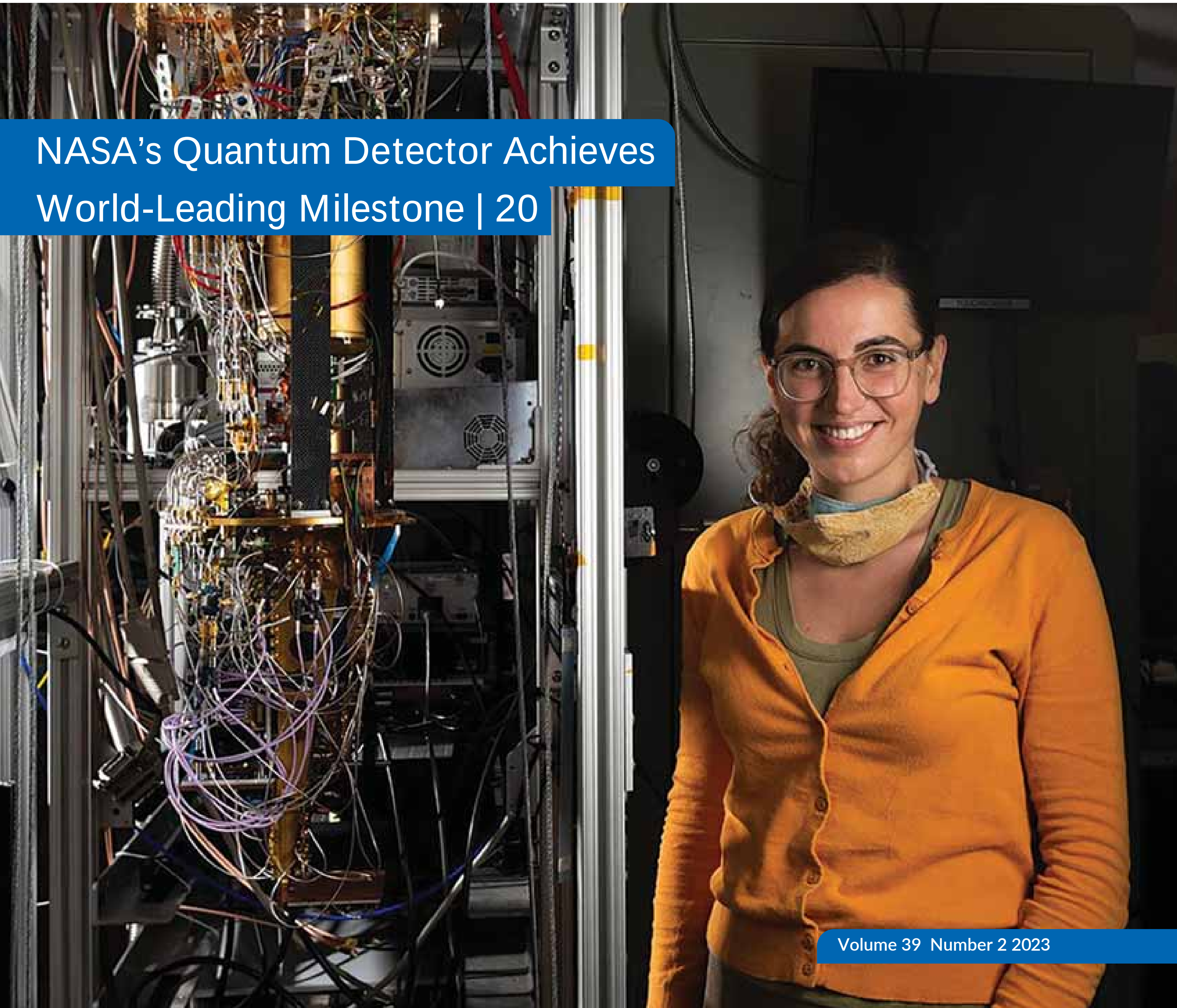
Cold Facts

The Magazine of the Cryogenic Society of America, Inc.

INTERNATIONAL



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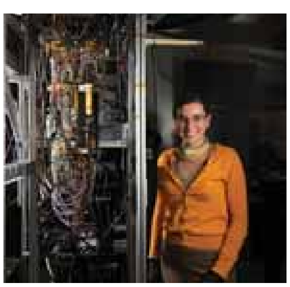

Ioana Craiciu, who led the study, stands next to the cryostat that was used to test PEACOQ at temperatures as low as a degree above absolute zero. At this temperature, the detector is in a superconducting state, allowing its nanowires to turn absorbed photons into electrical pulses.
Credit: NASA/JPL-Caltech

SPOTLIGHTS

GARDNER CRYOGENICS

Gardner Cryogenics was CSA's newsletter sponsor for April.

Lake Shore CRYOTRONICS

Lake Shore Cryotronics, Inc. was CSA's newsletter sponsor for March and May.

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Editor
Anne DiPaola

Advertising Coordinator
Joe Sullivan

Online Marketing Manager
Jo Snyder

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Israel Reza

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From the Executive Director

With the arrival of spring here in the Midwest, it's time to prepare for an action-packed summer! It's my pleasure to provide you with some exciting updates from CSA and the broader cryogenics community. As we approach the highly anticipated CEC/ICMC'23, which will be held in Honolulu, Hawaii, July 10-13, we are in the midst of planning several related events.

Prior to CEC/ICMC'23, on July 9, CSA will be hosting a series of short courses in Honolulu. We will be offering one full-day course and four half-day courses, covering various cryogenic-related topics. These courses are designed to provide a comprehensive understanding of different aspects of cryogenics and are an excellent opportunity for students and researchers to enhance their knowledge and skills in this field. (Please note that we are offering discounted early bird rates for those who register by June 9, 2023. For further details and to register, please visit the CSA website at **http://2csa.us/sc23**.)

Following CEC/ICMC'23, CSA will be partnering with NASA to host the 30th Space Cryogenics Workshop (SCW), July 16-18, 2023. This workshop will be held at the Outrigger Kona Resort and Spa in Kailua-Kona, Hawaii. This stunning oceanfront resort, situated on the Kona coastline, provides breathtaking views and a relaxing atmosphere that will serve as a perfect backdrop for this informative and engaging workshop. Further information on SCW, including registration and sponsorship opportunities, can be found at **https://spacecryogenicsworkshop.org**.

As a reminder – CSA has established the T.H.K. Frederking Space Cryogenics Workshop Student Scholarship to help deserving students attend the SCW. The scholarship will provide two $500 stipends to help cover the cost of student registration and defray some of the expenses associated with attending the workshop. Applications for the 2023 scholarship are now available for download on the CSA website at **http://2csa.us/scholar**. Interested applicants should complete the form and return it via email to me at megan@cryogenicsociety.org by the June 1 deadline.

Lastly, we would like to highlight an opportunity offered by the US Department of Energy's (DOE) Hydrogen and Fuel Cell Technologies Office. The DOE is seeking subject-matter experts in a variety of areas to help review applications for federal funding programs, especially relating to cryogens and liquid hydrogen. For more details on this opportunity, visit **http://2csa.us/DOE**. If you are interested in volunteering, please contact Ned Stetson directly at ned.stetson@ee.doe.gov.

We hope you are as excited as we are about these upcoming events and initiatives! At CSA, we are committed to advancing the field of cryogenics and supporting the next generation of researchers and scientists. Please don't hesitate to reach out to us if you have any questions or if there is anything we can do to support your involvement in CSA.

WOMEN *in* CRYOGENICS and SUPERCONDUCTIVITY

Cynthia Annema

Researcher, University of Twente

What projects are you working on now?
I am developing an affordable small-scale hydrogen liquefier. Currently, the main focus is on the conversion of orthohydrogen into parahydrogen using hydrous ferric oxide catalysts.

What accomplishments are you most proud of?
I started working in January 2023, after I finished my master's assignment in the same research as I am working on right now. Therefore, I haven't made any great accomplishments yet, but I feel this creates a space for accomplishments to come.

What advancements in cryogenics are you hoping to make in the future?
I hope to achieve a great innovating breakthrough in our research in the liquefaction of hydrogen with our research team. However, it is hard to say because I have been working on it for a short amount of time. I believe personal, professional and intellectual growth is gained during every project I'm working on now and projects I hope to work on in the future. Another goal I would like to achieve is to bring more recognition to cryogenics and all other STEM fields, and to show that with a bit of creativity and a fresh view on projects, the greatest achievements can be made.

What advancements for women would you like to see in the industry, and what is the best approach to attracting more women into the field?
Representation from highly motivated women that can show their motivation and hard work to other girls and women is key, but also promotion for the cryogenics and superconductivity fields, in general, is an important component to drawing more women into the field. To be honest, I didn't know a lot about our industry, and I found a course about it accidentally. However, it was the best mistake I made during my studies.
Luckily in our research group, the number of highly motivated women increases every year. Even if some are just students, like I was a year ago when I did my master's assignment in this research group, female representation and just pure "girl power" from an associate professor motivated me, and possibly such choices will motivate other women to continue to work in and join the field of cryogenics and superconductivity.

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Maria Barba

Ph.D. in Cryogenics, cryogenic engineer, Fermi National Accelerator Laboratory (Fermilab)

What projects are you working on now?
The field in which I work is performing cryogenic operations and engineering support in two large cryogenic facilities. One facility is used to test cryomodules for particle accelerators such as SLAC and PIP-II. The other facility supports several testing systems going from superconducting magnets for the HiLumi project at CERN to superconducting cavities for several applications including accelerators, fundamental materials research and quantum technologies.

What accomplishments are you most proud of?
Either at the end of my Ph.D. or the end of my Post-Doc, after a few years working on each experimental test stand, it was a pleasure to realize all the work done when summarizing everything in a final writing or transferring your knowledge to the next student. When you realize that you know every single inch of your experimental facility, every type of sensor, and when you recognize every single noise of your entire system, and you know every weak point, mastering the whole system is fascinating.

The main challenge is always related to the equipment and the applications: dealing with expensive and complex equipment (and, moreover, cryogenic fluids!) while trying to push different technologies to their limits.

What advancements in cryogenics are you hoping to make in the future?

My Ph.D. and postdoctoral experiences were both in cryogenics, the first one focused on cryocoolers to cool HTS and the other focused on liquid argon detectors. Now I am working on large-scale helium refrigeration systems, a completely different topic but still in cryogenics, which shows the large variety of the field of low temperatures. With this new position, I hope in the coming years to have solid experience in large scale cryogenic systems. New scale, bigger systems, new challenges!

What advancements for women would you like to see in the industry, and what is the best approach to attracting more women into the field?

Creating a large and accessible community of women in cryogenics and superconductivity, communicating and discussing frequently and exchanging different ideas, will probably help in finding new ways of communicating to the general public about our jobs and the transfer of our passion to the next generations of girls.

Motivating and stimulating little girls since the very early stages, not only in cryogenics and superconductivity, but in any engineering field is key. How can you get curious about how a plane flies if you never played with a miniature one when you were a child?

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Ashley Blasiole

Operations Engineer, Commonwealth Fusion Systems (CFS)

What projects are you working on now?

My current projects are building up, developing and implementing operational processes for SPARC, projects that specifically include the superconductive magnets and cryo-distribution systems.

What accomplishments are you most proud of?

My professional accomplishments include developing the CONOPs and outlining the operational modes for superconductive magnets and cryo-distribution systems for CFS; sitting as a launch conductor for two successful launches, most notably: Straight Up Launch, where I acted as the responsible engineer for the power, RP1 and service (helium, nitrogen, liquid nitrogen, compressed air and water) subsystems of ground support equipment; and developing the novel methodology for testing benzo[b]furan in smoke tobacco products.

What advancements in cryogenics are you hoping to make in the future?

For future cryogenics, I hope to run and optimize the cryo system for our tokamak successfully where we reach our objective of Q >1. I would like to make the cryogenic system more robust, reduce complexity and create optimized operational functionalities for all future tokamaks. One of the most important factors for superconductive magnets inside a tokamak is maintaining cryogenic temperatures across the system. Achieving temperature gradients can be operationally challenging for large systems, being able to pull concepts and knowledge from my past experiences and streamline SPARC for future tokamaks.

What advancements for women would you like to see in the industry, and what is the best approach to attracting more women into the field?

I would like to see more women publicly recognized for their achievements in the fields of cryogenics and superconductivity. I want to be a part of an all-women controls and operational team, recognizing the women who design, test and build controls systems, fluid systems and superconductive magnets. I want to see more women recognized for being successful at work and at home. Advancements start with changing the narrative on who can be an engineer, scientist or technician and by diversifying and supporting the talent already in the field.

One of the most challenging concepts as an adult woman in STEM has been redefining the bias centered around women in STEM. I have been fortunate enough to have female influences in my family who have helped pave the way for my achievements, including my grandmother who started as a draftswoman during a time when this wasn't favorable. Throughout my career, I have encountered challenges without having supportive mentors, hands-on experience, encouragement and resources. To redefine the bias for women in a control room, in a laboratory or any field where representation is lacking, requires outreach. Outreach can be programs for underprivileged areas, science and engineering camps, social media, podcasts, or any outward facing platform that focuses on all-encompassing groups in STEM. Creating a new narrative should start at home, but society should focus on redefining what the future will look like, and that is the responsibility we all have.

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Susan W. Butler

Research Associate 2, The Texas Center for Superconductivity at the University of Houston

What projects are you working on now?
These are constantly evolving but consistently there is always the characterization of new superconductors and novel magnetic materials as well as the in-depth characterization of existing materials through thermodynamic, resistivity, magnetic and pressure-dependent measurements.

What accomplishments are you most proud of?
Graduating on time, followed closely by appearing on NOVA in David Pogue's series: "Making it Colder" were accomplishments I am grateful for every day. Graduating on time was a challenge for two reasons, with the biggest hurdle occurring in my personal life as my husband suddenly passed away two years into my graduate program, and the second, finding a research project that would lead to a successful dissertation. Both challenges not only added to the hardships of going to graduate school, but in many ways, gave me a unique set of skills that have allowed me to successfully tackle a variety of difficult problems not only in my personal life but also in the lab as my career has advanced.

With that said, I wish I could say that all my mentors and colleagues helped advance me throughout my career. Many did not. I understand that opportunities for women have greatly improved, but sadly, I know many have encountered problems and barriers that ultimately resulted in having them leave research and sometimes science altogether. I fought so hard to get my degree that it is important to me, personally, to stay active in science. I feel it is my duty to help others see they can also be a scientist and even get their Ph.D.

What advancements in cryogenics are you hoping to make in the future?
I am excited to be part of the future with all the new cryo-free systems that are coming onto the market. The problems of obtaining adequate quantities of liquid helium for our low temperature measurements of superconductors and novel magnetic systems have been challenging.

What advancements for women would you like to see in the industry, and what is the best approach to attracting more women into the field?
Hiring equality that is based on experience rather than gender is important. I have personally experienced this throughout my career, and I know my fellow colleagues have as well. It would be an amazing start if we were all given the same opportunities as our male counterparts.

More of us in positions across the board is number one. I feel in my industry there are so few women that it makes it very difficult to convince new students to even try to start an advanced degree, let alone make a career out of it.

I started my career as a professional ballerina. My mother wanted us to have art in our lives. Growing up with a father who was a research chemist and a classical organist, I was always encouraged by his example. When injuries necessitated that I pursue another path, I obtained an associate's degree in music production from Houston Community College. The chemistry professor at HCC suggested that I transfer to the University of Houston, and I actually enrolled as a computer science major. I quickly determined that was not my cup of tea and enrolled in physics. Two professors influenced my decision to obtain my undergraduate degree in physics, and another student in Dr. Paul Chu's group and I became friends. Stephen Tsui, now a professor at Cal State San Marcos, convinced me to join Dr. Chu's group. I received my Ph.D. in 2010...and on schedule!

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Ioana Craiciu

Postdoctoral Scholar, NASA JPL

What projects are you working on now?
I work on optimizing superconducting nanowire single photon detectors (SNSPDs) for quantum communication and quantum information. We are currently working towards building a ground-based receiver for quantum communication. This is a cryostat which uses a pulse tube and sorption cooler to reach a base temperature of 1 Kelvin, in which we will install multiple Performance-Enhanced Array for Counting Optical Quanta (PEACOQ) detectors and cryogenic readout electronics (featured in this issue of *Cold Facts*). We are also working on improving the PEACOQ detector design. We would like to increase its efficiency, characterize and improve the photon number resolution of the detector and decrease the system timing jitter. These improvements will boost data rates and reliability in quantum communication demonstrations.

What accomplishments are you most proud of?
I am only one of eleven authors on our recent manuscript describing the PEACOQ detector, and while I am definitely proud of my contribution to that work, I am also very proud of all of my colleagues who contributed. There's a lot of talent among them. Another source of pride has been mentoring younger scientists and seeing them take off in unexpected and exciting directions. I'm also proud that I got my Ph.D., and I'm pretty proud that I unofficially ran a marathon during the pandemic.

