some exciting personal news to share with you. My family and I will be welcoming a baby boy in February of 2024. I will be taking some time off to spend with our newest addition to the family. In my absence, the CSA team will all still be here working hard to provide you with great content through *Cold Facts* and the many other resources provided by CSA.

As always, I hope you enjoy this special Buyer's Guide issue of *Cold Facts*! Happy New Year!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The Commonwealth Fusion Systems magnet factory will support manufacturing of all the magnets for the company's SPARC device, which aims to be the first system to achieve net energy from magnetically confined fusion and a proof of concept for subsequent commercialization. *Credit: Commonwealth Fusion Systems*

Commonwealth Fusion Cryo Team's Just-in-Time Engineering

by Andrew Dalesandro, Cryoplant Lead, Commonwealth Fusion Systems

High temperature superconducting (HTS) tapes, which have emerged over the last decade, are enablers for new technologies. Specifically, high temperature superconducting magnets to enable commercial fusion energy are arguably the most tantalizing and potentially impactful. Fusion energy would be a long-envisioned source of firm, safe, carbon-free electricity whose successful development requires creative, innovative cryogenic engineering.

Fusion power plants use high temperatures and pressures to create the conditions found in stars in which light atoms such as hydrogen fuse and produce helium and enormous amounts of energy that can be converted to drive generator turbines. One leading approach, being pursued by MIT spinout Commonwealth Fusion Systems (CFS), leverages the powerful fields of HTS-based magnets to create a "star in a bottle" capable of containing and managing a steady-state plasma; the company's SPARC device aims to be the first system to achieve net energy from magnetically confined fusion and a proof of concept for subsequent commercialization.

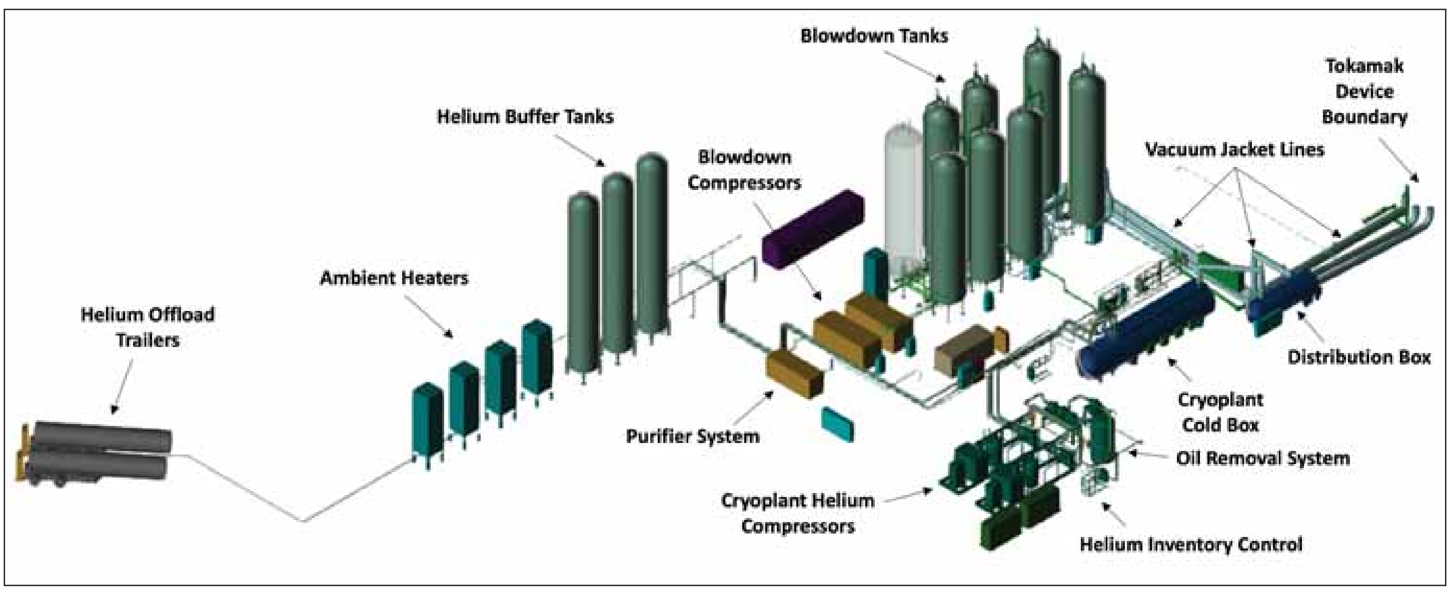
"One of my colleagues used the term 'just-in-time engineering'; a lot of work happens in parallel in order to accelerate the timeline to get SPARC operational as soon as possible," says Adam Weiner, Cryogenics Lead for SPARC

SPARC has several operating modes that pose a wide range of cryogenic requirements and duty cycles. These include steady-state static loads, elevated loading during multiday high temperature cleaning processes and, most demanding of all, the peak dynamic loads associated with an intensive daily schedule of fusion pulses that will begin after expected commissioning in 2025.

These pulses create as much heat as a small commercial power plant. SPARC is not designed to produce electricity, so instead of being sent to a generator, the heat must be removed by the cooling systems.

Some of the system's HTS components require cooling to 8 K and some to 15 K; other non-HTS elements require 80 K. Many design aspects of SPARC are still being finalized, so requirements can be imprecise and subject to change. CFS operates in an especially urgent environment because of fusion energy's potential as a game-changing technology to mitigate climate change.

Simplified layout of the major cryogenic system equipment. *Credit: Commonwealth Fusion Systems*



Rendering of the cryogenic plant installed within the utility building. *Credit: Commonwealth Fusion Systems*

"One of my colleagues used the term 'just-in-time engineering'; a lot of work happens in parallel in order to accelerate the timeline to get SPARC operational as soon as possible," says Adam Weiner, Cryogenics Lead for SPARC, who worked for over a decade at the Fermi National Accelerator Laboratory.

To meet these challenges, the SPARC cryogenics team is building a unique cooling plant and distribution system using supercritical helium coolant, which offers better thermodynamic efficiency and simpler single-phase heat transfer than liquid helium. Two main compressors provide redundancy, while an architectural combination of series and parallel turbines delivers operational flexibility.

But the system's most distinctive element is its blowdown system, which handles the intense dynamic fusion-pulse cooling loads. Described by Weiner as a "cryogenic rocket engine," it's

▶ *continues on page 10*

 Continued from page 9

capable of delivering a short-term burst of coolant to SPARC's toroidal field (TF) magnets for total equivalent cooling power of 2.9 MW over 10 seconds.

The team initially envisioned handling pulse cooling with a large pump, cold buffer and cold/warm expansion vessel, but instead opted for tanks pre-filled with 8 K helium pressurized up to 20 bar. During a pulse, peak flow of over 200 kg/s passes through the TF magnets and into recovery tanks. Re-cooling of the helium takes about four hours — fast enough to support the planned schedule of four high-power pulses per day.

Weiner notes that the tank-based blowdown strategy has made it easier to adapt to changes in flow requirements as SPARC's design has evolved. "Also, our site isn't that big, so we appreciate being able to use the tanks to store helium inventory."

Additionally, 100% of the cryoplant cooling capacity can be quickly delivered if needed to protect SPARC's TF magnets from serious damage.

A powerful enabler for the SPARC cryo work has been effective collaboration with supplier companies. "There's a lot of excitement among their technical teams, and they've worked with us very well, despite us pushing hard and asking them to do things they're not used to, like designing while building," says Weiner. "The fast pace of our procurement cycle can be tough, but it does result in quicker payment and project turnover, which we hope is good for their businesses."

CFS's roadmap envisions SPARC's successor, ARC, being the first on-grid fusion power plant by the early 2030s, followed by rapid commercial uptake. Cryogenics is playing a pivotal role in that endeavor and ultimately in decarbonization of the world's electrical supplies. **www.cfs.energy**

Commonwealth Fusion Systems has more than 500 employees from a variety of disciplines working together to build SPARC. *Credit: Commonwealth Fusion Systems*

The SPARC facility on the Commonwealth Fusion Systems campus in Devens, Mass. will house the SPARC tokamak, which will demonstrate commercially relevant net energy from fusion for the first time in history. *Credit: Commonwealth Fusion Systems*

Can LH_2 Preserve Our Last Clean Continent?

by Yulia Gitter, Graduate Research Assistant, HYPER Center at Washington State University; and Liam Turner, Fulbright scholar, Monash University

Antarctica is vital for cold research, from understanding our fragile climate to tracking local fauna. Energy is critical to this research as it supports expeditions and heating bases. Reliance on diesel import is leaving a dark legacy on the continent, as the buildup of black carbon is causing accelerated rates of animal birth defects and melting ice shelves.[1,2] We must transform our Antarctic fueling practices with urgency if we are to preserve our last clean continent.

Liquid hydrogen (LH_2) can offer a reimagining of clean Antarctic energy, with its versatility for import or onsite production to power bases and vehicles through combustion and fuel cells. Like diesel, LH_2 must undergo similar adaptations to withstand the harsh, isolated conditions of Antarctica. Adopting LH_2 will require an assessment of potential end-use technologies for enhanced research and an economic assessment of energy supply pathways. As a student team across Monash University, Australia, and the HYPER Center at Washington State University, we explored the potential of LH_2 for Australia's largest Antarctic base, Mawson Station.

Technology Assessment

Any Antarctic technology must advance the Australian Antarctic Division's (AAD) commitment to enhancing environmental research while minimizing the footprint of operations. Green LH_2's high gravimetric energy density could enable the use of near-silent fuel cell-powered unmanned aerial and submersible drones (UAV, UUV) for long duration surveying. A semi-quantitative assessment was conducted to identify the opportunities and challenges of adopting both technologies for Antarctic research. Factors considered ranged from technology readiness, performance in Antarctic conditions, safety, and perception by researchers. The major opportunities and challenges are highlighted in Table 1.

The assessment showed green LH_2 could cut carbon and improve Antarctic research. Small-scale demonstration of LH_2-fueled UAVs is possible by utilizing existing infrastructure. However, larger-scale LH_2 energy adoption would require personnel training and a larger supply chain.

Economic Assessment

Mawson annually imports 900,000 liters of diesel, costing $5 million AUD and 2.5 million metric tons of CO_2.[3] Economic studies assessed the cost of transitioning Mawson's energy supply from diesel to LH_2 import by considering the OpEx of liquefaction and shipping with the CapEx of storage tanks. AAD historical records indicated 65,000 kg/year of LH_2 would be required to substitute current diesel use. Importing LH_2 from S.E. Australia would incur a 3x shipping cost multiplier on top of an assumed production cost of $5 AUD / kg LH_2. The long-term costs of LH_2 adoption were quantified by considering the following energy supply scenarios:

Technology Assessment Criteria	Opportunities and Challenges for Hydrogen UAV/UUV Adoption in Antarctica.
Technology Interest	Interviewed AAD personnel expressed high interest for adopting LH_2-powered UAVs to expand Antarctic research.
Ease of Implementation	Electrolysers that are already used for inflating weather balloons could refuel UAVs. Recovering fuel cell heat would likely be required to moderate drone temperature.
Technology readiness	Hydrogen-powered UAVs and UUVs were undergoing technology demonstration level at the time of study. Demonstrating extended use for reliability will be critical for Antarctic adoption.
Skills Requirements	Two trained professionals would likely be required for UAV refueling and operation. AAD staff would require hydrogen training due to limited onsite personnel capacity.

