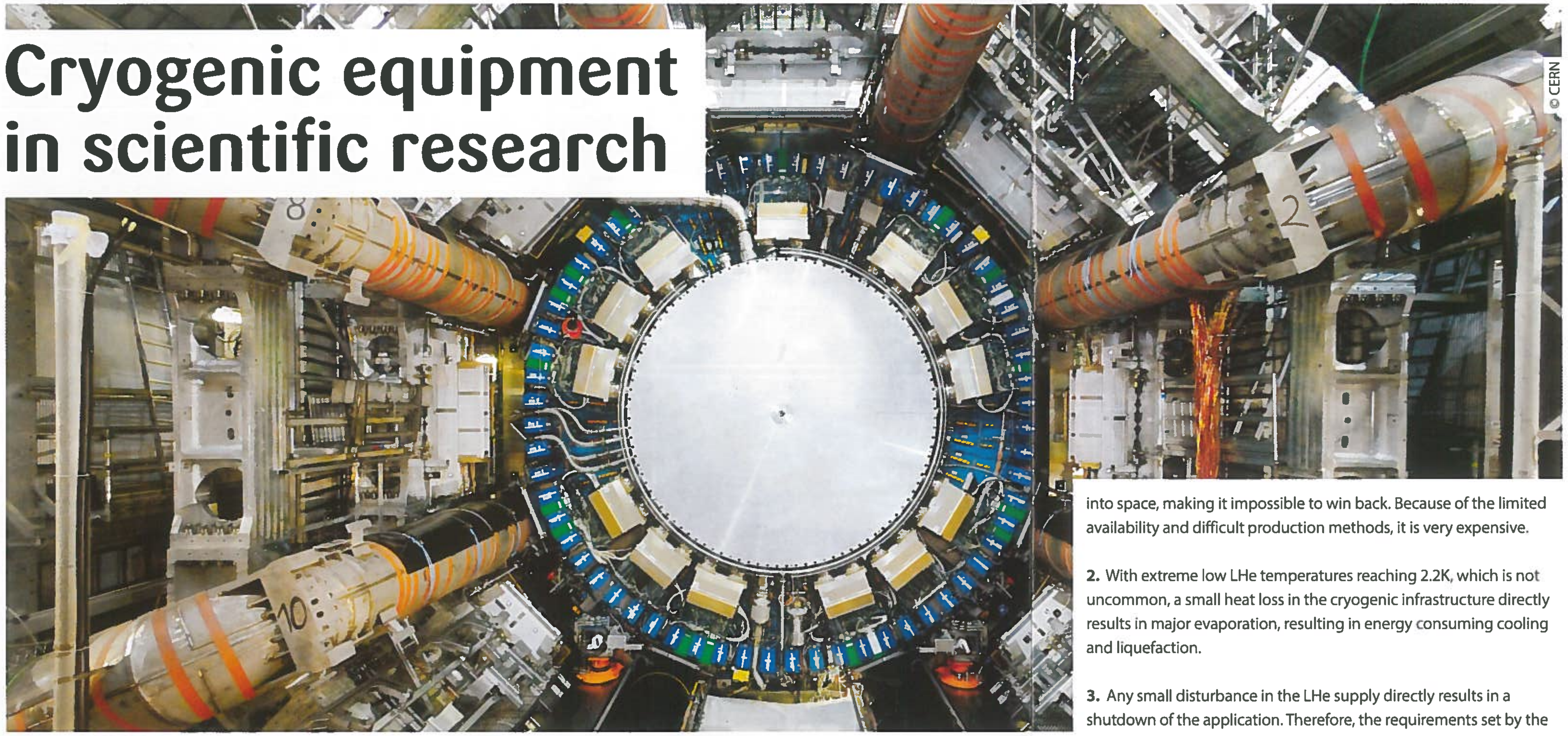
Cryogenic equipment in scientific research



Demaco's **Peter Rijneveld, Melle van den Berg and Ronald Dekker** discuss the production and use of cryogenic equipment in scientific research applications.

Scientific research institutes are a specialised part of the cryogenic infrastructure market and each institute faces its own challenges. Institutes depend on public funding. Tendering procedures are therefore carefully carried out, but can also take a lot of time. The challenge for both institute and supplier is to deliver the highest quality infrastructure in a limited period of time. These cryogenic infrastructures, consisting of vacuum insulated pipelines, distribution boxes and control systems, are used to transport liquid gases from A to B.

As the production of liquid helium (LHe) is difficult and expensive, creating a closed loop system with minimal boil-off gas and continuous helium flow is essential for the system's quality. The ultimate goal for an institute when operating liquid gas infrastructures is to achieve perfect functionality; operating a system that has an optimal gas flow, creating the best compromise between product cost and operational cost. The latter is kept low by creating a low heat load, low contents and low flow resistance, resulting in a continuous yield on the liquid gas.

