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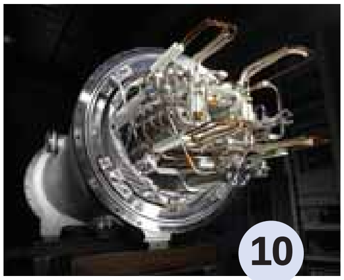

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ON OUR COVER

A High-Flying Mission: The OSAS-B Oxygen Spectrometer, aboard the HEMERA balloon gondola, can ascend to 33 km, capturing crucial data on atomic oxygen in Earth's upper atmosphere. IRLabs' innovative solutions ensured a successful high-altitude scientific expedition. *Credit: David Laneville*

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From the Executive Director

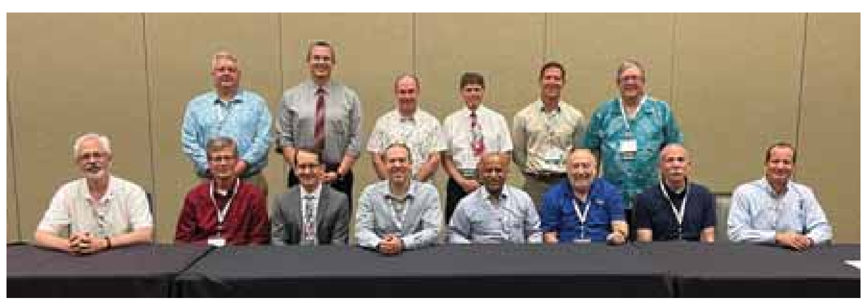
I hate to start this month's letter on a somber note, but I would be remiss if I didn't mention the wildfires that have recently devastated regions of the island of Maui. Many people from the cryogenics community, myself included, were in Hawaii just a few short weeks ago. While I didn't have the pleasure of visiting Maui, I know many colleagues who did. They raved about their time spent on the island and its beauty. I know I stand with the rest of the cryogenics community when I say that our hearts are with everyone affected by this unthinkable tragedy. We will continue to keep the residents of Maui in our thoughts over the coming months.

As previously mentioned, I had the pleasure of attending CEC/ICMC'23 which took place in Honolulu in July. CSA was able to host a variety of short courses prior to CEC/ICMC, all of which were a big success with nearly 70 people in attendance. I would like to, once again, thank our short course instructors for volunteering their time to teach these courses: Ray Radebaugh, John Weisend, Jacob Leachman, Konstantin Mateev, Fons de Waele and Scott Courts. Thank you!

During CEC/ICMC, the CSA Board of Directors hosted a productive in-person board meeting. We had a full room, with nearly all of the directors in attendance! It was great to see so many faces after a number of years with primarily virtual meetings.

Following CEC/ICMC, I headed over to the Big Island of Hawai'i for CSA's 30th Space Cryogenics Workshop. What a fantastic event it ended up being! With nearly 110 people in attendance, we had the biggest turnout in recent history. CSA will be publishing a recap of the event in our next issue of *Cold Facts*, so I won't give away too many spoilers. Suffice it to say, it was a great event with ample opportunity for networking. The Outrigger Kona ended up being the perfect backdrop for the event – what a beautiful property it was! Once again, I'd like to thank our workshop sponsors, Alloy Valve and Control (AVCO), OmegaFlex, Aerospace Fabrication, and Sunpower. Without their support, this workshop would not have been possible. Thank you!

As always, we hope you find this issue of *Cold Facts* enjoyable and informative!



CSA Board of Directors after the 2023 Board of Directors meeting held in Honolulu, Hawaii.
Credit: Megan Galeher

Image from OSAS-B camera taken at an altitude of 33 km. *Credit: German Aerospace Center*

IRLabs Pioneers Solutions for High Altitude Scientific Exploration

by Chris Foster, Director of Engineering, Infrared Laboratories, Inc

In the pursuit of scientific knowledge, the German Aerospace Center (DLR) embarked on a mission to explore the enigmatic properties of atomic oxygen in Earth's upper atmosphere. Understanding the impact of this element on satellite corrosion, deceleration in low-Earth orbits and its role as an indicator of climate change held great importance for DLR's research. Its ambitious endeavor involved deploying the OSAS-B oxygen spectrometer as part of Europe's HEMERA balloon campaign. For this intricate task, DLR sought the expertise of Infrared Labs (IRLabs), a respected industry leader boasting decades of experience in high altitude cryostats.

Challenges in High Altitude Scientific Endeavors

Operating in the upper atmosphere on a balloon gondola posed unique challenges for the OSAS-B project. The key concerns were ensuring airtight seals of the vessel during temperature and pressure changes experienced during ascent and descent, meeting strict size and weight budgets of the gondola, withstanding impacts during flight and landing, and maintaining cold plate temperature and stability despite fluctuating conditions that could hinder contact between the liquid cryogens and the cold plate.

IRLabs' Tailored Solutions

IRLabs' reputation in custom solutions and collaborative approach to projects made the company a perfect fit for the OSAS-B venture. Understanding the limitations of traditional O-ring seals in the upper atmosphere where freezing could lead to vacuum leaks, IRLabs innovatively designed two types of seals: O-ring seals for DLR team access in the lab and indium metal seals that endure freezing, ensuring an airtight seal during high altitude flight.

Achieving the perfect balance between vessel size, weight and capacity proved essential for the gondola's stability. IRLabs meticulously reduced the case mass by incorporating only the necessary features for sensor and equipment mounting, while removing any unnecessary material. Moreover, the team reduced flat mounting surfaces on the cylinder, streamlining the design and minimizing weight.

IR Labs HDL8 dewar customized for upper atmospheric research. *Credit: IRLabs*

These thoughtful enhancements ensured the vessel would accommodate extended hold times of over 24 hours while adhering to stringent size limits.

Resilience against high impact landings was of critical importance to the project. Balloon-mounted instruments are susceptible to shocks during flight and landing, putting the equipment's integrity at risk. To safeguard the OSAS-B during these potential impacts, IRLabs implemented rigid internal supports, securing the internal vessels and ensuring their survival even in challenging conditions.

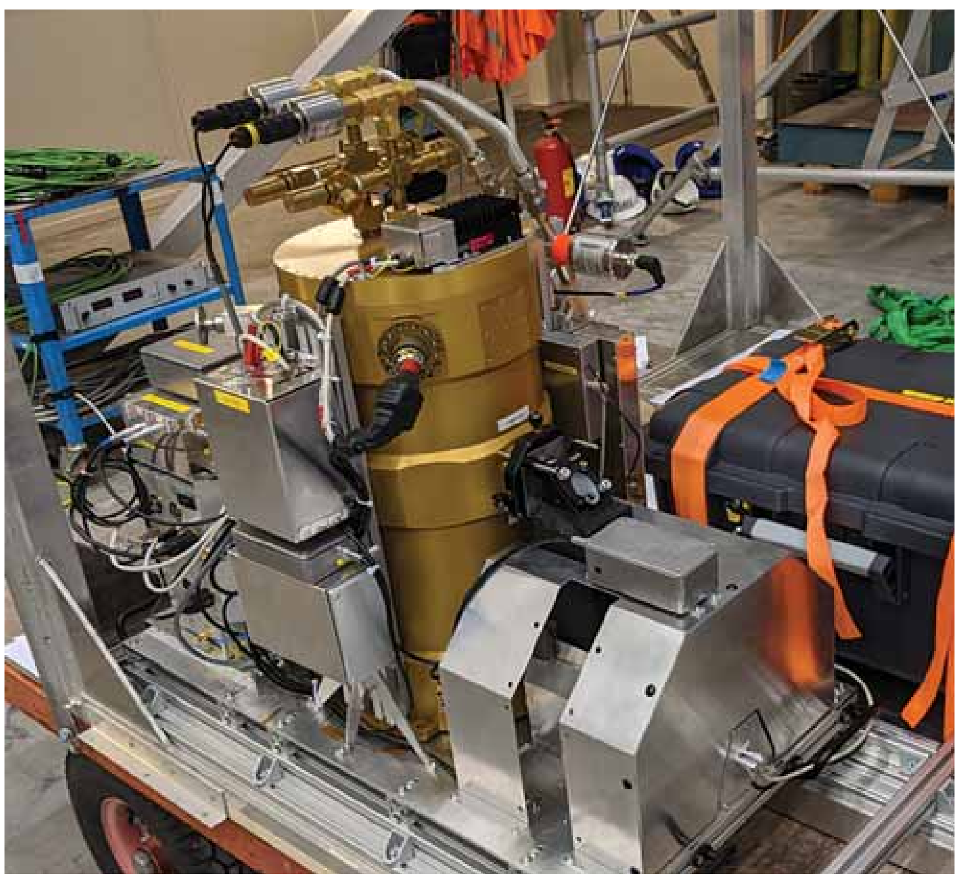
Likewise, thermal performance needed to be optimized for the project's success. The unique conditions of freezing liquid nitrogen during operation presented yet another obstacle. This interference threatened the contact between the solidified nitrogen and the cold plate, affecting thermal performance. IRLabs' dedication to excellence led them to conduct extensive lab testing to find the most effective solution. The upgrading of absolute pressure regulators to motorized regulators emerged as the ideal choice, providing precise control of internal pressure and cold plate temperature.

Triumph and Further Exploration

The collaborative efforts of DLR and IRLabs culminated in the successful launch of the OSAS-B to an impressive altitude of 33 km. It flawlessly collected valuable data, furthering scientific knowledge. The triumphant return to the ground has paved the way for future launches, reinforcing IRLabs' reputation as a pioneering force in high altitude scientific exploration.

IRLabs' remarkable contributions to the OSAS-B project exemplify their commitment to pushing boundaries and conquering challenges in the world of high altitude cryostats. As it continues to forge ahead with innovative solutions, IRLabs solidifies its position as a leading partner for groundbreaking research and exploration in the ever-evolving field of science.

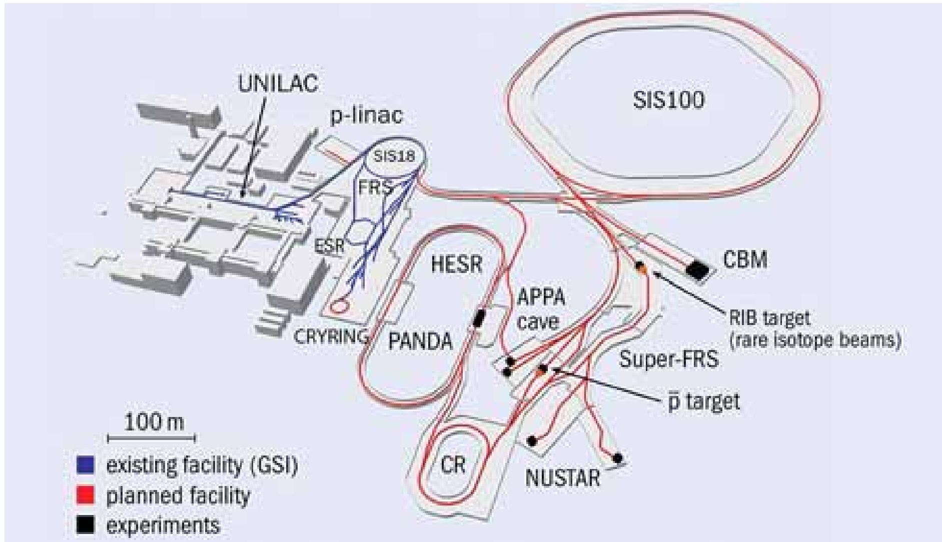
The HEMERA gondola being prepared for launch. *Credit: German Aerospace Center*



OSAS-B mounted on the balloon gondola. *Credit: German Aerospace Center*

Cryogenics at FAIR Unleashes the Power of Discovery

by Joe McEntee, CERN Courier



From here to FAIR: The existing GSI accelerators (blue) and the FAIR facilities (red). FAIR comprises the SIS100 synchrotron; the antiproton separator and the Super Fragment Separator; the collector ring; high energy storage ring; and experimental stations for the APPA, CBM, NUSTAR and PANDA research programs. The proton linac and the CRYRING (a low-energy storage ring for heavy ions) also belong to the FAIR instrumentation portfolio. *Credit: CERN*

The Facility for Antiproton and Ion Research (FAIR) in Darmstadt, Germany, is embarking on a pioneering mission that will transform accelerator research and expand our understanding of the universe. With its ambitious vision to explore an extensive research canvas, FAIR is set to become a global hub for scientific exploration, spanning diverse domains such as hadron physics, nuclear structure, astrophysics, atomic physics, materials science, radiation biophysics, cancer therapy and space science.

At its core, FAIR will generate primary beams of various particles, ranging from protons to uranium ions, along with secondary beams of antiprotons and rare isotopes. This state-of-the-art accelerator facility will deliver intense and energetic particle beams to multiple production targets, guiding these beams to fixed-target experiments or injecting them into specialized storage rings for in-ring experiments with high-quality secondary antiprotons or radioactive ions.

The driving force behind FAIR's cutting-edge research capabilities lies in its three main building blocks: the fast-ramping SIS100 synchrotron, responsible for generating intense primary beams; the Super Fragment Separator (Super-FRS), designed to filter out exotic ion beams; and the storage rings. Additionally, the existing GSI accelerators, UNILAC and SIS18, will serve as injectors and pre-accelerators for SIS100, while a new proton linac will facilitate high intensity injection into the synchrotron chain.

At the forefront of FAIR's scientific mission is the crucial role played by cryogenics, with Holger Kollmus and Marion Kauschke, head and deputy head of the GSI/FAIR cryogenics program, leading the way. Cryogenics has emerged as an indispensable aspect of FAIR's operations. As Kollmus explains, "The strategic decision to build FAIR placed ultralow-temperature technology at the heart of GSI's development roadmap. The Prototype Test Facility (PTF) was established to evaluate

▶ *continues on page 12*

Test and measurement: The STF (left) handled the volume testing of FAIR's SIS100 dipole magnets (110 in total). Meanwhile, CERN's specialist test facility (right) is overseeing acceptance of Super-FRS superconducting magnets prior to delivery to Darmstadt. *Credit: Gabi Otto/GSI; Stephan Russenschuck/CERN*

candidate magnet designs, while the Series Test Facility (STF) enhanced workflow efficiency for large-scale testing of the SIS100 dipole magnets." Commenting on the significance of the STF, Kauschke adds, "Custom building design and layout were pivotal in realizing workflow efficiencies at the STF. Through streamlined testing processes, we optimized throughput and successfully tested all SIS100 dipoles."

The cryogenics program at GSI/FAIR is a collaborative endeavor, fostering partnerships with other cryogenics groups across Europe. Collaboration with CERN, renowned for its superconducting magnets in high energy physics, has been instrumental in accelerating cryogenics advancements. Notably, superconducting magnets for the Super-FRS underwent acceptance testing at CERN before being integrated into FAIR's facilities.

The journey towards realizing FAIR's cryogenic infrastructure has been marked by meticulous planning and innovation. The cryogenic supply building features two independent halls with distinct foundations. The front hall, housing cold boxes and distribution lines, connects to the SIS100 tunnel without disrupting helium transfer. The rear section, housing the compressor station, is decoupled from the cold box hall to minimize vibrations on the SIS100 ring.

CRYO2, FAIR's central cryogenic plant, lies at the heart of this infrastructure, providing cryogenic capacity at ultralow temperatures. With variable-frequency drivers for compressors, the plant ensures adaptability to load changes, enabling parallel and independent operation for FAIR's diverse cryogenic consumers. The cold helium is distributed across the campus through an extensive network.

As FAIR's cryogenic infrastructure nears completion, the potential for groundbreaking discoveries is vast, and cryogenics at FAIR has opened up exciting avenues for unparalleled research. The eagerly anticipated inauguration of FAIR in 2027 holds the promise of unveiling scientific marvels that will significantly contribute to our understanding of the universe. FAIR's cryogenic journey highlights the profound impact of scientific discovery on society and the world at large, with the ability to explore the uncharted territories of the cosmos an extraordinary opportunity.

