Cryomodule assembly technicians rev up Jefferson Lab's electron-beam racetrack

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Cryomodule Assembly Technicians Mike Murphy, left, and Wayne Carter work in the Cryomodule Assembly area in Jefferson Lab's SRF Test Lab. Credit: Jefferson Lab /Aileen Devlin

At the U.S. Department of Energy's Thomas Jefferson National

Accelerator Facility, the underground Continuous Electron Beam Accelerator Facility (CEBAF) more closely resembles a racetrack than it does a racecar. As a DOE Office of Science user facility, CEBAF includes a particle accelerator that enables the research of more than 1,900 nuclear physicists worldwide.

The particle accelerator is shaped like a 7/8-mile oval, and its electron beam zips around the "track" at nearly the speed of light. There are no tires, transmission nor chassis to be found.

Leave it to a former auto mechanic to flip that comparison.

"It's like an old car down there," Senior Cryomodule/Vacuum Technician Chris Wilcox said. "Some of the original cryomodules that have been down there since the early 90s—they need some work."

In automotive terms, cryomodule assembly technicians are mechanics in Jefferson Lab's "garage"—the world-renowned Superconducting Radiofrequency (SRF) Institute. They repair and replace cryomodules, which are modular sections of an SRF particle accelerator. But replacing CEBAF's worn cryomodules is just one facet of their precision work.

Led by Accelerator Associate John Fischer, cryomodule assembly technicians are members of the Cryomodule Production team in the lab's SRF Operations Department. These master craftsmen custom build, test and install cryomodules, the complex machines that allow CEBAF to rev its electron beam to energies up to 12 billion electron-Volts, or 12 GeV. Their work for this unique facility and other national laboratories is instrumental in pushing the boundaries of scientific discovery.

Taking the leap

So, how did this group of former mechanics, fabricators, welders and other tradespeople shift gears into the world of accelerator technology? For many, it required taking a leap of faith driven by a shared commitment to expanding their skills and elevating their careers.

"Coming here, there's definitely a learning curve on the assembly process of cryomodules, because no one sees anything like that outside of here. But the welding aspect of it is very similar, and I had a lot of experience at that," said Cryomodule Assembly Welder/Technician Matt Morgan, who previously worked as a fabrication shop supervisor and pipe welder at Newport News Shipbuilding.

"The skills I brought to this position were working with hand tools and working on things that you need to be gentle with," added Cryomodule Assembly Technician Wayne Carter, who came to the lab from an automotive machine shop. "But here, it's very different, because you can destroy something costly very easily. I learned a lot once I came here."

Cryomodule Assembly Technician Troy Pollard agrees.

"Working on cars, you can be a bit rougher," said Pollard, a former mechanic, HVAC technician and construction worker. "But working on cryomodules, you have to be gentle and calculated."

After years of working at auto shops across the Hampton Roads region, Wilcox said he was ready for a change.

"I realized that I didn't want to be doing that for the rest of my life, and I didn't want to be unhappy just like everyone else around me," Wilcox said. "I would drive by the lab every day, going back and forth from work. One day, I pulled up the website, looked at some jobs and the descriptions, and I realized that I could do some of this stuff because it's all hands-on work."

Long-tenured members of the cryomodule assembly team like Wilcox and Cryomodule Assembly Associate Jared Martin have seen the scope of the SRF Institute's work grow and evolve.

In his 14-year career at the lab, Martin has seen both the size of the team and its workload nearly triple.

In addition to building the cryomodules that powered Jefferson Lab's 12 GeV CEBAF Upgrade and many other projects, the group has also assembled cryomodules for other DOE Office of Science user facilities, including the Proton Power Upgrade of Oak Ridge National Laboratory's Spallation Neutron Source and two upgrades to SLAC National Accelerator Laboratory's Linac Coherent Light Source: the LCLS-II upgrade and the LCLS-II High Energy (LCLS-II-HE) upgrade, which is currently in the works.