Table 1: Analyzing hydrogen-powered UAV/UUV adoption via Antarctic interviews and criteria. *Credit: Gitter and Turner*

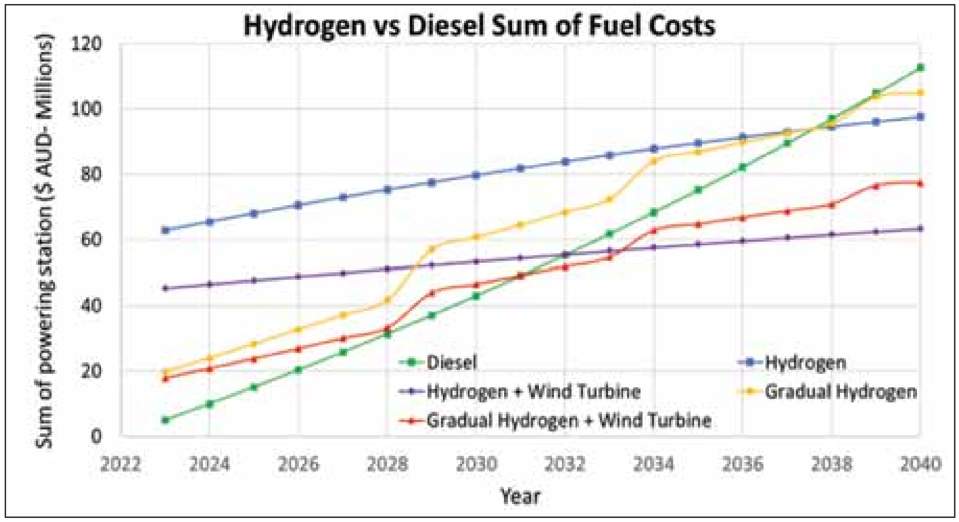


Figure 1: 18-year trends comparing current diesel usage and scenarios for LH2 energy transition. *Credit: Gitter and Turner*

100% diesel use continued; 100% immediate transition to imported H_2; installing a second wind turbine and import H_2 for firming; a gradual increase to 100% H_2 use over a 15-year period; and installing a second wind turbine and increase H_2 use over a 15-year period.

Figure 1 indicated that LH_2 import coupled with renewable generation would be more cost-effective than diesel in the long run. Further work is required to quantify the relative costs of energy to supply base power, heating and equipment and how on-site LH_2 generation scenarios with renewables could compare on cost.

Resolving the potential for LH_2 to advance researchers' commitment to minimize the environmental footprint of exploration will require further techno-economic modeling of on-site production and use scenarios. Expertise sharing on liquid hydrogen technology performance and personnel requirements for deployment will be critical in building the foundation for liquid hydrogen-fueled research. Antarctica is our world's most fragile natural environment, but it has the potential to be a sustainability role model for the rest of our world. HYPER Center and Monash are continuing this work, and expertise sharing from the nexus of cryogenic engineers could accelerate Antarctic liquid hydrogen adoption. **yulia.gitter@wsu.edu**.

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H2FLY Pioneers Emissions-Free Flight with Successful Liquid-Hydrogen-Powered Aircraft

by Rachel McDonald and Libby Adam, H2FLY

Stuttgart-based innovator H2FLY has achieved an unprecedented breakthrough in aviation history by successfully conducting the world's first piloted flight of an electric aircraft powered by liquid hydrogen. This remarkable milestone marks a pivotal moment in the journey towards sustainable aviation, showcasing the immense potential of hydrogen-based technology in revolutionizing the industry.

The HY4 can seat up to four fliers and has a range of 932 miles. *Credit: H2Fly*

Technological Advancements in HY4 Aircraft

The HY4 aircraft's propulsion system stands as a testament to cutting-edge engineering. It harnesses the power of a hydrogen-electric fuel cell system founded upon advanced low temperature PEM technology. This system's resilience is underscored by the presence of four redundant systems, ensuring unparalleled reliability even under low pressure conditions, maintaining functionality at a minimal 0.35 bar absolute.

Integral to the aircraft's operation is the cryogenic storage of liquid hydrogen, facilitated by a meticulously designed multilayer vacuum insulated dewar tank. Extracting hydrogen for the fuel cell system involves an intricate water-glycol evaporator mechanism, optimizing the evaporation of liquid hydrogen for efficient utilization in the aircraft. Stringent safety protocols in place adhere rigorously to industrial and aviation standards, ensuring the secure and safe handling of cryogenically stored liquid hydrogen during all phases of flight.

Performance Metrics and Environmental Impact

The adoption of liquid hydrogen as the aircraft's power source presents a substantial leap in performance. This innovative technology effectively doubles the range of the HY4 aircraft to an impressive 1,500 km, surpassing the limitations associated with gaseous hydrogen. Beyond its enhanced performance, the hydrogen-electric propulsion system boasts zero emissions during flight, contributing solely water vapor and significantly reducing the aviation industry's carbon footprint.

Industry Impact and Future Trajectory

H2FLY's groundbreaking achievement serves as a catalyst, propelling the aviation industry's collective efforts towards carbon emission reduction. Aligned with global environmental sustainability objectives aiming for net-zero emissions by 2050, this technological advancement serves as a cornerstone for transformative change in aviation.

The vision forward for H2FLY encompasses the strategic scaling of this pioneering technology, envisaging its integration into regional aircraft and diverse aviation applications. The company's unwavering focus remains on developing robust fuel cell systems, aimed at enabling emissions-free commercial flights and spearheading a sustainable aviation revolution.

Collaborative Endeavors and Key Partnerships

The success story of the liquid hydrogen-powered flights owes its realization to collaborative efforts with esteemed partners including Air Liquide, the German Aerospace Center (DLR), EKPO Fuel Cell Technologies, Fundación Ayesa and others. These partnerships, bolstered by support from European government funding and various ministries, have been instrumental in accelerating the progress of hydrogen-powered flight.

Pathway to Commercialization and Industry Transformation

H2FLY's ambition to commercialize hydrogen-electric aircraft by 2027 signals a transformative shift in the aviation landscape. The potential commercial availability of these aircraft would provide airlines and passengers access to revolutionary, sustainable air travel options, heralding a new era in commercial aviation. The successful completion of flight testing in Project HEAVEN signifies a critical stride towards realizing emissions-free, medium- and long-haul commercial flights. H2FLY's relentless commitment to innovation and sustainability positions them at the forefront of reshaping the future of aviation.

The groundbreaking liquid hydrogen-powered flights conducted by H2FLY represent not just technological achievements but herald a paradigm shift towards a more sustainable future for air travel. H2FLY's pioneering strides in hydrogen-based aviation technologies lay the groundwork for a cleaner, greener and more efficient era of aviation, setting new standards and inspiring worldwide transformation in the skies. **www.h2fly.de**

LCLS-II's 'First Light' Revolutionizes X-ray Science

by Eric Fauve, Cryogenic Division Director, SLAC National Accelerator Laboratory, with components attributed to Ali Sundermier

LCLS-II compressor skids. *Credit: TJNAF*

The LCLS-XFEL at SLAC National Accelerator Lab has launched its upgraded version, LCLS-II, generating its first X-rays. This advancement is set to revolutionize research, offering unparalleled capabilities for studying quantum materials with remarkable precision. Scientists worldwide are queued up to explore various applications, from improving computing and communication technologies using quantum materials to understanding fleeting chemical reactions for sustainable industries and clean energy. Additionally, the upgrade enables investigations into biological molecules' functions for pharmaceutical advancements and opens doors to entirely new scientific realms by studying the world's fastest timescales.

"This achievement marks the culmination of over a decade of work," said LCLS-II Project Director Greg Hays. "It shows that all the different elements of LCLS-II are working in harmony to produce X-ray laser light in an entirely new mode of operation."

Reaching "first light" is the result of a series of key milestones that started in 2010 with the vision of upgrading the original LCLS and blossomed into a multiyear billion-dollar project involving thousands of scientists, engineers and technicians across DOE, as well as numerous institutional partners.

Accelerator

The superconducting linear accelerator (Linac) relies on cryogenic cooling to hit temperatures close to absolute zero, around 2.0 K. This temperature allows niobium, a vital material for RF (radio frequency) cavities, to lose all electrical resistance, significantly cutting down energy loss during acceleration and boosting efficiency. By keeping the cavities at 2.0 K, they operate below niobium's critical temperature, enabling superconductivity and high accelerating gradients with minimal energy loss, unlike copper-based accelerators. Liquid helium in cryogenic cooling maintains the cavities at this critical temperature for optimal performance.

At SLAC's LCLS-II, running both the superconducting and copper-based accelerators in tandem is groundbreaking. The copper accelerator operates at higher energies, complementing the superconducting one by providing beams with different features such as higher energy levels and intense X-ray pulses. Cryogenics is pivotal in enabling the superconducting accelerator for continuous-wave (CW) operation, vastly broadening the spectrum of possible experiments.

Cryomodules

The cryomodules used in the LCLS-II project are a marvel of engineering, designed with high-purity niobium for the superconducting RF (SRF) cavities. These superconducting cavities operate at remarkably low temperatures, around 2.0 K. The 1.3 GHz cryomodules house eight 9-cell SRF cavities cooled with superfluid helium at this critical temperature, enabling their efficient operation and exceptional performance. "The collaboration between Fermilab, Jefferson Lab and SLAC was pivotal in the successful design and construction of the cryomodules. Fermilab's expertise in engineering cryomodules, coupled with Jefferson Lab's contributions in manufacturing a significant portion of these modules, was essential in bringing LCLS-II to fruition," remarks LCLS-II-HE Project Technical Director Marc Ross.

Cryoplant, Infrastructure and Process

The cryogenic system at LCLS-II operates through a complex infrastructure featuring two large helium cryoplants delivering substantial cooling power. Each cryoplant comprises a 4.5 K refrigerator coupled with a 2.0 K system capable to deliver 4.0 kW of isothermal refrigeration at 2.0 K. The 4.5 K refrigerators use oil-flooded screw compressors, liquid nitrogen pre-cooling and four stages of cryogenic turbo-expander to produce liquid helium. The 2.0 K system consists of a train of five cryogenic compressors allowing the cavities to operate at 31 mbar and 2.0 K. The supporting infrastructure includes a 1,900-square-meter building, housing the critical cryoplant's gear and necessary systems. An electrical switchyard delivers the 10 MW required to power the screw compressors, and five cooling towers deliver the 1,200 m^3/h required to evacuate the compression heat.

Commissioning and Operation

The LCLS-II Linac's commissioning began with a systematic cooling-down process in March 2022, carefully considering cooling speed, gradient and cryoplant capacity. Remarkably, within just five days, the cool-down was achieved, a significant

Transfer lines and distribution boxes *Credit: SLAC*

The launch of its upgraded version, LCLS-II, at SLAC National Accelerator Lab marks a groundbreaking advancement, generating its inaugural X-rays and promising a revolutionary leap in research with unparalleled capabilities for studying quantum materials with remarkable precision. *Credit: SLAC*

milestone in the project. Designed for year-round operation, the LCLS-II allows weekly maintenance called Planned Accelerator Maintenance (PAM), lasting 1 to 3 days for Linac maintenance, excluding cryoplant shutdowns or Linac warming. Until mid-2026, the cryoplant is expected to run continuously, pausing Linac operations for about a year to install 23 additional cryomodules for the LCLS-II HE (High Energy) Project.

Beyond 2027, the two cryoplants will support the LCLS-II HE Linac. Major cryoplant maintenance will then happen every three years or longer. During maintenance, the Linac will be supported at reduced capacity by a single cryoplant, ensuring continual operation of the cryogenic components.

Safety and Operation

Safety measures in the LCLS-II project focus on cryogenic operations, tackling risks like pressure hazards, cold gas exposure and potential oxygen deficiency. The engineering design meets ASME pressure codes, ensuring safety. All gas relief (vents and relief valves) are connected to exhaust pipes routed outside buildings to reduce oxygen deficiency hazard (ODH). All buildings are equipped with oxygen sensors connected to an oxygen deficiency monitor that will alarm if oxygen level decreases. SLAC maintains strict safety protocols for high voltage and industrial safety. Also automation and machine protection interlocks are widely implemented for efficient and safe operation.