Supercool innovation: The SIS100 ring comprises an array of dipole and quadrupole magnets. The magnets have to be ramped during the acceleration of the heavy ions, with the ramp and repetition rate adapted to the ions and experimental setup. Above: an SIS100 dipole magnet. *Credit: Babcock Noell*

Cryo connections: Cryogenic bypass lines supplied to FAIR through an in-kind contribution by WUST in Poland. *Credit: GSI*

NIF Journeys to Ignition

by Suhas Bhandarkar, National Ignition Facility, Lawrence Livermore National Laboratory

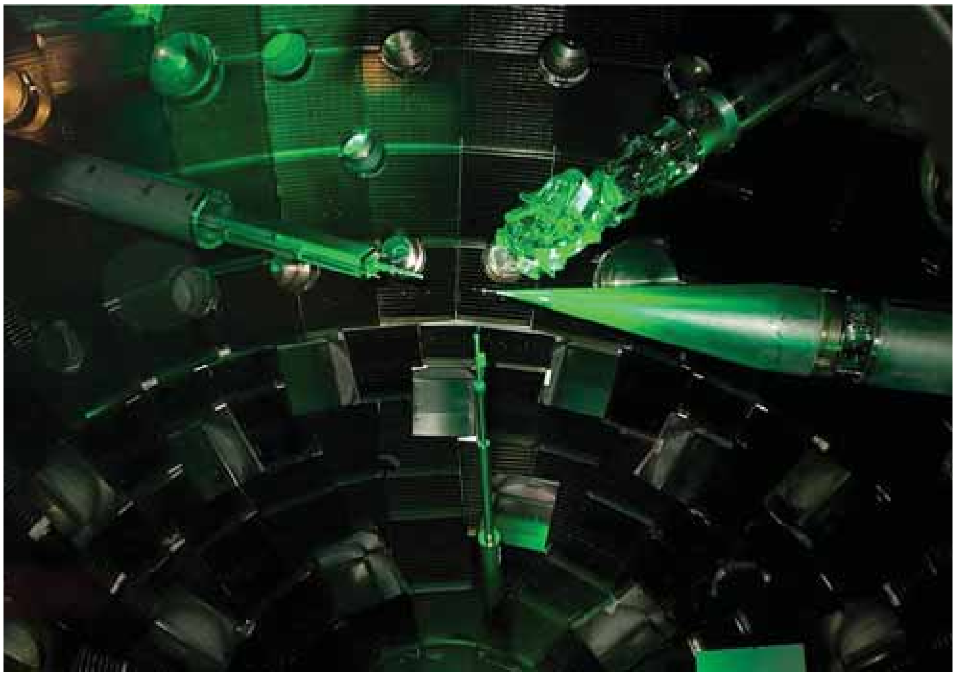
Dec. 5, 2022, marked a historic breakthrough in the field of fusion research as scientists achieved ignition, a momentous achievement that has been a scientific grand challenge spanning over 50 years. The National Ignition Facility (NIF) within the Lawrence Livermore National Laboratory (LLNL) achieved an igniting fusion reaction where the nuclear energy output surpassed the input of optical energy—a remarkable feat known as ignition.

The journey towards ignition has been a scientific grand challenge, a quest spanning over five decades. Scientists have relentlessly pursued the dream of harnessing the boundless power of nuclear fusion—a process that fuels the sun and stars—to potentially generate clean and virtually limitless energy here on Earth. Yet, this milestone was elusive, requiring revolutionary advancements in technology, extraordinary precision and a deep understanding of the intricacies of plasma physics and high energy density science.

NIF, renowned as the world's most energetic laser, played a pivotal role in this breakthrough. Armed with more than two megajoules of 351nm ultraviolet (UV) light, NIF focused its 192 laser beams with unparalleled precision. These beams triggered the generation of X-rays, which, in turn, compressed the deuterium-tritium (DT) fuel—an approach known as "Indirect Drive Inertial Confinement Fusion."

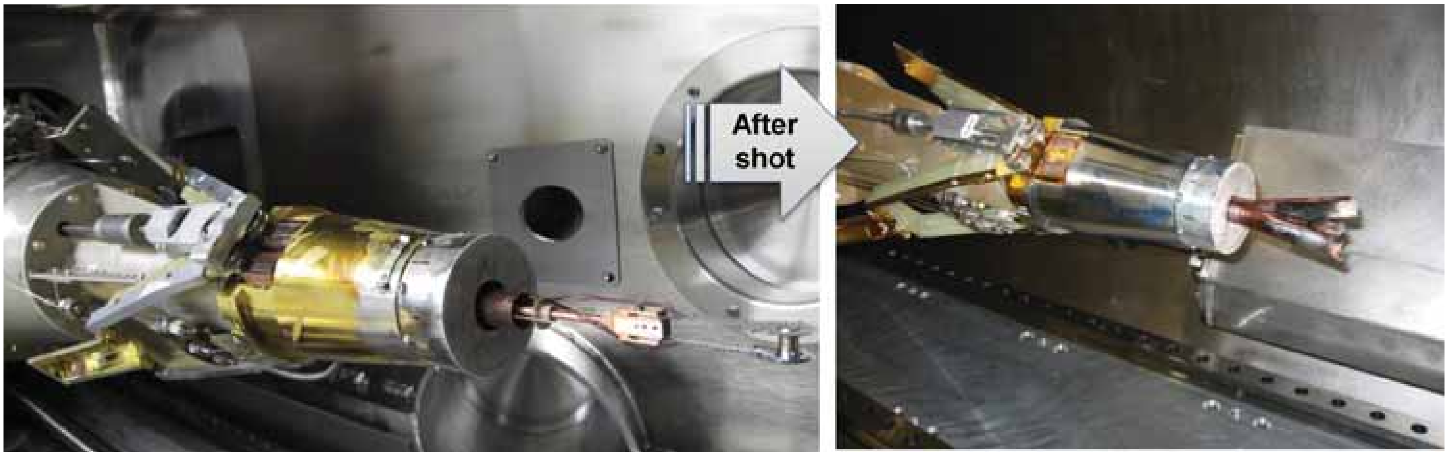
Achieving ignition demanded the meticulous fabrication of a micro-assembled "target," consisting of more than 100 intricate components. The heart of this target was a near-perfect, 50-70µm thin DT ice layer housed inside a spherical ablator sphere. To ensure perturbation-free compression, each component in the target had to work with precision. Of particular significance was the ablator capsule, featuring a nano-crystalline diamond with graphitic grain boundaries and centering to within 10µm using two 45nm thick membranes.

The fusion research system containing a cryostat at the National Ignition Facility. *Credit: Suhas Bhandarkar*



The target is tiny on the scale of the target chamber and requires careful alignment. *Credit: Suhas Bhandarkar*

Crafting the DT ice layer required a sequence of finely tuned steps—filling liquid DT, quenching to form DT solid, melt-back to leave a single seed and growing a single crystal layer. These processes were carefully orchestrated to control ice growth rates and minimize defects that could disrupt uniform compression of the fuel. A phenomenon known as beta-layering was employed to mitigate imperfections and facilitate the formation of a spherical layer inside the capsule.



ICF target on NIF. *Credit: Suhas Bhandarkar*

Accurate characterization and examination of the ice layers were made possible through sophisticated X-ray imaging and a suite of diagnostic instruments. Target thermometry and heaters were essential in achieving submicron uniformity of the DT ice. Grooves formed by vapor etching were effectively pinned by thermal gradients, generated by the beta decay of tritium, preventing them from interfering with the compression process.

With ignition achieved, the team now embarks on a new chapter, seeking even higher gains using NIF. While the road ahead may be challenging, the implications are profound. Beyond supporting the nation's stockpile stewardship mission, NIF serves as a springboard for Inertial Fusion Energy (IFE)—a pivotal vision of harnessing fusion as a practical and sustainable energy source.

The quest for IFE is not merely an ambition of scientific curiosity; it represents a transformative shift in humanity's relationship with energy. The promise of a clean and virtually limitless power source has long captivated the imaginations of scientists, policymakers and energy enthusiasts worldwide. While the journey towards commercial fusion energy is far from over, the achievement at NIF represents a significant leap forward. Achieving IFE requires not only continued technological advancements but also international collaboration and public support. Fusion research is a global endeavor that transcends geopolitical boundaries. Countries and research institutions around the world are pooling their knowledge and resources to collectively unlock the power of fusion. The international collaboration in fusion research reflects the understanding that the quest for clean and abundant energy is a shared global responsibility.

The significance of achieving ignition at NIF extends beyond the realm of energy production, with far-reaching implications for our understanding of astrophysics and high energy density science. The knowledge gained from these experiments expands our comprehension of the universe and holds the potential to provide invaluable insights into the fundamental workings of stars and supernovae. As the research community continues to explore higher gains and new frontiers, nurturing the next generation of scientists and engineers becomes of paramount importance. Fusion research demands a diverse and skilled workforce spanning multiple disciplines, from plasma physics to materials science and engineering. Investing in education and training programs is vital to ensure the sustainability of fusion research and to cultivate the bright minds that will carry the torch forward. Ignition at NIF marks a momentous turning point in the journey towards inertial fusion energy—a transformative vision that has never been more compelling. As researchers, policymakers and the public unite to support fusion research, we inch ever closer to realizing a future powered by the boundless energy of the stars. This journey towards fusion energy is not merely about fulfilling our energy needs; it is a quest to transform our world for the better.

Quench Detection in High-Field Magnets

by Carl A. Williams, Lawrence Berkeley National Laboratory

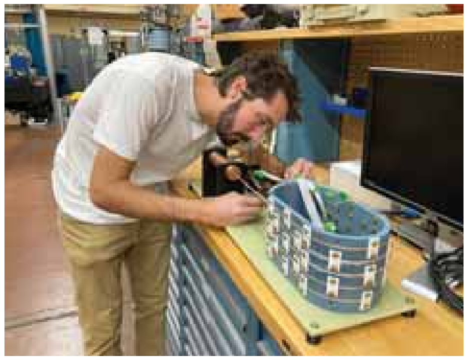
Researchers at Berkeley Lab's Accelerator Technology & Applied Physics (ATAP) Division have developed a method for detecting and predicting the local loss of superconductivity in large-scale magnets that are capable of generating high magnetic fields. These high-field magnets are a core enabling technology for many areas of scientific research, medicine and energy, where they are used in a range of applications, including in particle accelerators and colliders for high energy and nuclear physics, diagnostic and therapeutic medical devices and energy generation, transmission and storage technologies.

High-field magnets also show promise as an enabling technology for magnetic confinement fusion reactors, which aim to replicate the processes that power the sun by fusing two hydrogen isotopes (deuterium and tritium) to produce a carbon-free source of energy. They are used to confine the plasma of deuterium and tritium so that fusion can occur.

"To realize the full potential of these reactors will require high-performance superconducting magnets capable of generating large magnetic fields safely and reliably under the demanding dynamic conditions found in fusion reactors," says Reed Teyber, a research scientist at ATAP's superconducting magnet program who is developing diagnostic tools for monitoring the performance of both low and high temperature superconducting magnets. The work is published in Scientific Reports.

Superconducting cables, however, can experience sudden and unpredictable losses in superconductivity—a phenomenon referred to as quenching—that can generate temperatures high enough to destroy the magnets, costing millions of dollars in damage.

"While for older, low temperature superconducting magnets quenching is inherent, it must be avoided altogether in high temperature superconducting magnets to ensure their reliable and safe operation," explains Reed. "Detecting a quench and



Reed Teyber working on high temperature superconducting CORC cable. *Credit: Berkeley Lab/Carl A. Williams*

preventing it from damaging magnets is, therefore, a central focus for researchers looking to develop superconducting magnets for compact fusion reactors."

Rare-earth barium copper oxide (ReBCO) is a promising material for the fabrication of superconducting magnets used in fusion reactors. ReBCO tape, which is used in the cables that carry the currents in superconducting magnets, has a high critical temperature (making it a so-called high temperature superconductor), high critical field and the potential to form demountable magnets—an important property that improves maintenance access, simplifies materials component testing and allows for modularity to accommodate future reactor designs.

Superconducting magnets are familiar in such applications as colliders for high energy physics, so methods exist for quench protection in low temperature superconducting magnets like niobium-titanium or niobium-tin. These methods use voltage or temperature measurements to trigger energy extraction processes. However, Reed says quench detection in high temperature superconducting magnets, like those that use ReBCO, needed for fusion reactors is far more challenging and calls for new approaches.

These extremely powerful magnets, capable of generating magnetic fields exceeding 20 tesla, are characterized by a much slower initial rate of quench development compared to accelerator magnets, making it difficult to detect quenches using voltage- or temperature-based techniques.

To address this issue, Reed is working with colleagues at ATAP to develop a method that employs an array of Hall probes—devices that are used to measure the magnetic fields created when a current-carrying conductor is placed in a magnetic field—to measure the magnetic fields produced around ReBCO CORC cables. These cables are composed of numerous "conductor-on-round-core" wires made from tapes of ReBCO to achieve the required current capacity.

Current distributions for the individual conductors recreated from these measurements provide insights into the detailed dynamics of magnet operation, allowing the extraction of parameters for a predictive model. Although it shows promise as a powerful technique for quench detection and prevention, it currently has many limitations, notes Reed. "For example, it only works for specific magnet technologies with no inter-cable current sharing and cables of moderate length."

"However," he adds. "It turns out that demountable toroidal field coils wound from ReBCO cables meet these requirements. Toroidal field coils are the leading superconducting magnet technology for generating the enormous magnetic fields required for containing the plasma to ensure fusion reactions can happen. We are now looking into how we can use our technique to solve the problem of quench detection in these coils."

Reed says the work could be a "game-changer" not only for superconducting magnets used in nuclear fusion reactor experiments, but also for particle accelerators in high energy physics, magnetic energy storage technologies, medicine and various power devices such as electric motors, generators and transmission lines.

"This innovative technique conceived by Reed has the potential to serve as a key element in solving the quench protection for high temperature superconductor cables, a fundamental issue for the scientific community working on the next generation of superconducting magnets," said Paolo Ferracin, deputy program head of ATAP's superconducting magnet program."

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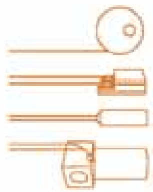

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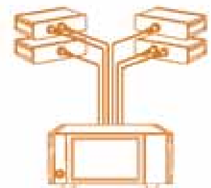

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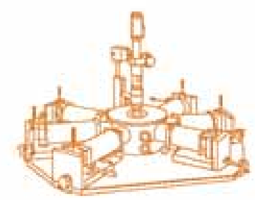

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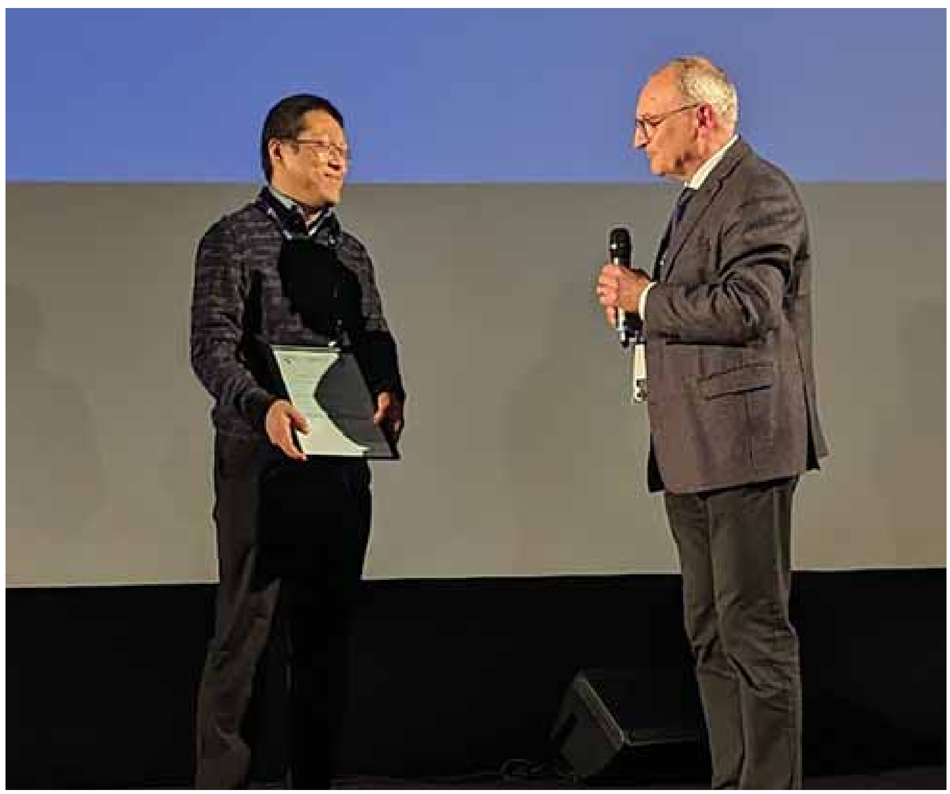
Fermilab Scientist Recognized for Enhancing Superconductors in Accelerator Magnets

by Fionna M. D. Samuels, Fermilab

Particle accelerators, such as those housed at the US Department of Energy's Fermi National Accelerator Laboratory (CSA CSM), are fundamental to particle collider experiments that explore high-energy physics. Xingchen Xu, a scientist in Fermilab's Magnet Technology Division, has been acknowledged by the European Physical Society for his contributions in developing a novel superconducting material that will enable more powerful accelerator magnets. Xu has been awarded the 2023 Frank Sacherer Prize for his work on a new type of superconductor called niobium tin. This material holds potential for enhancing accelerator magnets.

Fermilab scientist Xingchen Xu's work improving superconducting materials has been recognized by the European Physical Society. *Credit: Lynn Johnson, Fermilab*

The maximum energy achievable in a circular particle accelerator depends on the strength of the superconducting magnets that steer particles around the accelerator. By increasing the magnetic field, the beam energy can be amplified, thus expanding the scientific capabilities of the collider. Designs for the next generation of accelerators, such as the Future Circular Collider, aim to generate magnetic fields of 16 tesla, which is twice the strength used in the Large Hadron Collider. With such a high magnetic field, the FCC could potentially achieve collision energies of up to 100 trillion electron volts, surpassing the LHC's current record of 13.6 trillion electron volts.



Xingchen Xu receives the 2023 Frank Sacherer Prize at the 14th International Particle Accelerator Conference in Venice, Italy. *Credit: Sam Posen, Fermilab*

Improving magnet technology is crucial to realizing these goals. The construction of an accelerator magnet involves winding superconducting wires into coils and energizing them. The power of the magnet depends on both the amount of superconducting material used and the material's behavior as a superconductor. Among various materials suitable for building accelerator magnets, niobium-tin stood out to Xu.

