



Nitrogen blanketing to keep your product intact and your employees and equipment safe

Inerting and blanketing can help you improve process safety and product quality, as well as lengthen your equipment life—all while minimizing costs.



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Due to its purity and inert properties, nitrogen can be used when handling flammable or toxic materials, dealing with other fire and explosion hazards such as combustible dust, or ensuring product quality in a sensitive material to improve safety and product quality.

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Introduction

Nitrogen is used for a variety of applications including purging, pressure transferring, inerting and blanketing. Nitrogen blanketing is the process of applying the gas to the vapor space of a container to control its composition. The benefits of nitrogen blanketing include improved process safety, better product quality, and longer equipment life cycle. Nitrogen blanketing can be applied to a wide variety of container sizes ranging from a storage tank with a volume of millions of gallons down to a quart-size container or smaller.

Nitrogen blanketing, while widely used in the chemical, pharmaceutical, food processing and refining industries, is often overlooked as a way to improve safety, productivity and quality. Although blanketing is a simple plant practice, there are options for improvements that balance achieving desired safety or quality results with minimizing cost. Poor choices may add cost, waste nitrogen or increase plant emissions.

The following pages will share the practice of nitrogen blanketing and explain how to make the application more effective and efficient.

Overview

Nitrogen blanketing helps protect personnel, products and assets by reducing the oxygen content in the vapor space of a storage tank or process vessel, making it inert and eliminating the possibility of fire or explosion. It also decreases evaporation and protects the tank from structural corrosion damage caused by air and moisture. In addition, nitrogen blanketing is used to prevent air, moisture or other contaminants from entering the vapor space, causing product degradation or spoilage.

It is widely used for flammable or combustible materials, air/moisture sensitive products, combustible dusts, food products such as edible oils, and purified water. In the refinery, chemical, food and pharmaceutical processing industries, blanketing strategies are implemented during production, storage, transportation and final packaging. Blanketing is also a common practice in shipping, aerospace and other industries where flammable materials are used or generated. It can be applied to tanks or spaces on land, sea (shipboard) or air.

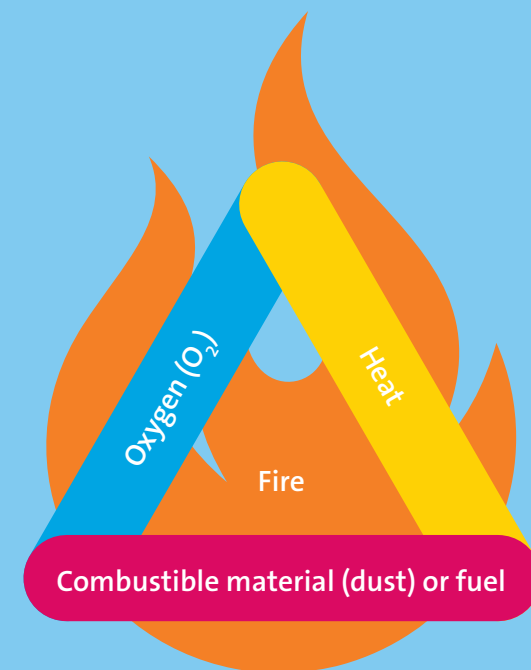
Nitrogen is the most widely used gas for blanketing due to its inert properties, wide availability and relatively low cost at any economic efficiency. Other gases, such as carbon dioxide or argon, are also occasionally used for certain applications.



Safety Benefits

In industries where combustible, flammable or explosive materials are processed, stored or generated, tank blanketing provides the greatest benefit—safety. Tank blanketing is used to shield these types of products from coming into contact with the oxygen in air, thus creating a non-flammable environment that prevents fire and explosion.

A fire requires three elements: an ignition source, fuel and oxygen. Removing any one of these three elements eliminates the possibility of fire. The headspace of a storage tank contains a mixture of air and the vapor of the flammable material being stored, for example, a solvent. The mixture of solvent vapor and air may ignite and burn if the vapor mixture is within the solvent's flammability limits and an ignition source is present. This can lead to tragic consequences such as severe injury to people and property damage. Although storage tank facilities may be electrically grounded to reduce the probability of ignition, static charges can develop within the system or within the solvent itself, creating a source of ignition. Since it is practically impossible to completely eliminate sources of static charge, and the fuel cannot be eliminated because it is the material being stored, oxygen is the only leg of the fire triangle that can be controlled.