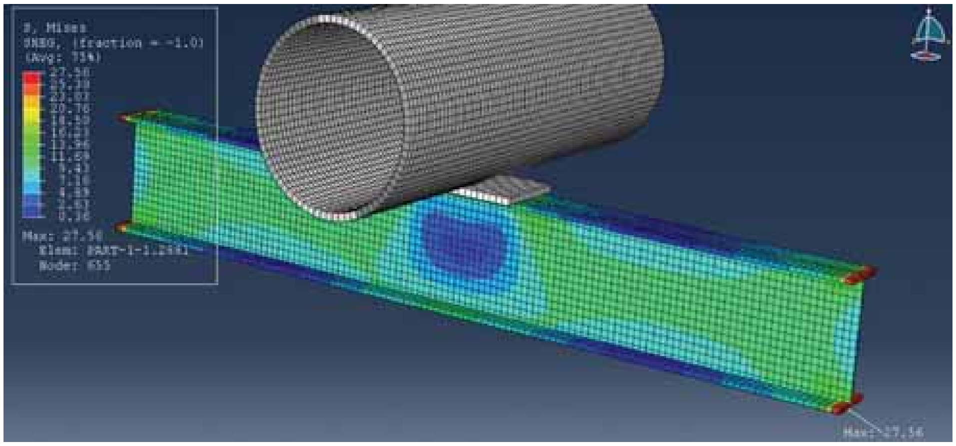
Impact

LCLS-II signifies a pivotal leap in X-ray science. It enables scientists to capture atomic-scale details of molecules, atoms and electrons in unprecedented ways. “This upgrade to the most powerful X-ray laser in existence keeps the United States at the forefront of X-ray science, providing a window into how our world works at the atomic level,” Secretary of Energy Jennifer M. Granholm notes. While Asmeret Asefaw Berhe from the DOE praises its potential impact on fundamental science, clean energy and national security through quantum information science. “I really look forward to the impact of LCLS-II and the user community on national science priorities,” she adds.

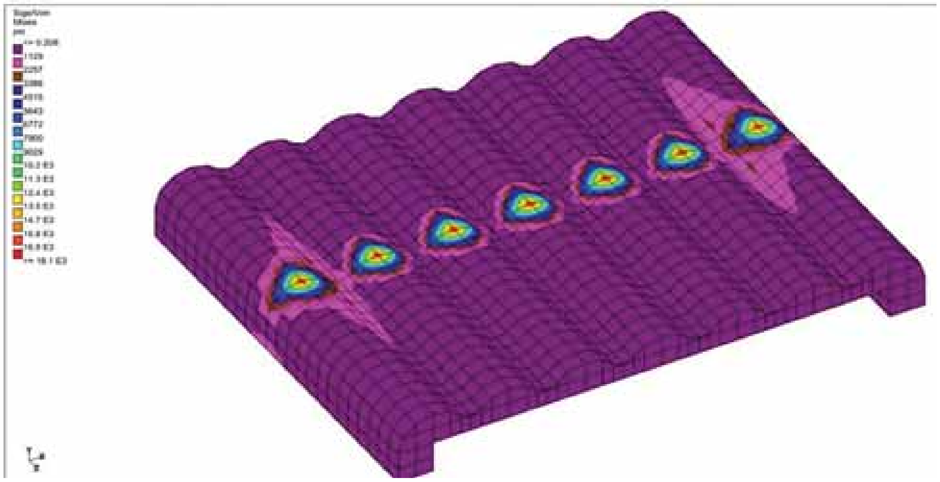
The profound impact of LCLS-II spans diverse scientific domains. Its capabilities promise breakthroughs in quantum materials, ultrafast computing, sustainable manufacturing and materials science. By capturing atomic-scale snapshots of reactions and creating 'molecular movies,' LCLS-II will revolutionize understanding in biology, chemistry and physics, attracting researchers globally for a wide array of experiments in the near future. Director Mike Dunne emphasizes that this facility, offered at no cost to users, is set to drive a revolution across academic and industrial sectors, ushering in a wave of innovation and discoveries. “Experiments in each of these areas are set to begin in the coming weeks and months, attracting thousands of researchers from across the nation and around the world. LCLS-II is going to drive a revolution across many academic and industrial sectors. I look forward to the onslaught of new ideas – this is the essence of why national labs exist.” **www6.slac.stanford.edu**

Elevating Pipe Support Systems with "Lift-Off" Innovation

by Martin Schutte, Lift-Off Pipe Supports



Loading the pipe across the full beam flange width was crucial. Supporting it differently led to stress increases of over 100% in simulations. *Credit: Lift-Off Pipe Supports*



Lift-Off Pipe Supports tested various models and supports, confirming their strength. The ultimate design, including polymer supports, proved effective even under 550-pound stress. *Credit: Lift-Off Pipe Supports*

One often underappreciated hero in the field of industrial piping plays a pivotal role – pipe supports. These unassuming components are tasked with the vital responsibility of ensuring that piping systems remain stable, safeguarding against overloading and the undue stress that could lead to catastrophic failures in the overall system. Pipe supports come in various forms, including hangers, struts, pick-ups, springs, beams and more. Without these critical elements, the operation of any industrial plant would teeter on the edge of instability. However, the history of pipe supports has been marred by a series of failures stemming from issues such as corrosion, excessive deflection and inadequate design considerations.

Common Faults and Standards

Various types of failures can affect pipe support systems. Corroded supports, resulting from the corrosion of structural steel, can undermine their load-bearing capacity, impacting the entire system. Excessive structural deflection occurs when support beams or columns deteriorate over time, leading to inadequate load-carrying capacity and compromising the system's integrity. Wall thickness degradation can happen due to wear and tear, causing pipe walls to fail under stress and poses significant safety risks. Vibrations and oscillations, whether from rotating machinery or external factors like wind, can create stress fractures in pipes, threatening system integrity. Pipe support failures can stem from incorrectly specified elements that degrade under environmental and operating conditions. Additionally, process failures may occur if industrial process conditions are not adequately considered during the initial design phase. Incorrect installation of pipe supports, subsidence of foundational supports and other issues can also lead to unforeseen complications and failures.

To ensure the reliability of pipe support systems, certain requirements must be met. These include considering process conditions, such as design temperatures and pressures, as well as external factors like slug flow and corrosive atmospheres. Evaluating climatic conditions, such as wind strength, seismic activity, and corrosive atmospheres, is crucial. In cases near urban areas, noise and acoustic requirements may necessitate additional insulation. Cathodic isolation may be needed to prevent corrosion, and supports must be fire-resistant to avoid contributing to the spread of fire events.

Moreover, the supports must meet specific criteria. They need to be adaptable for various applications, including guides, line stops and spring supports. Corrosion resistance is crucial to withstand highly corrosive atmospheres, and supports must be compatible with both high and low temperatures, including cryogenic conditions. A variety of materials should be used to allow flexibility and customization. Effective drainage capability is necessary to prevent damage in corrosive atmospheric conditions. Additionally, supports must be designed, manufactured and tested to withstand both static forces and shock loads, as specified or determined on-site. Lastly, compliance with relevant piping requirements and industry codes is essential to ensure safety and reliability.

Production

During the development of "lift-off" pipe supports, extensive research focused on materials, manufacturing techniques, standards, codes and compliance regulations to meet high performance and reliability standards. One critical insight was the need for even load distribution across support beams to avoid stress concentrations and eccentric loads. Addressing friction between pipes and support beams led to an innovative non-slide compound that eliminated the need for additional

▶ *continues on page 18*

fixtures, reducing the risk of corrosion and failure. The development phase included multiple models, process assessments and finite element analysis (FEA) studies to ensure safety and performance. Two key variants, "lift-off vertical" (LOV) and "lift-off rest" (LOR) supports, were rigorously tested and demonstrated the effectiveness of load distribution. The "lift-off" family also includes composite resin supports that resist loading, corrosion, UV rays and fire. Their material flexibility allows them to be tailored to specific project requirements and environmental conditions.

Manufacturing is done in-house with stringent safety and quality control measures. The facility's strategic location in Lake Charles, Louisiana, near the Gulf of Mexico, is ideal for the oil and gas industry. Every support batch undergoes comprehensive testing and documentation as part of the quality program. Regarding installation and safety, clients receive a thorough understanding of the risks associated with installing pipe supports, with a focus on safety and necessary precautions in live plant environments. Training for tradesmen and contractors minimizes incidents, ensuring personnel safety and system integrity.

Looking Ahead

The introduction of the "lift-off" pipe supports marks a significant step forward in the world of industrial pipe support systems. The "lift-off" supports have proven to be a reliable and robust alternative, capable of withstanding a wide temperature range, from -270 °F to +450 °F, with intermittent temperature spikes reaching up to 550 °F. Moreover, they exhibit excellent UV and corrosion resistance, making them well-suited for the demanding conditions of industrial settings. The even distribution of load across beam flanges, rather than concentrating on back mark offsets, has significantly increased the beam carrying capacity, enhancing overall safety and performance.

"Lift-off" pipe supports have emerged as a pioneering solution that addresses the historical failures and multifaceted challenges associated with traditional pipe supports. With unwavering commitment to quality, safety and performance, these innovative supports are poised to make a transformative impact in the industrial piping landscape. **www.liftoffpipe.com**

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Cryogenics Drives Advancements in Aerospace Welding

by Carlo Chatman, Tri Tool Representative

The aerospace industry is continually advancing, which is creating a demand for higher precision and durability in every component used. Among these critical elements, piping and tubing systems stand out as essential conduits for vital gases and liquids within spacecraft, aircraft and launch pad infrastructures. Working with these systems, however, poses substantial challenges, especially when it comes to welding.

The meticulous process of aerospace welding demands precision in preparing pipe and tube ends to exceedingly tight tolerances. It requires avoiding the introduction of contaminants and achieving specified surface finishes. As the industry shifts towards lighter, stronger materials like Inconel and other nickel superalloys to improve efficiency and reduce weight, the challenges escalate. These materials must withstand extreme conditions, including cryogenic temperatures, high pressures and intense environmental stresses. Inconel, a highly resistant alloy widely used in aerospace due to its robustness in high-temperature environments, presents a formidable challenge for machining. Its toughness makes it exceptionally hard to shape and work with, often causing tools to break or deform during machining processes.

In tight spaces, field machinists can rely on the 300STS—a compact, portable squaring tool. Its precision and lightweight build streamline operations, ensuring accurate cuts and boosting productivity. *Credit: Tri Tool Technologies*

"Aerospace companies are pushing the boundaries of what can be achieved every day. As a result, they are utilizing more advanced materials for piping and tubing, often with smaller diameters, thicker walls and more complex joint geometries than even ten years ago," says Chris Belle, CEO of Tri Tool Technologies. "The more inconsistent the machining, the more weld failures you will have. Unfortunately, materials such as Inconel only increase the chances of joint misalignment, poor prep angles and contamination," explains Belle.

"To minimize or eliminate weld failures for these critical applications, the key is achieving very consistent, high-quality weld prep every single time," continues Belle, who underscores the criticality of getting the weld prep right on the first attempt, especially when considering the expense of advanced alloys. Understanding these materials' properties and limitations is pivotal for machinists, who often require specialized cutting and facing equipment tailored for these demanding applications.

The aerospace industry relies heavily on semi-automated orbital welding machines for their ability to produce reliable, high-quality welds meeting stringent criteria. However, achieving precise welds demands immaculate pipe and tube end preparations with no room for error, necessitating tools that guarantee proper fit and alignment.