Unfortunately, the performance of niobium tin superconductors had reached a plateau since the early 2000s. However, Xu recently demonstrated a novel approach to increase the critical current density of niobium tin wires. The critical current density of a superconductor is determined by the flux pinning force, which involves magnetism's penetration into a superconducting wire in a magnetic field. Superconductivity requires stationary magnetism, but when an electric current flows through the wire, the interaction between the electric and magnetic fields causes the magnetism to shift. Imperfections in the crystal structure, known as pinning centers, keep the magnetism in place. However, these pinning centers have limits to the force they can withstand before failing.

By introducing artificial pinning centers, the critical current density of superconducting materials can be increased. Four years ago, Xu received the DOE Early Career Research Award for a project that aimed to introduce artificial pinning centers into niobium tin wires. His research has been successful, and he has developed wires capable of carrying higher current densities than those specified by the FCC design team. Xu achieves this by fabricating niobium-tin superconducting wire with nanoscopic zirconium or hafnium oxide particles that act as artificial pinning centers. These particles enhance the magnetic fluxon retention, effectively increasing the critical current density at high magnetic fields.

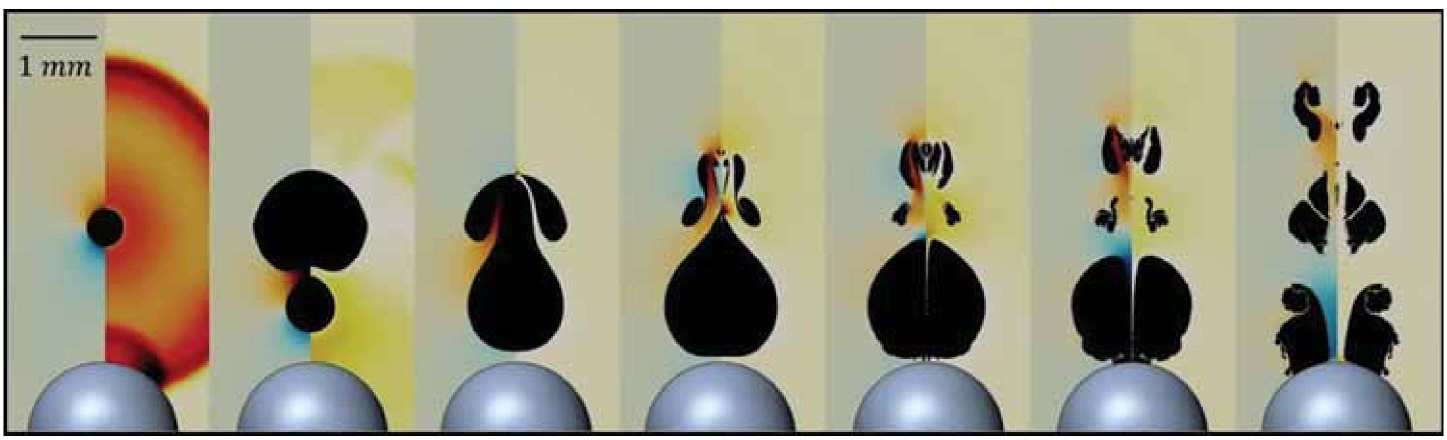
While the addition of artificial pinning centers into niobium tin wires has been attempted since the 1980s without success, Xu's approach has finally achieved positive results. Currently, Xu is working on fabricating wires long enough to be used in accelerator magnets.

In recognition of his accomplishments, Xu received the European Physical Society's Frank Sacherer Prize this year. Presented every three years, this award acknowledges early career researchers who have made significant and original contributions to the field of accelerators. The award was presented on May 11 at the 14th International Particle Accelerator Conference, where Xu also delivered an oral presentation on his work. While Xu appreciates the recognition, his primary hope is that this method will eventually yield a highly useful superconductor.

Fermi National Accelerator Laboratory is supported by the Office of Science of the US Department of Energy, which is the largest supporter of basic research in the physical sciences in the United States. The Office of Science is dedicated to addressing some of the most pressing challenges of our time. ***science.energy.gov***.

Exploring the Mysteries of Cavitation Bubbles for Eco-Friendly Plastic Recycling

by Arpit Mishra, Arjun Garva and Parthasarathi Ghosh, Indian Institute of Technology, Kharagpur, India



IIT Kharagpur researchers use cryogenic liquids to explore cavitation bubbles, leading to eco-friendly plastic recycling through cryo-comminution, a method of breaking down plastic waste using cavitation and cryogenic temperatures. *Credit: IIT Kharagpur*

Researchers from IIT Kharagpur embarked on an innovative exploration of cavitation bubbles, aiming to unravel their intricate interactions and harness their potential for eco-friendly plastic recycling. Utilizing cryogenic liquids, specifically liquid nitrogen (LN_2), the team conducted direct numerical simulations to observe the behavior of interacting bubbles near a curved surface, a previously unexplored scenario.

The simulations encompassed atmospheric conditions as well as over-pressurized states, exceeding the surrounding atmospheric pressure. By varying the overpressure levels from 40 kPa to 200 kPa, the researchers gained valuable insights into the effects of different pressure levels on bubble shapes, oscillation periods and the velocity of liquid microjets. These observations revealed the transformative impact of overpressure on bubble morphologies and their interactions, providing crucial knowledge about cavitation dynamics at cryogenic temperatures.

Moreover, the researchers explored the shearing action of high-speed microjets, a phenomenon associated with cavitation, as a potential means to generate micro and nanoparticles in cryogenic environments. This groundbreaking discovery hinted at the

▶ *continues on page 20*

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possibility of leveraging cavitation for sustainable material fragmentation, presenting eco-friendly recycling strategies for plastic waste. Building upon their understanding of cavitation dynamics at cryogenic temperatures, the team proposed a novel approach known as cryo-comminution for plastic waste recycling. This method involved subjecting plastic to cryogenic temperatures and utilizing the forceful microjets generated by cavitation to break down the waste into smaller particles. Cryo-comminution aimed to provide an environmentally friendly and sustainable solution to the global plastic waste problem.

Compared to traditional plastic recycling techniques, which often involve energy-intensive processes like melting and reforming, cryo-comminution offers several notable advantages. Firstly, the use of cavitation and cryogenic temperatures eliminates the need for high energy inputs, reducing the overall energy consumption of the recycling process. This not only helps lower greenhouse gas emissions but also makes the recycling process more cost-effective. Additionally, cryo-comminution allows for precise control over particle size and shape, which is crucial for producing high quality recycled plastic materials.

Furthermore, the utilization of cavitation and cryogenic temperatures in cryo-comminution offers a more efficient and effective method for breaking down plastic waste. The forceful microjets generated by cavitation can penetrate and fragment various types of plastic, including complex and hard-to-recycle materials. This means that cryo-comminution has the potential to handle a wider range of plastic waste, increasing the scope of recyclable plastics and reducing the amount of plastic that ends up in landfills or pollutes the environment.

Overall, the findings of this study highlight the significant advantages of cryo-comminution as an eco-friendly plastic recycling method. By harnessing the power of cavitation and cryogenic temperatures, this approach presents a sustainable alternative to traditional plastic recycling techniques, offering energy savings, improved control over particle properties and the ability to process a broader range of plastic waste. As we continue to address the global plastic waste problem, innovative solutions like cryo-comminution hold tremendous promise for creating a more sustainable and circular economy.

INOXCVA Indigenously Designs 4 K Helium Cryostat for MRI

by Michelle Crawley, Michelle.Crawley@TriComB2B.com

INOXCVA, a leading provider of cryogenic liquid storage, distribution and re-gas solutions, has achieved a significant milestone by successfully fabricating India's first indigenously designed zero-boiloff 4 K helium cryostat for a whole-body 1.5T superconducting MRI magnet system. This achievement marks India as the sixth nation in the world to manufacture MRI magnet systems and paves the way for reducing MRI expenses, making healthcare more affordable in the country. Named I-Amrit 1.5 (Indian Advanced MRI Technology 1.5), the MRI magnet system was fabricated at INOXCVA's state-of-the-art facilities in Vadodara, Gujarat.

The cryostat was developed by a team of scientists, engineers and research fellows led by Dr. Soumen Kar, principal investigator of the Indigenous Magnetic Resonance Imaging (IMRI) project at Inter-University Accelerator Centre (IUAC), New Delhi. The project, a national mission, was initiated under the leadership of Mr. Rajesh Harsh, chief investigator, IMRI project, at Society for Applied Microwave Electronics Engineering & Research (SAMEER), Mumbai, in collaboration with IUAC and Center for Development of Advanced Computing (C-DAC) and funded by the Ministry of Electronics and IT.

Dr. Kar expressed his gratitude to the INOXCVA team for successfully manufacturing the MRI cryostat. “The development of modern MRI magnets and the 4 K helium cryostat with zero-boiloff technology was an exceptionally challenging task, requiring the application of numerous complex indigenous technologies. Achieving the stringent performance targets required for clinical scanners demanded the highest level of technological perfection in integrating the magnet with the helium cryostat. The IUAC and INOX teams have worked tirelessly over the past few months to accomplish a remarkable feat, which now positions India as the sixth country in the world to manufacture MRI magnet systems.”

Harsh highlighted the significance of the MRI magnet system, combining the IUAC-developed magnet, indigenous RF technology from SAMEER Mumbai and software created by CDAC, Kolkata and Trivandrum. “Witnessing the complex manufacturing process at INOX’s factory gives us the confidence to pursue indigenous production of MRI machines in India, which will enable us to provide affordable healthcare to a wider population.”

“This groundbreaking achievement is a testament to our unwavering commitment to revolutionizing the healthcare sector in India with cutting-edge solutions. We are confident that this game-changing engineering masterpiece will help make high quality healthcare affordable and accessible to people across the country, and we look forward to continuing our work towards the betterment of society,” added Siddharth Jain, director of INOXCVA, who also expressed pride in manufacturing India’s first indigenously designed 1.5T superconducting MRI magnet cryostat.

INOXCVA, with operations in India, Brazil and Europe, has an extensive user base that spans across 100 countries and is recognized for its design engineering, manufacturing, supply and commissioning of cryogenic turnkey packaged systems. INOXCVA also plays a pivotal role in India’s utilization of LNG for industrial and automotive purposes and is involved in critical projects like providing large bore helium distribution piping for the ITER project in France. **www.inoxcva.com**

Partnership Revolutionizes Healthcare with the MAGNETOM Terra 7 Tesla MRI Scanner

by Jenna Kurtzweil, Beckman Institute for Advanced Science and Technology at the University of Illinois Urbana-Champaign

The University of Illinois Urbana-Champaign (UIUC) and Carle Health, a vertically integrated healthcare system with hospitals, physician practices and a medical school, have formed a unique partnership to co-own and operate a Siemens Healthineers MAGNETOM Terra 7 Tesla MRI scanner. This collaboration has significant implications for both research and clinical care. The scanner, with its high-powered magnetic field and advanced neuroimaging capabilities, offers transformative potential.

The Siemens Healthineers MAGNETOM Terra 7 Tesla MRI system combines cutting-edge technology with the power of a 7 Tesla magnet. This magnet strength is significantly higher than the 1.5-Tesla or 3-Tesla magnets commonly found in MRI machines. It was developed and distributed by Siemens Healthineers, the healthcare division of global conglomerate Siemens GA.

The acquisition of the 7 Tesla MRI scanner is a result of equal contributions from Carle Health and UIUC, marking a first-of-its-kind collaboration between the two institutions. The usage time of the scanner is equally divided, with each institution receiving three and a half days per week. Carle Health primarily utilizes the scanner for clinical patients and clinical translational research, while UIUC focuses on advanced neuroscience applications and technology development. Some projects, however, are collaborative, involving both institutions in terms of time, tools and expertise.

The scanner is housed at the Carle Illinois Advanced Imaging Center in Urbana, specifically in the Carle MRI suites, ensuring a comfortable and convenient environment for patient care. Placing this jointly owned scanner in a clinical setting serves the purposes of advancing scientific knowledge and benefiting the greater community. The collaborative effort between UIUC and Carle extends to researchers in Carle's Clinical Imaging Research Program and the university's Biomedical Imaging Center, a shared research facility within the Beckman Institute for Advanced Science and Technology, an interdisciplinary research institute located on the UIUC campus.

Three MRI scans of the same brain demonstrate the difference between 1.5 Tesla (left), 3 Tesla (center) and 7 Tesla (right) MRI. *Credit: Carle Health*

The 7 Tesla MRI scanner co-owned and operated by UIUC and Carle in the Carle Illinois Advanced Imaging Center in Urbana. *Credit: Carle Health*

Groundbreaking Imaging: How It Works and Its Unparalleled Distinctions

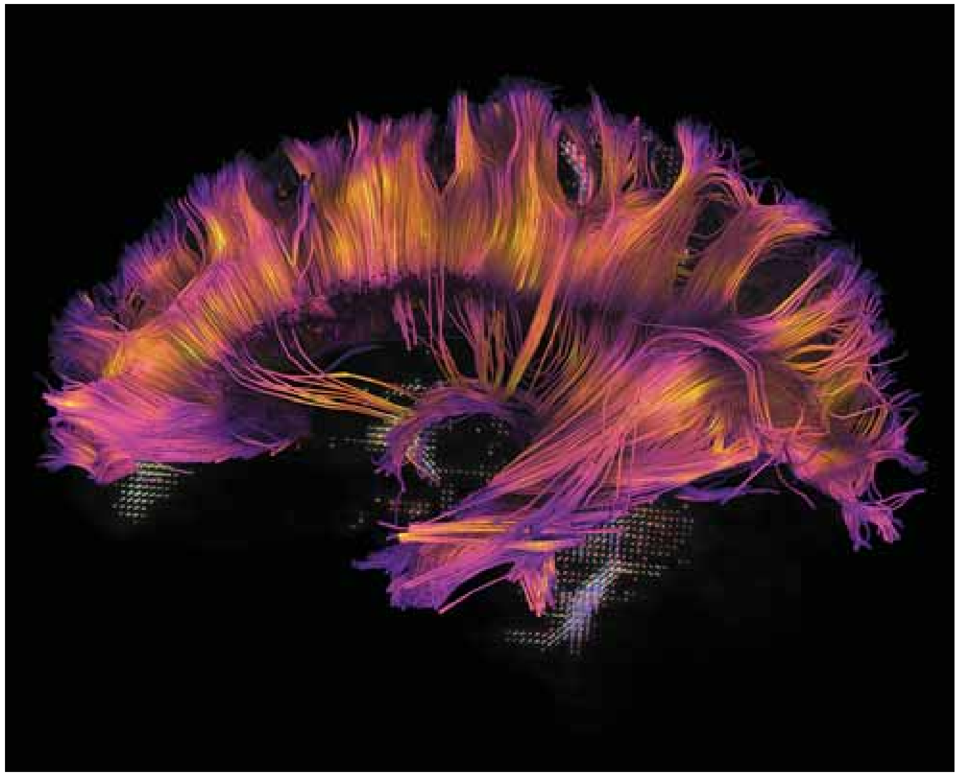
The MAGNETOM Terra 7 Tesla scanner possesses a unique dual-mode functionality, enabling seamless switching between clinical and research tasks according to the specific needs of Carle Health and the university. This versatility is not commonly seen in scanners of such strength, and it brings together clinicians, researchers and technicians to tackle new challenges. BIC is responsible for the university's engagement with the MAGNETOM Terra 7 Tesla scanner and currently operates three MRI scanners, including two MAGNETOM Prisma 3 Tesla human whole-body MRI scanners and one Bruker 9.4 Tesla preclinical animal MRI scanner, which are used for various research purposes in fields like biomedical, materials, agricultural and fluid mechanics research.

The excitement surrounding 7 Tesla technology stems from the exceptional image quality it provides. Images generated at 7 Tesla field strength are not only sharper but also transformative compared to those produced at lower field strengths like 1.5 Tesla or 3 Tesla. The level of detail enables researchers and clinicians to make observations that were previously impossible. This can have life-changing and even lifesaving implications. For example, imaging the brain at 7 Tesla field strength allows for the definitive identification and diagnosis of early signs of conditions like focal cortical dysplasia, which is associated with epilepsy and can cause seizures.

MRI scans, including those with 7 Tesla field strength, do not expose patients or research participants to radiation. However, standard safety precautions are still necessary due to the strong magnetic field. Extensive screening is conducted to ensure individuals do not have metal implants or devices that should not enter a strong magnetic field. While some electronic implants may be compatible with lower field strengths, ongoing testing is being conducted to determine their compatibility with 7 Tesla MRIs. The MAGNETOM Terra 7 Tesla scanner is approved by the Food and Drug Administration for human clinical assessments of brains and knees.

The excitement over the 7 Tesla MRI scanner has prompted several opportunities to learn more about its technology. An option at the Illinois MRI Exhibit at the Beckman Institute provides the chance to engage in the history of MRI technology in Champaign-Urbana, including Big Red, the very first human MRI scanner. Additionally, the Champaign-Urbana Population Study is actively recruiting participants, offering involvement in a comprehensive brain and cognitive health study inspired by the new scanner. Individuals can also reach out to the Biomedical Imaging Center at the Beckman Institute for inquiries regarding research projects related to the MAGNETOM Terra 7 Tesla scanner. Projects that are not UIUC-related can also be considered, as BIC is a resource available to university and non-university users who pay a slightly different rate to use the facilities.