What advancements in cryogenics are you hoping to make in the future?
Such a big question! For the near future, I'm excited to work on superconducting nanowire single photon detectors, and seeing what new applications we can enable by improving their performance

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across several dimensions, like efficiency, count rate, timing resolution and photon number resolution. This technology is only about 20 years old, and already so much has been demonstrated. SNSPDs are now commercially available, and they have made their way into research labs around the world. However, there is still not one SNSPD detector that can do it all. There are tradeoffs between active area and timing resolution, between sensitivity and maximum count rate, and there are areas where SNSPDs still need development, like readout for large arrays. There is still a lot of work to be done.

What advancements for women would you like to see in the fields of cryogenics and superconductivity?
One of the things I love most about my job is the people with whom I work every day. They have some important things in common, such as inquisitive minds and a willingness to work hard, but mostly they are very different from one another and contribute to our work in unique ways. I hope that people of all kinds, including women, can choose a career as a scientist or engineer in cryogenic technologies because it's the opportunity to solve problems with a diversity of minds, personalities and perspectives that makes the job wonderful.

What would be the best approach to getting more women into your field?
The barriers women have to overcome to be part of a field like cryogenic technologies have become smaller over the years, and I have hope they will become smaller yet. The next generation of scientists, boys and girls, have grown up with many female role models in STEM roles, and I think that will make a big difference. One area that still needs a lot of work here in the US is support for families. Women are disproportionately affected by this because they are often the primary caregiver for children. This can lead women to choose careers based not on their ability or affinity for the work, but based on the work schedule. For example, in many states, new parents have only three months of leave, and yet the CDC recommendation is that infants breastfeed exclusively for six months. For jobs that require you to physically be in a lab, that equation just doesn't add up.

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Tisha Dixit

Research Engineer (Physical Measurement and Cryogenics), Ph.D., French Alternative Energies and Atomic Energy Commission (CEA), Paris-Saclay Centre, France

What projects are you working on now?
I am currently engrossed in the investigative studies of cryogenic pulsating heat pipes (PHPs). Experimental investigation of cryogenic PHPs is presently conducted by only a handful of research groups around the world. At the Laboratory of Cryogenic Test Stations (LCSE) of the Department of Accelerators, Cryogenics and Magnetism (DACM) within the Institute of Fundamental Research of the Universe (IRFU) at CEA Paris-Saclay, we have developed a multi-objective experimental test rig for this purpose. We have the ability to experimentally characterize cryogenic PHPs of varying physical dimensions such as length ranging from several centimeters to a few meters, different capillary diameters and various cryofluids. Our recent design includes development of a nearly half-meter-long, 18 W class neon PHP.

What accomplishments are you most proud of?
Thanks to the opportunities I have received along my career path, I am proud to be a hands-on experimentalist. Slightly more than a decade ago, after completing my bachelor's in mechanical engineering, I joined the field of cryogenics by happenstance. This unique domain captivated my interest such that not only my master's, but I even pursued my doctoral research in cryogenic engineering from the Cryogenic Engineering Centre, IIT Kharagpur, India. My doctoral supervisor, Dr Indranil Ghosh, molded me with theoretical, computational and mainly experimental abilities. I observed myself to be most absorbed while materializing a concept into apparatus. After joining CEA, I have gained the real skill sets to call myself a cryogenic experimentalist. The credit goes to my current mentor, Dr. Bertrand Baudouy, and an extremely knowledgeable team of cryogenic engineers and technicians. I am happy to stand out as a female cryogenic experimentalist in this advancing digital age.

What advancements in cryogenics are you hoping to make in the future?
The goal of my current research on cryogenic PHPs is to employ these as thermal links to cool high temperature superconducting (HTc) magnet using a cold source (cryocooler in our case). For this purpose, a customized 10 T demonstrator magnet is under development at our associated Laboratory of Superconducting Magnet Research (LEAS) within DACM. Spearheading a team of seven engineers and two technicians, we are in the process of amalgamating the two technologies. It has been challenging as the successful implementation involves addressing several complexities. Nevertheless, this advancement – that has been developing for the last few years – will play a crucial role in next-generation HTc magnets. In parallel, I will continue conducting in-depth research on cryogenic PHPs with the aim to expand their deployment in space applications and clean technologies (for instance, hydrogen PHPs).

What advancements for women would you like to see in the fields of cryogenics and superconductivity?
Numbers-wise, women constitute less than 10% (perhaps even less) of the total cryogenic and superconductivity fraternity. This can be seen during the cryogenic conferences or in cryogenic laboratories and industries around the world. An attempt is necessary to increase this percentage. This could be achieved by having more women join as core professors and researchers in cryogenics and superconductivity laboratories, who can, in succession, mentor more women. Industries could offer their support to encourage women entrepreneurs wanting to expand their business acumen in this field. We recently celebrated our first woman head of LCSE. It would be inspiring to see more examples of such "cryogenic women" in executive roles as well.

What would be the best approach to getting more women into your field?

We must initially start by identifying all the women associated in this field around the world. This statistic is essential for creating inspirational cryogenic women role models. Second, we should reach out to the young minds at the undergrad and graduate level. At CEA, we frequently host educational visits from students who are awestruck not just by the cryogenics, magnet and accelerator test facilities, but also at the sight of liquid nitrogen and levitation train demonstrations.

However, one hindrance attached to this field is that the job opportunities are scarce location-wise. Some women choose to leave cryogenics at this stage to retain work-family balance. And this is where the need of progressive men arises, that ideally must begin at home. For instance, my husband has broken all norms while unconditionally supporting and appreciating my cryogenic career, to the extent that we both work in different countries. My current mentor is a true follower of feminism. I have been encouraged by a male junior to submit my candidature for this feature. Acceptance by men is crucial for women to work professionally at par. I believe that the work environment is steadily evolving to welcome more women. Recently, the option of teleworking – that was unimaginable for an experimentalist before the pre-covid era – is an added boost, especially for women to balance both professional and personal lives.

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Roza Doubnik

Ph.D., Senior Mechanical Engineer in the Cryogenics Group, Fermi Research Alliance, LLC. FRA manages Fermi National Accelerator Laboratory (Fermilab) for the US Department of Energy's Office of Science

What projects are you working on now?

I work in the Far Detector and Cryogenics subproject of LBNF/DUNE-US, supporting the international Deep Underground Neutrino Experiment (DUNE), a mega-science high energy physics project hosted by the US Department of Energy's Fermi National Accelerator Laboratory. The cryogenics infrastructure will support the first two 17.5-kiloton liquid argon mass detector modules. The scale of the LBNF/DUNE-US project is uniquely large, and a sizable portion of the equipment is in a mile underground in Lead, S.D. It is an interesting challenge for engineers, designers, scientists, project managers, administrative support, and technician specialists in cryogenic, mechanical, electrical, control and other fields from more than 30 countries to collectively participate in the installation process. I develop engineering drawings, documentation, calculations, cost estimates and specifications for proximity and infrastructure cryogenics, that will be located on top of and inside the cryostats, respectively. Additionally, I act as a point of contact for colleagues from Brazil, providing support, information and communication.

What accomplishments are you most proud of?

I was central to the successful pressure testing of the two cryostat vessels, installation of the cryogenics system, and operation of the ICARUS liquid argon neutrino hunter experiment at Fermilab. The ICARUS collaboration is investigating signs of physics that may point to a new kind of neutrino called the sterile neutrino. The challenge was effectively collaborating during the pandemic with remote contributors, who had limited access to their local university or to Fermilab. The pandemic also extended delivery time for cryogenics equipment and caused shortages in the supply chains for the test experiment, and it limited the availability of people to perform hands-on work in person. It took longer than initially planned to accomplish the test and get the results.

What advancements in cryogenics are you hoping to make in the future?

The advancement in cryogenics I see will be in the size of the equipment, all custom made. The largest prototype is 760 tons of liquid argon vessel, and by comparison these cryostats will be 17,500 ton. The filtration system will be uniquely large, suitable to purify the volume of cryostats. And the elevator to the shafts has limited dimensions, creating a challenge to deliver it underground and install, pressure test and operate it.

What advancements for women would you like to see in the industry, and what is the best approach to attracting more women into the field?

I would like to see more opportunities, challenges and support for young professional women to start and grow careers in cryogenics.

Getting more women in the cryogenics field is achievable via outreach, starting with middle and high school, and continuing into college via social media activity by young professional women in the field. I would love for women to get an exciting perspective of the social life, support and a sense of community in the workspace, like what we have at Fermilab. I also recommend recruiting talent at Society of Women Engineers annual conferences and similar events.

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Patricia Jovičević-Klug

Guest Researcher (Ph.D. in Nanosciences and Nanotechnology), Max-Planck-Institute for Iron Research, Düsseldorf, Germany-EU

What projects are you working on right now?

I am currently working on my own project, funded by the Alexander von Humboldt Foundation. In this project I am researching how cryogenic treatment of metallic materials can be used in applications for energy sector.

▶ *continues on page 14*

What accomplishments are you most proud of?
I am proud of all my work that I am conducting now and that I conducted during my Ph.D. When I started with my Ph.D., the biggest challenge was that I was the only one left in the given project. This required me to not only plan and organize my measurements for my doctoral research, but also for the whole project, which was planned for five people. Despite that, I pushed my own ideas and myself (where possible) beyond the set limitations.

What advancements in cryogenics are you hoping to make in the future?
I would like to successfully implement cryogenic treatment for the applications in the energy sector and to provide guidelines for its applications. I would also like to make advanced in-situ measurements of cryogenic treatment, which will probably challenge our understanding of cryogenic temperature on metallic materials.

What advancements for women would you like to see in the industry, and what is the best approach to attracting more women into the field?
As a proud STEMinist I would like to see that women are treated as equal fellow researchers; that we are heard with our ideas; and that we get deserved recognition for that. I would like to see more leading female researchers in this field, as first authors and leaders of research groups/departments/institutes. In addition, I want to see that appraisals of such women are achieved through objective evaluation of their work, endeavors and ideas and not by subjectively and politically appraising them because of being a "required quota." Cryogenics is a beautiful environment that requires an ensemble of different STEM disciplines, ranging from physics, chemistry, mathematics, medicine, biology to materials science, so there should not be a shortage of female researchers and candidates who are successful in such fields.

I believe that one of the most important and effective approaches would be to minimize the exclusion culture of women and, with this, gender parity in STEM. What I mean is that if we look closely at the statistics, there is no noticeable problem with involving and motivating young women to choose the selected field in STEM until the end of the bachelor's or even master's degree. However, the "great extinction" (defining it as a geochemist) of STEM women happens when one must choose to either pursue a doctoral degree in academics or go into the industry, and even later when the time comes to be an independent researcher, then a group leader and so on. Most of these women leave due to discrimination at the workplace, outdated job policies, archaic ranking systems, less flexibility and inappropriate behavior towards women in STEM.

The next way to bring more women into the field would be to include different generations of women in decision-making processes. This way, we get more easily a new generation of women in idea-forming groups, decision-making processes and leadership positions. Finally, we must involve men in the aforementioned agendas, men who are willing to listen to our challenges and support women in STEM. As such, they can help influence other male colleagues and advocate understanding towards the current situation of women in STEM and the reasons behind required changes that can hopefully change the mindset and work culture. With respect between and support for one another, I believe we can easily achieve the end goal of gender equality in STEM. Everyone is called to act and begin the change. Start small by reading about the issues at hand, educate yourselves, then continue to be bold in your message, writing and stepping in to defend/support and promote such initiatives.

Hanna Krueger

Mechanical and Optical Engineer for receiver development, Institute of Physics I (Astrophysics), University of Cologne, Germany

What projects are you working on?
For almost four years, I have been working on designing the cryogenic instrument CHAI for the Fred Young Submillimeter Telescope, which is currently under construction. CHAI will be the first 64-pixel heterodyne receiver for frequencies around 475 GHz and will observe the interstellar medium in the Milky Way and nearby galaxies. Currently, our team manufactures the cryostat and performs tests of the superconductive detectors and the signal processing chain so we can start the series production for all 64 pixels soon.

What accomplishments are you most proud of?
The dimensions of the cryogenic Focal Plane Unit (FPU) of CHAI are just 6.4x5.6x5.1 inch (162x142x130 mm) but contain the entire heterodyne signal processing chain for all 64 pixels. The entire FPU is cooled down to 4 K, using two powerful pulse tube refrigerators to cope with the power dissipation of the signal amplifiers. It took us more than four years of collaborative work to find a feasible design that fulfills all thermal, electrical, optical and mechanical requirements.

I am especially proud of the optical array nicknamed CHARM, which divides the telescope beam evenly into 64 sub-beams and feeds them into the signal mixers. It will be one of the first parts manufactured in series production this summer. The entire manufacturing will be done by our in-house high precision mechanical workshop.

What advancements in cryogenics are you hoping to make in the future?
Our plan for the next years is, of course, to successfully manufacture, assemble, test and commission the CHAI instrument which will be one of the first light instruments on the FYST telescope, currently planned for 2025. Apart from that, our working group wants to go into research and development of a new type of cryogenic detectors called MKIDs (Microwave Kinetic Inductance Detectors). From a cryogenic perspective, these detectors are much more challenging than our current instruments because they require millikelvin

▶ *continues on page 16*

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temperatures instead of 4 K. My team and I are looking forward to facing these upcoming challenges.

What advancements for women would you like to see in the industry, and what is the best approach to attracting more women into the field?

I have a feeling that there is increased awareness of diversity issues in our field presently and that current unbalances will be eliminated soon. I would like to see equality between women and men, especially when it comes to salary or application processes.

I am convinced that doing public outreach, especially for young graduates and students, is a practical approach. When I was attending university, there were not many opportunities to learn about the field of cryogenics and superconductivity, and, therefore, not many fellow students decided to take classes in this field.

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Sukanya Sagarika Meher

Technical Staff, HYPRES Inc.

What projects are you working on now?

I was involved in an IARPA-sponsored project called SuperTools along with our collaborators Synopsys, Yokohama National University, Stony Brook University and the University of Rochester. SuperTools aims at developing complete electronic design automation (EDA) toolset to design and analyze superconductor electronic (SCE) circuits.

What accomplishments are you most proud of?

Designing a circuit with automated placement and routing is a mature field in the semiconductor industry. These tools use algorithms to determine the optimal placement of the cell library and building blocks on the chip and the most efficient routing of the connections between them. In the SuperTools project, for the first time we showcased designing superconductor circuits with greater than 10 million Josephson junctions using the Synopsys Fusion Compiler, automated placement and routing tools. A cell library forms the key component that enables the adoption of such an advanced EDA tool. We have experimentally verified the performance of this cell library by designing and successfully testing the operation of an arithmetic logic unit up to 50 GHz of clock frequency. I am grateful to be one of the functional members of the HYPRES team for the development of such a cell library and the design of superconductor digital circuits using it.

The constraints imposed by superconductor electronics are different from those imposed by semiconductor technology. We need to start thinking about multiple domains to tackle those challenges and to enable the scaling of circuit complexity. An industry-standard EDA tool suite can significantly improve the efficiency of the superconductor design process by reducing the time and cost associated with manual design.

What advancements in cryogenics are you hoping to make in the future?

Superconductor circuits have some inherent properties which provide an edge over traditional semiconductor devices such as ultra-speed and energy efficiency. I want to be part of projects where superconductor electronics are used in a range of applications such as digital signal processing, sensors and communication systems.

Additionally, advancements in materials sciences and engineering could lead to the production of superconductor electronics that are easier and cheaper to manufacture, making them more widely available for the existing and emerging market.

What advancements for women would you like to see in the industry, and what is the best approach to attracting more women into the field?

In cryogenics and superconductivity, there is a need for more women to pursue careers in science and engineering, and to be represented in leadership and decision-making roles. Initiatives such as mentorship programs, networking opportunities and career development programs could help attract and retain more women in this domain. I would like to see more women highlighted for their technical and leadership accomplishments in this field through media and other platforms to raise awareness and encourage others to join the field.

I believe one of the best approaches is encouraging girls and young women to pursue STEM education early on through mentorship programs, internships and scholarships. These programs can expose them to superconductivity and other scientific fields and provide them with opportunities to work with experts in the field. Another way is by creating a network of women in superconductivity who can support and advise each other. Women role models in this field can also inspire and encourage younger women to pursue careers in cryogenics and superconductivity. Further, organizing conferences, events and workshops that focus on superconductivity and feature competent women speakers without gender bias to create a more inclusive environment for women to share their research and work experience can lead to awareness and curiosity.

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Cassie Kirkconnell Smith

Micro-Electronics Engineer, West Coast Solutions (WCS)

What projects are you working on now?

Since joining WCS, my primary focus has been on the design and development of advanced packaging schemes for cryocooler electronics. Cryocooler control electronics (CCE) is an area that is usually overlooked; however, these electronics are essential to ensure the cryocooler runs as efficiently as possible for its mission. In my engineering role, I have designed printed circuit boards (PCBs) and tested the electronics upon arrival at WCS. My testing of this hardware has mostly been related to vibration control tuning and performance verification. The objective of the testing is to get the cryocooler to operate as quietly as possible with as little vibration as possible, which is assessed by mounting the cryocooler on a Minus-K table and measuring accelerometers mounted along the axis of the compressor of the cryocooler.

What accomplishments are you most proud of?

