# How to Dose Liquid Nitrogen Effectively

Before adding a liquid nitrogen system to a food or beverage packaging production line, many factors must be examined.

**By John W. Ross, Vacuum Barrier Corp.**

Most production facilities are searching for ways to reduce costs. A small savings on the cost of a single container for a food or beverage packer quickly adds up to tremendous savings, based on the number of containers processed. Utilizing lighter weight containers or reducing utility costs are good savings methods.

But lighter weight containers for noncarbonated products can collapse when stacked unless special handling requirements are satisfied. When dosed into a container, liquid nitrogen will provide some internal pressure, which allows the containers to be stacked several pallets high. Gaseous nitrogen is one utility used in the food and beverage industry to expel oxygen from products and increase shelf life. Nitrogen consumption can be reduced by as much as 80% using a liquid nitrogen dosing system instead of gaseous nitrogen tunnels.

Plastic bottles can be pressurized at speeds of 1,000 bottles/min.

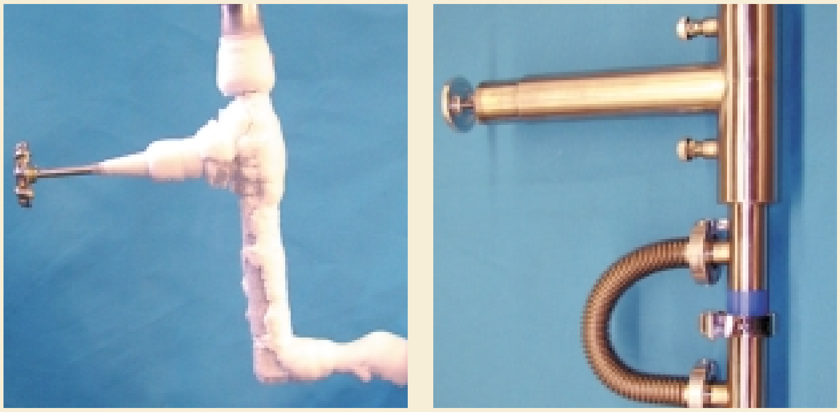
Because air is composed of 78% nitrogen by volume, nitrogen is abundant. Liquid nitrogen has a boiling point of -320°F (-196°C) at atmospheric pressure. Handling liquid nitrogen when pressurizing or inerting food and beverage containers on a production line poses challenges. To use liquid nitrogen injection, a production facility must have a storage vessel, liquid nitrogen piping and an injection device capable of metering small amounts of liquid nitrogen accurately and consistently. To store, transfer or inject liquid nitrogen, insulated equipment is a necessity because liquid nitrogen will boil away rapidly when exposed to room temperatures.

## Comparing Systems and Piping

Storage vessels generally come in two forms: large bulk outside storage tanks and small portable storage vessels called dewars. Both vessels use a double-wall construction creating a vacuum between the walls. This vacuum jacket is an effective insulation that allows the container's outside surface to be at nearly room temperature yet hold the liquid nitrogen inside for long periods of time. While no insulation system is perfect — some heat leak is inevitable with any storage container — most storage vessel manufacturers report a loss rate ranging from 0.5 to 2% per day. A piping system from the tank to the use point is required for large bulk tanks, but dewars need only a small amount of pipe because they typically are placed near the use point.

Liquid nitrogen piping must have some insulation to effectively transfer the liquid nitrogen with minimal vaporization or loss. There are two types of liquid nitrogen piping: vacuum jacketed and nonvacuum jacketed. Vacuum-jacketed lines are more efficient than unjacketed lines and operate frost-free.

A vacuum jacket is an annulus positioned around the inner liquid nitrogen pipe. The



The high nitrogen losses associated with uninsulated pipe are evident by frost (left). Vacuum-jacketed piping insulates the pipe carrying the liquid nitrogen, so frost does not develop.


