How to dose liquid nitrogen effectively

In today's competitive food and beverage market, most companies are looking to reduce costs. One way to do this is to reduce the cost of packaging used in their production facilities. Even small savings on container costs can result in large overall savings because of the quantity of units processed. To accomplish this per unit savings, containers are made more light-weight by removing material.

However, with less material the containers are also less structurally stable which can lead to collapse when stacked, or improper labeling and packaging. In carbonated soft drinks, the presence of carbon dioxide in the product provides internal pressure making the package rigid and stable. Liquid nitrogen can be used in non-carbonated beverages such as bottled water, juice, and teas to achieve the same effect but without adding the "bubbly" feel of carbonation, which may not be desired.

Gaseous nitrogen has been used to expel oxygen and increase shelf life of products. Liquid nitrogen can serve this same purpose while reducing nitrogen consumption by 80% over traditional gas tunnels.

EQUIPMENT OVERVIEW

Whether pressurizing or inerting food or beverage containers, handling liquid nitrogen on a production line poses challenges. Liquid nitrogen has a boiling temperature of -320°F (-196°C), and it will boil away rapidly when exposed to room temperatures. Therefore, insulated equipment must be used to ensure efficiency and safety. This equipment includes an injection device capable of metering small doses of liquid nitrogen into food or beverage containers, as well as storage vessels or tanks and piping to transport the liquid nitrogen to the injection location.

Storage vessels generally come in two forms: large bulk tanks and small portable tanks called dewars.

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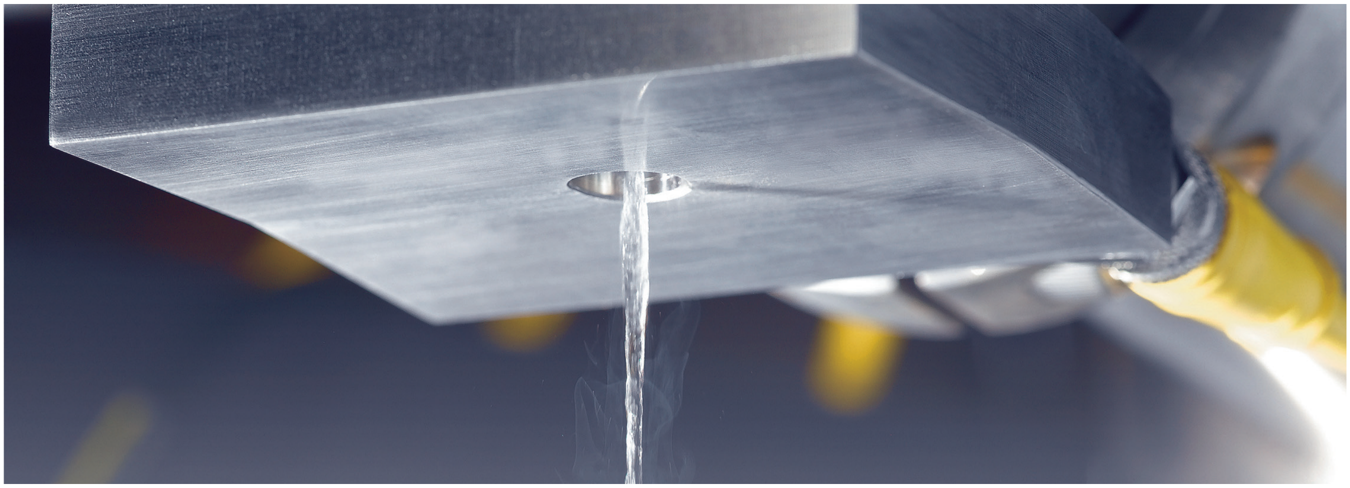

Both designs feature a double-wall construction with the inner and outer walls separated by a vacuum space. This vacuum "jacket" allows the tank's outside surface to be remain at ambient temperatures, while maintaining cryogenic temperatures inside. The nitrogen can be held in liquid form for quite a while, but even with this vacuum barrier, the insulation isn't perfect and tank losses can range 0.5% – 2% per day. Large bulk tanks are typically installed outside and require longer piping systems to transfer the liquid to the use point. Dewar tanks are portable and can be situated closer to the use point, therefore requiring a shorter length of hose.

For either type of storage vessel, insulated piping should be used to limit losses and improve efficiency. There are multiple types of insulated piping, but generally they can be categorized as vacuum jacketed and non-vacuum jacketed.

Vacuum jacketed piping is a similar concept to that found in bulk tanks or dewars. An internal pipe is surrounded by a vacuum annulus that provides the insulation between the cryogenic temperatures in the pipe and the ambient temperature outside it. This vacuum space greatly reduces the heat losses, giving the pipe its efficiency. Vacuum jacketed piping is more efficient than non-jacketed piping, and offers completely frost-free operation. The vacuum jacket on this type of piping is generated by attaching the pipe to a vacuum pump. In a dynamic-vacuum system, a vacuum pump is continuously pumping and the vacuum quality is consistently improving. With the need for a dedicated vacuum pump running all the time, the operating costs are slightly higher with this style. The vacuum on a sealed-vacuum system is typically evacuated at the factory and then sealed off. Over time, this vacuum will gradually degrade resulting in increased heat losses and decreased performance.