We recently celebrated the production of the first release of a WCS flight firmware that has active vibration control. However, I am most proud of our Compact Cryocooler Electronics (C3E) design effort, which was also the first project I took on as a full-time engineer with WCS. Essentially, we took the function, power and capabilities of a two-board system (auxiliary power conditioning board and main control board) and created a compact version on a 3” X 2” board. In order to successfully miniaturize this product, advanced design work went into the creation of the printed circuit board application (PCBA). With the collaboration of our team, we were able to develop a 12-layer PCBA that packages all the required functionality onto a 3” x 2” board with more than 200 components located on the tiny PCBA.

What advancements in cryogenics are you hoping to make in the future?

WCS is always looking to advance technology in new and different ways. One of the projects I am working on now is developing a high power (>1 kW), multi-board brassboard design of Cryocooler Control Electronics (CCE) for a 90 K, 150 W turbo-Brayton cryocooler. Along with continuing my technical work as a micro-electronics engineer, I have also recently taken on the role of project engineer for our first flight electronics program. My primary role on the flight program is to manage the day-to-day tasks of the team, tracking schedules and ensuring that we are ready to move into each consecutive phase of the program as we are moving along. Due to my experience in the design and testing of these electronics, I am able to better understand the project as a whole and assist in leading the team to a successful delivery in May 2023.

As I advance my career, I hope to push the boundaries of the capabilities of cryocooler electronics. Miniaturizing technology is a consistent challenge that all electronics face, and I want to be on the front lines of being able to make small, efficient and groundbreaking CCEs. I look forward to seeing how far WCS can go to change the game of cryocooler electronics, specifically for space applications. The challenge of developing electronics and hardware for space is something that deeply fascinates me. Cryocooler electronics, combined with the challenges of space flight, drives me to continue to think outside the box as an engineer.

What advancements for women would you like to see in the industry, and what is the best approach to attracting more women into the field?

I am a firm believer that in order to be the “best” in a field, you have to have a well-rounded team of individuals who can all share and respect different points of view, which includes women. To continue making the advancements we want to see in the future for cryogenics and superconductivity, women need to be well represented and need to continue to create substantial careers in cryogenics. Sarah Mitchell was the ICC conference chair in 2022. Seeing a woman in a leadership role in cryogenics is not the norm. There are 18 people on the International Cryocooler board, and only two are women. I hope to see more women move into leadership roles in the cryogenics field and encourage other women to continue to share their ideas toward advancement in our field.

I think the best thing we can do, as a society, is to continue to encourage women to follow their passions and look for open doors in different areas of interest. Cryogenics is a powerful and unique area of engineering that is not well advertised to the general public, especially in schools. I believe if we want to see more women enter into the world of cryogenics and superconductivity, it is important for us to spread awareness of our community and shine light on the amazing work we do as cryogenics engineers.

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Dr. Wenjuan Song

Lecturer/Assistant Professor in Electrically Powered Aircraft and Operations, James Watt School of Engineering, University of Glasgow, UK

What projects are you working on now?

I am leading my team to accelerate the net-zero aviation through electrification of aircraft, particularly on the fault management using superconducting technology. I am also working with my team to promote highly efficient and reliable renewable energy systems using high temperature superconducting applications.

What accomplishment(s) are you most proud of?

There are many accomplishments that I am proud of. The first includes acting as lead guest editor of a special focus issue on Superconductivity for Cryo-Electrification of Aviation and Other Transportation Applications, in *Superconductor Science and Technology* (SuST), together with guest editors Mohammad Yazdani-Asrami, University of Glasgow, UK (recently featured as a young professional in *Cold Facts* Vol. 39 No. 1, February 2023); Zigang Deng, Southwest Jiaotong University, China; Sastry Pamidi Florida State University; and Ludovic Ybanez, Airbus UpNext, France. A second accomplishment occurred in 2022 when I was interviewed and featured as a young professional by the European Cooperation in Science and Technology (COST) Action 19108, High-Temperature SuperConductivity for AcceLerating the Energy Transition. Other accomplishments include being endorsed as “Global Talent” by Royal Academy of Engineering, United Kingdom in 2021; being featured in the “Talented Women, Early Career Researcher for International Women’s Day” as a representative for the Department of Electronic & Electrical Engineering, The University of Bath in 2021; and

▶ *continues on page 18*

being awarded with "Excellent Ph.D. Thesis Award" at Beijing Jiaotong University, China in 2019.

What advancements in cryogenics are you hoping to make in the future?

The research activities in my group aim to advance the superconducting technology by incorporating artificially intelligence (AI) approaches into superconducting applications while increasing the power density of superconducting applications, particularly superconducting propulsion machines, cables, fault current limiters and transformers.

What advancements for women would you like to see in the industry, and what is the best approach to attracting more women into the field?

I would like to see more dedicated female cryogenic engineers or researchers to advance the technology maturity in the fields of cryogenics and superconductivity, in particular how hydrogen and liquid hydrogen could benefit the superconductivity technology and powertrain systems in electrification of aircraft in the aviation sector.

It is very important to consider equity, inclusion and diversity when one is recruiting the researchers and engineers both in academia and industry. In addition, dedicated scholarships in place to recruit and support female postgraduate and Ph.D. students will help on this in academia. Well-trained and skilled Ph.D. students could later help on both academia and industry in the field of cryogenics and superconductivity.

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Eve M. Vavagiakis

National Science Foundation Astronomy and Astrophysics Postdoctoral Fellow, Cornell University

What projects are you working on now?

I am developing cryogenic cameras for the CCAT-prime Project's Fred Young Submillimeter Telescope in the Atacama Desert, Chile. These cameras deploy optics and superconducting detector arrays, cooled by dilution refrigerators and pulse tube cryocoolers. They are designed to image the sky at millimeter and submillimeter wavelengths for precision measurements of the oldest light in the universe, the cosmic microwave background. When fully populated, the 1.8-meter diameter Prime-Cam receiver will field more than 100,000 polarization-sensitive kinetic inductance detectors (KIDs), the largest deployment of these detectors yet. Fielding large numbers of superconducting detectors like KIDs at 100 mK allows us to improve the sensitivity of our measurements, enabling precise constraints on cosmology, fundamental physics and astrophysics.

What accomplishments are you most proud of?

During my Ph.D., I designed the cryogenic receiver I am now developing for deployment. Over the past few years, I have been able to watch this camera turn from a CAD model into reality. Taking a large project from conception to testing was thrilling. It's an additional joy to be able to work with a team of students to teach a new generation of scientists the basics of cryogenics. One challenge was navigating lab work during the pandemic. For example, I had to single-handedly construct a large, heavy support frame when multiple people were not allowed in the lab at the same time. Another was working with a new team of students when I became a postdoc. I had to learn how to prepare a novel instrument for testing with several students who had not worked with cryostats before. We became a great team, and I'm excited to get this instrument into the field.

What advancements in cryogenics are you hoping to make in the future?

I am excited to continue pursuing the design and development of new cryogenic instruments for cosmology and astrophysics. I plan to test and deploy superconducting detectors in novel cameras for measurements of the cosmic microwave background and submillimeter sky. This work is needed to improve our understanding of the history, evolution and composition of our universe, and my career goal is to take a lead role in that pursuit.

What advancements for women would you like to see in the industry, and what is the best approach to attracting more women into the field?

I would like to see an improved public understanding of opportunities in cryogenics and superconductivity and how we need to pull talent from all parts of society to advance the fields. As subsets of physics and engineering, cryogenics and superconductivity are not well understood by the public. Neither is the importance of women's skills in these fields. Increased public awareness of these exciting opportunities, and how women are needed to progress our capabilities, would help get more talented minds on board.

Early education for children and early familial support of their goals would help level the playing field for women in physics, astronomy and engineering. There is still significant societal pressure on girls away from hands-on instrumentation roles, as well as a fundamental lack of understanding of modern research among the general public. I am writing children's books on science topics and developing educational programs for K-12 students in an attempt to address these gaps.

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Izzy Yeomans

Cryogenics Technical Intern, Commonwealth Fusion Systems

What projects are you working on now?

I am currently part of the cryo-distribution system team that delivers cryogenic helium gas from our cryoplant to the tokamak fusion device. Specifically, I am designing a "turnaround tool" device for the cryo distribution system commissioning. The "turnaround tool" connects the cryogenic helium supply to the helium return for each temperature circuit. This device will also be able to mimic the pressure drops and heat loads of the tokamak device. I am working with vendors to design and develop a solution for this device that considers project complexity, cost and schedule.

What accomplishments are you most proud of?
I have not worked at CFS for too long, but I am extremely proud of my progress thus far on the design of my turnaround tool. I am gaining experience in various areas of engineering, including technical design work, communicating with vendors, procurement and cost analysis.

What advancements in cryogenics are you hoping to make in the future?
Of course, the primary advancement in cryogenics that I am hoping to make is to contribute to the ability of CFS's SPARC design to produce net energy with its groundbreaking technology. The cryogenics system that my team is designing will be a catalyst for this advancement. Many technologies that operate at extremely high temperatures, like those of CFS, require cryogenic systems, so I am hopeful that the industry grows exponentially from where it is now.

What advancements for women would you like to see in the industry, and what is the best approach to attracting more women into the field?
As this is a traditionally male-dominated field, I would like to see more women in cryogenics that are part of exciting projects and companies. Once they involve themselves and are inevitably able to excel, they can take the lead to encourage more females to enter cryogenics or superconductivity fields. I would also love to see them holding leadership positions to provide a path for younger generations to follow suit.

I think the best approach to getting more women into the field of cryogenics is for women who currently work in the field to pave the way. Having women in leadership roles at a company encourages other women to believe that they, too, can reach these levels. It would be great to see more women leaders in the engineering field appearing at college campuses and job fairs so that female students can picture themselves in those roles. I am encouraged by the increase in the percentage of women in engineering roles, even since I started college, but we have a long way to go. Let's keep the progress going, and I hope to see more women in cryogenics in the future!

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Zhuo Zhang

Ph.D. Researcher, Applied Thermal Science Lab, University of Twente

What projects are you working on now?
The project I am currently working on is "Direct Freeze Concentration Using Liquid Nitrogen." In the existing progressive freeze concentration systems, a freezer based on a vapor compression cycle is used. In the present study, a direct progressive freeze concentration method is proposed where the freezer is replaced by cryogenic liquid nitrogen.

What accomplishments are you most proud of?
The thermodynamic model that I developed incorporates the simultaneous heat and concentration diffusion during freezing of a liquid solution. I validated this model with lab experiments. The reactor that we developed has a unique feature: we could extract microsamples of the solution to measure the concentration of the solute in the solution. This allowed us to track the concentration with time. Compared to what is reported in the literature, we have developed a robust phenomenological model of the freeze concentration process. The second major challenge I am investigating is understanding the evaporation of a liquid nitrogen droplet in the vicinity of liquid water. I developed a phenomenological model that includes capillarity physics, thermal diffusion and momentum transport. This model is far more accurate than the crude models proposed in the literature and fits well to the experimental data reported in the literature. This work will soon be published in a journal.

What advancements in cryogenics are you hoping to make in the future?
My goal is to continually develop and become a professional in the cryogenics field. I am motivated to investigate cutting-edge technology in the cryogenics field and tackle problems that can make a valuable contribution to the sustainable development of society.

What advancements for women would you like to see in the industry, and what is the best approach to attracting more women into the field?
The cryogenics and superconductivity fields require highly advanced and specialized knowledge. Women have been underrepresented in this area. Increasing in diversity and inclusivity can certainly encourage women to participate and be involved in this field. I hope to see more women involved in science and engineering, using their interdisciplinary skills to advance the cryogenics and superconductivity areas to meet the increasing demands for cleaner energy and sustainable processes.

It is important to change the perspective of the cryogenics field. The first impression one gets is large storage vessels, pipes and valves with which most women do not immediately associate. However, this is not true. Cryogenics is an interdisciplinary branch where knowledge of thermal sciences and mechanical engineering merge. Processes at lab scale that require low temperatures are increasing, similar to my Ph.D. work. Women choosing chemical engineering, mechanical engineering or physics as their major should find it comfortable to work in this field.

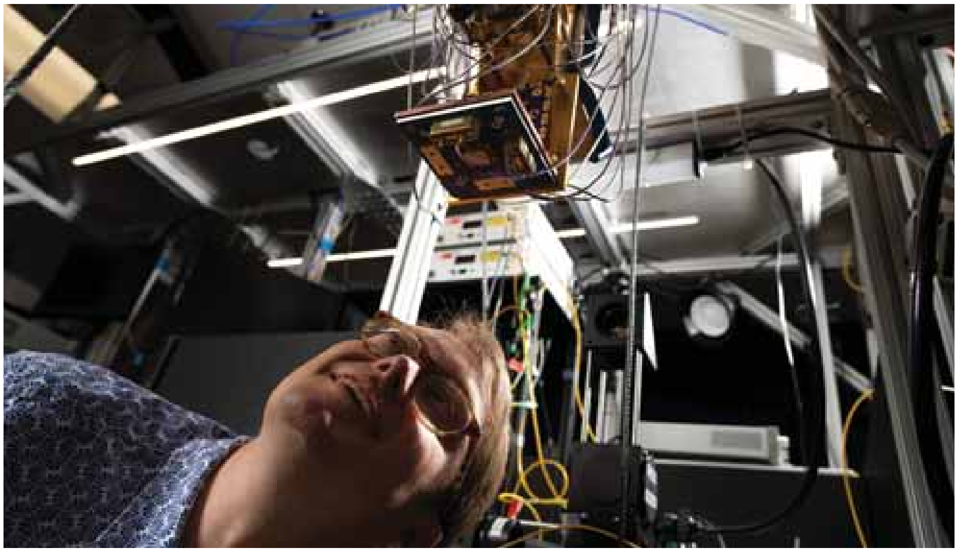
NASA's Quantum Detector Achieves World-Leading Milestone

by Ian J. O'Neill, Jet Propulsion Laboratory, Pasadena, Calif.

A new JPL- and Caltech-developed detector could transform how quantum computers located thousands of miles apart exchange huge quantities of quantum data. Quantum computers hold the promise of operating millions of times faster than conventional computers. But to communicate over long distances, quantum computers will need a dedicated quantum communications network.

To help form such a network, a device has been developed by scientists at NASA's Jet Propulsion Laboratory and Caltech that can count huge numbers of single photons – quantum particles of light – with incredible precision. Like measuring individual droplets of water while being sprayed by a firehose, the Performance-Enhanced Array for Counting Optical Quanta (PEACOQ) detector is able to measure the precise time each photon hits it, within 100 trillionths of a second, at a rate of 1.5 billion photons per second. No other detector has achieved that rate.

"Transmitting quantum information over long distances has, so far, been very limited," said PEACOQ project team member Ioana Craiciu, a postdoctoral scholar at JPL and the lead author of a study describing these results. "A new detector technology like the PEACOQ that can measure single photons with a precision of a fraction of a nanosecond enables sending quantum information at higher rates, farther."



Matt Shaw, who leads JPL's superconducting detector work, is shown here inspecting a PEACOQ mounted to a cryostat, which is used to maintain the extremely low temperatures required for the detector to work. *Credit: NASA/JPL-Caltech*

Dedicated Network Required

Conventional computers transmit data through modems and telecommunication networks by making copies of the information as a series of 1s and 0s, also called bits. The bits are then transmitted through cables, along optical fibers and through space via flashes of light or pulses of radio waves. When received, the bits are reassembled to recreate the data that was originally transmitted.

Quantum computers communicate differently. They encode information as quantum bits – or qubits – in fundamental particles, such as electrons and photons, that can't be copied and retransmitted without being destroyed. Adding to the complexity, quantum information transmitted through optical fibers via encoded photons degrades after just a few dozen miles, greatly limiting the size of any future network.

For quantum computers to communicate beyond these limitations, a dedicated free-space optical quantum network could include space "nodes" aboard satellites orbiting Earth. Those nodes would relay data by generating pairs of entangled photons that would be sent to two quantum computer terminals hundreds or even thousands of miles apart from each other on the ground.

Pairs of entangled photons are so intimately connected that measuring one immediately affects the results of measuring the other, even when they are separated by a large distance. But for these entangled photons to be received on the ground by a quantum computer's terminal, a highly sensitive detector like PEACOQ is needed to precisely measure the time it receives each photon and deliver the data it contains.

Superconducting Plumage

The detector itself is tiny. Measuring only 13 microns across, it is composed of 32 niobium nitride superconducting nanowires on a silicon chip with connectors that fan out like the plumage of the detector's namesake. Each nanowire is 10,000 times thinner than a human hair.