The partnership between the University of Illinois Urbana-Champaign and Carle Health, and their co-ownership of the Siemens Healthineers MAGNETOM Terra 7 Tesla MRI scanner, has paved the way for groundbreaking research and advancements in clinical care. The scanner's unique capabilities, along with its equal utilization by both institutions, highlight the collaborative efforts and dedication to advancing scientific knowledge and community well-being.



Unlocking New Frontiers: the 7 Tesla MRI scanner is innovation meets imaging. *Credit: University of Illinois Urbana-Champaign Beckman Institute*

A Quantum Leap in Next-Gen Optical Atomic Clocks

by Lisa Paddick, QunatX Labs

QuantX Labs, an Australian deep technology company, has achieved a groundbreaking advancement with its cryogenic sapphire oscillator, the Cryoclock. Operating at microwave frequencies, it offers unparalleled signal purity and stability, attracting interest from defense and commercial markets while also spearheading the development of advanced quantum technology for space applications.

QuantX Labs, a 100% Australian-owned deep-technology company based in Lot Fourteen, Australia's innovation precinct in Adelaide, South Australia, has achieved significant advancements with its groundbreaking cryogenic sapphire oscillator, operating at a microwave frequency of approximately 10 GHz and offering unparalleled signal purity, outperforming any competing commercial technology by 1,000-10,000 times near the carrier frequency. With short-term (one second) fractional frequency stability of order 10^{-16}, the Cryoclock effectively loses or gains only one second every 40 million years. Even after one day of averaging, the long-term frequency stability remains exceptional (about 10^{-15}), moving to 10^{-14} after one month of operation.

The innovative Cryoclock technology is composed of a 5 cm cylinder-shaped sapphire crystal, cooled to approximately 6 K. This extreme temperature allows the sapphire crystal to display the lowest microwave energy losses of any known substance on Earth. The oscillator's core principle is based on the Whispering Gallery phenomenon, discovered by Lord Rayleigh in 1878. Within the resonator, microwaves injected into the sapphire crystal propagate along its circumference, generating a stable resonant frequency. This single-frequency, spectrally pure source proves ideal for applications that demand exceptional timing precision, such as very long baseline interferometry radio astronomy, quantum computing development and radar technology. To achieve its extraordinary performance, the Cryoclock

The Cryoclock is a revolutionary cryogenic sapphire oscillator, offering unmatched signal purity and stability at microwave frequencies. *Credit: QuantX Labs*

actively maintains the sapphire temperature within 10 microkelvins of the set point, while meticulously controlling the amplitude and phase of the microwave signal entering the crystal. Probes detect the resonant microwave frequency Whispering Gallery mode, which is then amplified to produce a highly pure frequency.

Cryoclock's journey began in 1989 when Professor Andre Luiten created the first version while working toward his Ph.D. at the University of Western Australia. Professor John Hartnett further improved the technology between 2004 and 2012. Initially, the device required regular liquid helium refilling, but with the introduction of a cryogenic refrigerator and a specially designed ultralow-vibration cryostat, it became autonomous, facilitating deployment to remote locations for extended periods.

In 2021, the Australian government awarded QuantX Labs, through BAE Systems, a contract to develop the cryoclock system for inclusion in Australia's nationwide surveillance system, the Jindalee Operational Radar Network (JORN), which is the Australian Defense Force's key surveillance system. Consisting of three connected remote, over-the-horizon radars located around Australia, JORN monitors Australia's northern approaches and beyond, critical to the nation's defense posture. The integration of Cryoclock technology will significantly enhance the network's detection capabilities and sensitivity, where improved spectral purity enables this radar system to detect slow-moving (low Doppler shift) and small targets (weak reflected signals).

The developed Cryoclock system, which recently passed through full acceptance testing, is self-contained and features multiple inbuilt redundancy measures and monitoring software to maintain system health levels. Servicing is required only once every two years, streamlining its maintenance. With the inclusion of this advanced technology, Australia's defense force solidifies its commitment to the JORN surveillance system, propelling the nation's worldwide reputation.

The Cryoclock technology is just the start of the innovative products being developed at QuantX Labs. QuantX Labs is now considering options to scale down the size of the Cryoclock system by reducing the size of the cryostat system and integrating strip-line electronics, making the technology more compact and attractive to commercial markets and expanded export opportunities. Additionally, the Australian Space Agency has recently announced AUS$4M in funding to QuantX Labs to develop its next-generation optical atomic clock, to be launched into space as early as 2025. This project will showcase some of the most advanced quantum technology ever launched into space. This high-performance clock delivers capability that can be utilized for numerous high value objectives. Examples include enhanced autonomy and navigation in deep space or acting as an alternate source of network time synchronization for defense and commercial assets vulnerable to GPS-denied scenarios. **www.quantxlabs.com**

Specialists Prevent Rollover Dangers at Sea

by Mads Kaasgaard, in collaboration with Axel Proc, Service Manager at Svanehøj France and Audrey Hubert, R&D Deputy Manager of Liquefaction Lab at Engie Lab Crigen

LNG storage involves managing significant safety risks, but data on the behavior of LNG in floating storage and regasification units (FSRUs) is lacking. Now, tank control system specialists from Svanehøj and energy researchers at Engie Lab Crigen have joined forces to develop more effective safety measures. Svanehøj France develops advanced technologies for safer liquefied natural gas (LNG) and liquefied petroleum gas storage at sea and on land. Its solutions monitor tanks, measure stratification and offer accurate control systems for cryogenic conditions. Engie Crigen is a research institution specializing in energy and environmental solutions, collaborating with industry partners to develop advanced technologies and improve safety measures, particularly in the field of LNG.

Svanehøj and Engie are teaming up to enhance offshore LNG safety on FSRUs. Svanehøj's advanced technologies monitor and control LNG storage conditions, while Engie Lab Crigen conducts simulations to analyze offshore storage risks. *Credit: Svanehøj*

Stratifications and rollovers pose significant safety risks when natural gas is liquified and stored in a cryogenic state. Recognizing the crucial importance of rollover prediction software for LNG storage on FSRUs and the limited knowledge of the behavior of LNG on FSRUs necessitates the collaboration between industry experts to expand the research and devise effective solutions. As LNG plays an increasingly pivotal role in the energy infrastructure, a rise in the construction of FSRUs is anticipated, as they offer a more accessible alternative for LNG storage. But the significant knowledge gap concerning FSRUs and the behavior of LNG on them needs to be narrowed. “Together with Svanehøj, we can leverage our joint expertise to enhance our understanding of rollover occurrence on FSRUs,” explains Audrey Hubert, R&D deputy manager of Liquefaction Lab at Engie Lab Crigen.

Simulations Point to Offshore Storage Risks

Engie Lab Crigen has already conducted simulations to analyze the differences between onshore and offshore LNG storage and to identify the specific risks associated to rollover occurrence on FSRUs. Results show that predicting and simulating LNG behavior is needed to avoid unwanted events such as stratification, rollovers, pressure increase and excess vapor (BOG – boiloff gas). Simulations have focused on key factors that distinguish offshore LNG storage from onshore storage, namely a higher boiloff rate, resulting in a higher quantity of vapor-generated BOG, filling capacities often limited to bottom filling on FSRUs, higher pressure within FSRUs, and vessel motion in the sea, which adds in sloshing to the equation. The initial conclusion drawn from the simulations is that there remains a risk of stratification within FSRUs, highlighting the need for effective preventive measures and safety protocols to mitigate this risk. “Together with Svanehøj, we strive to deepen our knowledge and develop solutions that address the unique challenges associated with rollover occurrence on FSRUs,” explains Hubert.

Ensuring Safe Operation of FSRUs

Svanehøj's Tank Control Systems business, formerly known as Whessoe plc, was established in Calais, France, in 1961. The company has been involved in equipping gas carriers and LNG storage tanks since the 1970s and 1980s, respectively, pioneering in providing a level, temperature and density gauge for floating storage. Svanehøj was part of Wärtsilä from 2006 until it was acquired by Svanehøj in 2022. With Svanehøj's prediction software and safety instrumentation, operators can actively monitor and manage LNG storage conditions, enabling them to respond promptly to potential rollover risks. This ensures the integrity of storage tanks while safeguarding personnel and the surrounding environment.

Svanehøj recently provided safety instrumentation and rollover prediction software to the ENI Coral Sul FLNG facility off the coast of Mozambique. With a gas liquefaction capacity of 3.4 million tons per year and the production of LNG from the 450 billion cubic meters of gas in the reservoir, the Coral Sul FLNG needed the most effective safety measures. “Here, we utilized rollover prediction software to enable the operators to adjust the regasification process, modify LNG transfer rates or implement other preventive measures to avoid rollover incidents,” explains Alex Proc, service manager at Svanehøj.

Svanehøj and Engie Lab Crigen will co-op at LNG2023 to raise awareness on rollover concerns for FSRUs. **www.svanehoj.com**, **www.engie.com**

Space Cryogenics

by Jonathan R. Stephens, NASA Marshall Space Flight Center

NASA Team to Demonstrate 'Zero Boiloff' Liquid Hydrogen Storage Using Cryocoolers

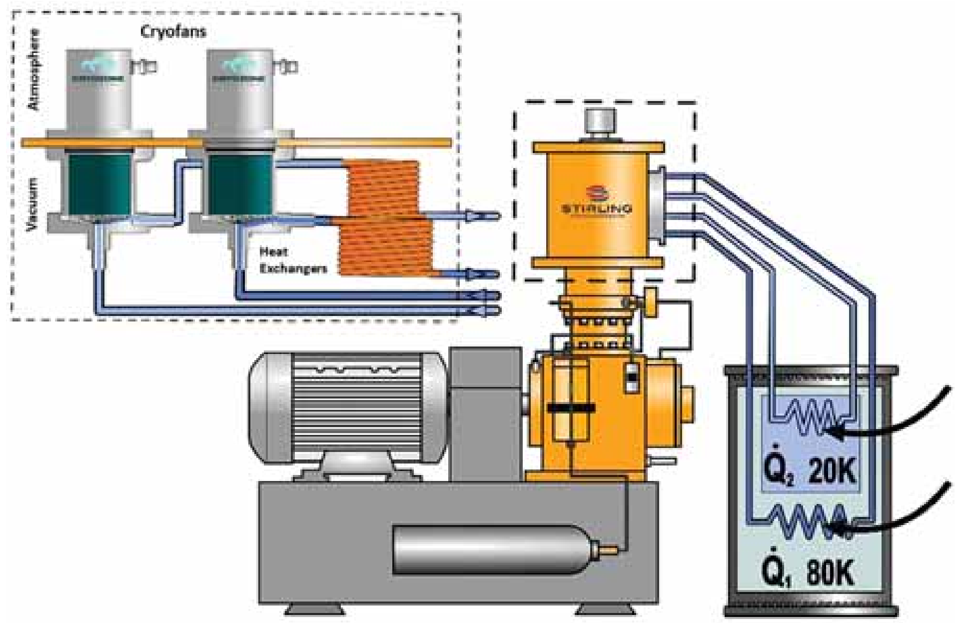


Figure 1: Two-stage cryogenerator. *Credit: Courtesy of Stirling Cryogenics*

Funded by NASA's Technology Demonstration Mission Program and managed by the Cryogenic Fluid Management Portfolio Project, a NASA team is developing a test article to demonstrate the "zero boiloff" storage of liquid hydrogen using active cooling (cryocoolers) and a two-stage cooling approach. The current state-of-the-art for storage of liquid hydrogen on-orbit is on the order of hours while future missions may require storage for months or even years. To enable such extended storage durations, "near zero" propellant loss, or "zero boiloff," must be achieved. This may be accomplished with the implementation of "near zero" leakage components, a high performing suite of passive technologies to minimize the environmental heat loads, and active cooling via cryocoolers to intercept and remove heat from the propellant tanks and associated structure. Of course, with any cryogenic vehicle and mission, a mass and power trade should be conducted to determine if it is, indeed, feasible to carry the additional dry mass associated with active cooling, or if one could simply carry additional propellants to accommodate propellant loss, which is typically not an option for a long duration mission.

Cryocoolers operating at 20 K are needed for "zero boiloff" storage of liquid hydrogen, while their 90 K counterparts are used for soft cryogens such as liquid oxygen, liquid methane or liquid natural gas. Since cryocoolers are a source of dry mass and require electrical power, it is desirable to minimize the refrigeration required to achieve "zero boiloff" conditions, which can be achieved by including technologies such as low conductivity structures and high performing insulation. Less refrigeration requirements lead to fewer or smaller cryocoolers, hence, mass and power savings. With active cooling and minimal environmental heat loads, "zero boiloff" conditions for liquid hydrogen storage can be achieved with 20 K units alone; however, they have a significantly larger specific mass (kg/W) and specific power (W/W) relative to their 90 K counterparts, meaning larger mass and greater electrical power required per watt of refrigeration.

This effort focuses on the development of a ground test article to investigate a two-stage active cooling approach which can potentially lead to mass and power savings when active cooling is implemented for long duration liquid hydrogen storage. Since the specific mass and specific power associated with the 20 K cryocoolers are high relative to 90 K cryocoolers, the objective is to intercept and reject as much heat as possible with a 90 K cryocooler, then use the 20 K unit for tank heat removal and pressure control. Previous efforts ([1], [2], and [3]) have shown, via analysis and testing, that this two-stage approach trades well against a single-stage approach in terms of mass and power savings.

Leveraging demonstrations and lessons learned from NASA's Cryogenic Propellant Storage and Transfer program, the test article will include a fully integrated suite of required technologies which includes a propellant tank equipped with a tube-on-tank heat exchanger, a load-bearing multilayer insulation inner blanket, a thin foil tube-on-shield broad area cooling heat exchanger located within the insulation and thermally strapped to the support struts and an outer multilayer insulation blanket. The thin foil tube-on-shield broad area cooling heat exchanger will be connected to the first-stage cooling loop of an industrial cryogenerator (Figure 1) and will be operating at temperatures of 80 Kelvin and below, while the second-stage loop will be connected to the tube-on-tank heat exchanger and operating at approximately 20 K.

Propellant Tank

The team procured a propellant tank outfitted with a tube-on-tank heat exchanger specifically for this test article. It is a "non-flight" ASME-rated tank constructed of Al 5083 and the tube-on-tank heat exchanger made from Al 1100, which has an extremely high thermal conductivity at liquid hydrogen temperatures. There are a total of nine tubes, each having a flow diameter of 0.18 inches. However, the tubing is D-shaped, thick-walled tubing, which is desirable to minimize the risk associated with welding and maximize the contact area between the tube and the tank surface. The tube-on-tank heat exchanger has a supply/return manifold on both the forward and aft ends to enable the refrigeration loops to be configured for flow in either direction. (An image of the 2-SC propellant tank is shown in Figure 2.)

Cryocoolers

The first phase of testing is planned to be conducted with a two-stage industrial cryocooler, or cryogenerator, with the first stage and second stages operating at 80 K and 20 K, respectively. This team recently procured such a unit with two separate heat exchangers and gas flow loops that would meet the requirements with extra margin to spare for future test programs: the Stirling Cryogenics SPC-1T (see Figure 1 and reference 4). Initially, this system will simulate the operation of the Reverse Turbo-Brayton Cycle cryocoolers, which are currently being developed for flight applications and planned to be used on a follow-on test series.

Insulation

The eventual use of the flight cryocoolers imposes constraints on the insulation system design. To enable a "zero boiloff" demonstration with the 20 K flight cryocooler, not only did the allowable pressure drop and helium flow capacity drive the sizing of the tube-on-tank heat exchanger, but there are limitations on heat lift which drives the design of the insulation system as well. A heat load budget was created assuming 20 watts as the cryocooler cooling limit. Allowing for parasitic heat loads associated with

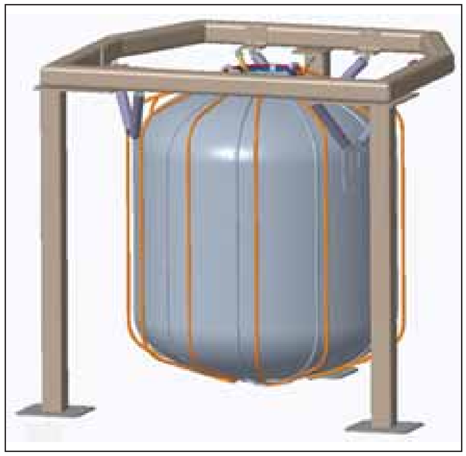


Figure 2: Tank with tube-on-tank heat exchanger with tube-on-shield coolant loops shown. *Tank Model Courtesy of PHPK*

cryocooler integration and including some conservative margin, the result is an 11-watt limit for the total propellant tank heat load, of which 3 watts is through the tank acreage, while the remaining is associated with support structure, penetrations and instrumentation. To achieve this low heat flux (~0.52 W/m^2), a high performing insulation system must be implemented.

NASA contracted Quest Thermal Group via the Small Business Innovation Research program for the design, build and installation of the test article insulation system that includes both insulation blankets, the thin foil tube-on-shield broad area cooling heat exchanger and a wrapped multilayer insulation system to be applied to the struts and refrigeration lines, as well as penetrations for filling, draining, pressurizing and venting the test article. The inner blanket will have the load-bearing capability needed to support the weight associated with the thin foil tube-on-shield broad area cooling heat exchanger and the outer blanket. Based on the most recent analysis, the inner and outer blanket configurations are expected to be 10 and 24 reflective layers, respectively.