One important application is a particle accelerator, such as at the Large Hadron Collider (LHC) facility at CERN in Switzerland. Here, particles are accelerated by superconducting magnets, which are made and held superconductive by LHe. The systems are built-up from different strings with cryomodules and cavities, and must be supplied with LHe during operation. The helium is liquefied in cold boxes. From there, complex multiple LHe transfer lines are needed to transport the LHe over several magnets and then transported back. Feed and End Caps are needed to connect the transfer lines with the cryomodules. Other important applications are the test facilities for superconductive cavities or cryomodules (magnets). Those components of an accelerator have to be tested at operational conditions of 2K (Kelvin) or 4K before they can be installed in the accelerator itself.

The main differences when partnering with research institutes, compared to other users of liquid gases such as food factories, are:

1. The use of closed loop systems to prevent LHe being wasted. Helium is only available in small, finite amounts in the world around us. When losing helium out of the system it will directly evaporate into space, making it impossible to win back. Because of the limited availability and difficult production methods, it is very expensive.

2. With extreme low LHe temperatures reaching 2.2K, which is not uncommon, a small heat loss in the cryogenic infrastructure directly results in major evaporation, resulting in energy consuming cooling and liquefaction.

3. Any small disturbance in the LHe supply directly results in a shutdown of the application. Therefore, the requirements set by the institute, supplier and the local law or governmental agencies are always of big importance.

A continuous and precise supply of helium is crucial for the system, therefore the tolerances are extremely small. Proper design and manufacturing, thus, becomes of major importance. In the system, slightly warmed up helium is cooled back to 2.2K using cryo-coolers, resulting in a system without helium waste.

Project requirements

To ensure a good and constant LHe delivery, the institute and its supply partner should always start a project by clearly specifying the actual wants and needs of the system – and check if these are actually possible considering functionality, safety and legislations. If this phase is neglected, it may take many weeks of engineering to recover. As delivery time is critical with most projects, a false start can directly result in project delay.

Next, a conceptual design, ultimately approved by the institute, is made to prove the specifications can be met. During this process, the project and product quality and assurance (QA) plan should also be set up and agreed on, to make sure all future necessary steps are taken and monitored. Besides the vacuum insulated lines, instruments such as valves, heaters, temperature sensors, pressure sensors, strain gauges and flow meters can be installed as part of the system, to monitor the system or the process of the institute. Safety valves must be added at the proper locations, properly dimensioned by the supplier to enable safe operation.

Besides engineering, there is also an important manufacturing aspect. Considering that the speed of delivery is important for institutes, producing high quantities of high quality transfer lines with low guaranteed heat load in a short amount of time puts a huge pressure on the manufacturability of the lot. Quality control during the production process is of major importance. If a flaw is detected during cold testing on site, recovery is difficult and will lead to considerable project delay. Therefore, each production step needs to be closely monitored and inspections should be built into the production process as part of the QA plan.

A trend that is clearly seen in the market is that institutes prefer to deal with suppliers that measure and can supply objective QA and HSE (Health, Safety and Environment) scores. As worker safety is of the essence, and even more so in a closed environment, not only at the institute but at all stakeholders in the supply chain, working conditions are continuously improved. To avoid well known cryogenic safety issues, the minimal requirements to achieve excellent HSE and QA standards are to high levels of:

a) Safety analysis **b)** Quality assurance **c)** A data book
d) Certification **e)** Employee training.

Installation

After production, it is time for installation. To ensure good HSE conditions for workers on-site, an extended risk assessment needs to be performed, based on local conditions, to make sure safety is guaranteed during the installation. The results may lead to changes in manufacturing steps to reduce or change the work performed on-site. Finally, after finishing all the tests, the system is certified to the norms agreed upon in the pre-engineering phase and is ready for use.

To ensure an optimal system, there is thus a constant weighing of several design options. On the one hand the high pressure, shrinkage due to cool down, and mechanical loads require an extremely strong design. However, on the other hand, a system also needs to be as light as possible, because of limited space availability at the institute and in order to minimise the heat load and high energy consumption. Often this leads to complicated, but solvable, contradictions. In order to achieve the best results, a combination of specialised engineering knowledge and the highest production quality are crucial. gw

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Demaco is the leading knowledge-driven cryogenic infrastructure partner for industrial gas companies such as Linde and Air Liquide, scientific institutes such as CERN, DESY, GSI and Triumf, and EP&C contractors worldwide. Its team of cryogenic specialists – 'Cryogeniuses' – is committed to supporting its partners in their daily effort to transport and condition all liquefied gases.