Identifying the Best Equipment for an Optimized Cryogenics Operation

by Chris Herman

Cryogenics: Overcoming the challenges of Extreme Cold in Modern Industries

Men with peculiar-sounding names like Cambyses II, Psamtik III and Candaules were traversing the highways and byways of Ancient Greece some 3,000 years ago when the Greeks invented the word "kryos," to which they gave a meaning of "cold" or "frost." However, it wasn't until the late 1880s, some three millennia later, that the word "cryogenics" – taken from the Greek root kryos and meaning "related to the branch of physics that deals with the production and effects of very low temperatures" – became mainstreamed in the science and technology vernacular, with the first cryogenic laboratory that was designed specifically for the production of very low temperatures constructed in 1882 in The Netherlands.

At that time, there wasn't even a consensus as to what an official cryogenic temperature range actually was. Some argued that cryogenic temperatures started at -238ºF (-150ºC), while others were more specific, claiming the starting point was -244ºF (-153ºC). Today, the widely accepted starting point for cryogenic temperatures is said to be -292ºF (-180ºC), namely because the boiling point of many permanent gases like helium, hydrogen, neon, nitrogen and oxygen are below -292ºF, while substances like freon refrigerants and hydrogen sulfide have boiling points above -292ºF.

No matter the mystery that might surround the invention of the word or the quibbles over its starting temperature, there’s no doubt that the use of “cryogenic” liquids and gases has become an integral part of manufacturing, transport, storage, dispensing and consumption within many markets, including aerospace, vehicle refueling, industrial manufacturing, medical, food and beverage, and electronics.

What’s equally true is that there are many inherent challenges in ensuring that the handling of cryogenic products is safe, reliable, efficient and cost-effective for those tasked with managing the substances and the wider environment. In this article, we will take a closer look at those challenges and suggest the various systems and equipment that can be used in cryogenic-handling processes and how those components are able to overcome critical cryogenic-handling challenges.

"In the world of cryogenics, precision and safety are paramount. As we harness the power of extreme cold for innovation, our greatest challenge is ensuring that every step of the process is meticulously managed to protect both the integrity of the technology and the safety of the environment."

The Challenge

Over the centuries, humankind has discovered abundant benefits and uses for low temperatures. In the cryogenic realm, this is best represented by the discovery that the production of lower and lower temperatures through the liquefaction of ambient gases like oxygen, nitrogen, hydrogen and helium could have many far-reaching positive benefits for countless technologies and industries.