Tri Tool Technologies addresses this need with products like the 300STS, offering precision cuts within a remarkable range of tube sizes and wall thicknesses. The company's emphasis on tool bit quality underscores its commitment to precision and durability, which is critical for aerospace applications where thousands of preps per week are commonplace. Moreover, the company's ability to customize solutions based on client requirements adds immense value. Recent modifications to Tri Tool's equipment, such as introducing miter cuts and proprietary cutting bits tailored for Inconel, highlight its adaptability and commitment to meeting evolving aerospace demands.

Tri Tool's innovative solutions have significantly impacted the aerospace sector, aiding in the acceleration of production timelines for launch vehicle platforms and solving intricate welding challenges in critical components like diffuser nozzles. As the aerospace landscape continues to evolve with the rapid expansion of private space companies and the development of next-generation aircraft, the necessity for precise, reliable, and adaptable machining solutions becomes increasingly evident. Tri Tool Technologies stands at the forefront, offering aerospace-specific pipe and tube squaring solutions that ensure weld integrity under the most demanding conditions. Its dedication to innovation and precision underscores its role in advancing aerospace welding technology. **www.tritool.com**

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Calling Women in Cryogenics and Superconductivity

Join us for our annual feature in *Cold Facts* as we honor the remarkable contributions of women in cryogenics and superconductivity. Seeking fresh perspectives and untold stories, we invite women who are yet to be included to share their insights.

Are you a trailblazer or know someone breaking barriers in these fields? Contact our editor, Anne DiPaola (editor@cryogenicsociety.org), to receive an applicant questionnaire. Return your responses and a headshot by January 26 to be featured in our March 2024 issue.

Help us widen the scope! Spread the word and encourage deserving women in cryogenics and superconductivity to step forward. Together, let's spotlight the innovation and impact of these remarkable individuals.

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by Quan-Sheng Shu, Retired Senior Scientist, and Jonathan Demko, LeTourneau University

Cryo-Engineering for SRF

Fifty-Five Years of Inextricable Success

Superconducting Radio Frequency (SRF) cavities are vitally central to SRF accelerators, boasting a Q factor about 10^5 times higher than copper cavities and the capability to produce accelerating fields (Eacc) on an order of magnitude greater than copper in CW. In the 1960s, SRF cavities were delicate instruments used by pioneering scientists in several prestigious labs. Over the past 55 years, the synergy between cryogenics and SRF accelerators has consistently proven mutually beneficial and successful. Today, the landscape has evolved significantly, with potential markets for industrial electron beams reaching \$10 billion annually. Various SRF cavities mainly made from Nb (Figure 1)[1-2] are widely used in high energy physics, nuclear science, FEL, XFEL, synchrotron lights, computer chips, and medical and industrial applications.

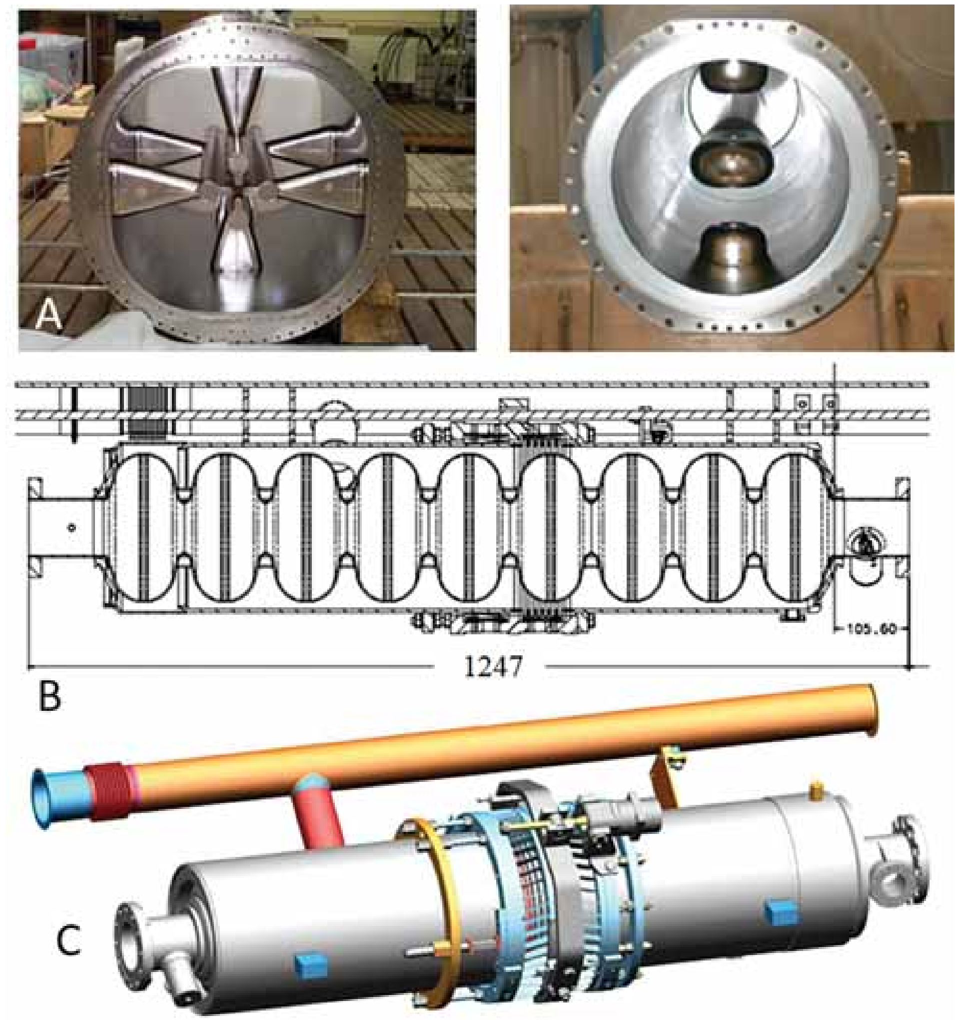

Figure 1. A- Low β Nb cavities,[1] B- TESLA style cavity, and C- Cavity in LHe vessel.[2] Credit: A. Lombardi et al. and C. Pagani

Theoretical Performance

Unlike DC applications, where a superconductor (SC) has zero electric resistance, SC in RF fields have a specific surface resistance (Rs) and allow magnetic fields to penetrate their surface to a depth (δ). In the SRF cavity, Eacc runs along the central axis. Near the cavity wall magnetic fields H are parallel to the cavity surfaces, with the highest Hmax around the cavity's equator. Electric fields are vertical to the surfaces, with the maximum Emax near the iris. Simplified formulas below can be used to derive several theoretical cavity performances.

Ideal (theoretical) Q_0.

The power dissipated P_d is given by the integral of resistive wall loss over cavity surface. Qo is the ratio of energy restored in the cavity (ωU) to the energy loss P_d. G-cavity geometry factor and determined by its shape only, μo - permeability of free-space and ω - frequency.

$$U = (\mu o/2)\int H^2 dV$$
$$P_d = (Rs/2)\int H^2 dS$$
$$Q_o = \omega U/P_d = G/Rs$$
$$R_{BCS} = Df^2(e^{-17.87/T}/T)$$

The $R_S = R_{BCS} + R_{res}$. R_{BCS} is the ideal minimum resistance by BCS theory. R_{res} depends on materials' purity, external H, etc. For example, a 9-cell TESLA cavity (Nb) has G=270 at 1.8 K and 1.3 GHz: R_{BCS}=4.55nΩ, $R_{res}=R_H$(earth H) =3.42nΩ, Rs=7.97nΩ, so the ideal $Q_o=3.4x10^{10}$. However, for a copper cavity at 300 K and 1.3GHz, $Q_0(Cu)=3x10^4$.

Ideal (theoretical) Eacc.

Currently, the Type II superconductor Nb is the most popular cavity material and has a magnetic quench field Hc2 about 2400-Oe at 1.8 K. Therefore, for this cavity, the ideal maximum Eacc is about 56MV/m, corresponding to the Hc2.

Journey to Ideal Performance

Qo vs. E curves are the primary measure of SRF cavity performance. Ideally, the cavity's Q_o should remain constant as the accelerating field E rises, up to the magnetic quench field, as shown by the "ideal" green line in Figure 2. However, in practice, the Q vs. E curve falls below the ideal due to various factors. Thanks to advancements in cavity fabrication, including shape design, high RRR Nb, e-beam welding, BCP, and RF processing, issues related to multipacting and thermal breakdown in cavities have been successfully addressed. Consequently, Cavity Eacc ranged to 7-12 MV/m with Q ~10^{10}

in the 1980s. This progress laid the foundation for SRF accelerator projects like KEK, HERA, LEP, and CEBAF.

However, as Eacc exceeds 10-15 MV/m, field emission (FE) becomes the primary limiting factor.[3-4] FE significantly reduces the cavity Q_0 due to the exponential increase in electron currents from FE origins. Extensive studies at Cornell, Wuppertal, KEK, Jlab, and DESY aim to understand and mitigate FE to reach higher Eacc. Various cavity treatment techniques, including thermometer mapping, He-RF processing, high-T treatment with Ti protection, and HPP, have been employed. These efforts culminated in achieving the Eacc of about 30 MV/m at Cornell in 1989-90,[3,4] generally meeting the TESLA requirement, as depicted in Figure 2. These achievements have helped make significant progress at TESLA, Jlab, FLASH, SNS, and LEP-II.[5]

The emergence of the Q-disease presents new, serious challenges for SRF cavities after FE reduction. Fresh efforts involving the development of large/single crystals of Nb, EP, HPR, and mild-temperature treatments (up to 120 °C) have yielded impressive results. In 2017-18, researchers at FNAL achieved a milestone with an Eacc of 48 MV/m and a Q above 10^{10}.[6] Since 2010, more XFELs and additional upgrades to SRF accelerators have been developed.

SRF Cryomodules

The SRF cryomodules demonstrate seamless collaboration between cryogenic techniques and SRF cavities, playing a vital role in ensuring the success of SRF accelerators. The SRF cavity is cooled within a LHe-II container, thermally isolated from room temperature using MLI blankets and the low thermal conductance support system within the cryomodule vacuum. The cryomodule also serves as the hub for high RF power to the cavities, cryogen distribution, and technical data collection.

The TESLA Collaboration, led by DESY, initially aimed to develop a 20 km e+e- linear collider but faced financial constraints that halted the project. However, core technologies from TESLA have since advanced worldwide.[7] Figure 3 illustrates a partial section of the TESLA/ILC cryomodule,[2] which spans about 12 meters and houses eight SRF cavities. Thermal shields are used to reduce radiation heat, featuring 30-40 MLI layers at around 65 K and 10 MLI layers at approximately 2 K. The low thermal conductivity posts are anchored at 50-65 K and 6 K. Each cavity has a sophisticated RF coupler for transferring high RF power to the cavity and a HOM coupler to extract unwanted RF fields. A large, cold He return pipe (HGRP, 300 mm) is necessary to minimize pressure drop and can also serve as the primary structural support for the module cold mass. Typically, a cryogenic unit consists of about 10 cryomodule strings, contingent on the specific cryogenic cooling system of the accelerator design.