Either type of vacuum jacketed piping can come in rigid or flexible sections. Rigid piping needs to be accurately dimensioned to ensure a proper fit in the field. Flexible piping is fabricated in sections making it easier to install as it's more adaptable in routing around obstructions. Vacuum Barrier Corporation custom manufactures both sealed and dynamic-vacuum versions in a variety of materials and sizes. Non-vacuum jacketed lines are often insulated with foam, and are not as efficient with heat losses as high as 20 times that of vacuum jacketed piping. As the foam degrades over time it loses its insulating qualities. These piping systems also have larger outer dimensions making it difficult to route through tight spaces.

Nitrogen dosing equipment is the main component of a liquid nitrogen system. It's often what production facilities are most interested in as it directly affects their ability to meet pressurization or inerting goals. Typically these are called dosers, and must operate frost-free and efficiently during dosing or idle times.

The reliability of a doser on a production line is very important as losses are calculated in minutes of downtime. As with any cryogenic device, internal exposure to moisture must be limited at all times as it's a doser's biggest enemy. Care must be taken during nozzle changes and maintenance to prevent contamination by moist air. In certain industries, there may be a requirement that the liquid nitrogen be delivered aseptically, and therefore the unit must be capable of being sterilized.

PRODUCTION GOALS

Aside from operating frost-free, a doser must also meet the goals of the production facility. Any bottling or canning operation will be looking for consistent pressurization or inerting of their containers. This requires the doser to consistently output an accurate dose of liquid nitrogen, whether dosing discretely or steady-streaming. Too small of a dose can lead to unstable containers and the possibility of collapse. For inerting processes this could lead to food spoilage. If dosed with too much nitrogen, there is risk of containers bulging or bursting, which could cause jamming and down time.

The challenge for the dosing equipment is to reliably and accurately control the liquid nitrogen dose for each container up to speeds of 2000 bottles per minute. In order for the production goals of pressurization to be met, a doser relies on consistent fill heights from the filler. Even a small change in fill height can lead to under or over-pressurization.

The doser does have the ability to adjust to changes in line speed of the filler. As the line ramps up or down, timing is adjusted automatically to ensure each dose enters the container. Likewise, dose compensation adjusts the amount of LN_2 dispensed as the line speed changes. For example, as a line slows down there is more time between filling and capping which means more time for the nitrogen to boil off. Therefore a larger dose is dispensed to maintain consistent pressures.

Other factors on the production line must be taken into account as well to ensure proper pressurization. Travel time from the doser to the seamer or capper should be minimized to prevent excess boiling or loss of nitrogen. Shaking or bouncing of containers on the conveyors can force nitrogen and product out of the package before closure. Reliable sealing closures are also needed to maintain the pressure within the container after dosing.

VBC offers a range of dosers to accommodate a variety of line speeds and budgets.

SAFETY

It is important to address worker and machine safety when dealing with liquid nitrogen. When boiling from a liquid to a gas, nitrogen expands roughly 700 times. Safety relief valves are installed on tanks, piping, and dosers to prevent over pressurization and potential equipment ruptures. Where there are shut off valves in a system there is potential for nitrogen to be trapped. A safety relief valve must be placed between any two such valves. On bulk tank-fed systems, the lowest rated relief device typically is placed outdoors. If a safety relief valve does relieve, it is safer if it happens outdoors rather than inside where workers are present.

COSTS

Cost is another key consideration of production facilities, and it's important to look at the full picture when measuring costs of an LN_2 system. Up front purchase price, installation, and operating costs must be considered jointly. When evaluating tank options, large bulk tanks cost more initially, but nitrogen is less costly in bulk. The need to continually change out dewars during a production run can also add hidden cost.

Using liquid nitrogen to expel oxygen and increase shelf life also allows for nitrogen consumption to be reduced by 80%, versus the use of traditional gas tunnels.

There are more options for cost reduction when it comes to piping. Inexpensive foam-insulated piping can reduce the initial price, but the operating costs associated with using more nitrogen can add up over the life of a system. Vacuum jacketed piping is more expensive up front, but it's more efficient and will reduce nitrogen consumption and therefore operating costs. As mentioned earlier, reliable operation is a key component for liquid nitrogen dosing systems, and downtime caused by an inexpensive, foam-insulated dosing system can offset any perceived gains from a low initial purchase price.

A production facility considering liquid nitrogen dosing must take into account costs, both upfront and operating, reliability of the system from tank through piping to doser, and the safety of their workers. To be successful in this and to collect the proper information, please consult Vacuum Barrier Corporation.

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