Both portable dewars and bulk tank-fed systems can be used with nitrogen dosing systems. Because of their size, portable dewars (left) must be refilled regularly, but bulk tank systems (right) do not.

evacuated annulus reduces the conduction and convection heat losses to extremely low levels, creating efficient inner liquid nitrogen pipe insulation. Dynamically pumped and static vacuum are types of vacuum-jacketed lines. Static vacuum lines typically are evacuated by the manufacturer and sealed off for vacuum integrity. This vacuum eventually will degrade, resulting in increased heat losses and decreased performance over time. Dynamically pumped lines utilize a vacuum pump on the vacuum annulus. The vacuum pump must run continuously, which adds slightly to operating costs. However, vacuum integrity will improve with time and last for years.

Jacketed lines can be either rigid or flexible pipes. Rigid pipes must be accurately dimensioned for proper installation into a facility, whereas flexible lines are easier to install and allow more versatile routing. By contrast, unjacketed lines typically are foam insulated and have a heat loss as much as 20 times greater than that of a jacketed line. They also have a larger outside diameter than jacketed lines. Foam-insulated lines typically lose their insulating qualities as the foam degrades over time.

## Evaluating Production Goals

Food and beverage plant personnel should consider a number of goals and criteria when selecting a liquid nitrogen system, including:

- Consistent container pressures or consistent oxygen reduction.
- Plant personnel safety.
- Reliable system operation.
- Reasonable acquisition and operating costs.

Each producer has different priorities for each goal, but safety usually is high on the list. It is important to remember that liquid nitrogen becomes a gas at room temperature and expands to 700 times its volume as a liquid. Adequate piping system and injection equipment protection, including safety relief valves, must be used to prevent overpressurization or equipment rupture. A safety relief valve must be placed between any two shutoff valves in the system. 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 someone could get hurt.

Most food and beverage producers are more interested in the dosing device than in the storage and piping system. Nitrogen dosing equipment is the main component of a liquid nitrogen system. For efficient operation, liquid nitrogen injection equipment should be frost-free, safe and able to reliably meet the production facility's goals for pressure or inerting specifications.

Reliability is important on a production line where losses are calculated in minutes of downtime. A liquid nitrogen dosing device will need some startup time from a room temperature condition because all internal surfaces must be cooled down to liquid nitrogen temperatures. As with any liquid nitrogen equipment, operating procedures must be adhered to because the danger of contaminating the equipment with moisture does exist. Moisture is the biggest enemy of the cold surfaces of liquid nitrogen equipment. It takes only a small amount to freeze up the equipment internally. A quality unit will work continuously (either idle or dosing) without being overcome with moisture or frost contamination. Equipment adjustments such as nozzle changes for different container sizes and maintenance must be able to be completed without moisture contamination or long downtimes. Each production facility has different specifications for liquid nitrogen delivery. Some applications require that the liquid nitrogen be delivered aseptically. In such a case, the dosing unit also must be capable of being sterilized.

Consistent pressurizing or inerting results are important to the entire operation. A water bottle with too little pressure could collapse when stacked or not label properly. A bottle with too much pressure possibly could burst when stored in the trunk of a car due to temperature effects. Inerted products could oxidize or spoil if the liquid nitrogen dose was too small; too large a dose on an inerted product could cause an overpressurized container to jam the production line. Nitrogen injection can be accomplished by dosing individual containers or with a steady stream of liquid nitrogen. Either method can yield consistent results.