The assembly process

While every cryomodule assembly process varies, the stages of building and testing these machines follow a similar progression. Wilcox offered Jefferson Lab's C100 cryomodules as an example of how the parts come together to accelerate CEBAF's electron beam.

It all starts with a "string" of eight connected SRF cavities, the bulb-shaped and hollow niobium cells through which the beam passes. To become superconducting, the cavities need to be cooled to a temperature of -456 degrees Fahrenheit, which is colder than deep space.

Vessels designed to contain super-cold liquid helium are built around each cavity. Atmospheric air is then evacuated from each vessel to create a vacuum, which is tested for leaks using helium gas.

According to Wilcox, leaks small enough to fill a thimble with helium over 10 years would fail the test.

Once the vessels are qualified, the cavity string is built out with magnetic shielding, multi-layer insulation (MLI) and welded process piping that supplies liquid helium to the vessel.

Now that the "core" of the cryomodule is complete, it is placed into a supporting structure called a space frame and encapsulated with thermal shielding and MLI. Working together with the lab's survey and alignment team, the technicians ensure precision alignment of the beamline typically within half a millimeter. Large variations could decrease the beam's performance.

Then, the "cold mass" is placed into a large vacuum vessel, onto which ports, gauges, sensors and pressure relief valves are installed. Two "end cans" designed to cycle liquid and gaseous helium are added onto each end of the module with warm-to-cold beampipes extended on both sides.

To extend the beamline through each end can, mobile Class 100 clean rooms—free of dust and particles—are used as technicians seal off the vacuum boundaries. Even the slightest amount of contamination can drastically affect the cryomodule's performance.

After acceptance testing, the completed cryomodule is installed into the accelerator.

Throughout this tedious process, if any components fail or the vacuum seals are compromised, the entire cryomodule may need to be disassembled and rebuilt, meaning months of additional work and a considerable cost increase.

"I like the constant pressure of it to be honest," Morgan said. "But you have to double check everything. Sometimes when I'm getting ready to cut something, I'm coming in right before I cut it and check it again right before the setup."

Pollard added, "It's definitely intimidating because of how complex these things are."

Cryomodules built for other national labs also need to be as close to perfect as possible. Recently, Martin shared the news that the eight cryomodules produced for the SNS-PPU project met their specifications upon arriving at the Oak Ridge facility.

A standard of excellence

When near-perfection is the standard, it's only natural that the team takes tremendous pride in their masterful work when everything comes together as intended.

"When a leak-tight cryomodule comes out of here, I'm proud of that," Willcox said. "When the performance of the cavities in the cryomodule is tested, and it meets or exceeds specs, that's a proud moment, because there are a lot of things that can make or break a cryomodule. But we won't know until after we test it.

"A completed cryomodule that works is a proud moment for everybody."

Beyond the work itself, societal benefits born from accelerator science and technology also tie the cryomodule assembly technicians to both the lab's mission and a higher purpose. For example, advances in medicine, including advanced imaging and cancer therapies, have been made possible through the research, development and production of particle accelerators.

For Carter, this aspect of his work is deeply personal.

"When I interviewed for the job, I was home because my wife had just had major colon cancer surgery. Later that year, she had surgery for uterine cancer," Carter said. "She has beat cancer. It really means a lot to me to be working on something that could possibly help end this terrible disease."

Amid the high-pressure, high-stakes work, the team still manages to embrace their camaraderie and moments of light-heartedness that come in between the intensity of their various tasks. Wilcox said the team's good vibes come from places of gratitude and professional accomplishment.

"We all know where we came from," Wilcox said. "A bad day here is better than a good day at our old jobs."

Morgan added, "This is a happy place to work because at a lot of other places, people are trying to go somewhere else to retire. When you get to Jefferson Lab, you retire from here. This is definitely the end goal, and that makes it a happy environment."

More information: Supercool Delivery: Final Section of Souped-Up Neutron Source Trucks Out of Jefferson Lab

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Provided by Thomas Jefferson National Accelerator Facility