Freedom from helium without compromising quality, performance or magnet longevity

By Stuart Feldham, PhD, Vice President—Resonance Module Innovation, GE HealthCare

Since the initial commercial development of MR imaging systems, helium has been used to cool the superconducting magnet, which generates the strong magnetic fields needed for detailed imaging of the human body. Conventional helium-bath MR systems typically require thousands of liters of liquid helium to cool and operate the magnet, maintaining the superconducting circuit and minimizing risks of a quench.

While helium is an abundant element in the universe, on Earth it is relatively rare and considered a non-renewable resource. In 2022, maintenance shutdowns and other events at several production facilities disrupted the supply of helium and caused a spike in price. While some academic research labs were impacted, many healthcare institutions were unaffected. However, these events further highlighted the need to conserve helium and ensure it is not unnecessarily wasted.

Fortunately, manufacturers have been investing in MR systems that require little to no helium to cool the superconducting magnet. GE HealthCare has been at the forefront of developing these new MR scanners—from being first to market with zero boil-off to sealed systems—culminating in Freelium,‡ a helium-free[1] sealed magnet platform that aims to dramatically reduce liquid helium usage without sacrificing power efficiency, operational security and clinical performance.

To maintain power efficiency, Freelium aims to operate with no additional facility cooling and power requirements compared to conventional helium-bath MR magnets. Additionally, the platform's intelligent Freelium sensor technology intends to remotely monitor the MR system and enable automated magnet protection and recovery capabilities without the need for field engineer intervention. This is particularly important in the event of power outages or disruptions caused by natural events.

Figure 1. GE HealthCare's Next Generation MR Platform features Freelium, a helium-sealed magnet that aims to dramatically reduce liquid helium usage without sacrificing power efficiency, operational security and clinical performance.

‡ Technology in development that represents ongoing research and development efforts. Not for sale. Not CE marked. Not cleared or approved by the U.S. FDA or any other global regulator for commercial availability.

Freelium magnets will be able to be transported and installed in hospitals and in markets where access to helium is limited or totally absent, as there is no helium loss during transport and no helium refills required at installation, enhancing patient access to care.

To support diagnostic accuracy and confidence, Freelium aims to uphold GE HealthCare's advanced quality and performance standards. Initial system testing confirmed Freelium has the same image quality performance as GE HealthCare's helium-bath magnet. The platform will be optimized to be compatible with GE HealthCare's leading artificial intelligence (AI)-enabled solutions. As important, Freelium was designed with GE HealthCare's SIGNA™ Continuum in mind, enabling future hardware and/or software upgrades without replacing the magnet.

A "no compromise" design approach

To bring the vision of Freelium to life, GE HealthCare engineers and scientists began with the premise that any helium-free magnet must maintain the same high-quality imaging, power efficiency and reliability as prior generation magnets. Accomplishing this vision required intentional innovation across multiple teams, not just those designing the magnet.

Like all superconducting magnets, a sealed magnet must be cooled to only a few Kelvins above absolute zero. This journey from room temperature to almost the same temperature as deep space is part of the challenge, with many materials contracting with this extreme cold—most doing so at different rates—making it vital to know and manage this phenomenon. Once cold, we must keep things stable. Helium-liquid-bath systems provide stability and work well at enveloping the magnet. A sealed magnet requires unique and innovative methods to do the same without leveraging a liquid coolant. This is where our many creative and talented engineers designed a way to make this happen.

In Freelium, GE HealthCare's technology intentionally delivers smart control and targets the cooling to where it is needed, allowing for optimal temperature control. This innovation dovetails perfectly with architectural changes in magnet designs completed with our latest generation of helium-bath magnets. In the new design, all elements are fully bound in place, decreasing the chances of any movement that may lead to friction and heat, and ultimately a quench. The superconducting wire is carefully bound to its neighboring components both thermally and mechanically to further minimize and extract heat from within the magnet. This approach further benefits from our next-generation cold head compressor that enables precision cooling when and where it's needed to provide more efficient power use.

Our approach to designing the new cooling system works like branches or limbs of a tree, with thin branches going to thicker ones and then to the trunk. The trunk must extract the heat, while each branch need only manage a portion of the heat. If each branch is right-sized, it can transport the heat away efficiently.