The fire triangle depicts the three elements needed for a fire: fuel, oxygen, and an ignition source.

Flammability Limits

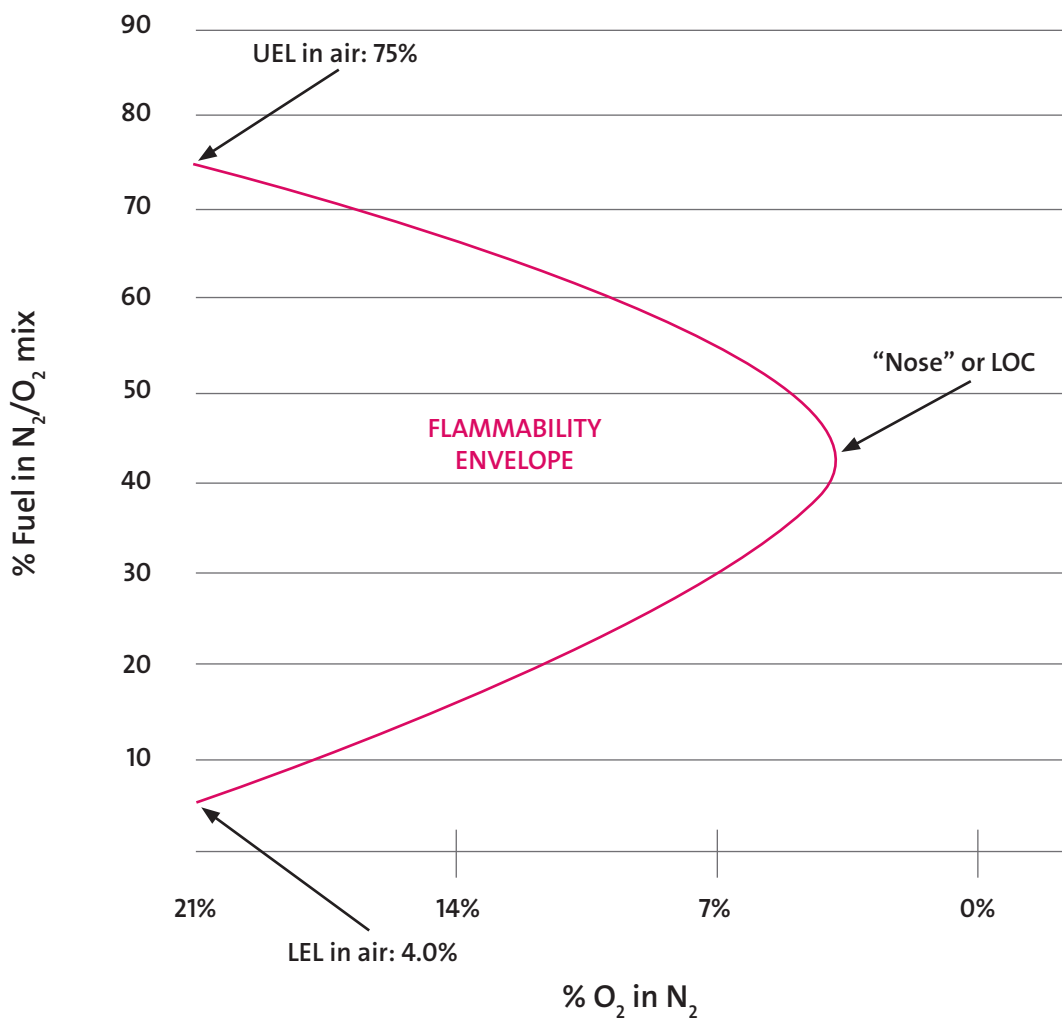
A storage tank can be made inert by:

- 1) reducing the oxygen content of the vapor space to a value that is less than the concentration that will support combustion (known as the Limiting Oxygen Concentration (LOC));
- 2) reducing the fuel concentration in the vapor space to a value less than the minimum concentration (Lower Explosion Limit (LEL) or Lower Flammability Limit) that can support combustion; or
- 3) increasing the fuel concentration in the vapor space to a value greater than the maximum concentration (Upper Explosion Limit (UEL) or Upper Flammability Limit) that can support combustion as shown in the figure on the right.

