MRI's Helium Footprint – And How to Make it Harder to Spot

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Helium is a finite resource. In fact, it is exceedingly rare on our planet, which is why efforts are underway to make helium-dependent industries more sustainable. Magnetic resonance imaging (MRI) is among these industries: One out of every seven litres of liquid helium consumed annually worldwide is used for cooling superconducting magnets in MRI machines. There are ways to get this figure down, both on the product and on the delivery side of the business. Achieving real helium sustainability for MRIs requires that several approaches be taken simultaneously.

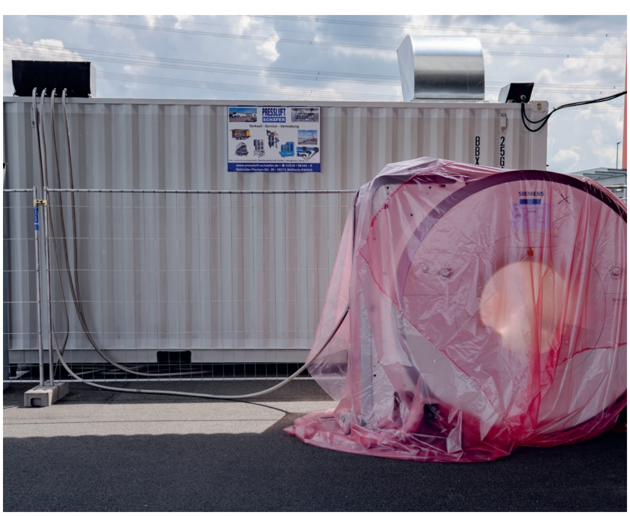
Helium is what makes party balloons fly, and this is all that many people know about it. But while it is true that party balloons account for a relevant – albeit variable – share of the annual global helium consumption, there is much more to know about this inert, noble gas. Were you aware, for example, that helium is among the most abundant elements that exist? Bar hydrogen, it is actually the second most abundant one in the universe. The sun, for example, consists of 73 percent hydrogen and 23 percent helium, while other elements only account for the remaining 4 percent.

The global helium economy

So there is definitely no shortage of helium out there in space. But not every celestial body is a thermonuclear fusion reactor. The sun is. The Earth is not. Down on Earth, helium is extremely scarce. It is, in fact, one of the rarest naturally occurring elements. The majority of Earth's helium comes from natural radioactive processes, i.e., decaying heavy elements. This process is as slow as it sounds, which means that helium is a non-renewable, finite resource.

Where does helium come from? There is no such thing as helium-specific mining. Rather, helium is a by-product of natural gas mining. "The US has traditionally been the largest source of helium worldwide," says Andrew Wade, Helium Commodity Manager at Siemens Magnet Technology in Oxford, UK. In recent years, though, the helium supply from the US has dried up, and Wade has had to turn to other countries for procurement: "The biggest producers at the moment are Qatar and Algeria. There will also be some large gas fields opening in Siberia soon."

Helium is not only finite, it is also volatile: When a helium balloon pops, its helium escapes into the atmosphere, from where it cannot be retrieved. In other words:



1 Container compressor facility to retrieve helium from old MRI systems that undergo refurbishing.

2 Looking into the 20-foot-long container.

Unless recycled, any cuts into our planet's helium reserves will be final cuts. The end of Earth's helium supply is not imminent: At current rates of consumption, the global reserves might in fact last some three centuries. But end they will, and thus there is a strong case to improve sustainability in helium-dependent industries.

Magnetic resonance imaging and helium

What is helium currently used for? There are several industries that cannot do without helium at the moment. Helium is a shielding gas for welding and for laser processing in industrial manufacturing, especially in the aviation industry. The space industry, too, uses helium for pressurisation and purging. Helium is needed for producing semiconductors and optical fibres, which makes it indispensable for the IT and microelectronics industry. Appreciable quantities go into gas chromatography analytics and into producing the breathing mixture for deep-sea diving. Finally, helium serves as a cryogenic cooling liquid for superconductors. The latter may in fact be the single most important use of helium today, with the MRI industries accounting for the biggest share: "About 15 percent of the total global helium production is consumed by MRI," says Wade.

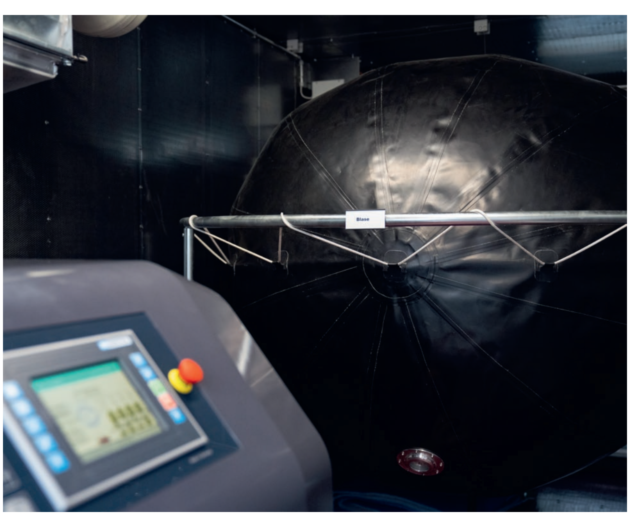
The MRI industry uses superconducting magnets to create strong and dynamic magnetic fields for modern-day MRI machines. Helium, which liquifies at about 4 K or −269° C, can create the low temperatures needed for supraconductivity. In essence, copper and niobium wires in MRI magnets are embedded in a bath of liquid helium. "The trick is stopping that helium from boiling," explains Wade. To do so, MRI machines use a cold head within a vacuum flask which recondenses any gas that arises. "The total amount of helium needed is different from MRI system to MRI system. As a rule of thumb, traditional MRI systems contain 1,500 litres of helium. About 2,000 litres are needed to get to a stable system. And after ten years, another 500 litres or so might have to be refilled. In the meantime, a well-managed magnet should not need any refilling."