Planned Testing

Once the build of the test article and cryogenerator characterization testing is complete, these components will be integrated into the Test Stand 300 20 ft. vacuum chamber facility at NASA Marshall Space Flight Center and undergo approximately 16 weeks of continuous testing with liquid hydrogen. A detailed test plan will first determine the steady-state heat load associated with the environment, followed by active cooling using both a single-stage and two-stage cooling approach.

Summary

Analysis to date and previous test programs indicate that the implementation of the two-stage cooling approach can potentially lead to significant mass and power savings when active cooling is used to enable the long duration storage of liquid hydrogen. The team plans to conduct a detailed test series which includes demonstrating "zero boiloff" utilizing a single-stage cooling approach (baseline with the 20 K stage only) and the two-stage cooling approach at different thin foil tube-on-shield broad area cooling heat exchanger temperatures. When the effort concludes, this approach and integrated suite of cryogenic fluid management technologies will advance to a technology readiness level of 6 for surface applications. However, due to the gravitational sensitivity associated with the tube-on-tank heat exchanger in a microgravity environment, the application will remain at technology readiness level of 5 until a flight demonstration can be achieved. Testing is currently planned for late 2024.

Acknowledgement: The author would like to acknowledge the Two-Stage Cooling Activity team, without whose hard work this effort would not be possible: Travis W. Belcher, Patrick A. Giddens, Ryan J. Grotenrath, Brian D. Hamill, Sarah Nguyen, Kevin W. Pedersen, James W. Smith, Juan G. Valenzuela, and Robert M. Witbrodt.

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Cool Cryo Guests

by Nils Tellier, PE, EPSIM Corporation (www.epsim.us), nils@epsim.us

Our Cool Cryo Guest feature highlights articles submitted by industry experts. We encourage you to send in your work for possible inclusion in a future issue. For consideration, please contact Anne DiPaola at editor@cryogenicsociety.org.

Tips for Cryogenic Air Separation Units: Thermal Cycle and Turboexpanders

This ongoing guest column of articles aims to provide tips for cryogenic air separation units, particularly in the context of increasing energy costs. Cryogenic Air Separation Units (ASUs) operation relies on simultaneous material and thermal balances. The following discussion will examine the thermal cycle and draw observations on turboexpanders.

Thermal Cycle of an ASU

ASU processes follow modified proprietary Claude cycles from plant manufacturers. (Figure 1 shows the basic elements of a Claude cycle, and Figure 2 illustrates the nodes qualitatively on a pressure-enthalpy diagram.)

The compressor-turbine loop, in green, is reminiscent of a Brayton cycle, except that the heat input between the compressor and the turbine is replaced by mechanical energy input to spin the air compressor. The compressor after-cooler and the expansion turbine brake remove this external mechanical energy, including heat leaks into the cryogenic insulation, such that the cycle is in thermal balance… until liquid is extracted from the separator, in which case it is necessary to increase the expansion turbine flow (path B to E) and compensate for the lesser vapor flow from the separator (path D to E) that results from the refrigeration loss with liquid production.

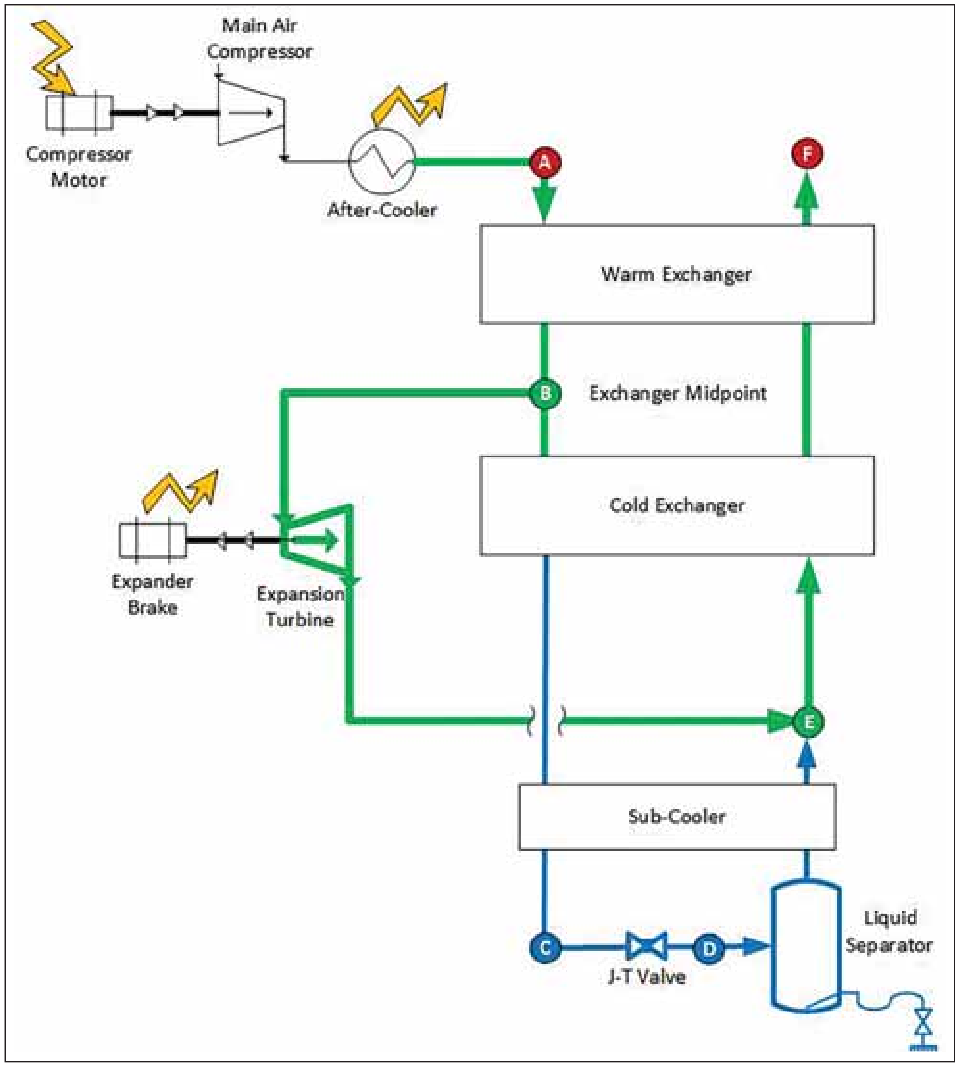


Figure 1: Modified Claude Refrigeration Cycle. *Credit: EPSIM Corp.*

This cycle utilizes three components of refrigeration:

- Isentropic expansion from the turbine reduces enthalpy and temperature (refrigeration and cooling).
- Heat recovery across the main exchangers (warm and cold) and the subcooler that provide enthalpy exchange between the incoming air and outgoing product gases at constant pressure within the limitation of end temperatures (temperatures cannot cross). Note that the high pressure air exiting the cold end of the cold exchanger is often a two-phase condensing fluid.
- Adiabatic expansion from the J-T valve, which provides temperature reduction (cooling) but not enthalpy reduction. Figure 2 shows that J-T expansion provides little cooling in the vapor and liquid phase regions because the isothermals are almost vertical. On the other hand, in the phase-change

region, J-T expansion provides the most cooling since the isothermals are nearly horizontal.

Cryogenic ASUs follow the principle shown in Figure 1, by placing the lower distillation column in lieu of the blue line between the cold exchanger and the subcooler, and the upper distillation column in lieu of the liquid separator. The J-T expansion is found on the two liquid lines from the lower to the upper columns, namely the rich liquid and the pure reflux valves. These liquid lines are subcooled by the waste nitrogen exiting the upper column (the top of the liquid separator in Figure 1).

The Turboexpander

Isentropic expansion is the extraction of energy from a vapor, a concept first introduced in 1857 by Carl Siemens. It entails coupling an expansion engine to a brake, so the vapor's enthalpy reduction is converted to mechanical energy. George Claude applied the concept to cryogenics in 1902, after six years of troubleshooting a steam piston engine converted to cryogenic applications. Pyotr Kapitsa developed the turboexpander in 1939 to replace the piston expansion engine. Today's turboexpanders have an adiabatic efficiency upwards of 80 percent:

$$Efficiency = \frac{H_{in} - H_{actual}}{H_{in} - H_{ideal}}$$, where H_{in} is the vapor's enthalpy at the expander inlet, H_{actual} and H_{ideal} are respectively the actual and isentropic enthalpies at the expander outlet.

The isentropic expansion provides immediate cooling where the isothermals intersect the isentropic lines, namely in the vapor phase region. However, the isentropic slope $\frac{dP}{dH}$, at the inlet temperature, limits the maximum ideal refrigeration. Figure 2 illustrates how isentropic expansion could generate more energy from the vapor at higher temperatures. For cryogenic cooling, it is apparent that the turboexpander's outlet temperature must be as cold as possible, even if the work extraction ΔH is less than in a warmer region, such that the cold end of the exchangers is near the phase change temperature of the incoming high pressure fluid. A limitation of the turboexpander is that it must operate in the vapor region to avoid damaging the high velocity turbine wheel with impingement of liquid droplets. For this reason, the expander's low outlet temperature trip must be set a few degrees above the condensing temperature at the discharge pressure.

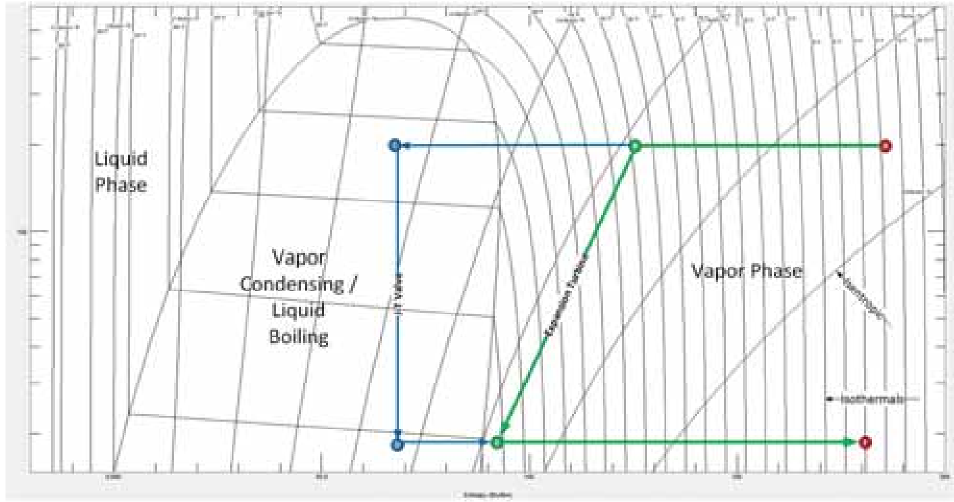


Figure 2: Pressure-Enthalpy diagram illustrating the Claude Cycle. *Credit: EPSIM Corp.*

Cryogenic turbine wheel. *Credit: Nils Tellier*

Operation and Maintenance Tips

Turboexpanders operate at high rotating speeds, often multiples of 10,000 RPMs. The cryogenic turbine wheel and shaft are typically cantilevered from the bearings located in the machine's warm part. This presents two challenges: process sealing to prevent traces of lubrication oil from entering the cryogenic circuits and balancing the shaft assembly. The expander must be scrupulously controlled, protected and maintained to avoid contaminating the exchangers and main condenser with hydrocarbons. Here are three cardinal rules of expander maintenance:

- Inspect/replace the labyrinth seals regularly and shut down the expander on loss of seal gas.
- Ensure that the expander shutoff valve, located as close to the turbine inlet as possible, slams close in under a second. Ensure that lubricating oil is available during the expander coast-down.
- Monitor the axial and radial vibrations, log the trend over time and service the expander as necessary.

It is not necessary to shut down the entire ASU when servicing the expander.

▶ continues on page 30

Refrigeration can be made up by injecting a small amount of liquid nitrogen at the top of the low pressure column. In doing so, dose the liquid injection for refrigeration, not for level control. (Over time, however, it will be the same.)

During plant cooldown, the expander will run at a higher speed than designed because the warmer inlet gas is less dense. It will produce more refrigeration because the isentropic line is leaning further to the right, as in Figure 2. Excessive flow through the expander can freeze the warm end of the exchangers and damage the plant. It is often necessary to throttle back the expander and increase the flow gradually as the columns cool down to maintain a temperature balance in the main exchangers.

When the expander trips, beware of sudden temperature differences at the exchanger ends caused by transient flow imbalance. Excessive localized temperature differences can damage the exchangers.

The expander separates the temperatures at the main exchangers' midpoint during normal plant operation and closes the ΔT at the cold end, as illustrated in Figure 3. A small ΔT at the exchanger's cold end indicates good product recovery (little oxygen in the waste), and a small ΔT at the warm end indicates good thermal performance (little refrigeration loss).

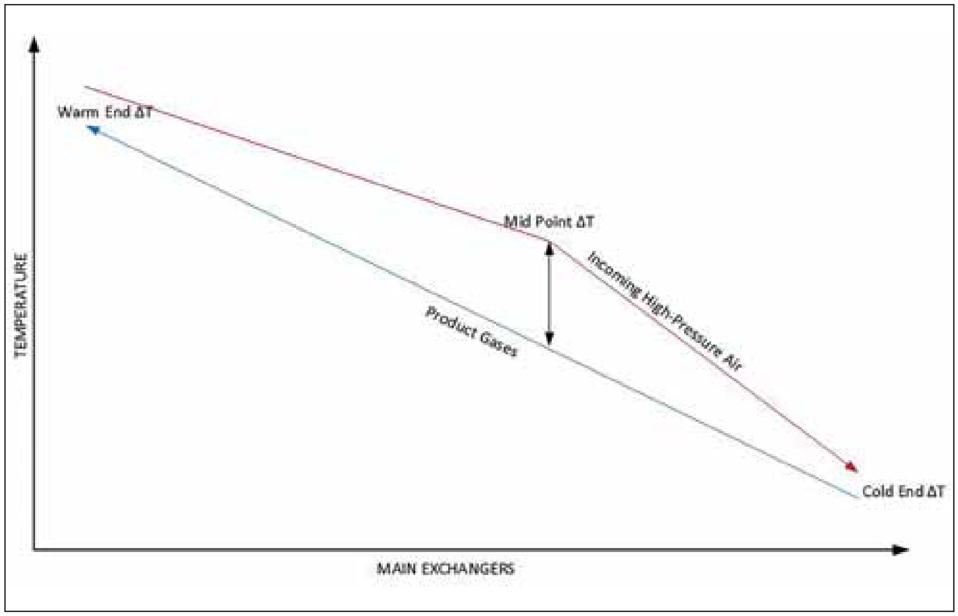
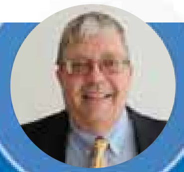


Figure 3: Expander effect on plant performance. *Credit: EPSIM Corp.*

The last two points will be further discussed in the next column, focusing on the heat exchangers.



Cryo Bios

by Dr. John Weisend II, European Spallation Source ERIC, CSA Chairman, john.weisend@esss.se

Olli Viktor Lounasmaa

Professor Olli Lounasmaa was born in Turku, Finland, in 1930. He earned a Bachelor's degree in physics at the University of Helsinki and then joined the very productive cryogenics group at Oxford University where he studied under R. Hill. His thesis work there was on precision measurements of the thermodynamic properties of ^{4}He between 1.5 K and 20 K. After earning his Ph.D. in 1958, he moved to the University of Turku where he continued research on liquid helium. After two years in Turku, Lounasmaa took a post-doctoral position at Argonne National Laboratory in the US. There, he developed one of the first ^{3}He evaporation refrigerators and made measurements of the specific heat of rare Earth metals below 1 K. These activities demonstrate Lounasmaa's interest and expertise in physics and engineering below 1 K.

In 1965 Lounasmaa joined the Helsinki University of Technology as a professor of physics and established the Low Temperature Laboratory. He led this laboratory for the rest of his career. Professor Lounasmaa, in addition to his great skill in experimental cryogenics, was an accomplished fundraiser and scientific leader. His efforts made the Low Temperature Laboratory one of the most significant places in the world for the study of sub-Kelvin cryogenics. Among the accomplishments of Professor Lounasmaa's group was one of the first experimental confirmations of the discovery of superfluid ^{3}He, development of nuclear demagnetization refrigerators capable of reaching below 100 microKelvin, and detailed studies of quantized vorticies in rotating superfluid ^{3}He.

Professor Lounasmaa and his team produced increasingly sophisticated systems, coupling dilution refrigerators with multiple stages of nuclear demagnetization cooling. Figure 1 shows the cross-section of such a device in which two stages of demagnetization cooling result in temperatures of less than 1 nanokelvin in the lattice of the sample under study. Such devices were used to study fundamental properties of solids like magnetism and ordering of the nuclei. One device was used for neutron scattering measurements of samples at/below 1 nanokelvin. In order to carry out this work, Lounasmaa developed new experimental techniques, including thermometry and thermal insulation systems. This work was described in his book *Experimental Principles and Methods below 1 K*, a text that is still useful today.