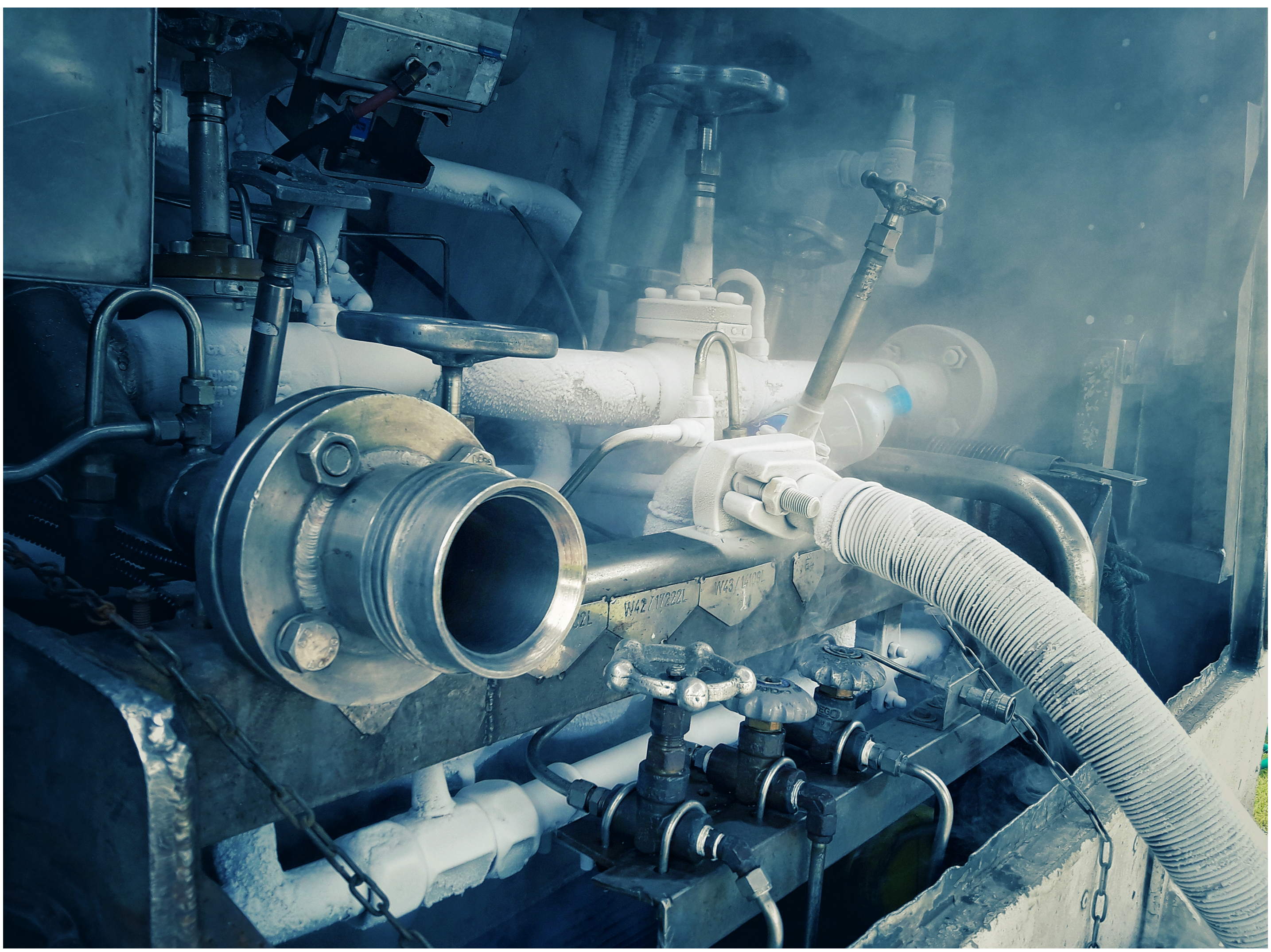
The discovery in the early 1900s that oxygen could be liquefied was the first significant cryogenic breakthrough as it enabled the creation of oxy-acetylene welding, which was a boon to the construction industry, among others. Over the years, it has been determined that there are seven general benefits attributed to the ability to produce and use cryogenic substances: preservation of biological food and material; reduced thermal noise; creation of high fluid densities through the liquefaction and separation of gases; low vapor pressures; achieving temporary or permanent property changes; creation of superconductive or superfluid substances; and mandatory tissue destruction.

To produce cryogenic substances that are able to deliver any of those seven benefits, cryogenic manufacturers must be aware of and overcome or satisfy a number of challenges. The first and most obvious is that handling substances at such excessively low temperatures can be dangerous for the person charged with handling them. Therefore, every due precaution must be taken to ensure that the handling is an inherently safe one. Then, for a cryogenic liquid to be useable, it must always remain in a frigid-liquid state. That can be difficult to achieve and maintain because the principles of thermodynamics make keeping extreme low-temperature fluids in a liquid state very challenging.

No matter the manufacturing or usage environment, there are always sources of heat present that work to warm up the cryogenic liquid. When that liquid reaches a certain temperature, it will begin to “boil off,” i.e., return to a gaseous state and evaporate. This evaporating gas can cause the operation to perform inefficiently or lose function entirely.

Because thermodynamic principles cannot be ignored, increased power output is generally required to produce cryogenic substances, which can be a budgetary drain for the manufacturer. A more basic disadvantage is that most cryogenic production facilities feature large, complicated setups that are expensive to construct, which can put a strain on capital and operating budgets. Other common challenges that may need to be overcome include excessive, noise, vibration, electromagnetic interference and heat rejection.