Does it have to be that much?

If that sounds like a lot, that's because it is, especially given that the MRI industry is growing. "At the moment, the installed base increases at about 4,000 systems per year globally," estimates Wade. Under these conditions, the finite nature of helium means there is a need to act. There are three roads that can be taken toward better helium sustainability, and Siemens Healthineers is proceeding on all three of them.

"An important lever is trying to improve logistics and delivery," says Karlheinz Hörner, Director Magnetic Resonance Supply Chain Management at Siemens Healthineers in Erlangen, Germany. To get an MRI machine from the production site to the customer, whether by ship, by air cargo, or by lorry, is a challenging task. The problem is that as soon as the cooling is switched off for transport, the helium starts to evaporate. "Without cooling, we lose about 3% helium per day," says Hörner.

This is not a problem in the first couple of days, but it becomes a problem at a certain point: "We aim to ship any of our MRI machines to the customer within 20 days. The critical time frame is around 25 days, which is when 70 to 80% of the helium is lost." Once at the target destination, such a helium-drained magnet has to be re-cooled with liquid nitrogen and, depending on the amount of helium lost, potentially re-filled with liquid helium. Refilling can come with its own challenges, especially in remote



3 Helium bubble connected to a compressor that densifies helium up to a pressure of 200 bar.

4 Highly compressed recycling helium is filled into gas bottles and returned to gas vendors.

destinations. Helium is a diva. The COVID-19 crisis hasn't made life smoother for MRI shipping, either.

Helium cooling to go

In order to reduce helium losses during transport and to gain more overall flexibility, Siemens Healthineers started to introduce innovative cooling containers for long-distance MRI shipping from 2016 onwards. "There are 25 of these containers now – seven in Germany and the rest in China. This fleet will grow in the years to come," says Hörner. The cooling containers essentially mirror the MRI cooling on-site, in the hospital. There is a cooling unit at the front end of the container that keeps the MRI's cold head working all the way to customer. Avoiding breaks in the cooling chain means that no helium evaporates or needs to be refilled.

With MRI cooling containers, MRI machines can be shipped to remote countries without using air freight. This is why MRI cooling containers not only increase helium sustainability; avoiding air transport is also better for the climate. "This is especially relevant for India, where we had to use planes until recently. Australia and New Zealand have already told us that they won't accept MRI deliveries by air cargo at all anymore."

Cooling trucks are the siblings of cooling containers for shipping when it comes to overland transport by lorry. Cooling trucks are especially important in Brazil, where Siemens Healthineers operates a small factory for the local market. The cooling trucks are used to ship MRI machines to cities in the Amazon region, like Manaus, or to Recife and other cities on the north-eastern coast of South America. The benefits are the same as with cooling containers for cargo ships: No planes needed. Helium refilling avoided.

Helium recycling: from bench to balloon

A second important method of ensuring helium sustainability is recycling. This is done at the Siemens Healthineers facility in Forchheim, Germany, where old MRI systems undergo refurbishing. Originally, MRI refurbishing was done without helium retrieval. But this has changed in summer 2021, says Hörner: "We are now using a specifically designed, 20-foot-long container. It features a helium bubble which is connected to a compressor that densifies the collected helium up to a pressure of 200 bar." In the end, the highly compressed helium is filled into gas bottles, which gas vendors like Linde in turn sell to welders, divers, or indeed party balloon providers.

How much helium can be retrieved from a magnet that comes in for refurbishing depends on the type of MRI machine and on its overall condition. "Typically, MRI machines arrive at Forchheim with 25 to 30% of their original helium load," says Hörner. With 50 to 80 magnets finding their way back to Forchheim per year, this adds up to a substantial amount of recycled helium. Between July and September 2021 alone, nearly 20,000 litres of helium were retrieved with the help of the new container-compressor facility.

Rethinking MRI by draining the magnet

In addition to transport and logistics as well as recycling, there are the magnets themselves. This is where most can be gained in terms of helium sustainability, but it is also a technically demanding avenue to go. Over the years, the helium consumption of MRI machines has improved substantially, says Andrew Wade. During a ten-year lifecycle, an MRI system from the late 1980s required about 14,500 litres of helium in total. In a system produced in the early years of the 21st century, that value is down to around 3,100 litres on average. This translates into global statistics: "As an estimate, the MRI industry has managed to reduce overall helium consumption by around 25% during the last seven years – even though the installed base increased," Wade believes.

But 3,000 litres of helium per machine is by no means the upper limit of possible reductions. These days, Siemens Healthineers is pioneering an entirely new MRI platform that can be considered a moonshot from a helium sustainability perspective. Presented to the public at RSNA 2020, it is not the next evolutionary step towards less helium consumption. Rather, it marks the beginning of a totally new class of MRI systems that are radically different from their predecessors.

At the heart of the new platform is a newly designed magnet, the DryCool magnet. In the MAGNETOM Free.Max and MAGNETOM Free.Star systems, it comes with a field strength of 0.55T. The new magnet is much lighter and requires much less niobium-titanium wire, which means that cooling can be reduced to a minimum: The system contains no more than 0.7 litres of liquid helium under normal operation. Needless to say, this platform has the potential to change the world's helium sustainability equations completely. MRI's helium footprint, which was once as conspicuous as a dinosaur track, may soon become much harder to spot.

Further reading

Keeping a Hot System Cool by system architect Stephan Biber available from https://www.magnetomworld.siemens-healthineers.com/hot-topics/lower-field-mri