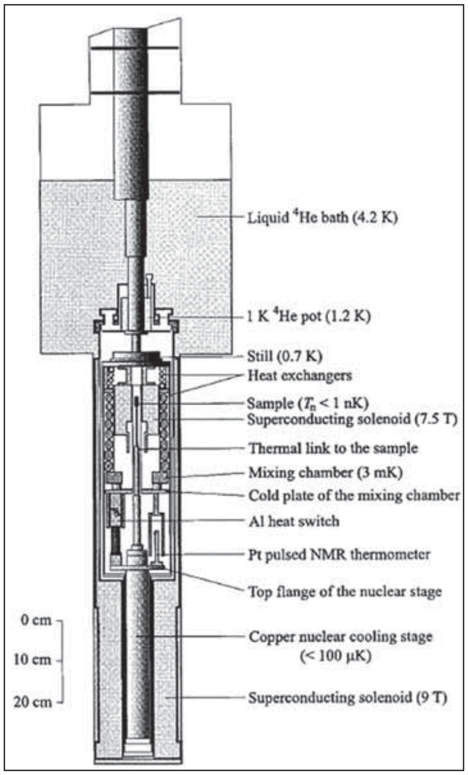
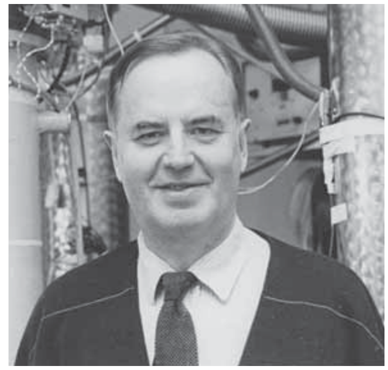


Figure 1: An example of a refrigerator developed at the Low Temperature Laboratory by Professor Lounasmaa and his team. Note that the sample temperature can be cooled below 1 nanokelvin. *Credit: Yao, W., et al. (2000). "A Versatile Nuclear Demagnetization Cryostat." Journal of Low Temperature Physics, 120(1/2), Springer*

In the late 1970s, Professor Lounasmaa started work on magnetoencephalography, which is the study of human brain function and behavior via the measurement of magnetic fields in the brain. Such fields are very small and studying them requires both the use of superconducting quantum interference devices (SQUIDS) and, thus, cryogenics, as well as a very magnetically quiet environment. Both the use of cryogenic temperatures and the need for precise low noise measurements were a good fit for Professor Lounasmaa's expertise, and he and his team made important advances in this field, many of which were used by other researchers. This included the design and construction of a cryostat containing SQUIDS that could be placed on a test subject's head. As a result of these efforts, Professor Lounasmaa cofounded two firms: Neuromag and the Superconductivity Helium Electronics (SHE) Corporation.



Olli Viktor Lounasmaa

Born August 20, 1930

Died December 27, 2002
Goa, India

During his career, Professor Lounasmaa published more than 250 scientific papers and supervised 45 Ph.D. students. He was a strong believer in international scientific collaboration, organized a number of scientific conferences in Helsinki and was a member of many editorial and conference boards. He received a number of honors, including the Fritz London Medal and the Mendelssohn Award and was appointed an Academician by the President of Finland. After his death in 2002, Aalto University's Low Temperature Laboratory was renamed the O.V. Lounasmaa Low Temperature Laboratory. Every four years, the O.V. Lounasmaa Prize is presented to an outstanding researcher in low temperature physics by Aalto University, the successor to the Helsinki University of Technology.

Clean Energy Future

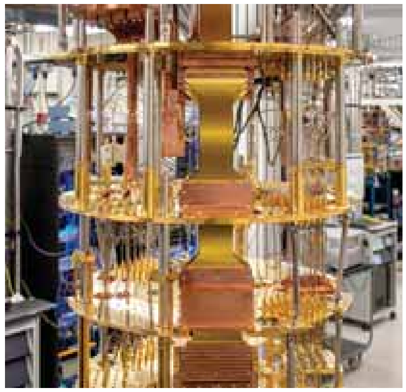
by James E. Fesmire, President, Energy Evolution LLC, james@321energy.us

Why is the Future Getting Colder?

With global warming at the forefront of the news and on a hot summer day of the hottest month in recorded history of the world, why is the future getting colder? Well into the 21st century, we see the drive toward electrification as well as advancements in energy, transportation, food, agriculture, medicine, medical equipment, manufacturing techniques, research, superconducting power devices, communications, electronics, computers, and many more. All of these areas are undergirded by cryogenic engineering, and many are core-level dependent on it. Temperatures for food preservation, agriculture processing, and pharmaceutical applications continue to expand and push to lower temperatures in the range from -50 °C to -150 °C. Electricity from hydrogen electric cells ("fuel cells") relies on liquid hydrogen (-253 °C), whether for forklifts at Amazon warehouses or for future living on the Moon. The future is indeed getting colder.

The value proposition for liquid hydrogen is to run the world on renewable energy. Only liquid hydrogen provides the pathway and potential for the at-scale storage of renewable energy, which is free and unlimited, and moving it around for use on demand wherever and whenever needed. And liquid hydrogen presents the same potential for producing and storing renewable energy at the smallest scale, even at the individual person level.

Another dramatic growth area is an entirely new type of computational process called quantum computing (QC). A quantum computer uses qubits rather than bits for the smallest unit of data. While the bits that we know working away in all our devices today are limited to being either a "zero" or a "one," a qubit has the power of "superposition" which means that it is either or both at the same time (a crude analogy is a two-sided coin forever flipping in the air). Also, quantum computers are not limited by the serial data processing of old-fashioned 20th-century computers but can enjoy "entanglements" across and among qubits. The combination of superposition and entanglements means that the modern quantum computer requires only a tiny fraction of the electrical power of a conventional bit serial process supercomputer to do the same job[1-2].



At left, the IBM Osprey quantum computer with 433 qubits. At right, the cryogenic platform, equipped with 24 loading ports, nine Cryomech pulse tube cryocoolers and three dilution refrigerators, maintaining temperatures as low as 0.010 K.
Credit: IBM and Bluefors

The catch? The qubits need an operating platform of <1 K (near absolute zero or minus 273 °C), a temperature readily achieved by a number of modern-day appliances called "dilution refrigerators" that make use of superfluid helium isotopes and their interactive mixtures. However, this fundamental requirement means much cryogenic engineering work for many years to come to make it energy-efficient, practical, and effective for the end users. The cold mass assembly of the 433-qubit Osprey quantum computer by IBM is shown in the figure; future plans include a 100,000 qubit machine by 2033.[3] Also shown is a large-scale cryogenic platform for quantum computing by Bluefors.[4]

The implications of QC and its potential are staggering. Supercomputers face limitations due to heat generated by processor chips and the energy-demanding refrigeration systems required for heat rejection. Today's data centers consume an astonishing amount of power, exceeding 1% of global electricity usage. A revolutionary shift would occur with exponentially more powerful and energy-efficient computational capabilities. QC's applications encompass climate change modeling, weather prediction, agriculture, renewable energy design, and chemical reactions. For instance, QC could reform the Haber-Bosch ammonia production process, responsible for 1.4% of global greenhouse gases. Abstract concepts like thermodynamics and entropy could transition from macroscopic observations to molecular insights, revolutionizing our comprehension of heat movement. The future holds immense promise, as we venture into the molecular realm to transform everything, echoing the words of visionary researcher Bud Skriba: *"The future - it changes everything."*

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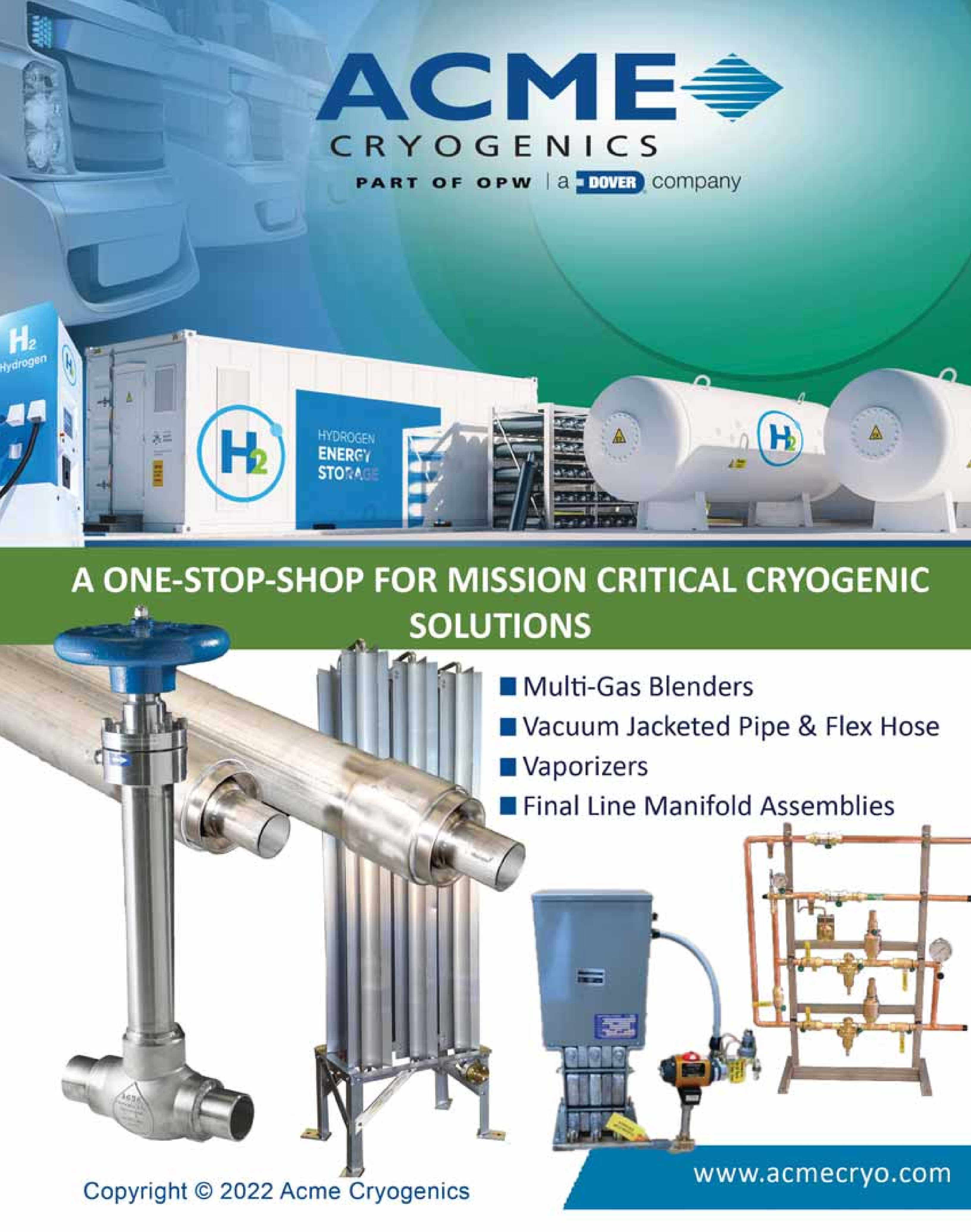
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Abbess Advances Cryogenic Cooling Technology

by Ryan Vandette, Abbess Instruments and Systems, Inc.

In the ever-changing landscape of scientific research and technology, maintaining precise temperature control is of utmost importance, especially in the realm of cryogenic cooling applications. Enter Abbess Instruments and Systems, Inc. (Abbess), a pioneering provider of cutting-edge cryogenic cooling solutions, presenting two game-changing products: The Snow River® C80-6 Cascade Chiller and Snow River® Thermal Systems.

Mastering Efficiency

Abbess's flagship offering, the Snow River C80-6 Cascade Chiller, takes the lead as one of the most versatile and efficient closed-loop cooling and heating systems available today. By ingeniously combining high and low-stage compressors, this advanced system achieves pinpoint temperature control across a wide range, from an impressive -96 °C to a toasty +200 °C, outperforming single-stage cascade chillers and liquid nitrogen systems with its unrivaled efficiency. Say goodbye to the high costs associated with LN_2 systems: the C80-6 Cascade Chiller brings exceptional control capabilities to a diverse range of scientific and industrial applications. The Abbess chiller is a game-changer and finds its place in a variety of fields, from thermal vacuum chambers to satellite testing for space simulation, environmental test chambers with altitude, temperature and humidity control, ultralow temperature freezers and beyond. With compact dimensions, including a total depth of 75.16 inches and a total height of 37.46 inches (31.84 inches with casters removed), the C80-6 Cascade Chiller offers versatility without compromise.

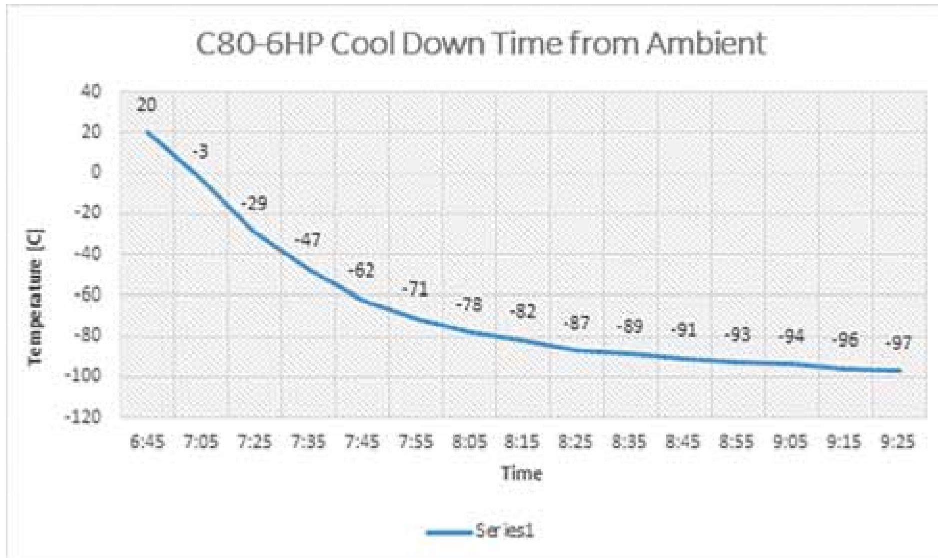


Figure 1: The expected cooldown rate of a C80-6HP chiller with no thermal load will vary with a test article (the cooldown and rates). The cooldown rate to -96 °C is about 2.5/hour. Credit: Abbess

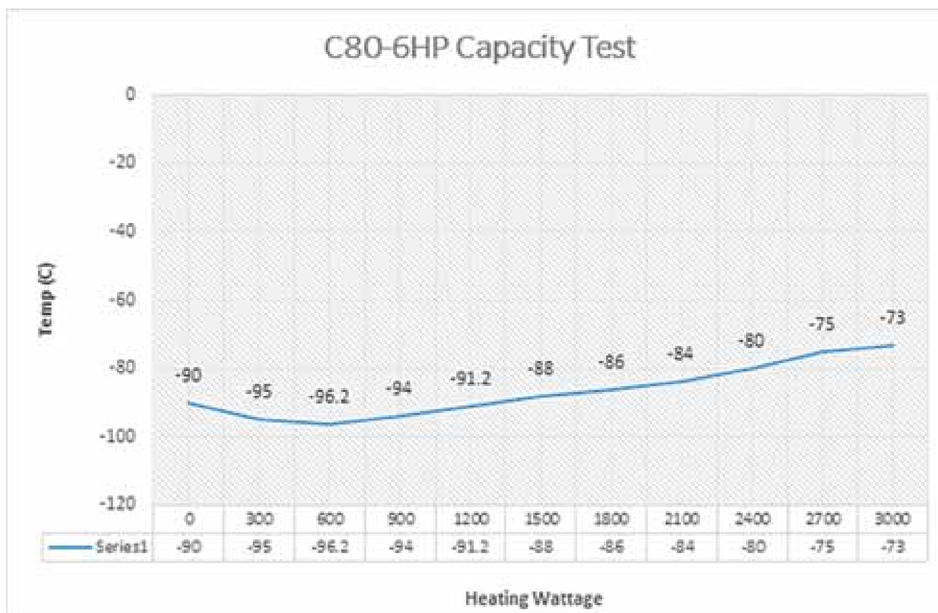


Figure 2: The C80-6HP chiller with a thermal load over time of varying wattages. (The cool down and rates will vary with a test article.) With the C80-6HP chiller, a user can maintain -73 °C at a 3,000-watt load. Credit: Abbess

Employing a cascade refrigeration system with two loops, each utilizing different refrigerants, the Snow River chiller advances technology. The low stage utilizes 508b refrigerant, while the high stage utilizes 404a refrigerant. This sophisticated design efficiently cools thermal transfer fluid as it passes through the evaporator, reaching ultralow temperatures. For optimal performance and longevity, operating the chiller at -90 °C is recommended for extended use, though it's capable of plunging as low as -96 °C. With a PID controller orchestrating the refrigeration compressors and heaters, precise temperature control between -96 °C and +200 °C is achieved easily.