The LEL and UEL for a given material can be found in the manufacturer's Material Safety Data Sheet (MSDS). Tabulated LOC values for many chemicals (see examples in Appendix 1) can be found in chemical industry handbooks and guides such as the National Fire Protection Association (NFPA) Guide #69.¹ The flammable limits of mixtures of gases, fuels and inerts at elevated temperatures and pressures can be determined by computational methods.

Flammability Diagram

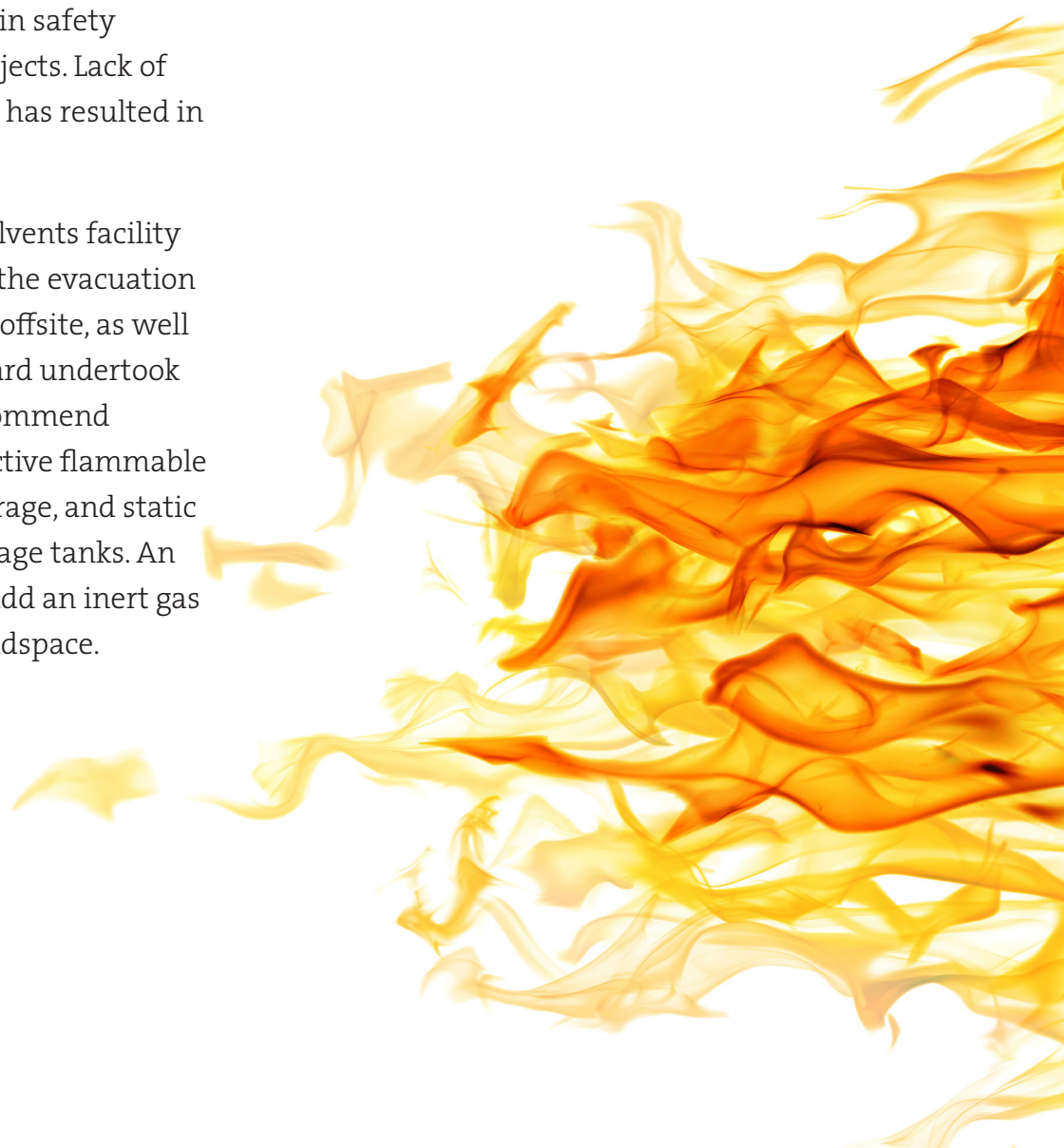
This diagram presents the flammability envelope for an example material (hydrogen in air in this case). Notice that beyond the LOC (Limiting Oxygen Concentration), combustion cannot take place.