In many instances, these challenges are unique to the specific cryogenic-manufacturing system. For example, if the system requires the use of an expensive cryocooler that added expense may not survive a cost-benefit analysis. A final challenge is finding the proper materials of construction for systems that will operate at temperatures within the span between the low temperature and ambient temperature. Zeroing in this variable can be difficult if sufficient operational data doesn’t exist for the application’s temperature range; in that case, some extrapolation of the known figures may be needed to determine what will work best within the specific temperature range.



The Solution

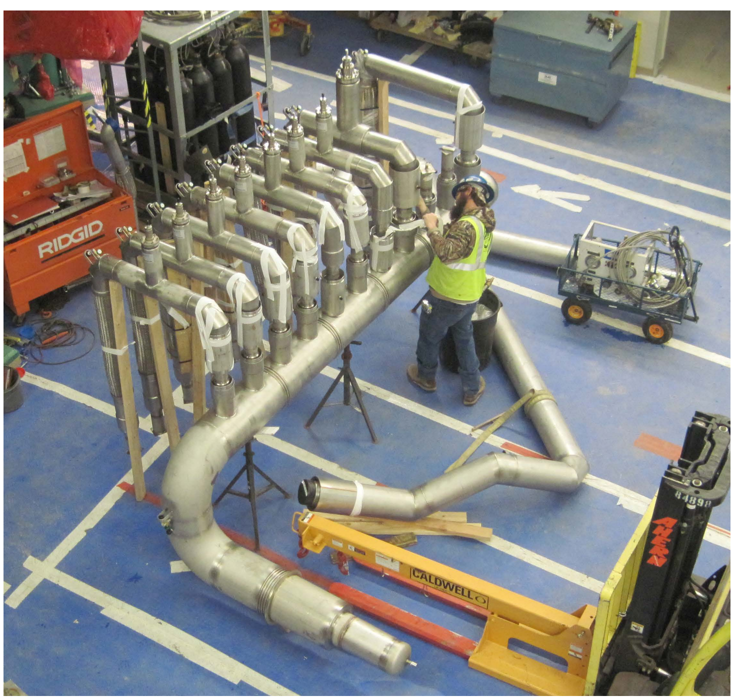
No matter the operational atmosphere, temperature range or cryogenic substance being handled, the systems and equipment used to facilitate those operations need to be able to satisfy the challenges that are inherent with the handling of cryogenic substances.

Cryogenics has revolutionized multiple industries, but the true test lies in our ability to handle these ultra-low temperatures safely and efficiently. As we push the boundaries of what's possible, meticulous control and robust systems are essential to turn potential risks into powerful innovations.

The roster of equipment and systems that can be incorporated in a cryogenic-manufacturing regime or be required to operate at cryogenic temperatures can include the following, with the knowledge that all or most will require the optimized use of valves or a valving system.

Vacuum-Jacketed Valves

These valves must conform to stringent regulatory standards so that they can reliably ensure seamless flow control and preservation of cryogenic temperatures. They must be designed to withstand extreme conditions, and only then will they be able to guarantee reliability and safety in critical applications while safeguarding the integrity of cryogenic processes across diverse industries. They are designed to utilize a vacuumed annular space between the process flow path and the outside wall (that is exposed to ambient temperatures) to make convection to the environment negligible.



Vacuum-Jacketed Piping (VJP)

VJP systems are engineered to handle a wide spectrum of cryogenic substances, from liquid nitrogen, oxygen and argon to helium, natural gas, carbon dioxide, hydrogen and liquefied natural gas (LNG), many of which are used extensively in aerospace applications. A properly designed VJP system will effectively and reliably mitigate convection-heat leaks, thereby enhancing operational efficiency and minimizing costs. When deploying a dual stainless-steel pipe setup, a VJP system can ensure optimal insulation, creating a vacuum-sealed layer that maximizes thermal performance. This superior insulation capability, which surpasses that of traditional foam and dynamic vacuum-pipe systems, also delivers exceptional efficiency throughout the aerospace operation.

