Safety, Quality, and Integrity of Gas Supply Depends on Equipment Competency

Protecting the integrity of gas throughout the supply chain, from manufacture to end user, is an ongoing challenge, particularly as gases and gas mixtures become increasingly sophisticated to meet needs across the full spectrum of contemporary global industry.

Gas molecules are continually in motion, filling every corner of every space and being capable of flowing through minute gaps. Gases stored within a container or in a gas supply system are constantly seeking ways to escape, while at the same time, other gases present in the atmosphere have the ability to migrate into the container or system. Unintended gas mixtures and contamination could adversely affect production processes and, at the extreme end of the scale, potentially damage the environment, cause safety risks and be harmful to human health.

Specialty gases applications are of particular concern. These are extremely sensitive high purity gases, often intentionally containing very low levels of trace components — in some cases as low as parts per trillion — which are used in equipment calibration and gas analysis. These trace components are easily compromised by a reaction with contaminant gases.

In response, leading gas manufacturers have developed increasingly hi-tech cylinders, valves, regulators and supply systems, developed from new generations of materials, to ensure that gas products remain pure and uncontaminated throughout their life cycle. This mitigates threats to the environment and human life, avoiding the exposure of all parties to the high cost of integrity failure.

Moving Gas in a Contained Way

When the intention is to deliver gas out of a cylinder, regulators are required to control pressure and valves to control flow rate. These are separate tasks and generally need multiple devices to achieve this successfully. Moving a gas or a gas mixture from a cylinder to the place where it is to be used requires a range of valves, regulators, piping and sometimes the inclusion of other gases and procedures, such as purge techniques, to achieve the correct result.

"We need to move gas in a contained way from supply point to point of use and be able to guarantee that there are no leak points which could allow the product to move out into the environment or allow atmospheric gases to get in," says Arron Varne, Director of Equipment Manufacturing, Linde Electronics and Specialty Gases, North America. "We also need to control how quickly gas flows from the storage container to the point of use. The device used to achieve this is a valve. Coupled with this, regulators are required to control the pressure of the gas. We store our gas products at high pressure to optimally fill their containers. However our customers generally use the product at much lower pressures and therefore regulators are required to reduce the pressure to the application."

Gas Supply Pyramid

Head of Specialty Gases and Specialty Equipment at Linde Gases, Stephen Harrison, says at the most basic tier of the gas supply pyramid are the industrial and technical gases used for applications such as welding and cutting in heavy industry settings. The associated equipment is robust, high flow and tough because of the often physically demanding environment in which the equipment is used and also the high volumes of gas passing through it. In these applications, ball valves are often used for tight shut off and needle valves used for flow control.

Quality and product sophistication increases in the next tier, which is occupied by medical gases such as oxygen and nitrous oxide. This is a safety-sensitive application where the principal concerns are the materials of construction and the cleanliness of the equipment supplying it. In this environment, errors can be life-threatening, therefore valves and regulators are specially designed to eliminate the possibility of connecting the wrong gas cylinder to the supply regulator. By using a combination of diameter, thread type and thread direction, CGA fittings used in North American make it virtually impossible to make the wrong connection. Pin index connectors used in Europe and other parts of the world produce the same result by using an identifying code, consisting of a specific combination of holes in the face of the valve into which connecting pins for a particular type of gas must fit in perfect alignment.

Food and pharmaceutical applications fall into the next tier — clean environments where gases and associated equipment are of a high quality and batch traceability is required. Valves and regulators are manufactured from materials that have no potential to harm the person consuming the end product. In the US, Generally Recognized as Safe (GRAS) is the American Food and Drug Administration (FDA) designation often used to specify equipment requirements for food and pharmaceutical applications.

Legislation impacting equipment delivering gases to food applications have also recently come into play in Europe, which has had far-reaching implications for the food processing industry. These are stringent regulations governing materials used in food processing. An example is Regulation No. 1935/2004, which is primarily intended to regulate the use of primary packaging of foods and to provide a legal framework to ensure that only safe materials are used as “wrapping” and other packaging materials that come directly in contact with food. Current European food legislation defines food gases as “food”. Therefore storage tanks, cylinders and valves, as well as gas supply systems and food processing equipment, such as freezers, fall under the requirements of this regulation.

The next tier in the gas supply pyramid is the area of specialty gases — extremely high purity gases that can also be toxic or corrosive. Storing, handling and using these gases correctly is critical, so there is a strong focus on the leak integrity of supply systems. In these applications diaphragm valves are considered “best in class” as process flow regulation devices, because they employ a flexible diaphragm to effectively control a process flow line either partially or completely as needed in order to regulate the transport of the gas stream and eliminate the possibility of contamination. “Leak-free” connections between these valves and other piping components are often achieved using NPT (national pipe tapered) thread.