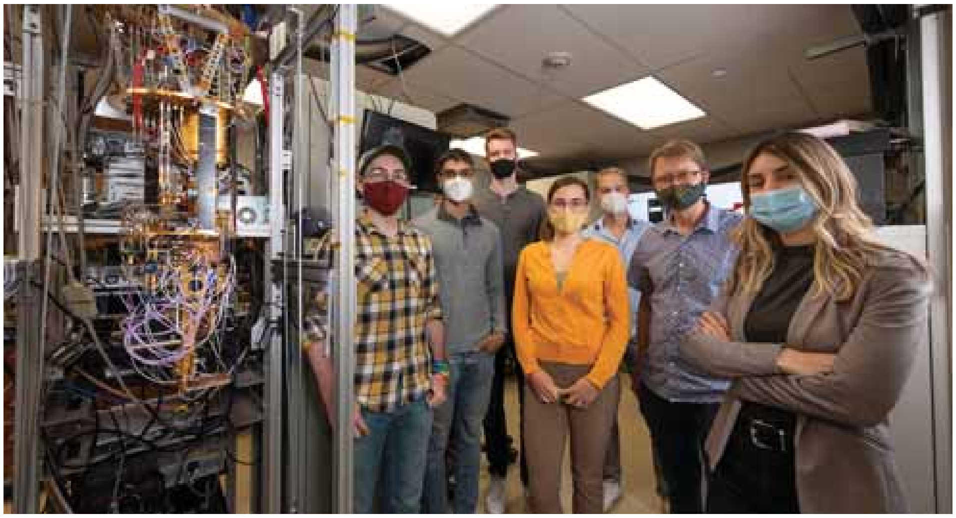
Funded by NASA's Space Communications and Navigation (SCaN) program within the agency's Space Operations Mission Directorate and built by JPL's Microdevices Laboratory, the PEACOQ detector must be kept at a cryogenic temperature just one degree above absolute zero, or -458 °F (-272 °C). This keeps the nanowires in a superconducting state, which is required for them to be able to turn absorbed photons into electrical pulses that deliver the quantum data.

Although the detector needs to be sensitive enough for single photons, it is also designed to withstand being hit by many photons at once. When one nanowire in the detector is hit by a photon, it is momentarily unable to detect another photon – a period called "dead time" – but each superconducting nanowire is designed to have as little dead time as possible. Moreover, PEACOQ is equipped with 32 nanowires so that others can pick up the slack while one is "dead."

"In the near term, PEACOQ will be used in lab experiments to demonstrate quantum communications at higher rates or over greater distances," said Craiciu. "In the long term, it could provide an answer to the question of how we transmit quantum data around the world."

Deep Space Test

Part of a wider NASA effort to enable free-space optical communications between space and the ground, PEACOQ is based on the detector developed for NASA's Deep Space Optical Communications (DSOC) technology demonstration. DSOC will launch with NASA's Psyche mission later this year to demonstrate, for the first time, how high-bandwidth optical communications between Earth and deep space could work in the future.



Members of the PEACOQ team stand next to a JPL cryostat that was used to test the detector. From left, Alex Walter, Sahil Patel, Andrew Mueller, Ioana Craiciu, Boris Korzh, Matt Shaw and Jamie Luskin. *Credit: NASA/JPL-Caltech*

While DSOC won't communicate quantum information, its ground terminal at Caltech's Palomar Observatory in Southern California requires the same extreme sensitivity in order to count single photons arriving via laser from the DSOC transceiver as it travels through deep space.

"It's all kind of the same technology with a new category of detector," said Matt Shaw, who leads JPL's superconducting detector work. "Whether that photon is encoded with quantum information or whether we want to detect single photons from a laser source in deep space, we're still counting single photons."

JPL, a division of Caltech in Pasadena, California, manages DSOC for the Technology Demonstration Missions program within NASA's Space Technology Mission Directorate and SCaN.

Novel Cryogenic Nanopositioning Technique Progresses into the Quantum Sensing Decade

by Max Kouwenhoven, CEO, Onnes Technologies, kouwenhoven@onnestechnologies.com

Quantum Sensing: Necessity for low temperature and low vibrations

Most quantum states are only visible and controllable when the thermal energy KBT is comparable or smaller than the energy difference ΔE between the quantum states. Therefore, to see the quantum properties of materials or devices, they often need to be cooled to and maintained at millikelvin temperatures. In the last ten years, we have seen great progress in improving the accessibility to millikelvin environments via advanced cryogenic platforms offered by industry. On the basis of these platforms, the application can be developed that would allow probing quantum states of materials or devices, for example by means of Scanning Probe Microscopy (SPM) techniques. However, for low temperature SPM techniques, besides the low temperature, low vibrations are also essential. First, the interaction distance between probe and quantum state needs to be maintained and second, in case of force-sensors like M(R)FM, the sensor needs to be decoupled from force-noise due to accelerations. It is to this end that quantum sensing will require progression towards low temperature and low vibration environments to use quantum-enhanced probe sensors for opening a new paradigm of Scanning Probe Microscopy: qSPM.

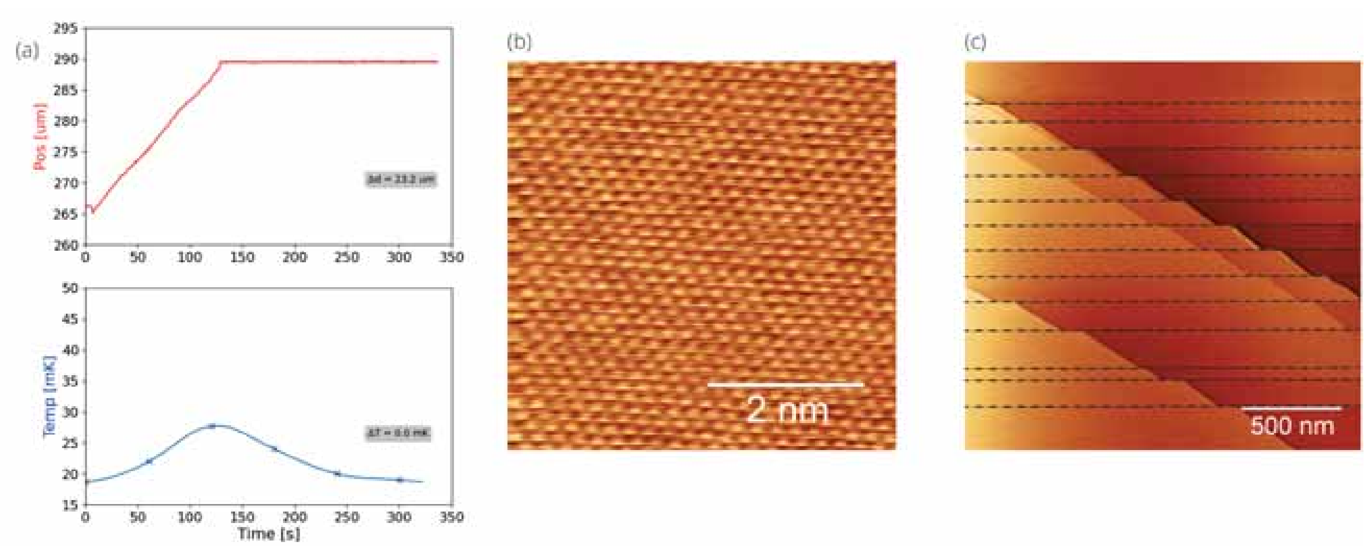
With the growing adoption of cryogen-free dilution refrigerators, the pulse tubes used for cooldown create quite a challenge for obtaining low vibration levels at millikelvin temperatures. Ideally, experiments require a connection to the refrigerator that transfers heat, but not vibrations. Practically, it results in a trade-off between vibration levels and available cooling power due to the suboptimal thermalization of vibration isolating connections. Having half of the available cooling power left at a vibration isolated platform compared to the millikelvin plate is currently recognized as an extraordinary result. The quantum SPM requires, therefore, overall performance regarding its stiffness and heat dissipation that respects this trade-off between available cooling power and vibration levels as such that the complete quantum microscope setup can be operated at millikelvin temperatures and pm/√Hz vibration levels.

Cryo-walking Technology

One of the essential components of the quantum microscope is the cryogenic nanopositioner to position probe and sample with sub-nm accuracy over hundreds of microns travel distance. It is required to do this positioning then with heat dissipation well below the decreased cooling power available at the vibration isolation platform, and offer reasonable stiffness to maintain the interaction distance between sample and probe while experiencing leftover vibrations coming through the vibration isolation due to the trade-off with the cooling power.

Since 2022, Onnes Technologies has launched a novel cryogenic nanopositioning technique called cryo-walking. It offers three major benefits, collectively opening the path towards qSPM applications. First, low-heat dissipation enables operation at millikelvin temperatures even with decreased cooling power. Secondly, the high stiffness lowers the impact of remaining vibrations and suppresses drift effects. Finally, cryo-walking eliminates the need for separate mechanically amplified piezo scanner components to do large area scanning.

Figure 1a shows the result as published in the white paper of Onnes Technologies demonstrating the heat dissipating characteristics at millikelvin temperatures. The



Figures 1a, 1b, and 1c: Figure 1a shows the result as published in the white paper of Onnes Technologies, demonstrating the heat dissipating characteristics at milliKelvin temperatures. High stiffness is demonstrated in Figure 1b, where atomic resolution is obtained on an HOPG sample. In Figure 1c, an HOPG sample is being translated a few hundreds of nm's while at all times being scanned by the STM probe. *Credit: Max Kouwenhoven, CEO, Onnes Technologies* heat dissipation was determined to be below 10 µW via a calorimetric method that verifies the main heat dissipating source is the piezo-based loss factor, estimated to be ~0.6%. Such a loss factor is a typical value for low temperature piezo dynamics operated in its lowest loss factor regime. However, it is quite remarkable that the cryo-walking technology allows for minimized operation in terms of driving voltage and frequency – and as such gives rise to operation in the lowest loss factor regime. This clearly demonstrates that cryo-walking is a very efficient nanopositioning technique.

The underlying modus operandi can be explained as follows. Instead of making use of the static and dynamic friction differences, cryo-walking is based on making and breaking mechanical contact with multiple actuators in parallel with specific phase differences. In this way, the piezo material is allowed to move the slider while connected, break connection at the end of its stroke, and reset while moving freely. Besides the thermal efficiency benefits, it also allows the slider to be mechanically rigidly connected to the outer environment because the amount of force between piezo and slider is not limited due to facilitating slipping behavior as is the case with alternative slip-stick techniques. The high stiffness is demonstrated in Figure 1b, where atomic resolution is obtained on a HOPG sample.

The well-controlled way of positioning, in combination with low heat dissipation, gives rise to the third benefit: scanning capabilities over long travel distances without the need for probe retraction. Cryo-walking allows sub-nm level accuracy over the complete mm's travel distance. Where traditionally SPM is strongly focused on material sciences at the lower temperatures and at atomic scale, we recognize a growing interest in researching quantum-based devices by means of SPM techniques at larger scales – above 100 µm. In Figure 1c, an HOPG sample is being translated a few hundreds of nm's while at all times being scanned by the STM probe. This demonstrates stable scanning capabilities without using mechanically amplified piezo scanners.

Outlook

Quantum sensing requires the progression towards low temperature and low vibration environments in order to leverage the quantum-enhanced sensitivity of novel quantum systems as a means of probing materials and devices. Yet, the available cooling power trades off against the vibration isolation attenuation. Cryo-walking technology opens a novel path for qSPM application development that is compatible with a platform of cryogen-free dilution refrigerators and passive vibration isolation operable at millikelvin temperatures and pm/√Hz vibration levels. **www.onnestechnologies.com**

Maybell Introduces Its Big Fridge, a New Platform for Quantum's Future

by Brian Choo, Maybell Quantum

Maybell Quantum launched the Maybell Big Fridge, a cryogenic platform designed for scale and engineered for the quantum future. Maybell Quantum is a Denver-based, venture-backed quantum hardware startup that aims to deliver quantum hardware solutions that are more accessible, reliable and scalable while advancing US quantum leadership. Last year, Maybell revolutionized quantum cryogenics with the Maybell Fridge, a dilution refrigerator which supports three times the qubits in one-tenth the space of competing systems. Its Big Fridge is ready for the most ambitious quantum workloads, with a base temperature under 10 mK, over 130 L of sample volume, 600 L of total internal volume, and more than 4,000 cm^2 of area on the mixing chamber plate.

"Our Big Fridge lets you cool more with less," says Kyle Thompson, Maybell's co-founder and CTO. "We've doubled the cooling power to 1000µW at 100 mK and quadrupled experimental volume compared with our original fridge, while increasing the system footprint by only 50%. The Big Fridge is the most capable and efficient dilution refrigerator ever made."

The Maybell Big Fridge: engineered for scale, designed for a quantum future. *Credit: Maybell Quantum*

The Big Fridge's outsized performance is facilitated by Maybell's robust patent portfolio, including groundbreaking Flexline wiring, a more efficient thermalization and attenuation layout, a proprietary integrated pulse tube, and a form factor that dramatically reduces footprint, thermal mass and radiative heat loads. For example, where traditional round dilution refrigerators dedicate 10-25% of plate area to user wiring, the Big Fridge dedicates over 50% of plate area to user wiring, reducing excess heat loads. This leads to a more efficient system and supports running multiple experiments simultaneously.

Maybell's unique parallel-loading wiring inserts make the Big Fridge the only system on the market that allows large samples to be wired outside the fridge and loaded as a single assembly. The Big Fridge is also backward-compatible, with plate spacing that matches competing systems, allowing users to embrace the Maybell advantage without changing wiring or custom fixtures.

"Maybell's commitment to ease of use, performance and reliability manifests in every detail of the Big Fridge's design," says Maybell's CEO, Corban Tillemann-Dick. "Our groundbreaking approach to cryogenics continues to win over the industry."

The Big Fridge is available to order and will begin deliveries in the third quarter of 2023.

Space Cryogenics

by Wesley Johnson and Ryan Grotenrath, NASA Glenn Research Center

Cryogenic Oxygen Liquefaction Demonstration for Lunar and Martian Surfaces

The production of cryogenic fluids for use as rocket propellant on surfaces beyond Earth has long been a sought-after sustainable capability for both NASA and the space industry. The liquefaction and storage of these fluids on the surface of the Moon or Mars is a key technology that needs development for the production cycle to work. While the liquefaction of cryogenic fluids has well-developed operations on the surface of Earth, initial small-scale production systems in extraterrestrial locations may look and operate differently, requiring new techniques and capabilities.[1,2] To begin addressing this need, a series of tests were developed. Each test improved the system-level maturation of the liquefaction and storage capability by either improving the fidelity of the hardware or testing the hardware in more realistic environments. The first of these tests was discussed in *Cold Facts*, Vol. 35, No 3.[3] Most recently, a second test was performed that improved the fidelity of the test hardware. As shown in Figure 1, the test used an industrial cryocooler system consisting of pulse tube cryocoolers and a cryofan that drove a forced convection loop of neon around an aluminum tank with tubes welded to the tank surface. The tank liquefaction flow was fed by an external oxygen trailer upstream from a flow controller. The storage tank was contained within a thermal vacuum chamber. The neon flow on the tank was oriented top to bottom, which significantly reduced thermal stratification within the tank to less than 1 Kelvin and allowed for the most efficient use of the refrigeration power. The tank was approximately half-scale of a Lunar or Mars lander tank by surface area and thus, the oxygen design flow rate was approximately half-scale of the target liquefaction rate. The design oxygen liquefaction rate was 1.1 kg/hr. When set to its best performance, the test system was able to achieve 1.6 kg/hr. at a constant pressure-steady state over a 48-hour time period.