Air Separation Unit (ASU)

An ASU is used to separate atmospheric air into its primary components: nitrogen, oxygen, and argon. ASUs operate at cryogenic temperatures and high pressures, making them integral to the production of industrial gases and other applications. ASUs are known for their efficiency and reliability, ensuring a steady supply of high-purity gases essential for a wide range of industrial processes. They are a cornerstone within the clean-energy sector, supporting the production of gases like hydrogen for fuel cells and other sustainable energy applications.

Liquid Cylinders

Liquid cylinders are specialized containers designed to store and transport cryogenic liquids, such as liquid nitrogen, liquid oxygen or liquid argon. They are constructed to withstand the extreme cold temperatures associated with cryogenic liquids. They also provide a convenient and efficient means of delivering these cryogenic liquids to various end-users. Liquid cylinders come in various sizes, capacities and pressures to meet the diverse needs of the user. They are known for their safety, reliability and versatility in providing a continuous and controlled supply of cryogenic liquids for a wide range of applications, including freezing and cooling processes, medical procedures and scientific experiments.

Liquid Delivery Systems

These are specialized systems that are designed to store industrial gases in their liquid state. These containers are typically equipped with advanced insulation and safety features to maintain the gases at their required low temperatures and high pressures. The delivery process involves transferring the liquid fluid from these storage vessels to end-users through a network of pipelines, hoses and valves. Flow-control devices, pressure regulators and monitoring systems are also integrated into these systems to ensure accurate and consistent delivery while adhering to strict safety standards. Liquid delivery systems are engineered to handle a wide range of products, including oxygen, nitrogen, argon and carbon dioxide, making them indispensable for industries that rely on these liquids and/or gases for their processes.

ISO Tanks

ISO tanks are specialized containers used for the transportation of liquefied industrial gases, such as LNG, which is created by cooling natural gas to a cryogenic temperature. LNG ISO tanks are equipped with advanced insulation systems and safety features to maintain the extremely low temperatures required for LNG storage and transport. ISO tanks provide a flexible and secure means of transporting both industrial gases and LNG globally. They conform to stringent safety standards and regulations, ensuring the reliable and safe distribution of these essential resources to support clean-energy and industrial processes.

Liquid Cylinder Filling Stations

Liquid cylinder filling stations serve as dedicated facilities for refilling and maintaining liquid cylinders used to store and transport cryogenic fluids like liquid nitrogen, oxygen, argon and others. These stations are equipped with specialized equipment and safety measures to ensure the efficient and safe transfer of cryogenic liquids from bulk storage tanks to individual liquid cylinders. Liquid cylinder filling stations adhere to stringent safety standards to prevent leaks, spills and over-pressurization, helping to ensure the integrity of the gas and the safety of personnel involved in the filling process.

From its humble beginnings in Ancient Greece to its indispensable use in the construction and deployment of systems and equipment that help send rockets and humans into outer space, it’s hard to argue that “kryos” and its close cousin “cryogenics” has not been one of the spoken word’s greatest contributions. However, cryogenics can only continue to be a contributor to the advancement of humankind if the substances that fall within its definition are produced, handled, transported, stored and dispensed safely, efficiently and reliably. That requires the use of equipment and systems that are able to take the sting out of the characteristics that can make handling cryogenic substances so challenging.

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OPW Clean Energy Solutions was formed in December 2021 when OPW acquired both ACME Cryogenics and RegO Products. ACME is a leading provider of mission-critical cryogenics products and services that facilitate the production, storage and distribution of cryogenics liquids and gases. RegO is a leading provider of highly engineered flow-control solutions for cryogenic and liquified gas end markets. Together, they are taking OPW beyond conventional fueling solutions and helping define what’s next for alternative energy markets.

For more information on OPW Clean Energy Solutions, please visit www.opwces.com.