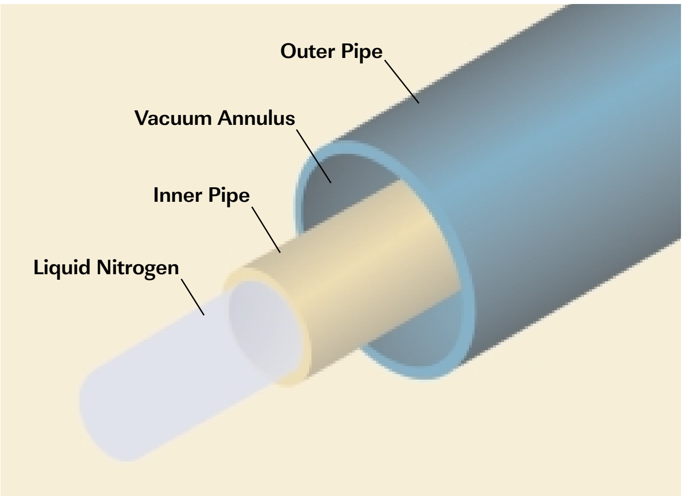
Liquid nitrogen will boil away rapidly once it is introduced into a container. Therefore, it is important to control the liquid nitrogen efficiently before dosing. A typical 18 fl oz (600 ml) polyethylene terephthalate (PET) bottle with a 1 fl oz (30 ml) headspace and pressure specification of 17 psig will need approximately 0.001411 oz (0.04 g) of liquid nitrogen. The dose of liquid nitrogen will boil away and expand to 1.163 fl oz (34.4 ml) of room temperature nitrogen gas after the container is sealed. Add 1.163 fl oz of gas to a sealed volume of 1 fl oz, and you end up with 17 psig.

The challenge for the liquid nitrogen dosing equipment manufacturer is to control the boiling liquid and deliver the 0.001411 oz consistently at speeds from 40 bottles/min to more than 1,000 bottles/min. The dosing equipment can control the liquid nitrogen up to the dosing point, but it cannot control the liquid nitrogen's behavior once it has been dosed into the container. The liquid nitrogen will boil away rapidly as the container travels to the capper or seamer, so travel time should be minimized for accurate results. The transfer from dosing to capping also should be smooth to prevent the boiling liquid from bouncing out of the container.

Another aspect to consider is consistent container fill levels. If container headspace varies because the fill levels are wildly different, the final bottle pressures also will be wildly different. For example, suppose the bottle previously mentioned had an 18 fl oz fill with a 1 fl oz headspace, and the next bottle on the production line had a fill of 18.3 fl oz (610 ml) with a 0.6 fl oz (20 ml) headspace. Both bottles receive a 0.001411 oz charge of liquid nitrogen. The liquid nitrogen dosing is consistent; however, in accordance with basic gas laws, the final bottle pressure on the 18 fl oz fill is 17 psig and the bottle with a 18.3 fl oz fill has 25.5 psig final pressure. Many factors determine final bottle pressure accuracy in addition to the dosing equipment accuracy. They include container volume consistency and good sealing closures. All factors must be addressed for good results.

Costs are a critical concern for manufacturers. It is important to remember that initial purchase price, installation expenses and operating costs must be considered jointly. Outside bulk storage tank vessels are more expensive to obtain than small portable dewars, but liquid nitrogen costs much less in bulk than dewars. The changing out process also adds to the hidden cost of using dewars — a 41.6 gal (160 l) dewar usually will last one 8-hr shift on a production line.

Vacuum-jacketed liquid nitrogen injection provides consistent pressurization when packaging water in lightweight bottles.




An evacuated annulus reduces conduction and convection heat losses and creates a well-insulated inner pipe for liquid nitrogen.

Piping is another area where processors try to save money. Most manufacturers can make a relatively inexpensive foam-insulated pipe. However, consider how much liquid nitrogen is lost during one year with a foam-insulated pipe. Acquisition and installation costs are higher for a vacuum-jacketed system, but the reduced loss rate due to superior insulation makes operating costs lower than with a foam-insulated system. An inexpensive foam-insulated liquid nitrogen injection device is not a bargain if downtime due to a frozen dosing device occurs.

Some dosing devices require a thaw out period of up to 24 hr after use. Startup and shutdown times also are important factors to consider when calculating liquid nitrogen injection system operating costs.

When considering liquid nitrogen dosing on a production line, it is necessary to look at many factors. Initial cost is only a small part of the puzzle. Most production plants considering using liquid nitrogen need the proper information and training to be successful and should consult a liquid nitrogen dosing equipment manufacturer before making a final decision. **PCE**

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