Improper Handling of Flammable or Combustible Materials

The safety implications of improper handling of flammable or combustible materials are severe. Yet at some manufacturing plants, there is a false sense of security and general belief that “it can’t happen here.” Consequently, inerting and blanketing are often overlooked in safety reviews or during maintenance turnarounds or upgrade projects. Lack of blanketing or inadequate blanketing of flammable products has resulted in serious fires and explosions.

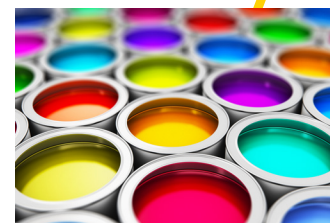
In one incident, explosions and fire erupted at the Barton Solvents facility in Valley Center, Kansas, on July 17, 2007. The accident led to the evacuation of thousands of residents and resulted in projectile damage offsite, as well as extensive damage to the facility. The Chemical Safety Board undertook a thorough investigation² to identify the root cause and recommend preventive actions. The key findings were that a non-conductive flammable liquid accumulated static electricity during transfer and storage, and static sparks ignited flammable vapor-air mixtures inside the storage tanks. An important recommendation from the investigation was to add an inert gas to the tank to reduce the concentration of oxygen in the headspace.



Quality Benefits

Some sensitive materials, especially in the food, pharmaceutical or nutraceutical industries, may experience degradation of product quality when contacted with oxygen, moisture or other contaminants. Blanketing creates a slight positive pressure inside storage containers, which prevents air and other contaminants from infiltrating and causing oxidative degradation and spoilage. The result is increased shelf life.

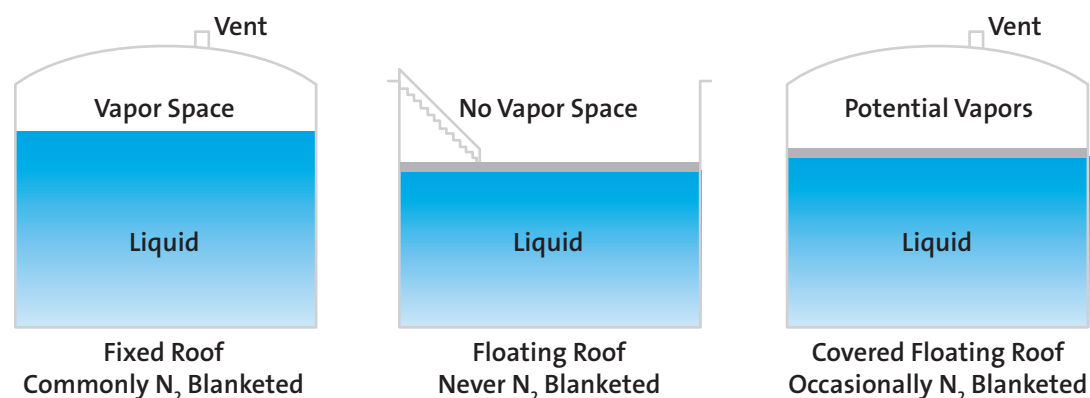
For example, oxygen and water vapor in the air cause undesirable reactions in edible oils, which are triglycerides. Water reacts with a triglyceride to form a diglyceride and a fatty acid. Oxygen will react with unsaturated fatty acids to form fat hydroperoxides and other undesirable products. These fat hydroperoxides may further react to form undesirable polymers, acids and aldehydes. Exposure to air causes low oil stability and change of color, flavor and aroma. Nitrogen blanketing of oil storage tanks, transfer lines and railcars removes both oxygen and water vapor from the container and prevents oxidation of the phospholipids, triglycerides and free fatty acids. Nitrogen blanketing of edible oil storage tanks is a common practice because it is a simple and effective way to maintain the integrity of the oil.