Impressive features set the Snow River C80-6 Cascade Chiller apart, including PID temperature controllers for fine-tuned thermal control and profiling. Its sealed bath temperature range, spanning from

The Abbess TVAC System with the integration of a C80-6 Cascade Chiller. *Credit: Abbess*

The Snow River® C80-6 Cascade Chiller, a highly flexible closed loop cooling and heating system with efficient dual-stage compressors, eliminating LN2 system costs and providing precise temperature control from -96 °C to +200 °C; the Snow River® Thermal Systems can be configured for diverse thermal loads and processes.
Credit: Abbess

-96 °C to +200 °C, offers a reliable and adaptable solution for an extensive range of applications. Furthermore, its modular cooling units allow for scalable cooling capacity, making on-site unit replacement and installation a breeze. Abbess goes the extra mile, offering flexible control interface options, including a touchscreen PC control system for full oversight and monitoring of multiple Snow River thermal systems. With analog 4-20mA signal or 0-10 volts control capability, achieving fast and precise temperature control of the thermal transfer fluid becomes a reality.

Alongside the Snow River C80-6 Cascade Chiller, Abbess presents the Snow River Cascade Refrigeration Systems, heralding closed-loop cooling prowess that achieves temperatures as low as -96 °C, without the burden of expensive liquid nitrogen systems. These refrigeration systems are masterfully customizable, making them a seamless fit for any thermal load, whether it's thermal plates, shrouds, cold fingers, cold traps, storage coolers or cabinets. From thermal vacuum chambers to cryogenic storage and genetic sample preservation, the Cascade Refrigeration Systems deliver reliable, stable and precise temperature control, mitigating cold spots and ensuring a consistent temperature gradient across the load.

The Future of Cryo Cooling

Abbess Instruments and Systems, Inc.'s Snow River C80-6 Cascade Chiller and Snow River Cascade Refrigeration Systems are true innovations in cryogenic cooling. With their precision temperature control, efficiency and adaptability, these systems are elevating scientific research and technological progress across diverse industries. The future of cryogenic cooling looks promising indeed, guided by cutting-edge solutions. **https://abbess.com**

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

American Industrial Gases, LLC

An independent cryogenic gases firm specializing in end user applications. AIG offers liquid vessels for sale, lease, or temporary storage, and its cryogenic truck fleet delivers top quality cryogenic gases in a cost effective and customer friendly way.

Ampo Poyam Valves (AMPO)*

Cryogenic valves for LNG or liquefied air gases, liquefied hydrogen or helium. Microflow control and shut-off valves, vacuum or non-vacuum isolation applications, axial check valves and top-load ball valves are part of AMPO's valve portfolio.

Carter Americas, LLC

US-based stockist, distributor, and technical partner for cryogenic bearings. Proven bearing solutions for LNG, LN_2, LH_2, LOX, and more. Unique bearings for maximized performance and tested in LN_2 prior to shipment. ITAR registered.

Cryogenix Ltd.

Providers of high quality deep cryogenic treatment services for motorsport, audio, machining, aerospace. Bespoke temperature profiles and fast turnaround times available.

DeTech LLC.

Designed for continuous monitoring of the health of LN_2 storage dewar tanks of all sizes, DeTech's device ensures comprehensive asset protection without needing sensors inside the tank. It provides customizable notifications to meet customers' needs.

IONEX Research Corporation

An integrated engineering design and manufacturing firm specializing in complete custom process systems, often involving applications at cryogenic temperatures requiring cryogenic piping, pressure vessels, heat exchangers, and controls/instrumentation.

Ningbo DSW International Co., Ltd.

DSW is one of the leading manufacturers and exporters of cryogenic tanks, pumps, nitrogen dewars and gas cylinders in China. The company enjoys a reputation as an industry leader in quality and performance, helping its sales grow worldwide.

UNASIS International

UNASIS has decades of experience in handling low temperature applications in the cryogenics sector, providing its employees with the deep knowledge and understanding required to aid in solving customers' cryogenic bearings problems.

Yetispace, Inc.

With expertise in cryogenic fluid management and propulsion for extreme environments, Yetispace's facility has a high flow transfer cryogenics lab, machine and wood shops, multilayer insulation fabrication laboratory, clean work area, and 3D printing.

***CSA CSM**

Canada's National Nuclear Laboratory is Helping Build Country's Hydrogen Industry

by Dr. Nirmal Gnanapragasam, Principal Scientist, Canadian Nuclear Laboratories; Lead, Canadian Hydrogen Safety Centre

As countries across the world increase efforts to reach their pledges of net zero emissions by 2050, hydrogen is in the spotlight as a key enabler for decarbonization. Decades of research and development have demonstrated the potential of hydrogen as the industrial feedstock in the production of oil, ammonia, fertilizer, rocket fuel and chemicals. In the last decade, the production and use of clean hydrogen (made from water and renewable resources) is transcending across multiple industrial sectors never before envisioned. Applications for rail, marine, aviation, heavy surface transport, and process and chemical industries are being realized.

Canadian Nuclear Laboratories launched the concept for the Canadian Hydrogen Safety Centre with key industry stakeholders at the Canadian Hydrogen Convention in Edmonton, Alberta in April 2023. Pictured at event (left–right), CNL's Ian Castillo, Adrian Vega, Nirmal Gnanapragasam and Jeff Griffin join Atomic Energy of Canada Limited's Amy Gottschling and Sam Suppiah (CNL). *Credit: CNL*

According to a report by the International Energy Agency, global clean hydrogen production could reach 269 megatons per year by 2050. In Canada, the 2020 government-released hydrogen strategy has laid a strong foundation for the country's plan to become a global leader in clean hydrogen production and hydrogen-based renewable fuels. Canada's most recent federal budget has allotted $17 billion in tax credits to help fund clean hydrogen projects until 2035.

However, this rapid increase in the deployment of clean hydrogen devices and applications is happening outside the proprietary safety fence of the traditional gas producers and handlers. Stakeholders from multiple sectors with different codes, standards and regulations are starting to generate and utilize hydrogen. Thus, the need to ensure safety and understanding of the challenges related to hydrogen across these multiple sectors is an issue. It's why Canada's national nuclear laboratory, Canadian Nuclear Laboratories (CNL), is using its decades of technical expertise and capabilities in hydrogen and hydrogen safety to initiate the development of the Canadian Hydrogen Safety Centre (CHSC).

The purpose of the CHSC is to develop tangible safety solutions to problems that would be encountered in newer ways of making, transporting and using hydrogen. We are envisaging the need and capacity required to deliver these solutions in a timely manner to various industries. These solutions would support safer hydrogen infrastructure growth as CHSC's outreach activities would provide education and training and help support the development and implementation of codes, standards and regulations. In addition, CHSC would support various levels of government with information, be an expert witness to regulators, advise policymakers on long-term implications of safety and forecast the needs of the industry on both safety-related issues and solutions.

The concept for the Centre is also built on a collaborative approach – being a convenor and not a competitor. It needs industry, government and academia working together as the stakes have never been higher.

The challenges are also no small feat. Back in late 2022, CNL, with the support of Atomic Energy of Canada Limited, brought many of Canada's key stakeholders in hydrogen together for a workshop to better understand the current state of the industry and assess gaps in the safe handling of hydrogen. Two top gaps identified from this workshop included: (i) a lack of nationally coordinated effort in research and development focused on hydrogen safety, and (ii) a lack of awareness of the breadth of hydrogen safety capabilities available in Canada (and internationally) and on capabilities that need to be developed or acquired as they don't yet exist.

For instance, Canada's gas distribution sector envisions blending hydrogen gas with natural gas in pipelines to counter carbon emissions. Knowledge gaps exist in comprehending the risks associated with higher hydrogen concentrations, affecting pipeline materials (permeation, reaction, and embrittlement), and addressing challenges such as hydrogen leak detection. CNL's expertise, along with other Canadian materials research groups, can contribute to assessing and managing these concerns. The establishment of the CHSC facilitates coordinated activities and solution development.

Presently, the CHSC is actively engaging potential members to establish the Centre. CNL is collaborating with various stakeholders, including government bodies, regulators, research institutes, gas industry, engineering firms, and hydrogen-related associations. **www.ch2sc.ca**

Fabrum and Chart Industries Join Forces for Innovation in Clean Energy Transition

by Sandra Lukey

Fabrum, a New Zealand-based company in zero emission transition technologies, has joined forces with Chart Industries, a leader in engineering design and manufacturing for clean energy and industrial gas markets. Their strategic partnership is a collaboration on the development and sale of microscale liquefiers designed for hydrogen and other gases. As industries strive to decarbonize and transition to new energy sources, there is a rising demand for liquefaction systems. Their liquefier, capable of producing small-scale liquid hydrogen under five tonnes per day, offers a promising future for sustainable transport, industry, and energy self-sufficiency. It is also applicable to liquid natural gas and other cryogenic markets.

Fabrum's sub-half-tonne hydrogen liquefier. *Credit: Fabrum*

Under the terms of the collaboration, Fabrum will incorporate Chart's products into the manufacturing of their Micro-Scale Liquefiers. In turn, Chart, renowned for its technology, equipment, and services related to LNG, hydrogen, biogas, and CO_2 capture, will expand its portfolio by including the microscale liquefiers and promoting them through its global network.

Dr. Ojas Mahapatra, CEO of Fabrum, expressed delight in the collaboration with Chart, which combines their expertise as leading players in the hydrogen and technology sectors, respectively. "We're delighted to enter this strategic collaboration with Chart as it brings together Fabrum, a leading hydrogen player worldwide, with one of the most prominent players globally for technologies and equipment across the entire molecule value chain. Our collective capability and talent will enable us to deliver game-changing technology to the market to allow microscale liquid hydrogen and liquid natural gas production." He also acknowledged the significance of the timing of the collaboration with Chart Industries and highlighted the increased interest in end-to-end liquid hydrogen production and refueling systems, attributing it to the various government investments in climate and energy initiatives aimed at addressing climate change. Dr. Mahapatra also emphasized that these public sector programs have sparked a new phase of decarbonization, propelling research and development, commercialization, and investment in cutting-edge technologies like clean hydrogen.

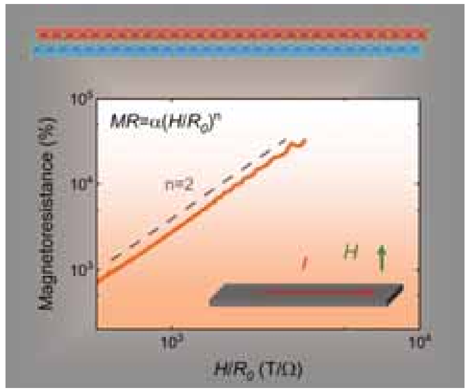
"We're excited to bring this combination to our customers in heavy transport, mining, and industry as we continue to support their transition to new and cleaner technologies with our extensive product and technology portfolio," adds Jill Evanko, CEO of Chart, who echoes the enthusiasm over the partnership that enables Chart Industries to expand its offering in microscale liquid hydrogen and liquid natural gas for refueling and energy applications.

Christopher Boyle, executive chair of Fabrum, considers the partnership with Chart as a significant milestone in accelerating the adoption of their zero emission transition technologies and promoting a lower-carbon economy. "Fabrum has already demonstrated the effectiveness of their hydrogen fuel solutions for small and medium-scale liquid hydrogen production, challenging the conventional approach of large-scale production and transportation." With Chart's established reputation as a technology innovator and supplier in the clean energy and natural gas markets, Boyle sees them as the perfect strategic partner to leverage Fabrum's world-leading technology, given their large customer base and expertise.

The collaboration between Fabrum and Chart Industries represents a crucial step forward in advancing zero emission transition technologies and contributing to a more sustainable future. By combining their capabilities, they are well-positioned to deliver innovative solutions that meet the evolving needs of industries as they embrace decarbonization and cleaner energy alternatives. **https://fabrum.nz**

Strain Manipulates $TaSe_3$ for Quantum Effects

by Rongying Jin, Joanna Blawat, and John Singleton, National High Magnetic Field Laboratory



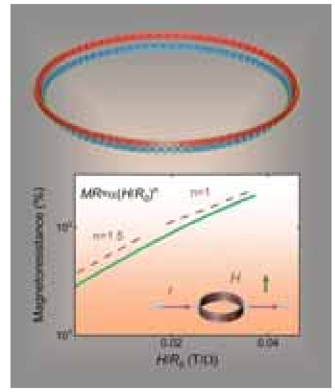


Figure 1 (left): Scaled magnetoresistance (MR) data obtained from a ribbon sample shows a conventional H^2 dependence.
Figure 2 (right): MR from ring-shaped samples deviates from conventional behavior and is~1/1,000 of that in the ribbons.
Credit: J. Xing, J. Blawat, S. Speer, A. I. Us Saleheen, J. Singleton, R. Jin, "Manipulation of the Magnetoresistance by Strain in Topological TaSe3", Adv. Quant. Tech. 5, 2200094 (2022)

Topological effects are predicted to have many potential uses in future electronic devices. Therefore, finding ways to control these effects is desirable. As predicted by first-principles calculations, the one-dimensional (1D) transition-metal trichalcogenide $TaSe_3$ is a strongly topological semimetal. It has a unique atomic arrangement of two inequivalent chains; the shorter distance between the Se atoms in the type-I chains (red in figures) creates strong covalent p-p bonding between the two Se atoms, whereas this bond is broken in the type-II chains (blue in figures) so that bonds form with the Ta atoms from the neighboring type-I chains. The chains are along the b-axis crystallographic direction. Calculations suggest that nontrivial topological phases can be induced by the distorted type-II chain under ambient conditions and/or strain. In collaboration with John Singleton at the Pulsed-Field Facility, National High Magnetic Field Laboratory, research led by Dr. Rongying Jin of the University of South Carolina (USC) investigated the effect of strain on $TaSe_3$ by measuring its magnetoresistance (MR) in fields of up to 60 T. Both ribbon-shaped (under ambient conditions) and ring-shaped (i.e., deliberately strained) samples were studied.

In the ribbon-shaped samples, the MR exhibits a quadratic magnetic field (H) dependence in both the transverse (H ⊥ current) and longitudinal (H // current) configurations, meaning MR $\propto H^2$. This MR reaches approximately 3.5×10^4% at 0.4 K and 20 T. Data collected at various temperatures can be scaled into a single curve, following Kohler's rule. Thus, strain-free $TaSe_3$ exhibits relatively conventional MR, as expected for a multiband system with nearly perfect electron-hole compensation. At high fields, conventional Shubnikov-de Haas (SdH) oscillations are observed with the frequency f = 97 T.

For the ring-shaped $TaSe_3$ samples, distinct features are observed. Firstly, under the same conditions, the MR in the rings is typically around 1,000 times lower than that in the ribbons. Secondly, the MR in different diameter rings does not follow Kohler's rule, but exhibits an $H^{1.5}$ dependence at low fields and a linear H dependence above 20 T. Thirdly, in specific field orientations, the MR of the ring exhibits H-periodic oscillations at low temperatures and high fields.

The differences between the MR of the $TaSe_3$ ribbons and rings show very clearly that forming the rings strongly modifies the electronic structure. Bending causes nonuniform strain along the b-axis of $TaSe_3$, resulting in deformation energy. On the one hand, atomic displacements caused by the strain alter the topological properties of the electronic bands, as shown in the rings by the lower MR, violation of Kohler's rule, and absence of SdH oscillations up to 60 T. On the other hand, defects and disorder are created in the crystal due to strain. Through meticulous analysis of the MR in the rings for various field and current configurations, the researchers found that the H-periodic oscillations are most pronounced when H is applied along the ring. This suggests that MR oscillations in the rings are not due to the Aharonov-Bohm effect but are likely of the Altshuler-Aronov-Spivak (AAS) type. AAS oscillations are due to carriers traveling a complete loop around a scattering center. Here, forward (weak localization) and back (weak antilocalization) scattering cause quantum interference. The effect occurs typically in weakly disordered systems that possess strong spin-orbit coupling and nontrivial topology.

Theoretically, MR oscillations periodic in H can also occur when the field pushes the system beyond the quantum limit, where only a single Landau level is occupied [C. M. Wang et al., Phys. Rev. B 102, 041204 (2020)]. The inversion of the lowest Landau level gives rise to oscillations of the Fermi energy in extremely large magnetic fields. While the linear field dependence of the ring MR above 20 T seen for H ⊥ ring also supports this beyond-quantum-limit scenario, the researchers are not fully convinced, as the linear MR in the rings persists at relatively high temperatures. Given that it requires around 100 T to reach the last Landau level of the $TaSe_3$ ribbons, further experimental investigation is needed on ring-shaped samples with various diameters to better understand the relationship between strain and the observed quantum effects.

This work was partially supported by the US Department of Energy under EPSCoR Grant No. DE-SC0012432, the U.S. National Science Foundation under Grant Nos. DMR-1504226, DMR-1157490, DMR-1644779, and the State of Florida. John Singleton acknowledges support from the DOE BES program "Science at 100 T," which permitted the design and construction of much of the specialized equipment used in the high-field study.

Lake Shore Fully Integrates with CryoComplete

by Nadia Dugan, Product Marketer for Lake Shore Cryotronics, nadia.dugan@lakeshore.com

When Lake Shore Cryotronics acquired the lab cryogenics business of Janis Research in 2020, it united two leading providers of solutions for low temperature research. The move also brought together particular specializations often required by customers: Lake Shore's expertise in instrumentation, applications and system engineering and Janis Research's strengths in cryostat and cryogenic system fabrication and design. But it also meant Lake Shore could offer significantly more complete solutions. These include measurement electronics, temperature control instrumentation and sensors, and the cooling environment—all designed to work together for a reliable experimental setup.