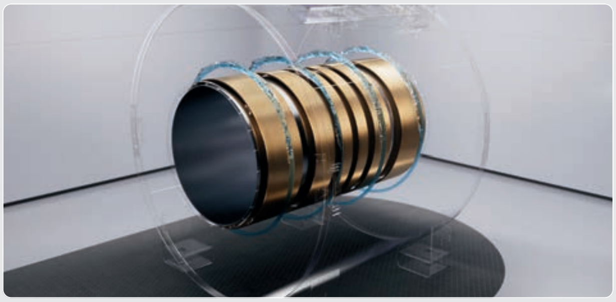

Figure 2. In Freelium, GE HealthCare's technology intentionally delivers smart control and targets the cooling to where it is needed, allowing for optimal temperature control.

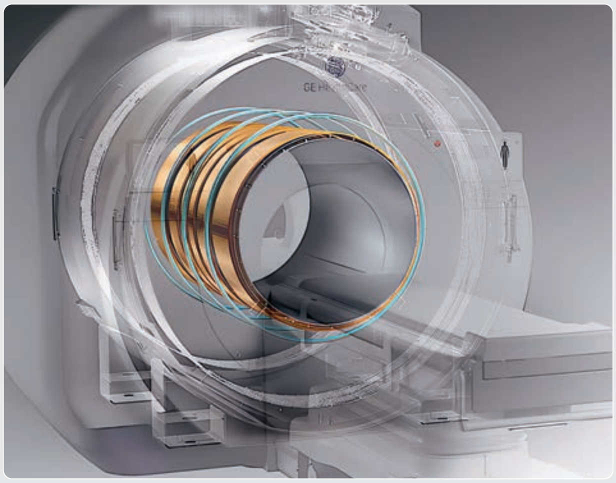

Figure 3. Freelium provides the same level of magnet homogeneity that customers have come to expect from existing GE HealthCare helium-bath magnets, with no compromise in image quality performance.

Additionally, there has been a significant amount of intentional design for the magnet's current leads to ensure our sealed magnets can be ramped down and ramped up whenever necessary and provide the option of local or remote operation. This requires a direct electrical connection to the magnet, which is at 4-degrees Kelvin. Deep consideration and masses of creativity are needed here because thermal and electrical conductivity tend to come as a package deal. High electrical conducting materials like pure copper also transfer heat very well too, so a mix of novel materials, design tradeoffs and much head scratching have landed us in, what we feel, is an optimal position.

A magnet's ability to maintain its cool temperature and the superconducting properties of the coils after the loss of electrical power supply is known as ride-through time, measured in hours. Magnet ride-through times must be sufficiently long to avoid the need to ramp the magnet down and back up upon the restoration of electricity. The goal is to have as much ride-through time as possible to avoid ramping down. In general, magnets with more helium encasing the magnet, such as the conventional helium-bath design, have longer ride-through times—it takes longer for helium to run out.

The liquid helium reserve boils off slowly if the coldhead is off, turning liquid helium to gas that is then vented into the atmosphere. While the ride-through time of these designs is desirable, this comes at the expense of a low-helium design. Our teams faced the very real challenge of finding a design that appropriately balances the volume of helium stored within the magnet with ride-through time. Additional design work was focused on minimizing different sources of heat leaks to maximize the magnet's ability to remain at very low temperatures as long as possible.

By controlling the pressure of the confined helium and allowing it to expand, it is possible to extend cooling power even during power outages. Freelium is designed with this concept in mind.

As with any MR magnet, homogeneity is crucial for acquiring high-resolution, artifact-free images. Homogeneity refers to the uniformity of the magnetic field (B_0) and the degree to which the precise strength of the field remains constant through the volume of the magnetic field. GE HealthCare magnets have class-leading homogeneity specifications down to parts per million or below. Freelium provides the same level of magnet homogeneity that customers have come to expect from existing GE HealthCare helium-bath magnets with no compromise in image quality performance.

While the magnet is the "heart" of an MR system, there are other components that are equally important, such as the gradient coils, the RF coils and the computer system. GE HealthCare's MR engineering team collaborated with the magnet design team to develop the "brain" of the system using AI to reduce the complexity for the user and allow the magnet to be effectively autonomous. This included the development of smart sensors. For example, in a power outage, the magnet can alert the user to how much ride-through time is available, or whether a ramp down needs to happen. If the facility has a system-wide UPS, then power interruption is not an issue and Freelium can leverage its reduced power consumption capabilities to maintain the preferred operating conditions for longer. Additionally, the system is built with cloud-based remote monitoring capabilities that can monitor system stability and provide information back to GE HealthCare engineers for continual improvements or to upgrade service and capabilities where and when needed.