Types of Tanks

When considering a new or improved blanketing design, the first item to take into account is the type of vessel. This will determine whether blanketing is needed and, if so, whether pressure control or concentration control is preferable. The most common type of tank is the fixed roof tank. When flammable or sensitive materials are stored in these tanks, nitrogen blanketing is highly recommended. A less common type of tank is the floating roof tank. These tanks usually are not blanketed because there is no headspace for flammable vapor build-up. The least common type of tank is the covered floating roof tank, also referred to as an internal floating roof tank. The headspace above the internal roof of these tanks is occasionally blanketed.

In addition to storage tanks and similar plant vessels, some enclosed spaces that do not hold pressure may also require blanketing, such as pneumatic conveyors, hoppers that contain powders and dust, or controlled atmosphere containers. Nitrogen blanketing systems are essential in spaces that are not tight enough to hold a slight positive pressure.



Implementing a new blanketing system or improving an older one involves several components. Considerations include: the type of enclosure to be inerted, typically a tank or vessel, but sometimes a tunnel or a conveyor; the control equipment needed, based either on pressure or the oxygen concentration; and the inert gas to be used, typically nitrogen, although argon or carbon dioxide are sometimes used.

Nitrogen Control by Continuous Purge

Continuous purge systems use a constant flow of nitrogen, which is simple to do but can result in high nitrogen consumption. The nitrogen also may strip the vapors in the headspace and put additional load on the plant's air emission handling system. Furthermore, air can infiltrate the headspace if the tank discharges too quickly and the liquid level drops too fast. Despite these issues, this type of system continues to be used because it is quick and easy to implement. Replacing this method with pressure or concentration controlled methods (discussed in the next two sections) can result in savings.