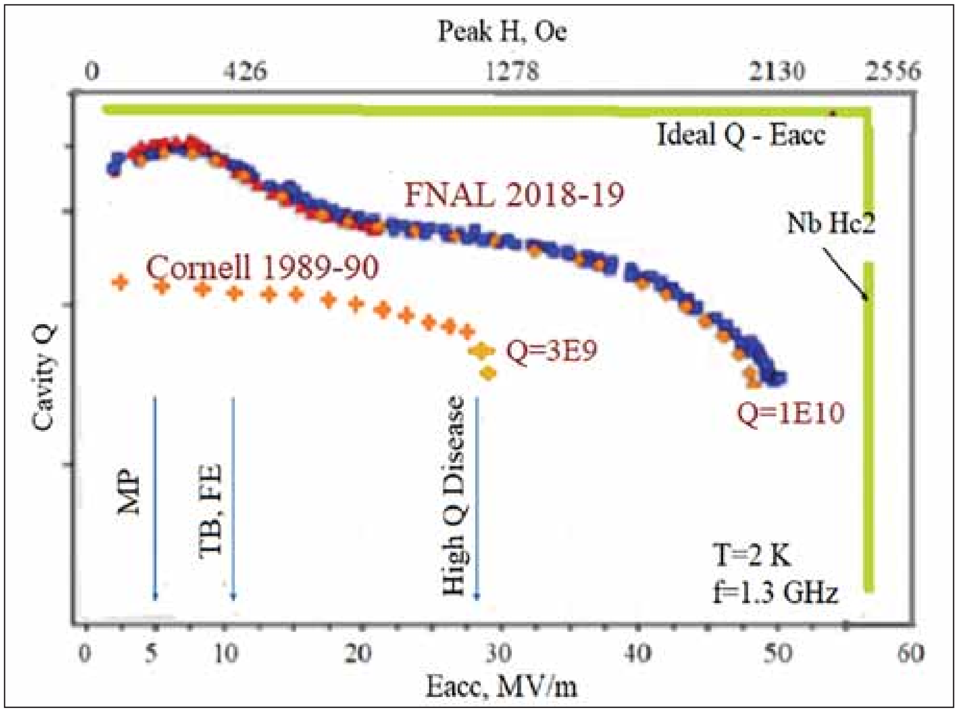

Figure 2. Simplified Q-Eacc plots used to showcase a few historical performances of the best cavities. Precise scaling in references: Cornell[3] and FNAL.[6] *Credit: Q. S. Shu et al. and A. Grassellino et al.*

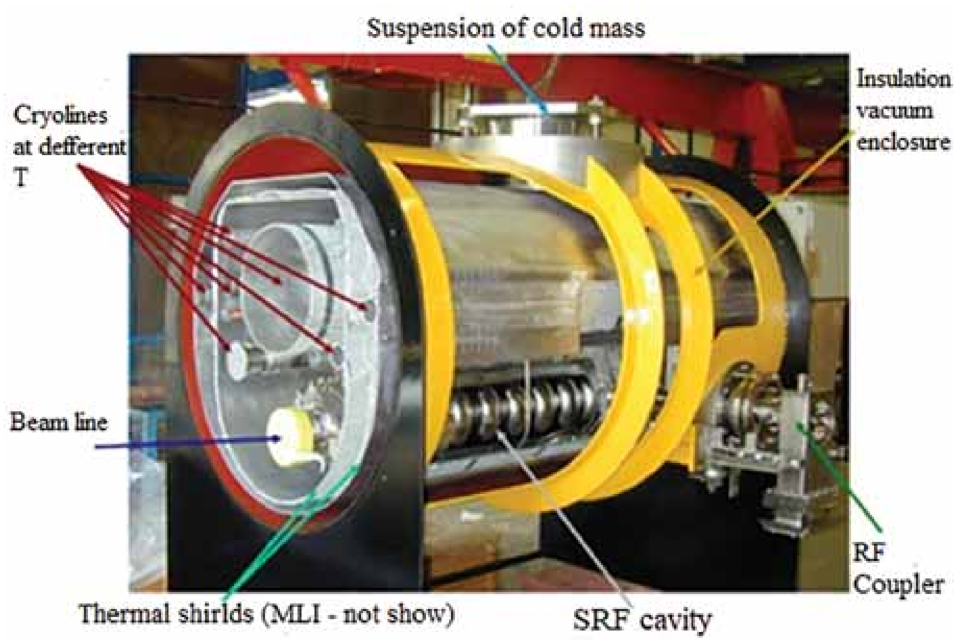

Figure 3. A mock-up of TTF3 style XFEL cryomodule.[2] *Credit: C. Pagani.*

Cooling of SRF Cryomodules

To build an SRF accelerator, it is crucial to further improve SRF cavity cooling, which involves two key aspects: 1. Enhancing the quality factor (Q_0) and improving heat transfer on the cavity surfaces to reduce Kapitza resistances. 2. Designing and developing a highly efficient cryogenic liquefier/refrigeration system capable of supplying sufficient LHe and cold He gas to cool the cavities and associated components in all cryomodules within the

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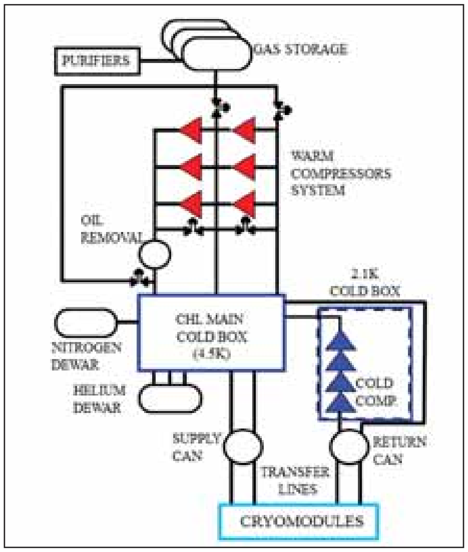

Figure 4. Diagram of the CHL at ORNL.[9] ***Top of form.*** *Credit: M. Howell et al.*

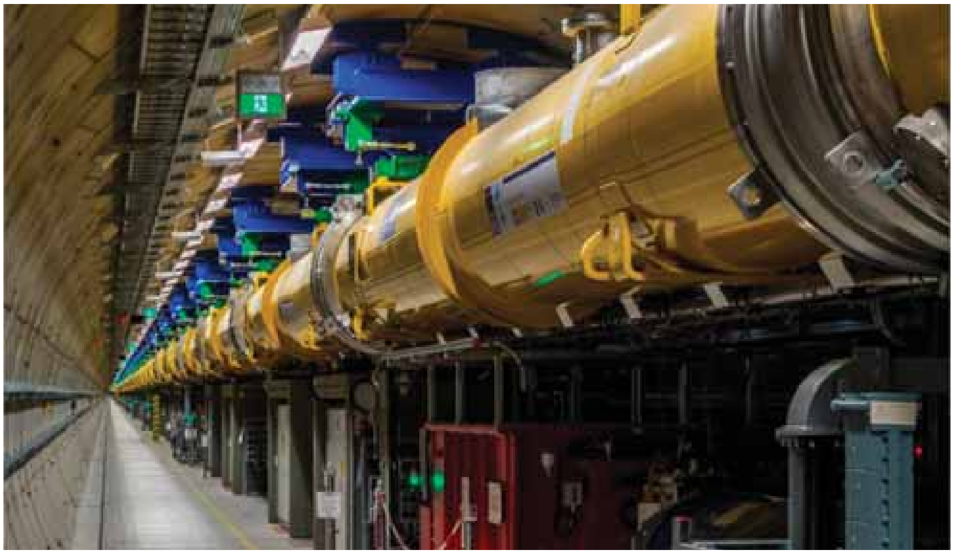

Figure 5. SRF accelerator in tunnel of European XFEL.[10] *Credit: Reschke et al.*

accelerator. The measured static and dynamic heat loads of an XFEL cryomodule at 16.5GeV operation are summarized as follows[8]: Static- 2K 6.1 W, 5/8 K 8 W, and 40/80 K 102 W. Dynamic- 2 K 7.2 W, 5/8 K 2 W and 40/80 K 32 W. These values are comparable with XFEL design.

The Spallation Neutron Source (SNS) at ORNL serves as another exemplary SRF accelerator, providing a 1 GeV, 2 MW beam for experiments. Its linac comprises over 80 SRF cavities (805 MHz) housed in a total of 23 cryomodules operating at 2.1 K. Figure 4 illustrates the central He liquefier as a highly automated and reliable system.[9] The CHL employs a group of cold compressors to force cold He vapors into the heat exchangers of the cold box.

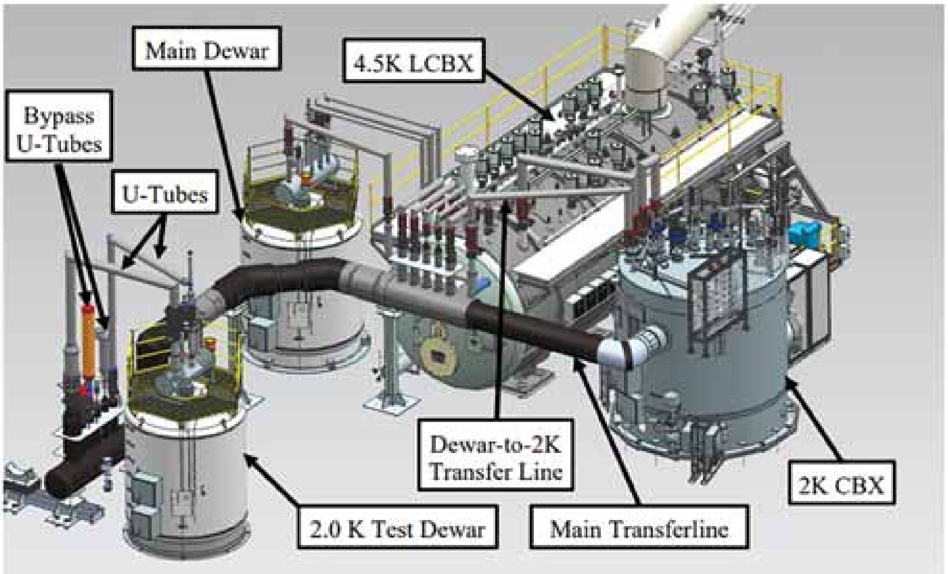

Figure 6. LCLS-II CHL system model.[11] *Credit: R. Bhattacharya et al.*

SRF Accelerator and Cryogenic System

SRF linear accelerators have diverse applications as "user" machines, such as proton linac (e.g., SNS and ESS), heavy ion linacs (like FRIB, ATLAS, ISAC-II), linac/ER-linac-based FELs (like FLASH, XFEL, Jlab-FEL/ERL), and future projects like Shanghai HRR-XFEL and the possible International Linear Collider (ILC). Due to space limitations, we will briefly discuss only two SRF accelerators. The European XFEL spans 3.4 km, reaches electron beams of about 18 GeV, and delivers X-rays from 0.25 keV up to 25 keV. It comprises 96 cryomodules (approximately 800 cavities with an average of over 25 MV/m and Q ~ 10^{10}), operating at 1.3 GHz with a 10 Hz repetition rate. These cryomodules run at 2 K, cooled by a cryogenic system with a 4-stage set of cold compressors (CC) that compress the cold helium vapor from 2400 Pa to about 110 kPa at a mass flow of up to 100 g/s. Figure 5 shows the XFEL in a tunnel with SRF cryomodules suspended from the ceiling and RF infrastructure on the floor.[10]

The Linear Coherent Light Source (LCLS-II) developed at the SLAC National Laboratory has 37 LINAC cryomodules operated at 2 K to accelerate a 4 GeV electron beam, generating hundreds of watts of intense X-ray laser light. The cryoplant includes two helium refrigerators, each with an equivalent 4.5 K cold box, 18 kW, and 2 K cold box 4 kW. Two five-stage cold compressors are used to compress the cold He vapors as shown in Figure 6.[11]

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White Paper Explores Gas Monitoring in Food Storage Safety

by Emily Mahlon, CO2Meter, Creative Director

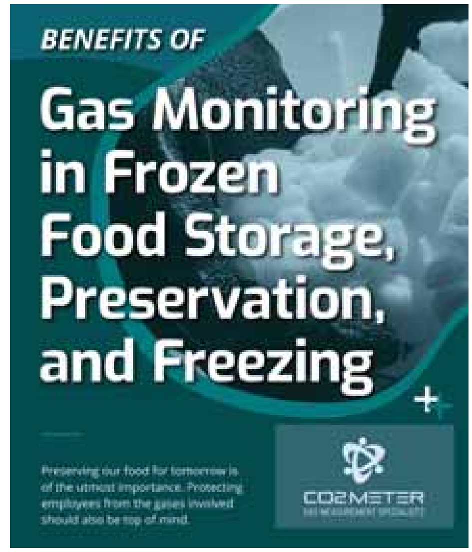
Gas monitoring in frozen food storage plays a pivotal role in maintaining employee safety, food integrity and overall quality. The use of refrigerants or gases in these facilities necessitates constant monitoring to swiftly detect leaks, as certain gases pose severe health risks and potential fatalities if leaked into storage areas. Continuous monitoring, using gas detection safety systems, serves as a crucial preventative measure, averting exposure to harmful gases. Additionally, adherence to regional regulations on gas storage and handling is facilitated through effective gas monitoring, averting potential legal complications.