The "no compromise" design approach was a guiding principle throughout product development. GE HealthCare's helium-bath and zero boil-off magnets were designed to last decades and be part of SIGNA Continuum, allowing for upgrades to hardware and software to extend its useful life. Freelium has been designed to be no different.

Freelium is robust, built to last and be economically viable for the customer. It maintains thermal stability and delivers high performance. From the beginning, our intention in the design of Freelium was to do everything we could to ensure our customers don't have to think about their MR magnet. Regardless of the GE HealthCare MR magnet a customer is using—helium bath, zero boil-off or helium free—they can expect the same high-quality, reliable imaging capabilities.

References

1. Helium-free: Helium is permanently enclosed in the magnet.

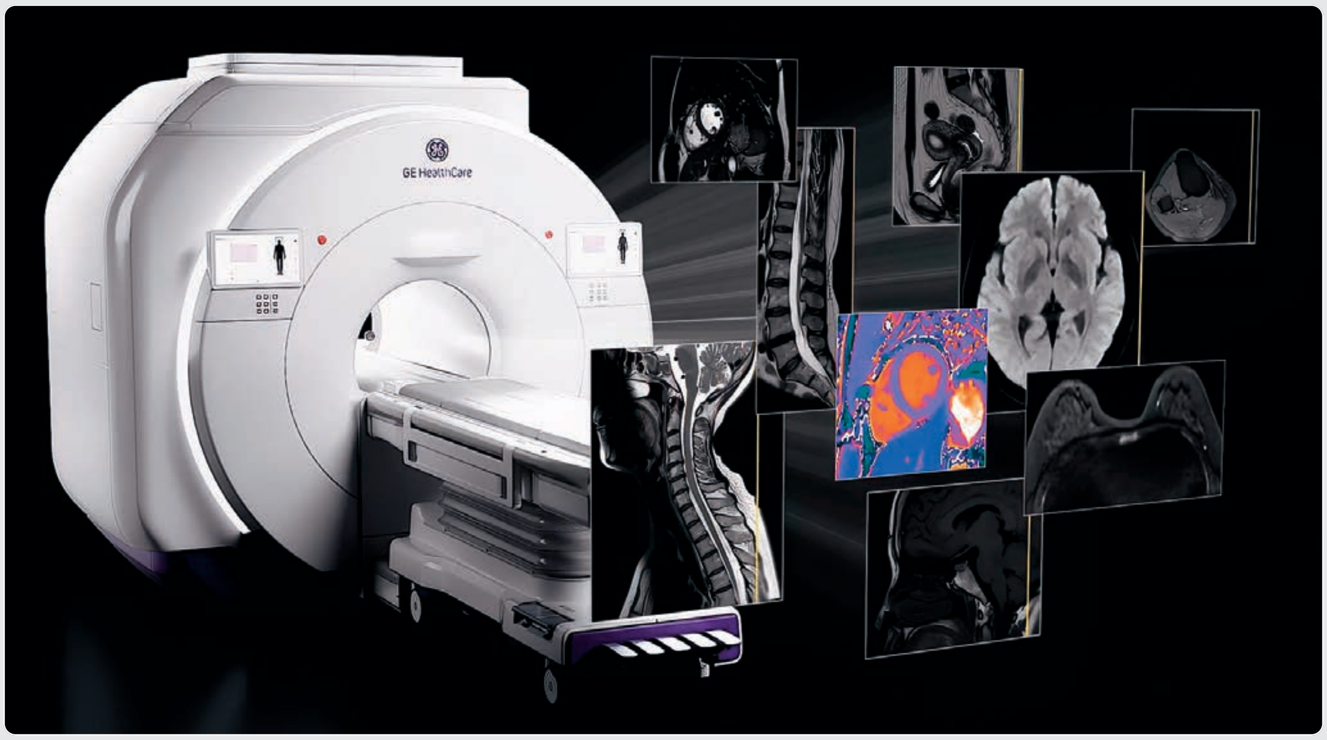

Figure 4. Freelium is designed to last decades and be part of SIGNA Continuum, allowing for upgrades to hardware and software to extend its useful life.