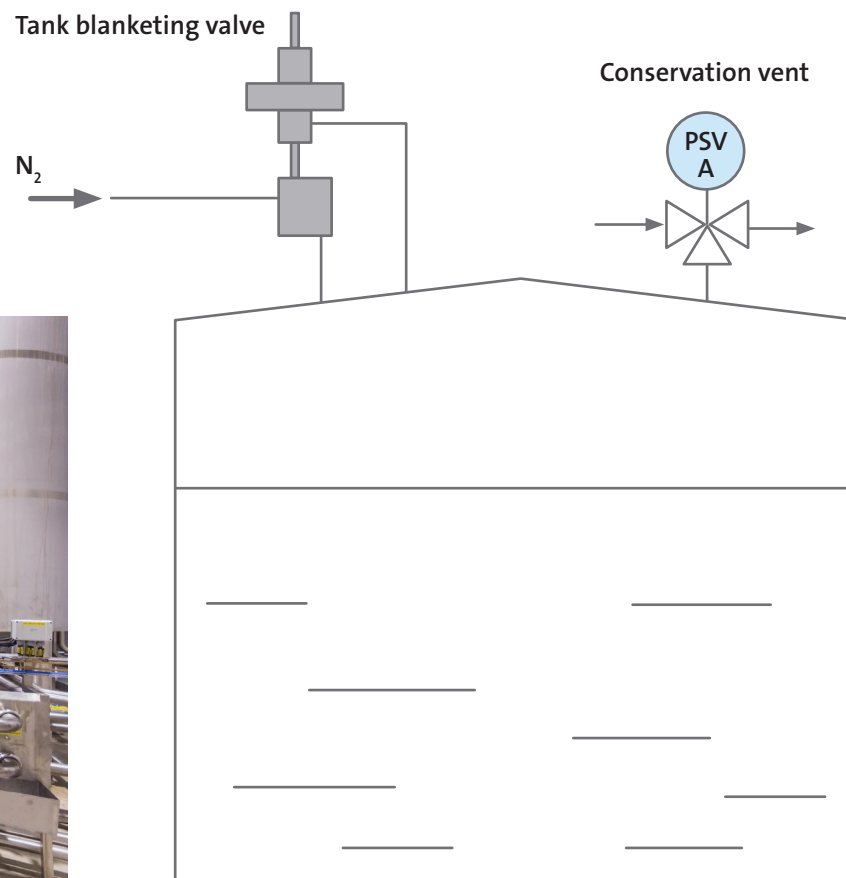


There are three commonly used methods for nitrogen control: continuous purge, pressure control and concentration control.



Nitrogen Control by Pressure Control

Pressure control systems are employed for sealed tanks, which can hold pressure. A valve senses the pressure in the headspace of the tank and delivers nitrogen accordingly. The headspace control pressure can be set quite low; less than an inch in the water column is sufficient. When the tank is discharging, the liquid level falls, the pressure drops and nitrogen is added. When the tank is filling, the pressure rises, and nitrogen exits through a vent valve. There are several systems available in the marketplace.



A tank equipped with pressure controlled blanketing will add nitrogen via the tank blanketing valve when the liquid level drops and will vent through the conservation vent when the liquid level rises. This helps ensure a safe headspace gas composition.

Nitrogen Control by Pressure Control

When a pressure control system is used, the volume of nitrogen for storage tank blanketing can be estimated by formulas and calculations. A simplified calculation is illustrated here. Basically, the nitrogen requirement for a blanketed tank has two parts: the nitrogen required by the throughput, or material flow through the tank (N_W); and the nitrogen required by thermal breathing, or the rise and fall of the liquid level owing to the external temperature conditions (N_{TB}). Of these two parts, normally the N_{TB} is significantly larger.

$$N_T = N_W + N_{TB}$$

$$N_W = (V_T)/7.48$$

$$N_{TB} \text{ (ft}^3\text{)} = V_{HS} * \left(\frac{T_{\text{high}} - T_{\text{low}}}{555} \right) * \frac{1}{7.48 * F}$$

N_T = Total volume of nitrogen required per month (ft³)

N_W = Nitrogen required by the material flow through the tank (working throughput)

N_{TB} = Nitrogen required by the rise and fall of the liquid level owing to the external temperature conditions (thermal breathing)

V_T = total # gallons discharged from the tank per month

V_{HS} = Average empty headspace (gal)

T_{high} = Max temperature in tank (°F)

T_{low} = Min temperature in tank (°F)

F = Estimated number of temperature swings per month

555 = A constant (°R) pertaining to the vapor space expansion factor

7.48 = Gallons to cubic feet conversion factor

Nitrogen Control by Pressure Control

Based on the formula, the N_w component can be easily calculated from the total volume of liquid discharged from each tank per month. The N_{TB} component is a function of the size of the tank, the average level in the tank, and atmospheric conditions affecting the temperature in the tank, which will vary due to several factors such as unpredictable temperature cycles caused by changing daily weather. Furthermore, the actual temperature in the headspace of the tank is not always that of the ambient air. On sunny days, it is much warmer, which in turn causes greater temperature swings and leads to greater nitrogen consumption. However, the thermal breathing (N_{TB}) component is usually much smaller than the working throughput (N_w) component. Therefore, the uncertainties associated with calculating this component result in relatively small errors in estimating total nitrogen usage per month.

Although the N_{TB} component of the average monthly nitrogen usage can be relatively small, the peak usage can be surprisingly large due to fast thermal changes. Knowing the peak nitrogen requirement and frequency is important when selecting and sizing the nitrogen supply system. For a liquid nitrogen supply system, peak nitrogen requirement is the basis for sizing vaporization capacity and nitrogen control systems.