Gas and equipment related to electronic and semi-conductor applications occupy the highest level of the pyramid. These are ultra-high purity gases that can be extremely toxic — in some cases, a leak of only a few parts per million could be fatal — as well as highly corrosive or pyrophoric, meaning that these gases ignite as soon as they come into contact with the air outside the system. Therefore the level of leak integrity must be absolute and as such, face-seal fittings and welded connections are often used.

Design Evolution in Specialty Gases Supply Systems

Several decades ago, specialty gas supply generally incorporated a gas cylinder featuring an on/off valve to which the customer would connect a regulator to drop the pressure to suit their system. More recently such systems have evolved to include a first regulator to drop pressure to a mid-level and then a series of other regulators to reduce the pressure down to the point of use. This approach provides much finer pressure and flow control.

In terms of piping, orbital welding is also often used now to seal connections and provide maximum system integrity. This involves rotating the welding arc mechanically through 360° around the pipe in a continuous motion to deliver a high integrity weld.

There is also a growing trend towards integrating the control equipment directly into the body of the cylinder — physically combining the valve and regulator into one unit to deliver accurate and precise low pressure flow control, which eliminates many traditional leak areas.

Varne suggests that another example would be the Demand Flow Regulator (vacuum actuated) designed for use with instruments that use a pump to draw calibration gas and provide the precise amount of gas required by the instrument pump. Simple to use, this regulator makes calibration quick and easy by eliminating the need for sample bags, flow-meters or special operator training. This innovative regulator is frequently supplied with Linde's SPECTRA protocol gases.

Harrison says there is another definite trend towards what he calls "integrated monoblocks". "For example, if a customer wants to conduct a purge, he will often need a system of three valves connected together," he says. "One way to connect these three valves is to screw them together with connections like NPT threads or metal-to-metal face seals with electropolished surfaces — or just weld the three valves together, which is the most leak-proof connection possible. However none of these methods are completely fail-safe.

"This is where the monoblock comes into play. The metal is either cast as one single block, or machined to create one single piece of metal that incorporates three different valve mechanisms. This way there is minimum possibility of gas leakage, because the number of potential leak points has been reduced.

"Recent developments over the past five years or so have made this approach much more an established norm and one that is set to become the standard to replace the sequence of three valves joined together in the most sophisticated specialty gas supply systems. It is cost effective, and at this level of gas usage, such high quality equipment has become imperative in terms of human safety and environmental protection."

Harrison stresses that, like the proverbial chain, a gas supply system is only as good as its weakest component. All components should be of compatible quality. This is the only way gas users can guarantee the safety and purity of the products they use — ideally, the gas that leaves the cylinder should be exactly the same as the gas that emerges at the point of use.

"There's absolutely no point in choosing a Rolls Royce valve for your system if the regulator you incorporate is sub-standard," says Harrison. "The system must be designed to be appropriate for the application, from valves to regulators to piping, and the installation process is also important. One poor component could wreck the whole system. The right connections must be selected — o-rings, compression fittings, welds, etc. — and once the system is commissioned, it must be tested for pressure integrity and gas purity before the installer certifies the system as safe and ready for use.

"Correct use of the system is a key factor. Purging is always recommended when pure gases or corrosive gases are being used, but incorrect purging methods or lack of purging that allow the ingress of moisture, for instance, can damage or destroy the entire supply system through corrosion; sometimes additional cleaning with solvents must be undertaken. The next issue is on going maintenance, which must be defined according to best practice during use, right through to the close out of the system and scrapping when its useful life is over."

He says the safety and quality of a gas supply system is also influenced by the choice of equipment construction materials, since gases can react with certain materials. At the heavy industry level of gas supply, materials such as plastic and rubber are commonly used for their cost effectiveness and flexibility. However, when moving into the medical area, system designers must ensure that the gases will not react with the system materials or pick up particles from its surface. Copper and brass are therefore commonly used in medical gas supply systems for their inert properties, and where necessary, stainless steel can be used.

For the most critical gas applications stainless steel is the material of choice for supply systems. Here however, different grades of stainless steel are suitable for different applications. Harrison points out that certain alloys are cheaper than others, but are unsuitable for specific gas applications. Other alloys are more costly and difficult to work with, but are more corrosion resistant, such as grades 304 and 306 or the “superalloy” Hastelloy®, or even titanium, as is sometimes used for certain applications in the electronics industries. A variety of internal surface finishes are also available for specialty gases applications, with electropolished surfaces at the top end for use with very pure gases.

“In the world of specialty gases, the equipment supplied should be thoroughly tested before it is shipped to a customer site, for example by leak testing using helium detectors or by monitoring pressure retention over a period of time,” concludes Harrison.

Article courtesy Linde.