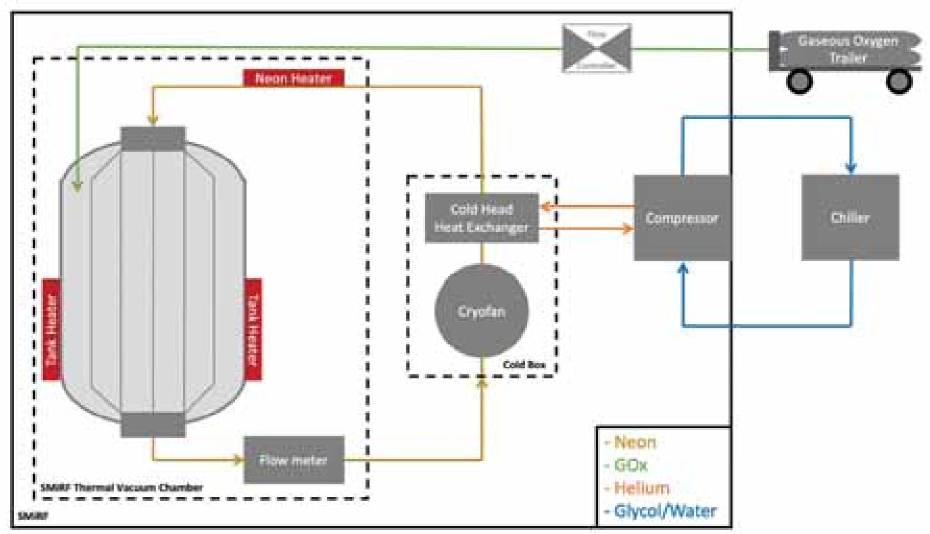


Figure 1: Cartoon representation of oxygen liquefaction test system. *Credit: NASA*

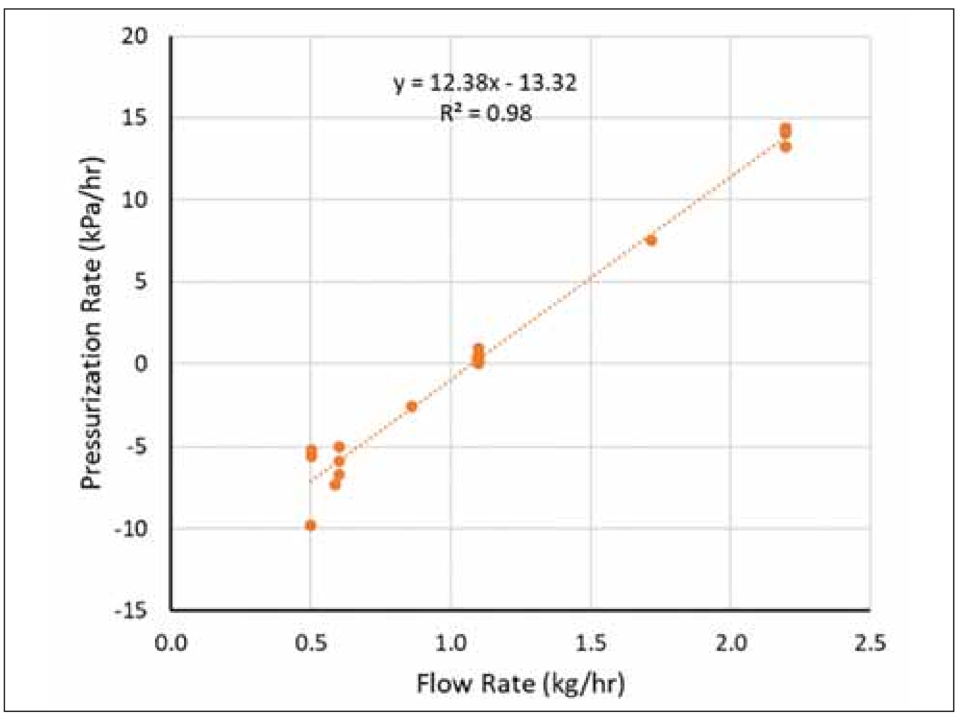


Figure 2: Oxygen tank pressurization rate as a function of incoming oxygen flow rate at a fill level of < 10%. *Credit: NASA*

Testing was focused on three main areas: determination of nominal operation variables of the liquefaction system;

understanding steady state sensitivities on the nominal operation of the system; and transient operations of the system. The main variables that were allowed to change from nominal operations were the tank heaters (simulating variations in parasitic heat load), neon heaters (simulating variations in cryocooler input power), gaseous oxygen flow rate (as might be driven by the balance of a propellant production plant), environmental temperature, fill level and location of gaseous oxygen insertion.

Once nominal operations of the system were demonstrated, system-level sensitivities were tested. One of the tests evaluated tank pressurization rate as both a function of oxygen flow rate and tank pressure. As can be seen in Figure 2, the main variable in the pressurization rate is the incoming gaseous oxygen flow rate. However, the scatter in the data, especially at low flow rates, can be attributable to tank pressure as shown in Figure 3. The linear behavior of this response allowed the test team to predict and then perform repeatable transient tests where a flow rate of 0.44 g/s for seven hours was selected for daytime operations that drove the tank pressure up and then a second flow rate of 0.24 g/s for 17 hours that brought the tank back down to its original pressure. This simulated a situation where the plant might be driven to a more cyclical production rate due to power balance challenges, and its results are plotted in Figure 4. These variations also averaged out to the goal flow of 1.1 kg/hr of liquefaction over the full 24-hour period. The cycle was repeated three times to show the stability of the response of the system. This flow transient was then repeated at >90% full tank fill level with similarly repeatable results. Similar steady state parametric and transient tests were performed with varying environmental temperature of the thermal vacuum chamber and varying neon heater powers to simulate changing of cryocooler heat removal.

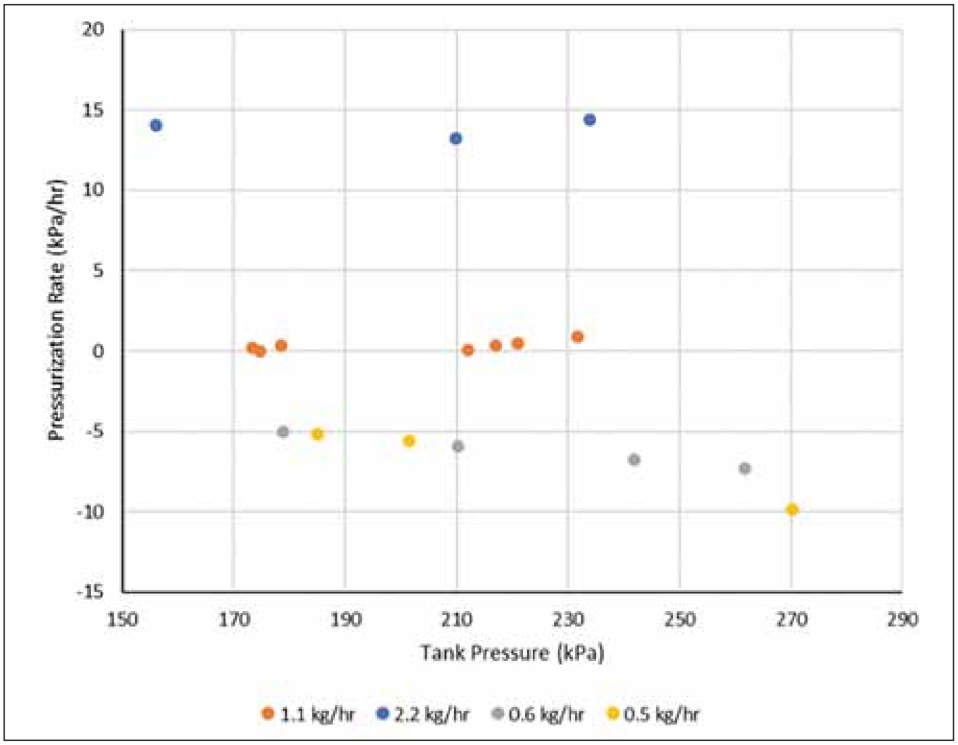


Figure 3: Oxygen tank pressurization rate at different flow rates as a function of tank pressure at a fill level of < 10%. . *Credit: NASA*

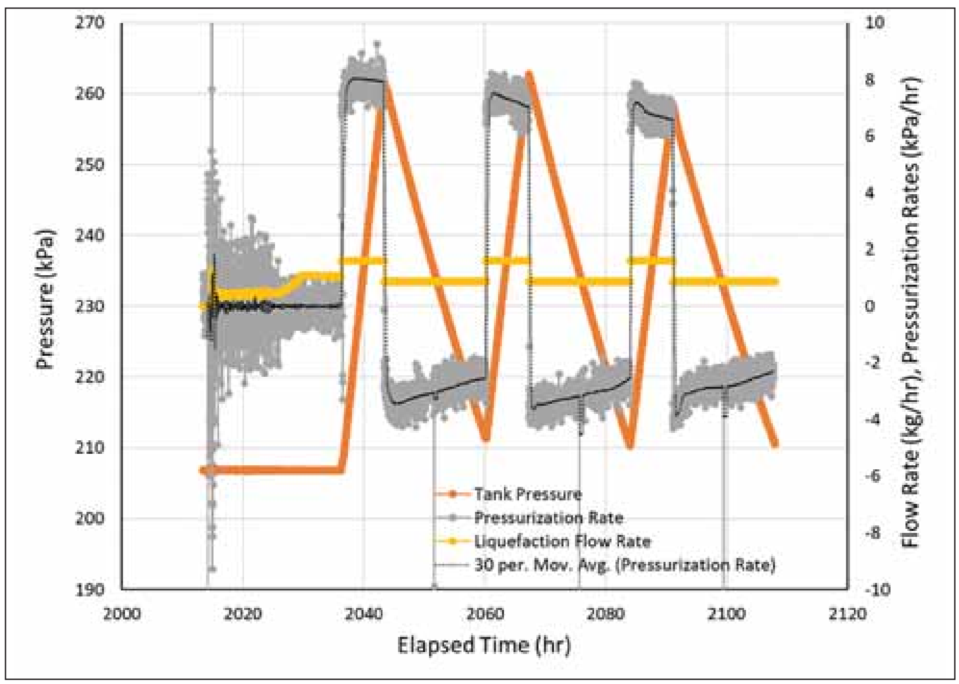


Figure 4: System transient response to a pre-determined variable flow rate input. Included are the calculations of instantaneous pressurization rate and 30 min averaged pressurization rates. *Credit: NASA*

Three different control operations were demonstrated. Setting an oxygen flow rate, environmental temperature, and cryocooler configuration while allowing the pressure of the system to respond was the main operational approach. A second operational approach was controlling the tank pressure by varying the incoming gaseous oxygen flow rate and holding the environmental temperature and cryocooler configuration constant. The third control technique varied the neon loop heater power (representative of cryocooler heat removal) to control the tank pressure. All three control operations were successful and could easily be implemented on a flight system. It was determined that it is easier to validate nodal models developed using SINDA/FLUINT as the first form of control where the pressure is allowed to vary.

▶ *continues on page 29*

Cool Cryo Guests

by Nils Tellier, PE, EPSIM Corporation

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 The Cold Box

This series of articles aims to provide tips for cryogenic air separation units, particularly in the context of increasing energy costs. After reviewing the major warm-end components of an air separation unit (ASU) in previous articles, it is now time to dive into the cold box.

Brief History of the Reboiler-Condenser

Fractional distillation consists in separating a component from a mixture by condensing it from a vapor or vaporizing it from a liquid. The process requires a tray column with a condenser at the top to generate the falling liquid and a reboiler at the bottom to create the rising vapor. The problem with cryogenic air separation is that the condenser must be colder than the top of the column, which is the coldest point of the plant, to condense the vapor and rain it back on the trays. This could only be achieved in the late 1800s by running the column at a high enough pressure to accommodate the refrigeration technology available at the time.

It all changed in 1910 when the Linde Group developed the double column. The distillation column was cut in two, the lower half was "welded" on top of the upper half, and the condenser and reboiler were combined (see Figure 2). This is an absolute feast of engineering, yet it must be remembered that the Group's founder, Carl Von Linde (1842 – 1934), who got in trouble with his dad for refusing to become a Lutheran minister, left home to study under Rudolf Clausius (1822 - 1888) and, after a hiatus, under Rudolf Diesel (1858 – 1913). He founded an ice machine company in 1879, Gesellschaft für Lindes Eismaschinen Aktiengesellschaft (Linde AG), with Spatenbrau and Guinness as notable clients. By 1895, Carl Von Linde had developed a commercial air liquefier and pursued the separation of air.

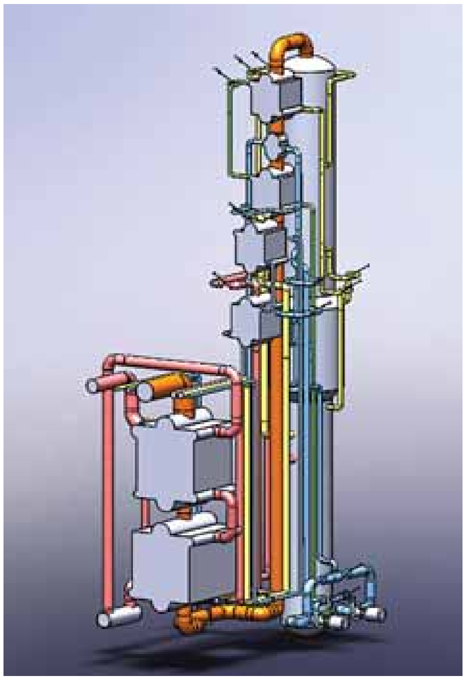


Figure 1: ASU Rendering. *Credit: EPSIM Corporation*

At the Other End of the Air Chain

The reboiler-condenser, also called reboiler or condenser, is the destination point of the air that was so carefully compressed and cleaned on the plant front end. The reboiler duty is of the same order of magnitude as the air compressor power. Put differently, the reboiler is a massive heat exchanger and the operation of an ASU is driven by two giants harnessed together, the air compressor and the reboiler.

The reboiler is a two-sided heat exchanger. One side sits in the sump of the upper column and runs at low pressure. The other side is connected to the top of the lower column and operates at high pressure as a thermo-syphon. The reboiler deals with two-phase fluids on each side: a boiling liquid – mostly oxygen - in the sump of the upper column and a condensing vapor – mostly nitrogen - at the top of the lower column. The carpet is unrolled for Gibb's Phase Rule, which might be the only behavioral law the reboiler knows. The fluids are two-phase (condensing vapor and boiling liquid), with two components (oxygen and nitrogen… argon does not really count here). This means that only two independent state properties are needed to define the thermodynamic system. Luckily, there are three easy-to-grab properties, namely the temperature, pressure, and fluid composition.

Putting this into practice, the composition and pressure of the liquid oxygen are constantly measured on an ASU. This dictates the temperature of the oxygen bath in the sump of the upper column where the reboiler is hot-tubing. Since the reboiler is a heat exchanger, its high-pressure side is at the same temperature. This provides the temperature at the top of the lower column, plus a few degrees due to the approach. Applying Gibb's Phase Rule again, this time on the high pressure side, the fluid composition and condensing temperature are known, hence the condensing pressure.

This condensing pressure is the information the air compressor needs. Once the feed air pressure reaches the reboiler condensing pressure, the compressed air vapor is pulled upwards in the lower column, liquefied, and rains back into the column. Liquefying the compressed air increases its density by a factor of 24. Put differently, liquid air is 24 times smaller than vapor. Or

24 times heavier. And the reboiler asks for more compressed air. The gasping reboiler's condensing pressure now controls the air compressor's discharge pressure, and a stable equilibrium is achieved.

The reboiler can liquefy more air than the compressor, front end, and main exchangers can handle. Left unchecked, the excessive airflow will trip the ASU because the heat input will overcome the refrigeration from the turboexpander, and the boil-off will block the falling liquid in the upper column. It is critically important to control the mass flow of air to the reboiler from the compressor's inlet guide vanes.

Reducing the Electric Bill

Gibb's Phase Law demonstrates that the main air compressor discharge pressure is dictated by the liquid oxygen composition and pressure in the sump of the low pressure (upper) column.

Changing the pressure in the upper column changes the pressure in the lower column, typically by a 5x factor. For example, decreasing the upper column pressure by one PSIG will decrease the lower column pressure – and the main air compressor discharge pressure – by five PSIG. And vice versa. Lowering the upper column pressure will reduce the electric bill.

Conversely, high purity liquid oxygen boils at a higher temperature than low purity. Higher temperature means higher condensing pressure and, therefore, higher compressor discharge pressure. Want to reduce the electric bill some more? Reduce the oxygen purity requirement.

Feedback and questions to the author are always welcome by emailing to nils@epsim.us.

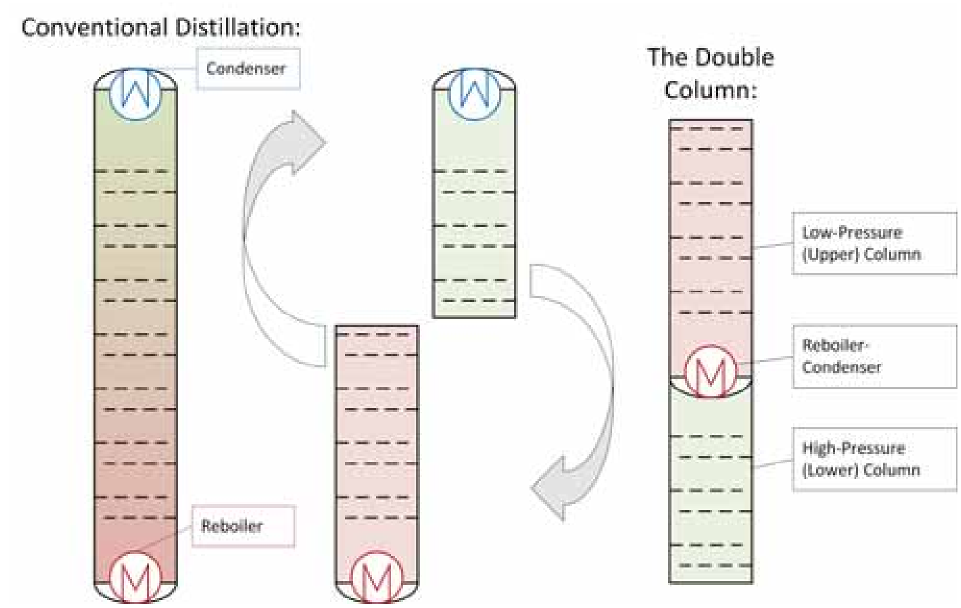


Figure 1: Air Separation Distillation Column Evolution. *Drawing by Nils Tellier.*

Cryogenic Oxygen Liquefaction Demonstration... Continued from page 27

Results of the oxygen testing confirmed many of the results of previous nitrogen testing: fill level was not a large driver in system operations (with the exception of pressure response swings above 90% full); transient pressure responses were much smaller when bubbling oxygen through the liquid than when inserting into the ullage of the tank; and the tank could be filled to greater than 95% full without having to reduce the oxygen flow rate while holding tank pressure constant. New lessons learned included the sensitivity of the system to neon loop pressure and temperatures, and pressure sensitivities of liquefaction rates.