The peak usage can be estimated by the following calculation, which can be applied for tanks up to 840,000 gallons:

$$N_M = 8.021P + 0.02382C$$

N_M = Maximum nitrogen flow rate (scfh)

P = Pump-out rate (gpm)

C = Total tank capacity (gal)

8.021 = Unit conversion factor from gpm to scfh

0.02382 = A factor based on cooling an empty tank from a high of 120°F at rate of change of 100°R/h

For tanks larger than 840,000 gallons, the peak usage can be estimated by the calculation:

$$N_M = 8.021P + G$$

N_M = Maximum nitrogen flow rate (scfh)

P = Pump-out rate (gpm)

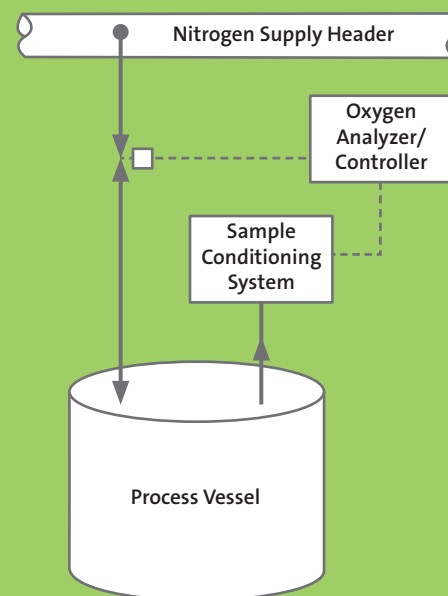
G = Nitrogen inbreathing requirement (scfh) from Appendix 2

Nitrogen Control by Concentration Control

Concentration control systems are suitable for unsealed tanks, which cannot hold pressure. Nitrogen usage is optimized because it is only added when needed. An oxygen analyzer system directly measures the actual concentration of oxygen in the headspace vapor and controls the amount of nitrogen flow to the tank. An integral part of the analyzer system is the sample conditioning equipment. The conditions that exist inside most processes are much too harsh to permit the use of an in-situ type oxygen sensor. A properly designed sample conditioning system will allow the analyzer to measure reliably over a wide range of process conditions including extremes in pressure, vacuum and temperature, and even under heavy particulate or high moisture conditions.

The advantage to continuous concentration monitoring and control is that it optimizes nitrogen usage and results in nitrogen consumption conservation. The usage savings can provide an accelerated payback on the cost of the monitoring and control equipment, resulting in operating cost reduction while providing the highest level of safety. There are several commercially available systems on the market in various price ranges and degrees of complexity.

A process vessel that is inerted via concentration control directly measures the amount of oxygen in the headspace and controls nitrogen addition to the tank to maintain the desired set point. A key feature of this type of control is the sample conditioning system, which enables the oxygen analyzer to provide reliable measurement even at extreme conditions of temperature, pressure, particulate, or moisture level.



Nitrogen Supply – Delivery

A new blanketing requirement will necessitate nitrogen, and a project to improve an older blanketing setup may involve a new nitrogen supply mode. Nitrogen supply options include delivered liquid nitrogen stored in bulk or microbulk tanks or dewars, as well as delivered gaseous nitrogen stored in large tubes, cylinder banks or cylinders. Nitrogen also can be generated onsite by a cryogenic plant or pressure swing adsorption (PSA) or membrane units.

The choice of delivery method depends on specific requirements for purity, usage pattern, volume, portability, footprint and local power cost. Analyzing these requirements determines which method or system makes the most technical and economical sense. New blanketing requirements will require calculations of nitrogen consumption based on tank volumes and throughputs as previously shown. When optimizing existing installations, these calculations can also be compared with actual flow data over a period of time, usually about a week, taken from the plant's existing nitrogen lines.