In CO2Meter's endeavor to highlight the significance of gas safety in frozen food storage, it aims to educate and raise awareness about the inherent hazards associated with handling compressed gases in the food industry. While preserving, storing and freezing are all fundamental processes, so is protecting employees from the gases involved and ensuring everyday facility safety. In response, CO2Meter published a white paper, "The Benefits of Gas Monitoring in Frozen Food Storage, Preservation, and Freezing," which focuses on elucidating the role of gases in food preservation, identifying potential hazards, and emphasizing the necessity of gas detection safety systems. Key takeaways of the white paper include understanding the role of gas in the frozen food industry; deciphering the use of gas across food production applications; identifying gas hazards and source points; discovering the benefits of gas detection safety monitoring; interpreting how to choose a gas safety monitor; and gaining a free gas safety guide and training checklist.

This educational resource empowers readers to safeguard themselves and their workplace by identifying potential hazards, employing standardized procedures, and installing gas detection safety monitors. All information provided is supported by thorough research and credible statistics, advocating for prioritizing employee safety in any work environment.

As a leading provider of gas detection safety solutions, CO2Meter has served more than 300,000 locations worldwide since 2006. Its clientele includes national restaurant chains, cold storage facilities, multinational food processors and Fortune 500 companies like Tyson Foods, Kraft Heinz, Chipotle, Walgreens, and Dippin' Dots. These partners rely on CO2Meter's safety solutions for real-time gas monitoring, protecting their staff from overexposure, hypoxia, and fatalities. CO2Meter is committed to offering education, safety resources and superior gas monitoring solutions to ensure workplace safety for its partners presently and in the future. **www.co2meter.com**

CO2Meter invites readers to read "The Benefits of Gas Monitoring in Frozen Food Storage, Preservation, and Freezing" by following **https://co2meter.club/food-storage-whp**.



CO2Meter has released a white paper about the fundamentals and best practices for gas monitoring in the growing cryogenic food industry. *Credit: CO2Meter*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CryoCoax Revolutionizes Cryogenic Connectivity

by David Phillips, CryoCoax

Intelliconnect has announced the availability of its CryoCoax (a division of Intelliconnect) Q-CON high density cryogenic connectors; these connectors are making waves in the rapidly advancing world of quantum computing. As the quantum computing landscape evolves with the development of large-scale high-qubit machines, there is an increasing demand for microwave cables to facilitate control and readout lines to the quantum processor. Traditionally, these cables were individual coaxial cables fitted with SMA connectors that offered limited packaging flexibility due to their 8 mm hex coupling. They required extra space for tooling during installation.

Quantum processors, designed to operate at temperatures near absolute zero, require special- ized equipment to facilitate their functionality. Enter the dilution refrigerator, a crucial compo- nent in quantum research labs. These refrigerators are engineered to create and maintain extremely low temperatures, often below 20 mK, at their lowest stage. At these frigid temperatures, quan- tum processors come to life, enabling ground- breaking research and computation. Within the dilution refrigerator, the challenge lies in ensuring that all components, including microwave cables, connectors and attenuators, operate seamlessly to facilitate the quantum computing process while minimizing passive heat load and thermal noise.

Enter CryoCoax, with its innovative high density multiway connectors based on the SMPM interface. These connectors not only provide a higher density of coaxial lines within a given space but also simplify installation and customization within a dilution refrigerator. Unlike the typical 16 mm spacing between SMA connectors, the new Q-CON high density connectors boast a compact 4.75 mm pitch. The SMPM interface offers a straightforward push-to-mate connection, requiring only a hex key to tighten the two fasteners securely.

The materials used for these connectors are crucial for their performance. CryoCoax ensures top-notch quality by machining the connector components from high-purity and beryllium copper. These components are further enhanced with

CryoCoax's high-density SMPM connectors simplify quantum processor installations in dilution refrigerators, offering improved spacing and thermal conductivity for demanding low temperature operations in quantum computing. *Credit: CryoCoax*

gold plating to optimize thermal conductivity. If non-magnetic versions are needed, CryoCoax can accommodate those specifications as well. These versatile connectors are compatible with 0.047-inch (1.19 mm) size coax, available in various options, including semi-rigid, flexible, or conformable versions. Semi-rigid cables come in a range of materials, including niobium-titanium, stainless steel, copper, cupronickel and beryllium copper, often combined with silver-plated conductors. This variety offers users the flexibility to select the ideal cable for their specific application, balancing thermal conductivity and attenuation.

In cryogenic applications, minimizing passive heat load is a primary concern. Typically, cables with low thermal conductivity are preferred to achieve this goal, although this often results in poor electrical conductivity. For connections between the top of the dilution refrigerator and the control electronics at room temperature, flexible cables with silver-plated copper conductors are commonly used and can be terminated with conventional SMA connectors. Additionally, conformable copper coaxial options are available and are frequently employed in the lowest stage of cryogenic systems.

In quantum applications, superconducting niobium-titanium cables are often specified. However, soldering this material can be challenging, if not impossible. CryoCoax has addressed this challenge by developing solderless connections for high density connectors, as well as traditional SMA, 2.92 and SMP connectors.

The standard configurations of the new Q-CON high density connectors come in 8-way, 16-way and 24-way options, with choices of smooth bore or full detent. These connector blocks can be grouped together, potentially providing hundreds of coax lines within a dilution refrigerator. A mated pair consists of two connector blocks, one featuring a full detent male SMPM interface and the other a smooth bore SMPM male interface. These pairs are complemented by "bullet"-style, female-to-female SMPM adaptors, which are retained in the full detent connector block. Furthermore, CryoCoax offers 8-way, 16- way and 24-way attenuator blocks with options for 0 dB, 3 dB, 6 dB, 10 dB and 20 dB attenuation. Attenuators serve to suppress thermal noise and thermalize the center conductors, enhancing signal quality and reliability.

In collaboration with the National Physical Laboratory, CryoCoax has validated the low temperature reliability of the Q-CON connectors over numerous thermal cycles. Rigorous in-house durability testing has confirmed stable RF performance and DC resistance even after multiple mating cycles. The significance of CryoCoax's innovation has not gone unnoticed. It has been named a finalist in the Interconnection Product of the Year category at the 2023 Electronic Industry Awards. This recognition reflects CryoCoax's dedication to pushing the boundaries of cryogenic connectivity and its commitment to delivering cutting-edge solutions to meet the evolving demands of the quantum computing and cryogenics industries.

CryoCoax is at the forefront of this revolution, providing high density cryogenic connectors that are instrumental in the development and deployment of quantum technologies. These connectors offer a quantum leap in efficiency, installation simplicity and customization flexibility within dilution refrigerators with the promise of more breakthroughs on the horizon, **www.cryocoax.com**

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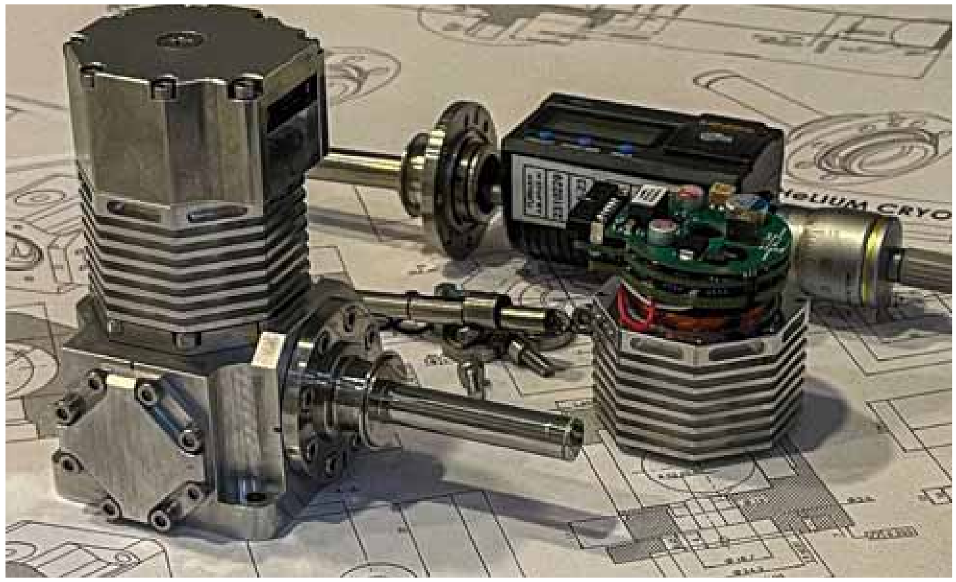
HeLIUM Cryogenics Redefines Cryogenic Technology

by Izgin Ozdas, Lead Manufacturing Engineer, Imtek Cryogenics

In an era where technological innovation is not just an advantage but a necessity, HeLIUM Cryogenics™, stands at the vanguard, continually pushing the boundaries of what's possible in cryogenic technology. Presently, a significant milestone is being marked in HeLIUM's journey as it unveils its latest innovation: a new line of mini and mid-range Stirling coolers. These coolers, exemplifying the pinnacle of engineering and design, stand as a testament to HeLIUM's commitment to excellence, offering performance that competes head-to-head with the best in the market while seamlessly integrating efficiency, compactness and environmental sustainability into an advanced product series.

Recognizing the evolving demands of industries, HeLIUM initiated a project to develop an effective and environmentally conscious cooling solution. Its mini-sized coolers are specifically engineered for infrared detectors, marking HeLIUM's initial focus, while its mid-range models are designed for integration into its cryoplants. Shifting from the Gifford-McMahon cycle to the more efficient Stirling cycle for nitrogen liquefaction, this product range reflects HeLIUM's deep commitment to innovation and sustainable practices in cryogenic technology.

At HeLIUM Cryogenics, its R&D initiatives in Stirling coolers involve an interdisciplinary team comprising mechanical, chemical, physics, material science and electronics engineers. HeLIUM Cryogenics' journey since 2015 has been a focused endeavor, steadily advancing and refining the company's cryocooler technology. As a newcomer in the industry, HeLIUM is committed to learning and growing, consistently improving products to meet evolving needs. The first members of HeLIUM's product family are mini rotary Stirling coolers delivering a total cooling power ranging from 250 mW to 1000 mW at 77 K in a 71 °C ambient environment, followed by a 40 W at 77 K mid-range rotary Stirling cooler. Through enhancements in the design and optimization of heat losses within its coolers, HeLIUM has managed to reduce cooldown times and power consumption. This advancement is crucial for applications requiring quick deployment, like emergency response equipment and mobile infrared imaging devices.