While this series of testing met all of its performance goals, further testing is required to mature the technologies into a flight-like system. The next step is to incorporate a more flight-like cryocooler to better understand the cryocooler driven responses of the system. Eventually, the additional pieces of a Lunar or Mars surface oxygen production system, including electrolyzers to separate water and associated hardware, could be incorporated into this system. Documentation and further discussion of the test results will continue through the Cryogenic Engineering Conference, the Space Cryogenics Workshop (hosted by CSA), and the NASA publication series.

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

Liquid Hydrogen Onboard for Electric Ship Propulsion

Last time we looked at the advent of liquid hydrogen (LH_2) onboard in different transportation applications. There is such a buzz of activity that a second look is in order with a focus on hydrogen-powered ships. There are dozens of ship applications in the works, most notably a project for ferry operations in Norway. The MF Hydra is an LH_2-driven ship for Norled, a major ferry operator in Norway. The Norled-led project is a collaboration that includes LMG Marin, Westcon Power and Automation, Linde and others. The development work follows the first all-electric but battery-powered ferry boat, MF Ampere, which launched in 2015.

With the next step of transitioning to hydrogen electric with onboard LH_2, the MF Hydra began operations this year. This ferry boat (see Figure 1) is 82 meters long and carries up to 80 cars and 299 passengers. The topside located LH_2 tank provides a four-tonne storage capacity (57 m^3 or 15,000 gallons) and is a vacuum-jacketed horizontal cylindrical tank with dimensions of 10 meters in length by 3.5 meters in diameter. The LH_2 tank provides enough hydrogen for 12 days of sailing.

The operational pressure is from two to three bar liquid (approximately -250 °C) which feeds a vaporizer to then provide a continuous supply of gaseous hydrogen to the hydrogen electric cell from three to five bar (from 10 to 30 °C). The electric plant consists of a pair of Ballard Fuel Cell Wave units for a total of 400 kW power output. At an average speed of nine knots, the MF Hydra has the endurance for 1,000 nautical miles. The ship also includes lithium-ion, air-cooled battery packs for redundant and auxiliary power that work in tandem with the hydrogen electric cells.[1]

Figure 1. The MF Hydra, a liquid hydrogen powered, all-electric ferry boat, in operation in Norway. *Credit: MF Hydra. Courtesy of Norled*

Figure 2. Bunkering station with the LH_2 tanker trailer connected to the onboard LH_2 storage tank. *Credit: Linde*

One interesting note in the current operations is that the LH_2 is produced in Leuna, Germany, and is delivered via tanker truck to Viganeset, Norway, with 3.2 tonnes supplied every third week. The direct route is a one-way, 1,331-kilometer distance, including a ferry, and takes at least 17 hours. By about 2025, the plan is to have green hydrogen production and liquefaction onsite in Norway. Novel bunkering hubs are under development, as a demonstration to create quick, safe, and efficient transfer operations with no venting. The current tanker offloading and ship-servicing system is shown in Figure 2.

The technologies are available today to put liquid hydrogen to work for transportation applications. But there is plenty of room for further advancements in technology and engineered systems design. Hurdles include the fledgling infrastructure and the liquid transfer/dispensing problem. Next time, we will look into the technical challenge connected to onboard LH_2 storage tanks – the transfer problem and the need for zero-loss servicing systems.

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[1] Baird Maritime. "Vessel Review I: Hydra – Norled Takes Delivery of Ferry Designed to Run on Liquid Hydrogen." August 12, 2021.

Cryo Bios

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

Sir William Ramsay

William Ramsay's contribution to cryogenics was not in developing new cooling techniques or describing the properties of helium but rather in discovering many of the gases used in cryogenics. His work resulted in the definition of an entirely new family of elements: the Noble Gases.

Ramsay was born in Glasgow, Scotland, and after completing secondary school, he started to study chemistry at the University of Glasgow. He left prior to completing his degree and went to Germany to study organic chemistry at the University of Tübingen under Professor R. Fittig. After earning his Ph.D. in organic chemistry in 1872, Ramsay returned to the UK and took a series of research and teaching positions at Anderson College, Scotland (1872-1874), University of Glasgow (1874-1880) and University College in Bristol (1880-1887). During this period, he taught and conducted research in organic chemistry and physical chemistry. Ramsay was a skilled experimentalist; he learned glassblowing and built his own apparatus. He made a number of important discoveries in the fields of organic and physical chemistry and became particularly skilled in measuring the properties of liquids and vapors. By 1887, Ramsay had published 21 scientific papers on these subjects.

Ramsay moved one more time, in 1887, to University College in London, where he became the Chair of the Chemistry Department. Ramsay spent the rest of his career here. His work on noble gases started when he attended a lecture by Lord Rayleigh (John William Strutt) in 1894 at the Royal Society. Lord Rayleigh was making precision measurements of the densities of elemental gases and observed that the density of nitrogen derived from air, after all the oxygen was removed, was larger than that measured of nitrogen derived from chemical sources such as ammonia. Ramsay and Rayleigh spoke after the lecture and decided to work on the problem together. Two possible solutions were a lighter gas released with nitrogen in the chemical process,

Ramsay and Rayleigh in 1894. From: "Sir William Ramsay and the Noble Gases," A. G. Davies, Science Progress (2012), 95(1), 23-49.

Flasks of argon (top) and helium (bottom) provided by Ramsay to Karol Olszewski. From: "A Tribute to Wroblewski and Olszewski" H. Kubbinga, EuroPhysics News 41/4 (2010).

and a heavier gas remaining with the nitrogen in air after the oxygen was removed. Ramsay and Rayleigh quickly decided that the second solution was more likely. Working independently and using different techniques but with frequent communications between them, Ramsay and Rayleigh were able to announce the discovery of a new element called argon in 1895. This inert gas was found to make up about 1% of Earth's atmosphere.

Not long after this announcement, an American geologist described to Ramsay that the mineral cleveite, which contained uranium, would release an unknown gas when treated with sulfuric acid. Ramsay repeated the experiment and found via spectroscopy that the gas was neither argon nor nitrogen, but rather helium. Helium had been discovered in the solar spectrum in 1868 and was first seen on Earth in 1882 by Luigi Palmieri when he observed the spectral line of helium while analyzing lava from Mount Vesuvius. Ramsay's discovery in 1885 was only the second observation of helium on Earth. While he didn't know it at the time, Ramsay had also discovered the principal source of terrestrial helium; that is, from the alpha decay of radioactive isotopes like uranium.

Ramsay provided samples (Figure 1) of both argon and helium gas to Karol Olszewski (*Cold Facts* Vol. 35 No. 1) who was able to both liquefy and solidify argon but was unable to liquefy helium. Helium wouldn't be liquefied until 1908 when H. Kamerlingh Onnes (*Cold Facts* Vol. 35 No. 2) accomplished this at Leiden University. Having samples of both argon and helium, Ramsay realized two things: first, one could logically add a family of inert gases on one side of the Periodic Table, and second, given the observed weight of helium and argon, there were likely other inert gases in this family. Ramsey started to look for other inert gases in the atmosphere and, working with the chemist Morris W. Travers, he discovered neon, krypton and xenon in 1895.

The last and heaviest of the noble gases, radon, was discovered by Friedrich Ernst Dorn in 1900. However, it was Ramsay, working with Robert Whytlaw-Gray, who was able to make precision measurements of radon's density and locate it correctly in the noble gas family. Ramsay, working with the chemist Frederick Soddy, also observed that as radon, which is radioactive, decayed, helium was produced. This was one of the earliest observations of one element being produced as another decays.

William Ramsay earned many honors including a knighthood and being made a fellow of the Royal Society. In 1904, he was awarded the Nobel Prize in chemistry for his discovery and explanation of the noble gases. Fittingly in the same year, Lord Rayleigh won the Nobel Prize in physics for his work on the discovery of argon. Further details on Ramsay and his discovery of noble gases, including information on the separation techniques and spectroscopy that he used, may be found in "Sir William Ramsay and the Noble Gases," A. G. Davies, Science Progress (2012), 95(1), 23-49.

Cryogenic Treatment Applications Find Potential in the Energy Sector

by Patricia Jovičević-Klug [1,2]

Energy Sector and Metallic Materials

Simultaneously improving known materials and exploring new alternative material options for applications in demanding environments for the energy sector (offshore wind power, solar power, biomass power, fission and fusion, geothermal power, hydroelectric power) is one of the leading engineering research endeavors today[1]. A unique combination of high corrosion resistance, toughness, strength, machinability, and wear resistance is required for materials used in energy applications.[2] Metallic materials used in the energy sector can be classified into ferrous and non-ferrous alloys. The most commonly used ferrous alloys in the energy sector are various grades of stainless steels, structural steels, duplex steels, low alloy and high alloy steels[1-5]. When selecting non-ferrous alloys, it is important to consider the application and its environment. Generally, the commonly used non-ferrous alloys are copper alloys, titanium alloys, aluminum alloys and nickel alloys[1-5].

Energy Sector Diversity

The challenges of each energy sector are unique.[1-5] This is due to the different environments to which the materials used to produce energy are exposed (high temperature, high pressure, saline environment etc.).[1-5 For example, in the wind and solar sectors, one of the common challenges that cannot be avoided is particle erosion of the material[1-3] Compared to other sectors, corrosion is the main challenge in geothermal and hydropower.[4,5] What is common to all sectors, however, is the desire to prolong the life of the material (component, tool, etc.), which can be achieved by manipulating the microstructure, applying coatings or heat treatment.[3]

Cryogenic Heat Treatment of Materials

In the last five years, cryogenic treatment has emerged strongly (in spite of its origins in the late 19th century and its observations and applications in the NASA program in the ’60s and ’70s) as an additional

Author Patricia Jovičević-Klug works in the developing field of cryogenic heat treatment for energy applications. *Credit: Patricia Jovičević-Klug*

step in the heat treatment of various ferrous and non-ferrous alloys, providing improvements in various properties.[3] Cryogenic treatment fundamentally changes (Figure 2) material properties (hardness, toughness, strength, ductility, corrosion and wear resistance, etc.) through the primary mechanisms of enhanced austenite to martensite transformation and increased carbide precipitation[3] (when discussing ferrous alloys). Cryogenic processing exposes materials to temperatures below 273 K.[3] There are three known cryogenic treatments: conventional (CT in range 273-193 K), shallow (SCT is in a range of 193-113 K) and deep cryogenic treatment (DCT is below 113 K).[3] For cryogenic treatments, liquid nitrogen is usually used (77 K).[3,6] There are four parameters to consider when subjecting material to cryogenic processing: soaking temperature, soaking time, cooling rate, and cryogenic processing sequence.[6] The cryogenic treatment is usually followed by one cycle of tempering (Figure 1) or, in some cases, even this step is no longer necessary.[3,6] In recent years, so-called multistage cryogenics has emerged. In this case, the heat treatment consists of a rapid cooling down to deep cryogenic temperature and a subsequent heating up to a shallow cryogenic temperature in a cyclic manner with several repetition cycles.[6] Various studies on different materials have shown great potential for cryogenic treatment, which can be tested and applied in the energy sector.[6]

Cryogenic Treatment Missing Link for Widespread Use

Despite the positive feedback on the cryogenic treatment of materials, there are still some contradictory results on the same tested material, where, on the one hand, there was an improvement in properties and on the other hand a deterioration after the application of cryogenic treatment. This demonstrates the need for studies to move from a trial-and-error approach to a scientifically supported and systematic framework for the application and development of cryogenic treatment. With advanced techniques and novel research we will be able to gain in-depth fundamental knowledge of the various mechanisms of this treatment and its impact on the desired properties.[3,6] This is further important not only in relation to the changes of the base material, but also with respect to the phenomenon of DCT-induced surface changes, such as whisker growth.[7]

Current Research

The previous and current results of my work and research have shown that low temperature treatment has a great potential to become a major technical development in materials science, while at the same

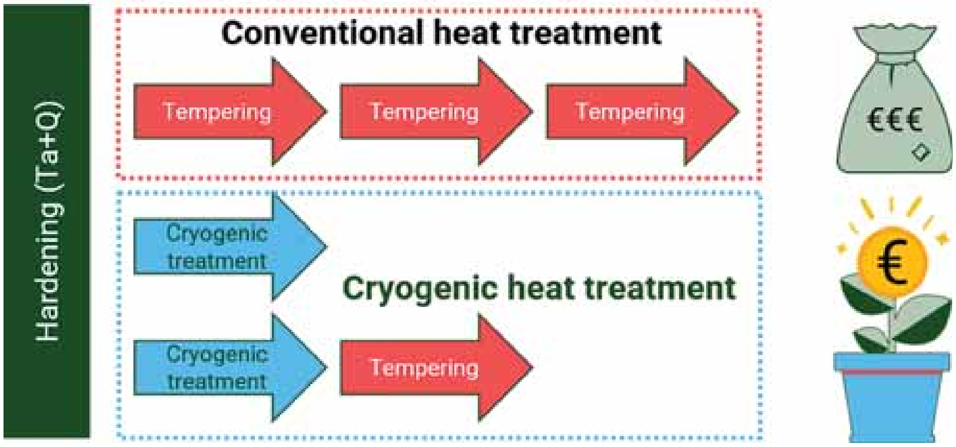

Figure 1: Conventional vs. cryogenic heat treatment. *Credit: Patricia Jovičević-Klug*

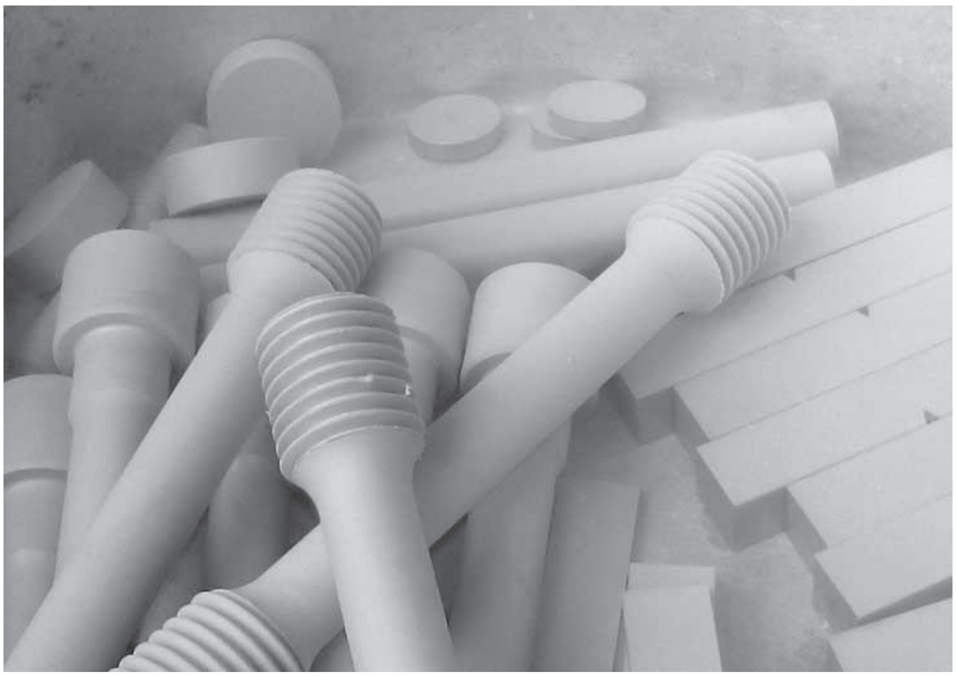

Figure 2: Example of cryogenically heat-treated samples for further material testing. *Credit: Patricia Jovičević-Klug*

time, being a green and effective technique. Additionally, the process can have a beneficial effect on both the bulk and surface of the material. Within the current work, in response to the increased demand for material improvement in the energy sector, I/we are trying to achieve the optimized microstructure, improved residual stress state, surface and corrosive resistance of selected ferrous alloys with the combination of DCT.

Acknowledgement

The project is funded by Alexander von Humboldt Foundation under PostDoc Fellowship.

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2. *Alexander von Humboldt Research Fellow, Bonn, Germany*

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

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

Four Nine Design

High performance optical cryostats with large cold plates, large cooling power, ultrahigh vacuum and low vibrations. Options exist for RF, DC, fiberoptics, magnetic fields, SPM and translation stages.

Haier Biomedical Co., Ltd.

A leading digital scenario solution provider internationally, Haier Biomedical has complete cold chain solutions for biological sample banks, blood safety, vaccine safety, medical supplies and reagent safety covering the full range of –196 °C to +8 °C.

Quantum Coax

Designs and manufactures coaxial and other custom cable assemblies for quantum computing and other applications of low temperature research, delivering high quality cable solutions that perform at sub-Kelvin temperatures and ultrahigh vacuum environments.

SENIS Group, Switzerland

The SENIS K3A cryogenic low noise magnetic field transducer accurately measures the amplitude and direction of magnetic fields down to about 1 K. Its sensor head is very compact, and it features a field sensitive volume of less than 0.6 mm^3.

Magna Energy Storage Systems (Magna ESS)

A leading manufacturer of alternative energy storage systems for automotive applications, Magna ESS produces custom systems to meet specific needs for vehicles with liquid hydrogen storage systems (LHSS) and compressed hydrogen storage systems (CHSS).