Nitrogen Supply – Purity

Nitrogen costs are reduced if a lower purity can be accepted. Many flammable materials have limiting oxygen concentration in the neighborhood of 10%. NFPA 69¹ would require operating at 60% of the LOC. Therefore, operating at 94% nitrogen would meet NFPA guidelines, although a more conservative 25% of the LOC, or 97.5%, adds an even larger safety buffer. From a quality perspective, lower nitrogen purity also may be investigated. For example, blanketing edible oils with 99.5% nitrogen can achieve the desired oil quality and shelf life.



Nitrogen Supply – Usage Pattern

Usage pattern is another important parameter to determine the appropriate delivery method. There are three basic usage patterns: constant baseline, erratic and periodic. In the constant baseline pattern, the flow is constant, such as the blanketing of a large tank farm. On-site generation is an excellent choice for this pattern. For an erratic pattern, the flows are inconsistent and unpredictable, often due to transfer or purging. In this case, liquid nitrogen is often preferred in order to match the variable flow requirements. In the periodic usage pattern, nitrogen consumption is predictable, but not constant. A generated gas plant backed up by liquid nitrogen may be optimal. Many plants exhibit a combination of usage patterns. A plant's usage pattern can be determined by measuring the nitrogen flow rate over time, typically one week.



Conclusion

Nitrogen blanketing offers significant benefits in terms of product quality and process safety. Choosing the appropriate method of nitrogen supply and nitrogen control system depends on the vessel design and application. Nitrogen blanketing is a common and simple procedure that, when done properly, pays dividends in terms of efficiency, effectiveness and cost. It is well worth an expert analysis for each specific facility and application to maximize the desired safety and quality results while minimizing capital and operating expenses.

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- ¹ National Fire Protection Association, "Standard on Explosion Prevention Systems," NFPA 69, NFPA, Quincy, Mass. (2008)
- ² U.S. Chemical Safety and Hazard Investigation Board, "CSB Issues Final Report on Barton Solvents Explosion ...," www.csb.gov/newsroom/detail.aspx?nid=36, CSB, Washington, DC (2008)
- ³ American Petroleum Institute, "API 2000: Venting Atmospheric and Low-Pressure Storage Tanks," 6th ed., API, Washington, DC (2009)
- ⁴ International Organization for Standardization, "ISO 28300:2008 -- Petroleum, Petrochemical and Natural Gas Industries— Venting of Atmospheric and Low Pressure Storage Tanks," ISO, Geneva (2008)

Appendix 1

This table shows the LOC (Limiting Oxygen Concentration) for some common materials at ambient temperature and pressure. A full table of materials can be found in NFPA 69¹. Note that the LOC of zero for Ethylene Oxide means that it must be blanketed with pure nitrogen, as no oxygen level is safe.

Material	LOC (vol. % O ₂)
Propylene Oxide	5.8
Methanol	8.0
Ethanol	8.5
Acetone	9.5
Benzene	10.1
Vinyl Chloride	13.4

Appendix 2

For tanks larger than 840,000 gallons, peak nitrogen requirements due to thermal breathing are shown as per API Standard No. 2000/ISO 28300³ for non-refrigerated, above ground, un-insulated tanks. The calculation method for peak usage or tank inbreathing is taken from API 2000 Sixth Edition Annex A³ or ISO 28300 First Edition⁴. This method has been used successfully in North America for the past fifty years. Another method was included in API 2000 Sixth Edition and also in ISO 28300 as Annex F. This method, provided for information only, provides "Guidance for inert-gas blanketing of tanks for flashback protection." This guidance, which is based on the German Regulation TRbF20, has not gained wide acceptance in North America at this time.

Tank Capacity		N2 Inbreathing Requirement
Barrels	Gallons	SCFH
20,000	840,000	20,000
25,000	1,050,000	24,000
30,000	1,260,000	28,000
35,000	1,470,000	31,000
40,000	1,690,000	34,000
45,000	1,890,000	37,000
50,000	2,100,000	40,000
60,000	2,520,000	44,000
70,000	2,940,000	48,000
80,000	3,360,000	52,000
90,000	3,790,000	56,000
100,000	4,200,000	60,000
120,000	5,040,000	68,000
140,000	5,880,000	75,000
160,000	6,720,000	82,000
180,000	7,560,000	90,000

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