Unified Experiment Software

One of the components aiding with the integration is MeasureLINK software. Common to all new material characterization products introduced and available (as an add-on) to any cryostat, MeasureLINK provides complete coordination over the experiment with pre-written functional steps for controlling the measurement environment and collecting measurement data. With no programming required—it features drag-and-drop control—the user can construct an entire experiment by selecting combinations of pre-programmed steps. Users can build sequences that include multilevel parameter sweeps over the temperature, magnetic field and rotation angles of the sample while also coordinating electrical measurements at each parameter sweep.

Also, if a user's setup includes a temperature controller and cryostat, the software can change temperature control setpoints and monitor cryostat internals to better understand temperature variations. It can also show temperature trends in real time, allowing you to monitor an experiment and ensure it progresses as intended.

Combined Expertise Realized

The CryoComplete™ system is a newly developed solution that leverages the combined expertise of Lake Shore and Environment by Janis engineers while relying

CryoComplete offers a monitor, keyboard, and PC with MeasureLINK, featuring software that unifies configuration, experiment control, data charting and system monitoring.
Credit: Lake Shore

on MeasureLINK software for experimental control. Lake Shore designed CryoComplete using cryogenic best practices to deliver end-to-end system specifications.

Its benefit is that it provides everything the user needs to take temperature-dependent, low-level measurements right out of the box. It is a fully integrated electrical characterization system that provides an easy-to-implement platform for characterizing samples while providing low temperature control and electrical test automation. For electrical characterization measurements, the system contains Lake Shore's ultralow-noise M81-SSM synchronous source measurement system, which includes an instrument for three full channels of lock-in AC capability as well as a balanced DC/AC current source module and a differential DC, AC, and lock-in capable voltmeter module with a combined noise performance (differential) of 4.1 nV/√Hz.

The M81-SSM components ensure synchronous measurements using Lake Shore's patent-pending MeasureSync™ signal synchronization technology, which provides synchronized sampling to remove sampling misalignment for improved measurement accuracy. The system also provides the absolute precision of DC plus the detection sensitivity performance of AC instrumentation, with all source and measurement channels capable of DC and AC to 100 kHz signals.

Additionally, CryoComplete simplifies the setup and operation of complex characterization operations by reducing the number and types of instruments required for material or device measurements. Plus, it reduces the number and lengths of signal cables between the source, measure, and sample, minimizing the measurement's parasitics (leakage, noise, resistance, and reactance) to provide a more reliable characterization.

For the cooling of samples, the system includes an Environment by Janis VPF-100 sample-in-vacuum liquid nitrogen cryostat with four fused quartz windows, a pre-wired sample mount, and cabling. It provides a variable temperature sample environment from 77 K to 500 K, and the pour fill design allows for quick and easy LN_2 refills with no valves or adjustments required.

And for regulating the temperature of the cryostat, CryoComplete comes with a two-channel Lake Shore Model 335 temperature controller with a precision-calibrated silicon diode temperature sensor. The instrument enables the user to control temperature within 50 mK and features advanced PID autotuning and default cryostat tuning for quick setup and operation.

In addition, CryoComplete includes a monitor, a durable slide-out keyboard, and a PC with MeasureLINK. The software unifies all configuration and experiment functions through a single interface and enables a wide range of capabilities, including data charting, instrument control, and system monitoring with a cryostat-specific process view.

Lake Shore expects the system to be particularly attractive to any researcher starting out with temperature-dependent characterization. The company received a lot of positive feedback during its debut at this year's American Physical Society (APS) March Meeting in Las Vegas, where they demonstrated how it could be used to stimulate and measure small detector photocurrents of a diode mounted in the cryostat when illuminated by a laser source. **www.lakeshore.com/cryocomplete**

Conference Connect: CEC/ICMC'23 Innovates with the Aloha Spirit

The aloha spirit of Hawaii was in full swing at the 25th joint Cryogenic Engineering Conference and International Cryogenic Materials Conference (CEC/ICMC'23), held from July 9 to 13, 2023, in Honolulu. With a focus on cryogenic-related topics encompassing industry and research and development, CEC/ICMC'23 showcased the latest advancements in cryogenics, including superconductivity, cryocoolers, transportation, medical applications and cryogenic materials. For the first time in four years, attendees from around the world enjoyed five days of stimulating discussions, shared experiences and the sparking of future collaborations, all under the canopy of Hawaii's tropical paradise.

The conference was preceded by five short courses attended by more than 60 participants, organized by CSA. The courses covered various aspects of cryogenics, including cryocooler fundamentals, cryostat design, the science and engineering of cryogenic hydrogen and practical cryogenic thermometry and instrumentation. The exhibit hall included many CSA Corporate Sustaining Members and other companies and was packed with demonstrations and product samples from cryogenic companies worldwide. It not only provided an opportunity for exhibitors to share their contributions but also inspired important reconnections that will further advance the impact of cryogenics on the world.

Five distinguished plenary speakers offered valuable insights into cryogenics and related fields. Amanda Simpson from Airbus Americas discussed the incorporation of cryogenics into aircraft and Airbus' progress in developing a hydrogen-powered airliner for commercial service by 2035. Paul C. W. Chu from the Texas Center for Superconductivity at the University of Houston presented a historical overview of high temperature and room temperature superconductivity, highlighting achievements and challenges. Suhas Bhandharkar from Lawrence Livermore National Laboratory focused on the National Ignition Facility's goal of exploring controlled nuclear fusion and the associated challenges. Rod Badcock from the Robinson Research Institute discussed New Zealand's commitment to renewable energy integration and the commercial use of superconducting technology. Finally, Nicholas Masluk from IBM presented the fabrication and characterization of IBM's 433-qubit Osprey processor, released in 2023.

The conference featured more than 300 oral and poster presentations, showcasing groundbreaking research in cryogenic materials and sciences. Many speakers were CSA members or familiar names from *Cold Facts*. There was considerable discussion of developments from around the world on the topic of hydrogen generation and the uses of hydrogen for large trucks and aircraft, among other applications. Joint special sessions were held focusing on government and industrial uses of hydrogen in clean energy, mobility and transportation with a special focus on countries around the Pacific Rim. Other special sessions focused on the development of additive manufacturing and the measurement of material properties at cryogenic temperatures, in-space cryogenic fluid demonstrations, superconducting quantum systems, and topological materials for electronics.

The event also celebrated outstanding contributions to cryogenic engineering through various awards. Shrikant Pattalwar received CSA's George T. Mulholland Memorial Award for Excellence for his leadership in cryogenics and systems integration at the UKRI-STFC Daresbury Laboratory. Rich Dausman was honored with CSA's Robert W. Vance Award for his long-term commitment and support to CSA, now serving as the current CSA president-elect and board member.

Other prestigious awards at CEC/ICMC'23 recognized exceptional achievements in cryogenic engineering. Marcel ter Brake received the Samuel C. Collins Award for his exceptional work in solving cryogenic engineering challenges and his dedicated leadership in the cryogenic community. The Russell B. Scott Memorial Award honored exemplary papers published in *Advances in Cryogenic Engineering*. A. Anand, A. S. Gour, T. S. Datta, V. V. Rao, received the award for "50 kJ SMES Magnet Design Optimization Using Real Coded Genetic Algorithm," and I. Wells, J. Bussey, N. Swets, L. Reising, C. Butikofer, G. Wallace, S. Kulsa and J. Leachman were recognized for their outstanding contribution in "Liquid Nitrogen Removal of Lunar Regolith Simulant from Spacesuit Simulators."

John Weisend with his "Aspects of Cryostat Design" short course attendees. *Credit: CSA*

CSA Board Member Chris Rey awards Shrikant Pattalwar the George T. Mulholland Memorial Award for Excellence. *Credit: Tom Nicols*

The ICMC Lifetime Achievement awards honored David Evans from Rutherford Appleton Laboratory and Advanced Cryogenic Materials Ltd. and Professor Xavier Obradors from Institut de Ciència de Materials de Barcelona and Royal Academy of Sciences and Arts of Barcelona. Dr. Shreyas Balachandran from Thomas Jefferson National Accelerator Facility received the ICMC Cryogenic Materials Award for Excellence. Noteworthy papers were acknowledged, including Y. Kunitoku, Y. Akiyama, Y. Manabe and F. Sato's "Study on Irradiation Effect of Insulating Materials for Fusion Superconducting Magnet: Effect of Low-temperature Irradiation," which received the ICMC Best Structural Materials Paper award.

In addition, student researchers were recognized with Meritorious Paper awards for their remarkable contributions. The Cryogenics Best Paper Award was bestowed upon Kishan Bellur, Ezequiel F. Médici, Daniel S. Hussey, David L. Jacobs, Jacob LaManna, Juscelino B. Leão, Julia Scherschligt, James C. Hermanson, Chang Kyoung Choi and Jeffrey S. Allen for their exceptional work titled "Results from Neutron Imaging Phase Change Experiments with LH_2 and LCH4."

An important moment of CEC/ICMC-23 featured the election of the new CEC board. Christoph Haberstroh from Technical University of Dresden, Maria Barba from Fermi National Accelerator Laboratory and Parminder Banga from Bluefors Cryocooler Technologies, Inc., were newly elected as representatives of academia, government and industry, respectively.

The 24th joint Cryogenic Engineering Conference and International Cryogenic Materials Conference successfully brought together experts in cryogenics for five days of stimulating discussions, knowledge sharing and networking. The conference celebrated outstanding contributions and achievements that are driving advancements in cryogenic engineering. Anticipation is high for the next CEC/ICMC, which is scheduled for 2025 in Reno, Nevada. Further details will be announced in due course.

Ram Dhuley of Fermilab presents at the poster session. *Credit: Tom Nicols*

Rich Dausman was honored with CSA's Robert W. Vance Award by Chris Rey. *Credit: Tom Nicols*

Credit: Tom Nicols

Credit: CSA

Credit: Tom Nicols

James Fesmire, Jonathan Demko and Quan-Sheng Shu pictured with their book Cryogenic Heat Management. *Credit: CSA*

"**_Cool Fuel – The Science and Engineering of Cryogenic Hydrogen_**" **_short course, presented by Jake Leachman._** *Credit: CSA*

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 **http://2csa.us/psc**.

CryzoTraq™ 2D-Barcoded Cryogenic Tubes

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Ziath's CryzoTraq™ 2D-barcoded cryogenic tubes set a new standard in biological specimen storage, ensuring sample integrity at -196 °C. Leak-resistant caps, produced through a two-stage injection molding process, prevent contamination. Tubes feature a 2D data matrix barcode for traceability, inserted using ultrasound welding. Compliant with ISO standards and sterilized with electron beam radiation, CryzoTraq tubes are available in two ml and five ml volumes, certified free from DNA, DNase, RNase, pyrogens and ATP. Ziath offers affordable and high performance DataPaq™ multirack and cube scanners for efficient 2D-barcode decoding. **www.ziath.com**

Cryogen Reclamation System

JEOL Ltd.

Developed in collaboration with Japan Superconductor Technology, Inc. (JASTEC) and Ulvac Cryogenics Inc., this system combines cutting-edge technologies to reduce liquid helium and liquid nitrogen evaporation in nuclear magnetic resonance (NMR) instruments. Benefits include a lightweight, space-saving design, reduced cryogen refilling frequency and costs, minimized helium shortage risks, vibration reduction for improved spectrum quality and compatibility with existing NMR instruments while maintaining the magnetic field. Specifications include zero boiloff for both helium and nitrogen, applicability to JEOL's superconducting magnets and cooling capacity ranging from 7.1 kW (50Hz) to 8.8 kW (60Hz). **www.jeol.com**

2.6 Tesla Cryogen-Free Mu3e System for Muon Decay Study

Cryogenic Limited

The magnet system uses four controllable solenoids to generate a homogeneous 2.6 T field over a large cylindrical volume. Varied coil currents enable precise field profile adjustments. A 25-tonne steel shield surrounding the magnet and cryostat redirects magnetic flux, minimizing stray fields. Accessible through semi-circular steel doors, the room temperature bore is supported by two aluminum cradles with 10 mm height adjustment. The 28.5-tonne system utilizes four two-stage Gifford-McMahon cryocoolers to maintain coil temperatures at 3.2 K. Magnet coils are wound with NbTi conductor and supported by an aluminum former. **www.cryogenic.co.uk**

UHV (STM) Magnet Cryostat

CryoVac

The UHV (STM) Magnet Cryostat is a versatile cryogenic system for housing superconducting magnets in ultrahigh vacuum (UHV) conditions. It offers low-loss helium bath cryostat options (1 K pot or JT stage), nitrogen shields and vapor-cooled radiation shields for enhanced performance. Fully HV compatible and bakeable up to 80 °C, it supports conventional superconducting magnets with field strengths up to 22 T in solenoid or split pair configuration. Features include vapor-cooled current leads, SPM/STM/AFM compatibility, a persistent switch and ultra-low cryogenic consumption of liquid helium (LHe) and liquid nitrogen (LN_2). Customizable tank configuration, cold plate, flanges, push/pull mechanisms and radiation shields are available to meet specific requirements. **www.cryovac.de**

People & Companies in Cryogenics

CryoWorks, Inc. (CSA CSM) has achieved the prestigious ISO 9001:2015 certification, signifying its commitment to the highest standards of quality and reliability. This certification validates its customer-centric practices, process-oriented approach and dedication to continuous improvement. With the mission of "Making It Happen" at the forefront, CryoWorks provides high quality products and services, including cryogenic piping, valves, tanks, safety equipment, and turnkey systems. The ISO certification further reinforces their promise to deliver world-class solutions that meet the highest quality assurance standards.

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A multiyear contract has been awarded to **Air Products**, an industrial gases company, to provide a large cryogenic plant for the Deep Underground Neutrino Experiment (**DUNE**). DUNE is part of the Long-Baseline Neutrino Facility hosted by **Fermilab**, aiming to study neutrinos' behavior in great detail. The cryogenic plant will cool tens of thousands of tons of liquid argon used in the experiment's detectors. Air Products will engineer, manufacture, and install a liquid nitrogen refrigeration system for this purpose. The unique system will use turboexpander technology and the Joule-Thomson effect to condense nitrogen gas back into a liquid, allowing efficient cooling of the argon. The completed system is expected to become operational in 2026, making it the largest underground cryogenic system in the world once in place.

Participants from the project's kickoff meeting, with representatives from Air Products and the LBNF team, gather in Fermilab's Wilson Hall with Fermilab Director Lia Merminga (center, front). Credit: Ryan Postel, Fermilab

....

US-based **General Atomics (GA)** and UK-based **Tokamak Energy Ltd.** have partnered to advance High Temperature Superconducting (HTS) technology for fusion energy and other industries. GA's expertise in manufacturing large-scale magnet systems will be combined with Tokamak Energy's pioneering HTS magnet technologies. Fusion power stations, enabled by strong magnetic fields, promise clean and sustainable energy, providing power to communities and heat to industries without harmful emissions. The collaboration aims to accelerate HTS technology development for applications in aviation, naval, space and medical fields. By utilizing HTS tapes with rare earth barium copper oxide superconducting material, more powerful HTS magnets can be developed, improving fusion power plant efficiency and cost-effectiveness. General Atomics has a rich history in fusion research, while Tokamak Energy has been a leader in HTS magnet development, with notable milestones in testing and operations. The collaboration combines their world-leading capabilities to drive progress towards commercial fusion energy.

General Atomics and Tokamak Energy Companies are partnering to cooperate on HTS technologies for fusion energy and other applications. Credit: GA

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The first batch of data from the **Dark Energy Spectroscopic Instrument (DESI)** includes nearly two million objects such as galaxies, quasars and stars. The data set, totaling 80 terabytes, was gathered over six months during the survey validation phase. DESI's data will not only contribute to the study of dark energy but also aid research on topics such as dark matter, gravitational lensing and galactic morphology. DESI uses robotic positioners and optical fibers to collect light from distant objects, allowing researchers to build a 3D cosmic map. The data release also includes early measurements of galaxy clustering and studies of rare objects. DESI's early findings include evidence of star migration into the Andromeda galaxy and the discovery of distant quasars. DESI is currently being conducted at Kitt Peak National Observatory using the Mayall four-meter telescope. The Department of Energy's Office of Science is providing support for DESI as it endeavors to carry out a Stage IV measurement of dark energy. This will be achieved by employing spectroscopic measurements and techniques like baryon acoustic oscillations. The experiment is ahead of schedule and plans to collect more than 40 million redshifts during its five-year run.

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Oxford Instruments NanoScience (CSA CSM) announces **Dr. Samuli Autti**, EPSRC Fellow at the University of Lancaster, as the winner of the 2023 Nicholas Kurti Science Prize. The award recognizes his groundbreaking research on macroscopic quantum systems at ultra-low temperatures, contributing to the understanding of exotic topological defects, time crystals, quantum turbulence, and unconventional superfluids.

Meetings & Events

EUCAS 2023: 16th European Conference on Applied Superconductivity
September 3-7, 2023
Bologna, Italy
eucas2023.esas.org

MT-28: International Conference on Magnet Technology
September 10-15, 2023
Aix-en-Provence, France
mt28.aoscongres.com/home!en

International Workshop On Emissions Free Air Transport Through Superconductivity
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