Showcasing HeLIUM Cryogenics' innovation: the 1000 mW @ 71 °C Stirling Cooler alongside its advanced controller, a testament to our precision and expertise in the forefront of cryogenic technology. *Credit: Imtek*

HeLIUM Cryogenics' state-of-the-art machining workshops utilize high precision turning and vertical machining centers, achieving sub-micron tolerances of ±0.1 µm and surface roughness as low as Ra = 0.010 µm. This precision is crucial for manufacturing compressors and cold-finger components with oil-free dry gas bearings, demanding tighter circularity/cylindricity even in 70 HRC materials. Such exacting standards enhance HeLIUM's coolers' cryogenic technology, enabling effective cooling of substantial heat loads. Moreover, this precision-driven approach reduces induced vibration, a critical concern for sensitive equipment. Through design enhancements and the integration of vibration-dampening materials and techniques, HeLIUM has successfully minimized vibration levels in its coolers. HeLIUM Cryogenics handles all design and manufacturing processes internally. The conceptual design phase prioritizes efficiency, user experience and product strategies, setting the groundwork for form, interface features and functionality. Moving into critical design, HeLIUM rigorously assesses the model and its components for thermal and mechanical stresses using finite elements and experimental methods. This step is pivotal in establishing manufacturing tolerances, understanding limits and optimizing design parameters through modeling and simulation studies. This iterative approach ensures high-quality tests and measurements, facilitating a robust feedback loop for optimization.

HeLIUM Cryogenics stands out with more than 90% of its components precision-crafted in-house, underscoring its dedication to quality. Its advanced component verification lab, equipped with tools like CMM and surface roughness measurement systems, ensures HeLIUM's machining processes are both reliable and efficient. This commitment extends to maximizing thermodynamic efficiency, as it innovates to minimize input power while enhancing cooling performance. The company's coolers consistently deliver under diverse conditions, reflecting our journey beyond mere technological advancement. At HeLIUM Cryogenics, they are not just developing cryogenic technologies; they are shaping the future of the field by blending scientific innovation with practical utility, setting new benchmarks with its Stirling and Joule-Thomson cooler technology, backed by their advanced Cooler Driver Electronic (CDE) system. HeLIUM Cryogenics is driven to enhance industry standards and expand the realm of possibilities in cryogenic technology. **imtekcryogenics.com/en**

**HeLIUM Cryogenics™ is a registered trademark of IMTEK Cryogenics.*

Advances in Manufacturing Yield a Clean ID Hose

by Robert P. Barker, President, Penflex

The manufacturing of metal hoses commences with thin material strips that are brought together to form a straight tube. Corrugations are then introduced, enabling flexibility and adaptability across various applications. Different methods are employed to create these corrugations: **Hydroforming** utilizes high-pressure water to push the material from the inside into dies, determining the shape of the corrugations. **Mechanical forming** involves the use of dies split into two sections of a ring, which either squeeze the tube to form a bulge or employ a series of rotating dies around the tube to create corrugations progressively.

While both production methods yield quality hoses for most applications, they possess trade-offs that render them unsuitable for certain uses. In helium-based cryogenic applications, a critical concern arises: “Can a hydroformed hose ever be entirely free of moisture?” Hoses carrying helium demand thorough cleaning to eradicate detrimental contaminants when produced via hydroforming. Contaminants encompass moisture, oils, greases and solvents, as well as any residues from welding or cutting. However the cleaning process itself can lead to recontamination. For instance, while a cleaning agent may remove oil, it might leave solvent, acid, or alkali residues.

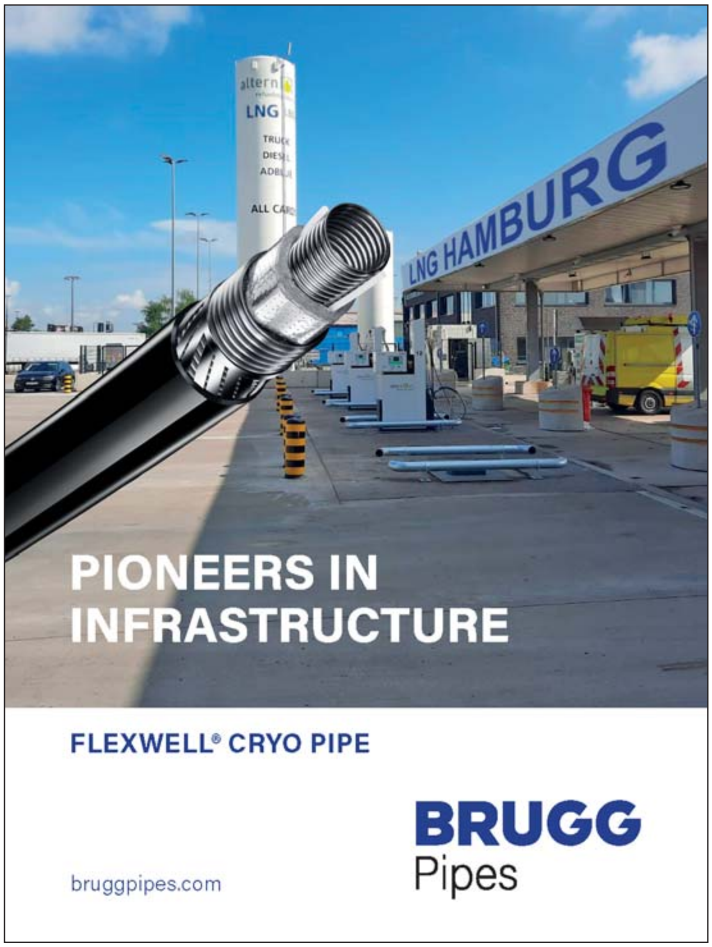
Frequently, specifications for metal hose assemblies necessitate post-production cleaning. These specifications detail methods such as cleaning with a spar nozzle or interior mandrel using aqueous solutions, which involve extensive labor followed by draining and oven drying. Additional testing for hydrocarbons or particulate matter is also conducted to ensure cleanliness. However, such post-production processes and tests can be eliminated. Mechanical forming, as employed in Penflex's CL3 process, generates hoses devoid of internal water, oils, solvents and tooling marks. These hoses are clean and devoid of stress risers.

The CL3 mechanical forming process pioneered by Penflex represents a seismic shift in the realm of cryogenics. Its profound impact reverberates across diverse applications within this critical industry. Consider, for instance, the transportation of liquefied gases like helium or hydrogen – where cleanliness and purity are non-negotiable. Some traditional manufacturing methods pose substantial risks to these sensitive substances. However,

Skills of Penflex’s ASME Sec. IX certified welders can be seen on small diameter hose assembly. *Credit: Penflex*

the CL3's precision-engineered approach ushers in an era of unparalleled purity within hoses. This innovation isn't merely about eliminating post-production cleaning: it's a fundamental paradigm shift. The absence of moisture exposure during mass spectrometer leak testing ensures the reliability of critical equipment – a game-changer for research, medical, and aerospace applications reliant on accurate cryogenic systems.

Moreover, the CL3 process's streamlined production and reduced need for additional cleaning makes it a catalyst for operational efficiencies across the cryogenic supply chain. As industries push the boundaries of low temperature applications, the CL3 process emerges as a cornerstone of reliability, setting new benchmarks for cleanliness, efficiency and safety in cryogenics. For those in the cryogenics field, a truly clean inside presents opportunities for streamlined supply chains and operational efficiencies. By employing a process that doesn’t use water or lubrication on the inside, the need for post-production drying or cleaning – incurred costs that extend delivery times – is eliminated. This allows for faster and more reliable mass spectrometer leak testing, reducing the risk of moisture exposure to testing equipment. In essence, what was never there to begin with doesn’t need removal. **www.penflex.com**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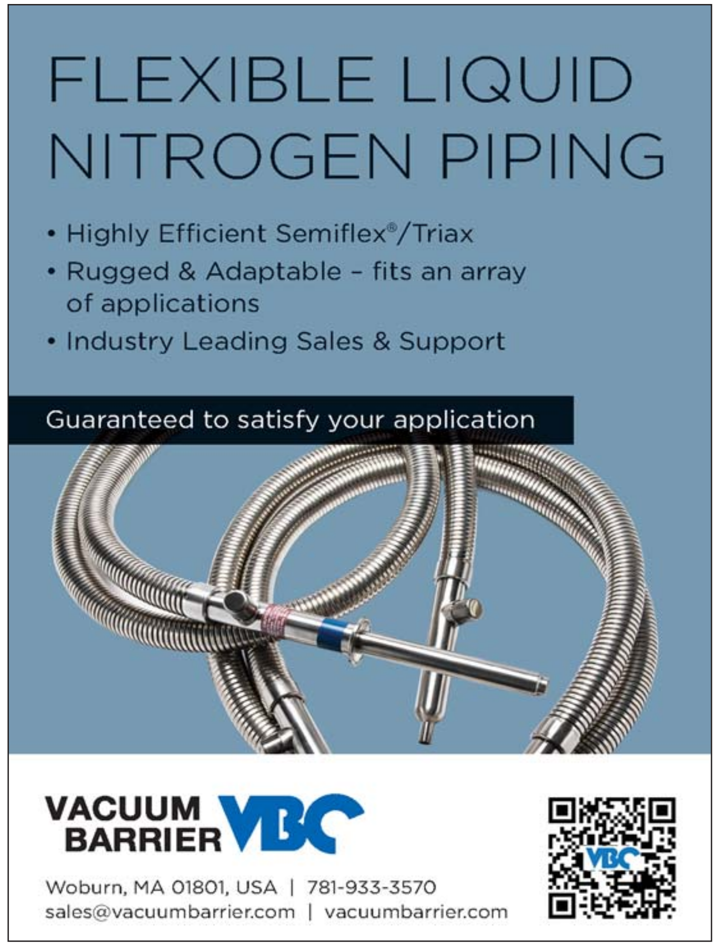
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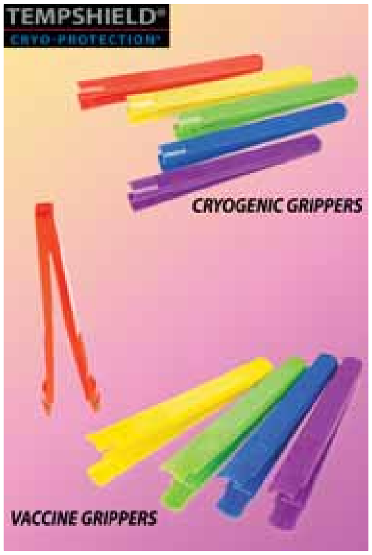
Product Showcase

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



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CryoCarts are designed for the loading of biological samples into canes, boxes, racks or frames. When used as a portable workbench, the unit will provide a safe and controlled environment for samples for up to eight hours with the lid open. CryoCart is ideal for transporting large quantities of samples from one tank to another within the same facility. In addition to the approximate hold time of eight hours with the lid open, 18 hours is the approximate hold time with the lid on. Omega temperature monitor with type T thermocouple. Traceable calibration certificate with RS232 PC interface. LN_2 transfer hose connection with ball valve and relief valve. **www.princetoncryo.com**

Fluoramics, Inc.