Scientists Elucidate Heat Flows in Liquid Hydrogen Tanks

by Jae-Eun Lee

Hydrogen has been touted as the fuel of the future, but challenges remain in improving the storage efficiency of liquefied hydrogen fuel for large scale commercial transport and storage. Researchers from South Korea have conducted experiments and simulations to investigate the heat flows and phase changes within a cryogenic fuel tank using multiphase thermal flow simulations, with the goal of designing safe and efficient cryotanks.

The transportation industry sees hydrogen fuel as the most promising alternative energy source to fossil fuels, and researchers are increasingly looking at the use of liquefied hydrogen fuel. However, liquefied hydrogen fuel can only be transported in cryogenic tanks that maintain temperatures below -253 ºC, which results in vaporization. Excess internal pressure inside the tank can lead to cracks and fissures, making understanding and controlling the boiloff gas (BOG) a key factor in cryotank design.

Led by Professor Jong-Chun Park of Pusan National University in South Korea, a research team investigated how BOG varies with tank filling ratio (FR) – the ratio of the mass of liquefied fuel in the tank to the capacity of the tank at 15 ºC. The researchers found that BOG increases quadratically with FR, and while the temperature within the liquid phase remained constant, the temperature of the vapor phase decreased nonlinearly with FR.

"In our study, we performed experiments, as well as simulations, to analyze the thermodynamic characteristics of the tank," says Professor Park.

The researchers used multiphase thermal flow simulations of the tank using computational fluid dynamics to visualize the heat transfers, thermal flows and vaporization within the vacuum-insulated tank. They adopted the Rohsenow phase change model for the simulations, which allowed them to reproduce the vaporization process within the tank.

"From our simulations, we were finally able to reveal the mechanism of BOG as a result of vaporization," explains Professor Park. The researchers validated their simulations using data from experiments conducted through a collaboration with Daewoo Shipbuilding & Marine Engineering Co., Ltd.

The study's multiphase thermal simulation technique could accelerate the design of safe and efficient commercial cryotanks for liquefied hydrogen. The applications of this research are wide-ranging, from automobiles and aerospace to offshore power plants, making it a critical step forward for the realization of a hydrogen-centered society.

Researchers from South Korea have explored, experimentally and numerically, the thermodynamic characteristics and thermal flows inside cryogenic liquefied tanks used in transportation by studying the changes in boiloff gas (BOG) with variations in tank filling ratio. *Credit: Pusan National University*

Review of *Cryogenics – Fundamentals, Foundations and Applications*

Review by John M. Jurns, Cryogenic Engineer

I was given a copy of *Cryogenics: Fundamentals, Foundations and Applications* edited by Tom Bradshaw, Beth Evans and John Vandore, and asked to write a review of the book. The book is available in both hardcover and electronic versions. Happily, I have the hardcover version to review, but of course, the reader can decide what version works best for them.

The book's abstract includes phrases such as: "... provides a practical, hands-on reference source ... in all areas of cryogenic science and technology;" "...designed to aid those practitioners coming newly into cryogenics, giving them a context and signposts for where to go for further information;" and "...spans a broad range of applications and undoubtably will contain new information useful to those already involved in cryogenics."

So now that we have an idea of the goals of this book, let's dig into how it delivers on those promises.

One of the first things to notice was its great number of contributors. Contributors have roles in academia, industry, space, medical/health care and power, guaranteeing that the book would provide a broad view of cryogenic technology across the many areas where it is used. What also excited me when perusing the table of contents was the chapter titles. I have several excellent cryogenic reference books on my shelf, but this is the first book I have seen that gives the reader a picture of the many areas in which cryogenic technology is applied.

Chapter 1: Fundamentals of cryogenics lays out what we mean by the term "cryogenic," and how cryogenic technology is relevant to areas from quantum computing to medical technology and everything in between. The chapter sets the stage for the subsequent chapters.

Chapter 2: What is cryogenics lays out the fundamentals of not only the science of

cryogenics, but also its history. The chapter shows how cryogenic technology has progressed from its inception and its future outlook.

Chapter 3: Cryostat design jumps into one of the fundamental components of cryogenic design – the cryostat. At the heart of many cryogenic systems often lies some sort of cryostat. The chapter explains why we need them, their design and construction, how they are insulated and how the efficacy of the insulation is maintained. The section on multilayer insulation (MLI) is particularly well done. The instrumentation section is comprehensive in describing not only what sensors are appropriate for cryogenics, but where and how to use them.

Chapter 4: Closed cycle refrigerators—Whereas the third chapter talks about how to keep things cold, this chapter focuses on the machines we use to get there. The chapter gives an excellent overview of the different types of closed cycle refrigerators, how they work and typical applications.

Chapter 5: Very low temperature techniques—The previous chapter discusses refrigerators that work down to liquid helium range (as low as 2-4 K), and there is a whole other world of applications requiring temperatures approaching absolute zero. The techniques to achieve these extremely low temperatures are exhaustively detailed, describing the physics involved in obtaining these sub-kelvin temperatures.

Chapter 6: Cryogenics in particle accelerators and fusion reactors dives into yet another important area of cryogenics – how cryogenic systems are integral to "big science" facilities such as particle accelerators and fusion reactors. Without cryogenics, these systems would not be able to exist in the form we know them. Discussion on topics such as cooling of superconducting magnets, cooling of radio frequency (RF) cavities in particle accelerators and distribution of cryogens over the large distances in these facilities is very well detailed.

Chapter 7: Propulsion, energy storage and renewables is currently a hot topic, where the world is searching for energy technology options that will reduce reliance on traditional hydrocarbon fuels, minimize the risk of global warming and provide clean, renewable energy for our future. This chapter includes a good section on electric propulsion and power systems and how cryogenics can enable these technologies. I felt that a little more space should have been given to the topic of liquefied natural gas (LNG). The chapter section on hydrogen makes a strong argument for hydrogen as a viable energy alternative for many terrestrial applications. The chapter ends with an interesting discussion on liquid air energy storage (LAES) that describes how one can store energy thermally (that is, as liquefied air), and then use that stored energy to produce mechanical power.

Chapter 8: Life science and healthcare is one of the chapters that grabbed my attention immediately. Many of us who work in the field of cryogenics have little exposure to the importance of cryogenic technology in the field of healthcare. This chapter provides an excellent technical discussion on how biological specimens are affected by cryogenic temperatures and what methods are used to maintain viability when frozen. There is an interesting section on cryogenic techniques in biological electron microscopy. The chapter also discusses cryosurgery, where low temperatures are used in the controlled destruction of tissue by freezing. The chapter continues with a discussion of cryotherapy – the use of low temperatures for the medical treatment of pain. The section focuses on cryotherapy chambers, where a patient is exposed to extreme low temperatures for a short period of time. This therapy is used in certain parts of Europe but is not yet recognized as an accepted therapy in the US. The final section discusses proton beam therapy for radiotherapy.

Chapter 9: Industrial applications—The introduction to this chapter states "Given the classic, ubiquitous, enabling nature of cryogenics, this chapter could be endless." In my opinion, this should have been one of the most significant chapters in the book, considering the myriad industrial applications of cryogenics. However, the chapter covers only four technologies: cryogenic condensation for solvent recovery, superconducting magnetic separation, deep cryogenic treatment, and applications in the food industry, the last two sections given only a few pages each. Considering the introduction's take on cryogenics' importance to industry, I felt this chapter could have been a little more comprehensive.

A few words on my overall opinion of the book: each section on its own shows the obvious expertise of the individual authors; however, with the number of contributors, in some cases, the flow of the book feels a bit disjointed. Many figures and illustrations were clear and helpful in augmenting the text, but in some cases, figures were clearly lifted out of previous reports with sometimes undefined and unreadable text when reprinted. However, to give credit where it is due, they all show the significant effort that goes into the design of these intricate and complicated systems.

In summary, as the abstract states, this book is a reference, not a textbook. The strength of this book is a comprehensive, up-to-date presentation of the many areas that cryogenic technology touches on. Its primary value, as I see it, is as a reference source. (At the end of each chapter are many useful references, giving the reader ample resources to dig into whatever details they wish to pursue.) The question I needed to ask after reviewing this book is this: do I want this on my bookshelf along with my other cryogenic books? The bottom-line answer is definitely, yes. The book has a lot of strengths and can be a useful resource for pursuing further research into the wide field of cryogenic technology. I definitely recommend grabbing a copy, either hardcover if you have room on your bookshelf, or electronic version if you have room on your hard drive!

Hardback: $190 USD
Ebook: $159 USD

http://2csa.us/lh

Tackling the Rapidly Expanding Hydrogen Power Industry

by Maximální délka řetězce

PBS cryogenic turboexpanders, HEXT/CTE 100. *Credit: PBS*

PBS Velka Bites has been in the cryogenic business for more than 35 years. Today, its cryogenics engineering capabilities include everything from preliminary calculation through design, manufacturing and assembly, to testing and user optimization of its cryogenic products. Since the late '80s, PBS has been developing and supplying cryogenic turbines for the liquefaction of helium. Both liquid and gaseous helium applications must meet extremely demanding technical requirements not only in the design and construction phase but also in terms of production processes, final assembly and testing. PBS became one of the few companies in the world able to independently provide all these stages of cryogenic device production under one roof. The company's offering of cryogenic devices has gradually expanded to include turbines and compressors, designed to work with other gases utilized in modern cryogenics. To date, all cryogenic products of PBS have been used for inert gas applications, but their design applies to other gases as well. Today, PBS is a major supplier of cryogenic turboexpanders, compressors, pumps and cryogenic drive units for the world's leading manufacturers of cryogenic products.

Cryogenic turboexpanders manufactured by PBS benefit from the use of aerodynamic bearings. This design solution brings several advantages in the form of maintenance-free operation, the absence of contamination of the working gas with lubricant from the bearings and the absence of an oil management system for the turboexpander. Another competitive advantage of turboexpanders with aerodynamic bearings compared to turboexpanders with magnetic bearings is significantly lower acquisition and operating costs.

Based on extensive practical experience in the field of small cryogenic turboexpanders, PBS is now well prepared for the current and future rapid development of hydrogen technologies. This year, the HEXT/CTE 300 turboexpander will be introduced to the global market. The new cryogenic turboexpander is designed with hydrogen applications in mind and builds on the successful turboexpanders HEXT/CTE 100 and HEXT/CTE 200. Thanks to the unique design of aerodynamic bearings, the shafts of HEXT/CTE expanders are placed on a film of working gas. Various models of cryogenic turboexpander HEXT/CTE 300 with an electric generator will be suitable for high volume liquefaction, especially of hydrogen and helium, and for air separation. Its cooling power reaches up to 100 kW, and the mass flow starts at 300 g/s.

The significant competitive advantage is the integration of a high-speed electric generator, which allows the output energy of the thermodynamic cycle to be converted into electrical energy that is returned to the liquefaction process. The energy reuse process reduces the energy demands of the entire liquefaction process and increases its overall efficiency. The HEXT/CTE 300 can be customized for various applications and a wide range of inert and other gases, according to specific customer applications.

PBS provides direct and indirect support for all its cryogenic products during installation, commissioning and after-sales service, and we also offer professional technical training for service personnel. PBS cryogenic products are used in healthcare, science and research, air separation, CO_2 capture and the aerospace industry. PBS has supplied Linde Kryotechnik with a number of its cryogenic products, which now work reliably in a range of research and development institutes including CERN in Switzerland, ESS in Lund, Sweden, ILK in Dresden, Germany, and The Max Planck Institute, also in Germany.

PBS has been involved in precision engineering for more than 200 years and has gained significant expertise in high-speed cryogenic equipment during the last 35 years. As a result, PBS is well-prepared to manage the fast-paced advancement of cryogenics and the rapidly expanding hydrogen power industry of the future. **www.pbs.cz/en**

Inside ORNL's Second Target Station's Cryogenic Moderator Design

by Jim Janney, Oak Ridge National Laboratory

The Second Target Station (STS) is the future of forefront neutron scattering science at Oak Ridge National Laboratory, which started with the first neutron scattering measurements in the 1940s at the X-10 Graphite Reactor and continues today at the High Flux Isotope Reactor (HFIR) and Spallation Neutron Source (SNS). STS will be a 700 kW, 15 Hz pulsed-spallation neutron source designed to provide the world's highest peak of brightness cold neutron beams, meeting the demand for neutron scattering resources for physical, chemical, biological, geological, materials and human health sciences. The STS will utilize one out of every four proton pulses from the SNS accelerator, delivering the 1µs pulses to a rotating water-cooled tungsten target and producing neutrons by the spallation process. To convert high energy spallation neutrons to high brightness cold neutron beams, two compact liquid hydrogen moderators are located adjacent to the target's peak neutron production zone and surrounded by light water premoderators and beryllium reflectors to increase neutron flux.

The STS moderator geometries were chosen to be a cylinder moderator, serving 16 neutron beamlines, and a tube moderator, featuring three tubes arranged in a triangle that will serve six beamlines. The dimensions of the moderators and reflectors have been optimized through parametric Monte Carlo neutron production simulations to maximize cold neutron brightness, resulting in a brightness gain of an order of magnitude compared to SNS. The cylinder moderator is 30 mm in height and 100 mm in diameter, while the tube moderator is 30 mm in diameter. The longest tube length is 170 mm. The spin state of the hydrogen in the moderators is critical to the STS moderator performance due to the large difference in neutron scattering cross-section for cold neutrons between ortho and parahydrogen and the large hydrogen depths of the moderators. Those cold neutrons which are moderated deep in the moderator are unable to efficiently exit the moderator if significant orthohydrogen is present due to the higher scattering cross-section. The tube moderator performance will drop by nearly 20% if the orthohydrogen content in the moderator is increased to 1% from the equilibrium orthohydrogen ratio of 0.2% at 20 K. Additionally, the neutron interactions with the hydrogen atoms drive orthohydrogen production in the moderator, resulting in higher orthohydrogen ratio than equilibrium at the operating temperature. This back conversion process is slow, but so is the conversion to equilibrium hydrogen without the presence of an ortho para converter. At SNS, where no ortho para converter is installed, the steady state orthohydrogen content is estimated to be 30% due to back conversion in the moderators, which would result in catastrophic performance losses to STS moderators.

The STS Moderator Reflector Assembly locates two liquid hydrogen moderators adjacent to the rotating tungsten target. *Credit: ORNL*

The prototype tube moderator features a vacuum insulated hydrogen vessel with six extraction ports. *Credit: Forschungszentrum Juelich ZEA-1*

The Cryogenic Moderator System (CMS) will supply the two STS moderators with 20 K or less hydrogen and a parahydrogen fraction of 99.8% or greater. The two moderators will be connected in series in a single hydrogen loop cooled by a helium refrigerator with a cooling capacity of approximately 2.25 kW at 17 K. Because of the neutron production and associated radiological hazards in the target monolith, most of the CMS will be located in an adjacent building while hydrogen is supplied to the moderators via 40 meter-long transfer lines. The hydrogen loop, based on the CMS design of the SNS, will consist of a hydrogen circulator, hydrogen helium heat exchanger, ortho paraconverter, accumulator and heater. The hydrogen loop will have a constant flow rate of 0.5 L/s and remove a nuclear heat load of 860 W from the two moderators, which is deposited both directly in the hydrogen and the adjacent moderator structures. Because the nuclear heat load is accelerator-driven, the hydrogen system must remain stable when the heat load is removed instantaneously during beam trips. The hydrogen loop will operate at a constant hydrogen mass after cooldown with the heater maintaining temperature and the accumulator passively mitigating pressure excursions from temperature variations. General hydrogen temperature control is provided by controlling the flow rate of helium to the heat exchanger. The ortho para converter is being designed to guarantee maximum ortho hydrogen content of 0.2% and is located immediately downstream of the heat exchanger to take advantage of the lower equilibrium ortho hydrogen content at lower temperatures. STS CMS is in the early stage of preliminary design, and the current focus is evaluating component sizing and system stability during beam transients.

SNS and HFIR are Department of Energy Office of Science user facilities. **www.ornl.gov**

Essex Marks 75 Years with LOX Advancements and Portfolio and Employee Growth

by Scott Jackson, Essex Industries

Humble Beginnings

Essex Industries began as a family affair more than 75 years ago in St. Louis, Mo. Returning home from his service in World War II, Harold Guller recognized a business opportunity in jet aircraft – a new mode of transportation back in 1947. In his father's basement, he developed and sold a radio noise filter for the F-214. Harold's brother, Sidney, helped with accounting while earning his degree and then joined the company. That first product laid the foundation for the company's future. As the company evolved over the 20th century, Essex Industries became a leading supplier of aircraft controls and components, life support systems and emergency breathing equipment. Essex life support systems include crew oxygen delivery systems for ground-based and airborne medevac liquid oxygen (LOX) life support. Essex has been a part of virtually every major military and commercial aerospace program since the company's founding.