Tufoil Air Tool Oil

Fluoramics introduces new sizes for Tufoil Air Tool Oil, ideal for air compressor tools: 16.5 mL and 118 mL dropper tip bottles. Infused with Fluoramics' Tufoil Technology, this oil ensures optimal lubrication, moisture displacement and rust resistance for compressor-driven tools like hammers, nailers and more, without hazardous solvents. To maintain air tools, disconnect the air line and add a few drops to the air nipple daily, enhancing efficiency and longevity by reducing corrosion and o-ring wear on internal parts. Adding oil to the air coupler is recommended. End-of-day application safeguards interior components from moisture buildup. For continuous daily use, consider using a filter/regulator/lubricator device with the air line. Tufoil Air Tool Oil is available in quart and gallon sizes for industrial lubrication systems. **www.fluoramics.com**

Chart Industries

LH2 Transport Trailer,
ST-18600H 155 Pressure Transfer System

Chart has developed the industry's first 10,000-pound payload ST18600H trailer to improve efficiency and logistics in delivery operations, helping to meet the increasing demand for LH_2. In times of driver shortages, this trailer with the largest payload in the industry meets US DOT requirements and is California-bridge-law compliant when paired with an appropriate tractor – including alternative fuel tractors utilizing the 82,000-lb GVWR exception. The double-insulated trailers meet the same high performance and operation standards that come with the Chart brand. **www.chartindustries.com**

Aerospace Fabrication & Materials, LLC

AstraWrap™

Aerospace Fabrication & Materials, LLC (AFM) is rebranding its SpaceWrap™ line as AstraWrap™, focusing on safeguarding spacecraft in orbit and beyond. This rebrand enhances AFM's reputation for innovative passive thermal control solutions employing cutting-edge thin films and engineered fabrics. According to Brent Anderson, Business Development Manager at AFM, their strength lies in combining technical materials with optical and physical properties to mitigate heat flow in space systems. The Astra™ brand aids in conveying component-level data for versatile applications in custom end-use devices for the space industry. The Astra™ brand encompasses multiple product lines, such as AstraWrap™, AstraWrap™ HT, AstraPair™, AstraLam™, AstraLoft™ and AstraTape™, offered in user-friendly forms to create single layer insulation (SLI), multilayer insulation (MLI) blankets and other passive thermal control products. **https://aerospacefab.com/products/spacewrap-ht**

Arrow Finishing Inc.

Tumble Polishing and Cryogenic Treatment for Extended Wear

Arrow Finishing Inc. offers a comprehensive service combining cryogenic treatment and tumble polishing for various components, promising extensive benefits. This approach enhances wear resistance by fortifying materials against abrasion and refining surfaces to diminish friction, contributing to prolonged component lifespan and reduced maintenance. The synergy between cryogenic treatment and tumble polishing ensures structural reinforcement and improved aesthetics, applicable across diverse materials and industries. Notably, this process delivers superior wear resistance, enhanced surface finish, extended maintenance intervals and increased component longevity and cost savings over the component lifecycle. While these benefits are significant, Arrow Finishing advises tailored consultations to align the treatment strategy with specific component needs, emphasizing the expertise of their materials and surface finishing specialists. **www.arrowfinishing.com**

People & Companies in Cryogenics

Dr. Marcia Rieke, principal investigator for the near-infrared camera on **NASA's James Webb Space Telescope is the Astronomical Society of the Pacific's** (ASP) 2023 recipient of its most prestigious award. ASP's Catherine Wolfe Bruce Gold Medal honors Rieke, a regents professor of astronomy at the University of Arizona. Rieke's research has focused on infrared observations of the center of the Milky Way and high redshift galaxies in the early universe. Rieke is considered by many to be one of the "founding mothers of infrared astronomy," and it is for her groundbreaking contributions to astronomical research at these wavelengths that she is being recognized and celebrated. Rieke's award and achievements were recognized at the ASP Awards Gala in November in Redwood City, Calif.

Marcia Rieke. Credit: George Rieke / UAZ

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University of Florida's **Professor Peter Hirschfeld** has been awarded the 2023 Jesse W. Beams Award for his pioneering work in condensed matter physics, particularly in understanding unconventional superconductivity. His research on repulsive Coulomb interactions, multi-orbital bands and innovative theoretical models has advanced our understanding of these materials. The award, given annually by SESAPS (Southeastern Section of the American Physical Society) since 1973, recognizes physicists in the southeastern United States whose work leads to new discoveries, fundamental insights, or crucial experimental/theoretical techniques in physics.

Professor Peter Hirschfeld. Credit: UF

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Stirling Cryogenics B.V. has inaugurated its sales arm, Stirling Cryogenics Inc. (CSA CSM), in the US. Concentrating solely on the US and Canada, the new office in North Carolina appointed Scott Smith as sales manager. This expansion aims to better cater to customer needs, especially in supplying specialized cryogenic systems with the distinctive Stirling cryogenerator. Burgeoning projects in energy transition like LNG and liquid hydrogen production in North America, Stirling foresees substantial contributions in these fields. While the company's headquarters and production facilities stay in the Netherlands, the US operations will prioritize sales and service.

Scott Smith. Credit: Stirling Cryogenics

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The **U.S. Department of Energy Office of Science** has allocated $115 million for the High Rigidity Spectrometer (HRS) project at Michigan State University's Facility for Rare Isotope Beams (FRIB, CSA CSM). This innovative instrument, a centerpiece of FRIB's fast-beam program, will analyze rare isotopes created at nearly half the speed of light, characterizing their mass, charge and velocity. This seven-year funding will facilitate HRS's establishment, supporting more than 500 scientists and significantly enhancing FRIB's scientific reach. HRS, operating with near-perfect efficiency, will vastly increase the sensitivity of FRIB's scientific program, extending its capabilities by more than a hundredfold for studying neutron-rich isotopes, enabling experiments impossible elsewhere. Collaborating with a diverse team of institutions globally, FRIB serves a vast community of researchers, fostering discoveries in nuclear physics, astrophysics and societal applications. The investment reflects DOE-SC's commitment to advancing rare-isotope research capabilities through FRIB, a prominent user facility in the field of Nuclear Physics.

The High Rigidity Spectrometer project at FRIB is highlighted in an artistic rendering showing where it will fit in the FRIB experimental area. Credit: MSU

Meetings & Events

American Hydrogen Forum
February 28-29, 2024
Houston, TX
https://ushydrogenforum.com

European Hydrogen Energy Conference
March 6-8, 2024
Bilbao, Spain
https://ehec.info

BCGA Annual Conference 2024
May 16, 2024
Manchester, England
https://bcga.co.uk/conference2024

23rd International Cryocooler Conference
June 3-6, 2024
Madison, Wisconsin
https://cryocooler.org

Cryogenic Operations 2024
July 17-19, 2024
Grenoble
www.cryo-ops-2024.fr

International Cryogenic Engineering Conference/ International Cryogenic Material Conference 2024
July 22-26, 2024
Geneva, Switzerland
https://icec29-icmc2024.web.cern.ch

2024 Applied Superconductivity Conference
September 1-6, 2024
Salt Lake City, Utah
www.appliedsuperconductivity.org/asc2024

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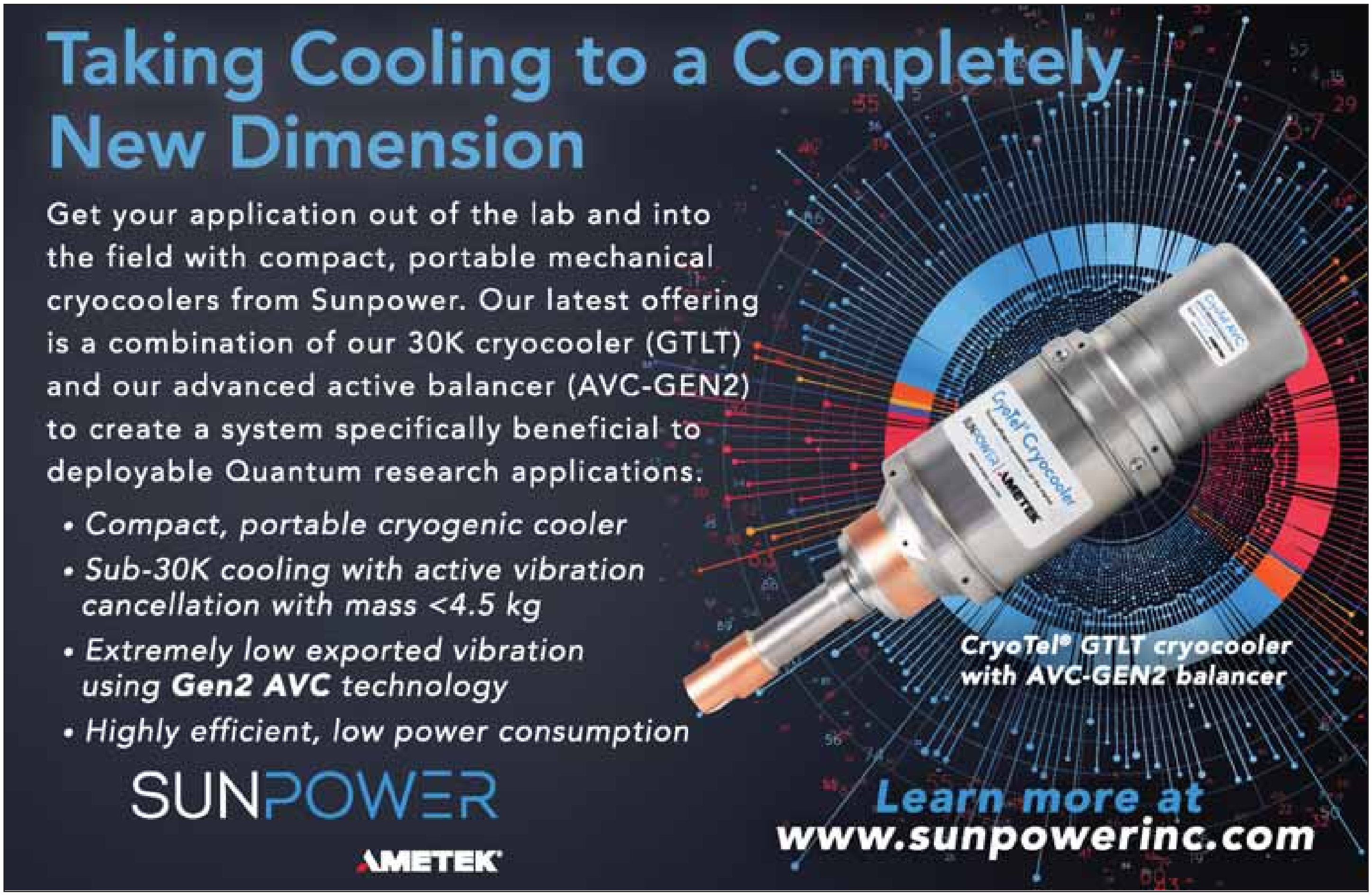
NASA's Deputy Administrator **Pam Melroy** served as the keynote speaker at the **American Geophysical Union** annual meeting in San Francisco. Melroy highlighted NASA's Artemis program and its mission to establish a sustained presence on the moon for exploration and scientific research. Throughout the week, researchers shared insights in Earth sciences, planetary science and heliophysics.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Index of Advertisers

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Aerospace Fabrication. 88
American Magnetics. 81
Avco. 93
Brugg Pipes. 89
Chart Inc.. 85
CPC CryoLab. 21
Cryo Technologies . . . . .Inside Front Cover
Cryoco LLC 7
CryoCoax (Intelliconnect) 87
Cryocomp 7
Cryofab, Inc. . . . . Inside Back Cover
Cryomech, Inc. 24
CryoWorks, Inc. 82
Gardner Cryogenics 17
Lake Shore Cryotronics. 23
Linde Engineering NA . . . . Inside Back Cover
Magnatrol Valve 7
Omega Flex, Inc . . . . Back Cover
Penflex Corp 83
PHPK Technologies . . . . .Inside Front Cover
Scientific Instruments Inc. 13
Star Cryoelectronics 81
Stirling Cryogenics 18
Sumitomo SHI Cryo America 3
Sunpower 93
Technifab. 22
Tempshield Cryo-Protection 22
Vacuum Barrier Corp. 89
Vacuum Energy 81
Wessington Cryogenics 89

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