A 50-gallon liquid oxygen life support cart in use. *Credit: Essex Industries*

Liquid Oxygen Equipment

Essex entered the cryogenics market in 1963 with designs and the capability to manufacture LOX converters, a highly efficient oxygen storage and delivery method. LOX systems provide several advantages over gaseous systems in these military applications because LOX increases volume 860 times as it converts from a liquid to a gas. This saves both weight and space on the aircraft and results in portable units that are easier to carry without sacrificing capability. They also have low operating pressures, less than 100 psi, which increases their safety factor, especially in battlefield situations. While originally used by aircraft pilots and crew, Essex took the attributes of LOX and designed systems that provided therapeutic oxygen for wounded soldiers transported via aircraft to military hospitals. The technology supports both air and ground-based medical life support requirements. One of those products has developed into the NPTLOX – Next Generation Portable Therapeutic Liquid Oxygen System—with six patients able to receive oxygen simultaneously while in transport.

The pneumatic properties of LOX allow the systems to distribute or transfer without needing external power. With Essex's design and engineering efforts, medical oxygen can now be reliably provided nearly everywhere. Recognizing that additional support was needed in combat, Essex coordinated with special operations medics to design the Backpack Medical Oxygen System (BMOS). This lightweight unit can be carried or worn by parachutists and ground support personnel to provide immediate oxygen to the wounded. Essex also designed a filling station (BMOS-FS) to support the BMOS. The technology developed for military LOX systems has led Essex to similar advancements in the commercial medevac marketplace. Essex LOX systems are currently on 80% of the winged and rotary platforms that provide aeromedical transport from an accident scene to a medical center. Essex has provided more than 100,000 new LOX systems for military and commercial applications, ranging from a five-liter converter to 500-gallon LOX trailers.

75 Years of Manufacturing

Essex celebrated its 75th anniversary in 2022. Throughout its history, Essex's ability to manufacture highly engineered products and its commitment to taking exceptional care of its customers and employees has consistently positioned the company as a top aerospace and defense competitor. Today, Essex reaches coast to coast, with 450 employees supporting six facilities in St. Louis, Huntington Beach, Calif., and Milford, Conn. The business remains family owned and operated. Third-generation CEO Evan Waldman is excited about the company's future and continued growth. “Essex's 75th anniversary is a testament to so many talented and committed people who have worked in this business over the years,” Waldman said. “It is also a call to action for the incredible team working at Essex today to write the next chapter in the Essex story. Whether the Essex team is designing and qualifying its own products to meet customer specifications or collaborating with its customers to bring product designs to life, Essex is energized for the future and filled with purpose."

Continued Growth

Essex's strategy has been to expand capabilities by acquiring technology and businesses and using our manufacturing experience to deliver high quality products. In October 2022, Essex acquired Precision Aerospace, Inc (PAI), an aerospace and defense manufacturing company in Seymour, Conn. PAI provides clients with precision machined components, including pressure sensors, pressure transducers, oil debris monitoring technology, and more. The acquisition supports Essex's business strategy of expanding its product portfolio while enhancing its capability in the northeast region.

One Essex

Essex Industries' commitment to diversity and inclusion is directly connected to its mission and values. Essex has been building programs inside and outside the company to help its values shine through and uplift employees and customers. Essex is a proud corporate member of Women in Manufacturing (WiM) and continues building an inclusive work culture. WiM is a global trade association dedicated to providing year-round support to women who have chosen a career in the manufacturing industry. Through this membership, Essex supports employee career growth and development in the manufacturing sector. The organization provides a wide variety of professional development opportunities to its members.

Essex Industries' company has robust manufacturing capabilities that allow it to be agile and flexible, and able to adapt to new requirements. Essex will continue to learn and grow as it moves forward. **www.essexindustries.com**

Bluefors Acquires Cryomech, A Landmark Move in the Cryogenics Industry

by Arifin Budihardjo

Bluefors (CSA CSM), a leading Finnish manufacturer of cryogenic measurement systems, has acquired Cryomech (CSA CSM), a premier cryocooler design and manufacturing company located in Syracuse, N.Y. This move is a milestone for Bluefors as one of the largest cryogenic cooling organizations in the world. Bluefors builds easy-to-operate, cryogen-free dilution refrigerator measurement systems that can be cooled down with the push of a button. Its dedication and expertise to its craft has ensured trouble-free and reliable products that have helped some of the world's largest companies push quantum technologies forward.

Quantum technology is on the rise, and Bluefors is positioning itself to enable technology and industrialization advancements in this emerging industry. Through the acquisition, Bluefors significantly increases its direct presence in the US with approximately one-third of its employees based in the state of New York. Consequently, Bluefors will become an important part of the US-based supply chain for cryogenic products used in quantum technology, fundamental physics research and other select industries, while also strengthening the support presence for the Cryomech portfolio in Europe.

"We have a long history of working together with Cryomech, and this agreement is really the next stage in the evolution of collaboration between the Bluefors and Cryomech teams," said Rob Blaauwgeers, CEO and founder of Bluefors. "The acquisition gives our new, combined company an even better opportunity to secure technological leadership, which will help us continue to serve our customers and continue our strong growth in the rapidly developing ultralow temperature cryogenics market."

Cryomech provides advanced cryocooler solutions for new and existing applications as required by their diverse customer base. It developed and produced the world's first commercial 4 K pulse tube cryocooler and Gifford-McMahon cycle cryocooler. It continued its innovation to achieve the largest 4 K pulse tube cryocooler in the world. Other products include liquid helium plants, liquid nitrogen plants, helium recovery systems and 1 Kelvin cryostats.

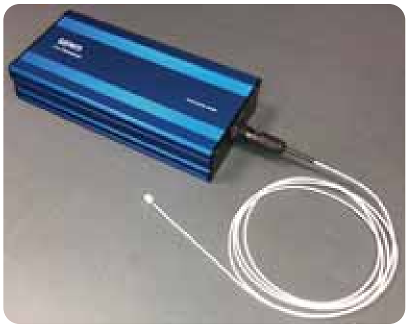
"We're excited to join Bluefors," said Rich Dausman, president of Cryomech and CSA president-elect. "We're both pioneers in our fields of expertise; we share the entrepreneurial mindset that serves our customers; and most importantly, both companies value and care for the wellbeing of all our co-workers. Our team in Syracuse has already experienced firsthand the impact Bluefors has had on our market and the growth it has generated. We will continue that trend, serving our customers as before and with our complementary product portfolios. Together, Cryomech and Bluefors will serve a larger portion of the cryogenic market as one."

This announcement comes on the heels of other exciting news from both companies. Bluefors delivered its 1,000th system. Further, it had its XLD system on the cover of the February 13 issue of TIME Magazine while also celebrating its 15th anniversary. Cryomech is celebrating a major milestone as well. 2023 marks its 60th anniversary in the cryocooler market, and with this achievement came a fitting announcement of their new PT450 pulse tube cryocooler and CP3000-series helium compressor at the 2023 American Physics Society March Meeting in Las Vegas, Nevada. The combined company, Bluefors, is dedicated to delivering the most reliable, versatile, and easy-to-operate systems on the market under Bluefors and Cryomech brands.

At the time of this article's submission, the acquisition was expected to close by the end of March 2023.

Product Showcase

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



SENIS K3A 3-Axis Cryogenic Low Noise Magnetic Field Transducer

SENIS Group, Switzerland

The SENIS K3A 3-axis cryogenic low noise magnetic field transducer accurately measures the amplitude and direction of magnetic fields at cryogenic temperatures down to about 1 K. With a size of 4.5 x 4.5 x 9 mm, its sensor head is very compact. It features the world's smallest field-sensitive volume at less than 0.6 mm^3. The high precision electronics has very low drift, ultrahigh resolution and low noise. The instrument provides an analog voltage for each magnetic field direction. Accurate calibrations (0.25%) and high field calibrations (up to ±9 T) at cryogenic temperatures are available as an option. **www.senis.swiss**

Model I Dilution Refrigerator

Zero Point Cryogenics

The Model I is a complete rethinking of the traditional dilution refrigerator, designed at every stage to make operation simple and straightforward. Samples can be exchanged rapidly from the top plate, or the fridge can be opened completely when rewiring is required. With a cooldown time of less than 24 hours, rapid warm-up heaters and reliable long-term operation, the Model I keeps experiments running around the clock. The compact footprint of the Model I allows users to add a dilution refrigerator where previously it had never been possible; plus the intuitive, easy-to-use touch-screen control means users do not have to be low temperature experts to access mK temperatures. **www.zpcryo.com/model-i**

CryoComplete™

Lake Shore Cryotronics

The new CryoComplete™ system from Lake Shore Cryotronics provides everything you need to start taking temperature-dependent, low-level measurements out of the box. The fully integrated system contains Lake Shore's ultra-low-noise M81-SSM synchronous source measure system, which includes a multichannel instrument, 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 system also contains a 77 K to 500 K sample-in-vacuum LN_2 pour-fill cryostat with pre-wired sample mount and cabling, a two-channel Model 335 temperature controller with precision-calibrated silicon diode temperature sensor, and a PC that includes Lake Shore's MeasureLINK™ software for automating entire experiments. The software enables a wide range of capabilities, including data charting, instrument control, and system monitoring with a cryostat-specific process view. **www.lakeshore.com/CryoComplete**

Cryogenic Regulator, MINI (CRM), 1/4" NPT Inlet 600 Psig (41.4 bar)

Generant Company Inc.

CRM Series pressure regulators provide high flow and quick, positive shutoff at the desired set pressure. The regulator design is a non-balanced, spring reference, pressure reducing type regulator. They were designed especially for use as pressure build regulators for cryogenic liquid cylinders but can be used in many other applications. Solid, non-tied diaphragm provides leak-free and long-lasting performance. Optimized diaphragm and adjustment spring designs provide high flow performance. All CRM Series regulators are supplied factory pre-set and cleaned for oxygen service. **www.generant.com/product/cryogenic-regulator-mini-crm**

Cryogenic Storage and Cryogenic Transport CLD/CHD Series

Cryofab

With the lowest guaranteed loss rates available, enhanced suspension system for extended service life, and user-friendly plumbing for operation and maintenance, Cryofab's liquid distribution systems are designed to deliver liquid cryogens, such as liquid nitrogen, liquid natural gas, liquid argon or liquid oxygen, to a customer site in a quality-made product. A common vent stack for simple pipe-away connections and a mounting scheme that is quick and easy, all the cryogenic transportation models exhibit a thoughtful design that is user friendly and easily serviceable. Its structural dimensions fit easily into enclosed vans, and its liquid level gauges read in liters and pounds. Piping components can be replaced without solder joints, and the series is designed and manufactured to DOT 4L specifications. This transport series comes with a stainless steel front head for welding integrity and cosmetic improvement, plus a regulator on the pressure builder for liquid savings and unattended operation. Users can select a capacity (liters) from series CLD 300, CLD 425, CHD 425. For more information, visit **www.cryofab.com/products**

Raman Rxn-41 Probe

Endress+Hauser Group

The Rxn-41 probe is a rugged insertion probe designed to optimize in situ process analysis of cryogenic liquids. Analyzing LNG as a cryogenic liquid eliminates the errors associated with vaporizers commonly used with traditional process analyzers, greatly improving the certainty of the value of LNG transacted during custody transfer. The combination of the Rxn-41 probe and the Raman analyzers yields powerful process analytical tools for real-time composition analysis of LNG and mixed refrigerants using quantitative Raman spectral analysis. The configurable design of the Rxn-41 probe enables the sampling point to be customized for each customer's facility, providing flexible integration via direct flange mounting onto transfer pipes or integration into a slipstream or fast loop for easier maintenance. Its single cable design further streamlines installation, eliminates risk scenarios, and minimizes installation cost for long fiber runs in the process environment. The Rxn-41 probe for cryogenic liquids is manufactured to meet Category 1 pressure equipment safety standards. **www.endress.com/en**

PS-CC Closed Cycle Cryogenic Probe Station

Advanced Research Systems

The ARS PS-CC Closed Cycle Cryogenic Probe Station provides a high vacuum cryogenic environment of up to <4 K-800 K (with appropriate high temperature interface) for measuring multiple devices consecutively without breaking the vacuum or warming the system. The ARS PS-CC probe station features up to eight probes with 1 µm sensitivity, two-inch measurement area, <1 µm vibration levels, fast sample cooldown, custom wiring for DC and microwave measurements (0-67 GHz), large optical access and optional 7:1 zoom microscope with ring light. This integrated approach ensures consistent performance and also facilitates diagnostics and service of the integrated system. **www.arscryo.com**

Turboexpanders

Rotoflow

As one of the only OEMs both manufacturing and operating turbomachinery, Rotoflow brings a unique expertise to the design, manufacture, and repair of turboexpanders and expander spare parts used in hydrocarbon, LNG, petrochemical and industrial gas applications around the world. Rotoflow is ISO 9001 certified and its core products include companders, generator-loaded expanders, and reciprocating cryogenic pumps. Rotoflow offers both standard and custom-engineered cryogenic and warm gas centrifugal turbomachinery used for refrigeration and power recovery in diverse market segments. Depending on a user's needs, it can customize equipment to meet customer requirements and applicable regulations. Its focus is on delivering the right solution, and Rotoflow will take the time to understand a user's application in order to provide a total solution no matter how small or complex. **www.rotoflow.com/product/turboexpanders**

People & Companies in Cryogenics

Quantum computer startup **PsiQuantum** has opened its first research lab outside the US in the Daresbury Laboratory in Cheshire, England. The collaboration will enable PsiQuantum to develop the advanced cryogenic systems that are critical in its mission to build the world's first useful quantum computer. Daresbury is a key laboratory for the UK's Science and Technology Facilities Council (STFC) and hosts one of Europe's largest cryogenic cooling facilities, developing cryomodules for large-scale research facilities across the world.

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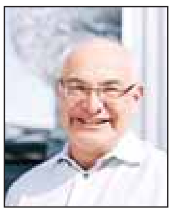

Credit: Berkeley Lab

Physicist and Associate Director for In-Kind Management at the European Spallation Source **Dimitri Argyriou** has been selected to serve as the next director of the **Advanced Light Source (ALS) at the US Department of Energy's Lawrence Berkeley National Laboratory**. The ALS is an X-ray synchrotron scientific user facility that produces extremely bright X-ray, infrared, and extreme ultraviolet light for more than 1,800 visiting scientists each year. Up to 40 experiments can be performed simultaneously using the synchrotron, resulting in nearly 900 peer-reviewed scientific articles each year across a range of fields, from chemistry and materials sciences to biology and environmental sciences. Argyriou's appointment is expected to begin this June.

....

Credit: NASA/JPL

NASA Jet Propulsion Laboratory (JPL) announced **Kirstie Belmonte** as its new Group Supervisor for Cryogenic Services. JPL's work in cryogenics applies state-of-the-art cryogenic, thermodynamic, and chemical technologies to a variety of space applications.

....

The **James Webb Space Telescope** has captured unique details of the remnants of Cassiopeia A, an exploded star, its glowing gas and dust becoming remnants in a supernova. Cassiopeia A is located in the Cassiopeia constellation, 11,000 light-years away. The findings will allow scientists to learn more about occurrences of stellar explosions. "We've nicknamed it the Green Monster in honor of Fenway Park in Boston. If you look closely, you'll notice that it's pockmarked with what looks like mini bubbles," said Danny Milisavljevic of Purdue University in a statement. Milisavljevic is a principal investigator of the Webb program that captured these observations.

....

The **U.S. Department of Energy's (DOE) Hydrogen and Fuel Cell Technologies Office** is looking for reviewers for federal funding program applicants in a variety of areas relating to cryogens and liquid hydrogen. For more information, interested parties should go to **http://2csa.us/review**.

....

Vacuum Barrier Corporation (VBC) is pleased to announce three exciting promotions. **Jim Fallon** has been promoted to the position of international sales manager and will focus on the Europe and Asia markets. **Dana Muse** has been promoted to the Reliability and Technical Support manager position, a

***Jim Fallon, Dana Muse, Greg Neville**. Credit: VBC*

new department at VBC responsible for driving continuous improvement in equipment reliability, training, and technical support. **Greg Neville** has been promoted to the position of sales manager of The Americas, managing the home office team of application engineers and coordinating VBC's efforts with outside sales representatives in Mexico, Central, and South America.

Meetings & Events

Cryocourse 2023
May 18-26, 2023
Espoo, Finland
www.aalto.fi/en/cryocourse2023

Hydrogen Technology Expo
June 28-29, 2023
Houston, Texas
www.hydrogen-expo.com

CSA Short Courses at CEC/ICMC
July 9, 2023
Honolulu, Hawaii
www.cryogenicsociety.org

Cryogenic Engineering Conference/International Cryogenic Materials Conference (CEC/ICMC)
July 9-13, 2023
Honolulu, Hawaii
www.cec-icmc.org/2023

Space Cryogenics Workshop
Kailua-Kona, Hawaii
July 16-18, 2023
spacecryogenicsworkshop.org

BCC Advanced Cryogenics Course
July 18-20, 2023
Abingdon, Oxfordshire
bcryo.org.uk/bcc-advanced-cryogenics-course-july-2023-oxfordshire

Society for Cryobiology: CRYO2023
Minneapolis, Minnesota
July 25-27, 2023
cryo2023.com

Cryogenic Engineering and Safety Annual 5-day Course
Golden, Colorado
July 31 - August 4, 2023
www.cryocourses.com

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
October 4-5, 2023
Bristol, UK
efats.info

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