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REFERENCE DATA SHEET ON INERT GASES AND ATMOSPHERES

By: Richard Gullickson, CIH

POTENTIAL USES OF INERT ATMOSPHERES

- Reduced opportunity for ignition or explosion
- Minimize oxidation reactions
- Promote other non-oxygen reactions
- Allow certain metallurgical processes
- Purging and blanketing storage tanks
- Shipping liquid natural gas and crude oil
- Control oxidation during arc welding
- Transfer of flammable chemicals
- Stop aerobic biological processes
- Enhance anaerobic biological processes
- Preserve agricultural products in storage
- Food packaging

INTRODUCTION

The term "inert atmosphere" usually refers to a gaseous mixture that contains little or no oxygen and primarily consists of non-reactive gases or gases that have a high threshold before they react. Nitrogen, argon, helium, and carbon dioxide are common components of inert gas mixtures. More rare or exotic gas mixtures can also be used for special purposes. Inert atmospheres are usually intentionally produced for these purposes in one of four ways.[1] Gases can be purchased that contain no oxygen or other reactive gases, and are introduced into the location where an inert atmosphere is needed. Purchased gases are often generated by cryogenic methods that employ compression, refrigeration, and fractional distillation cycles. The gases usually produced by this method are nitrogen, oxygen, and argon, the three most common gases in the atmosphere. The advantages of such procedures are that highly purified gases can be generated and multiple gases can be simultaneously produced.

The other three common methods of generating an inert gas are typically used for producing the gases on location. One method is by combustion processes. The other methods use air separation techniques such as adsorption or diffusion methods.

The combustion processes typically burn natural gas or propane under fuel-rich conditions to consume, for all practical purposes, all the available oxygen, generating a gas stream of mostly nitrogen, carbon dioxide, water vapor, argon, and some carbon monoxide, a toxic gas at relatively low levels. The advantages of this method are that it can be produced on site, variable quantities of inert gas can be generated, and it does not require large storage facilities. Typically about eight and a half cubic feet of dry inert gas are produced for every cubic foot of natural gas burned. To assure minimum oxygen levels, the combustion process is often adjusted to use slightly more than the optimum amount of fuel, which may result in the formation of significant quantities of carbon monoxide. The inert gas produced by combustion processes may require water vapor removal and temperature reduction.

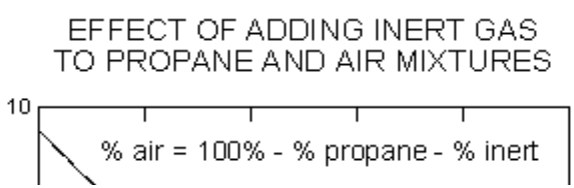
The second category for the on-site production of inert gases consists of the use of an adsorbent, known as a molecular sieve. Two beds of molecular sieves are used. While one column is being used to absorb the unwanted gas, the other is being purged or regenerated to prepare it for the next use. These devices selectively remove or separate unwanted gases to allow for the production of oxygen enriched or oxygen deficient gas streams. Such methods do not produce carbon monoxide. A third on-site method of inert gas production uses bundles of very small tubes that are more permeable to some gases than to others. Gases in a mixture that can diffuse through the membrane can be collected on the other side. The gases that do not readily diffuse through the membrane flow through the tube, to be collected separately. Carbon monoxide is not produced through the use of this generation method.

IMPLICATIONS
The process of generating an inert gas atmosphere may add hazards that were not originally present. Since practically all of the oxygen that was originally present has been removed, the atmosphere will no longer support human life. If enough of the gas escapes the process to lower the oxygen content sufficiently in an area, and is breathed by the workers, they may become asphyxiated. In addition, combustion methods may also produce carbon monoxide in concentrations of up to several percent. Leakage of atmospheres with high concentrations of carbon monoxide into areas occupied by workers may cause inadvertent exposure of the workers to carbon monoxide.

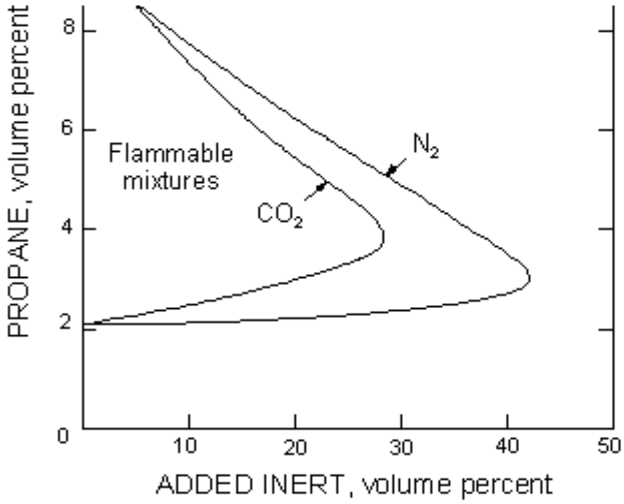
CONDITIONS OR HAZARDS CONTROLLED BY INERT ATMOSPHERES
The major hazard controlled by inert atmospheres is flammability and/or explosions. The three components of the "fire triangle" define conditions necessary for a fire to occur:[2]

1. Fuel, such as a flammable solvent or gas.
2. An oxidizer, usually oxygen.
3. Energy, in the form of heat, usually from a spark or flame.

If any one of the three elements or conditions in the fire triangle is missing, a fire cannot occur. The inert atmosphere operates by removing or reducing the oxygen, the oxidizer usually necessary for a flame or explosion.



An additional hazard mitigating factor is the effect of an inert atmosphere on the lower explosive limit (LEL) and the upper explosive limit (UEL).[3] Any flammable material present



in air must be present at a concentration higher than the LEL and lower than the UEL for an explosion to occur. If the concentration is lower than the LEL, there is not enough of the flammable material to propagate a flame or explosion. If present above the UEL, there is not enough oxygen to propagate a flame.

The figure at the left[4] illustrates the effect of adding an inert gas to a mixture of air and propane. For propane in air at normal temperatures and pressures, the LEL is 2.1% and the UEL is 9.5%. However, if nitrogen is added, the LEL remains fairly constant, but the UEL is rapidly reduced. When about 42% nitrogen has been added, the mixture will no longer support combustion, and will not explode, even though as much as 11.5% oxygen could still be present. If carbon dioxide is used as the inert gas, 14% oxygen could be present while still not supporting combustion.

A second important use of inert atmospheres is in metal processing and welding. Inert gases such as helium or argon are used during welding to prevent oxidation of the metals during the process. Inert gases are also used in some furnace operations in which metals are processed, in order to reduce or eliminate the production of oxides and scale. An example is annealing of brass and copper,[5] and die casting of aluminum.[6] These materials readily form oxides that can be a cause of undesirable qualities in the metal parts.

A third important use of inert atmospheres is in the production and storage of food products. During the production and storage of wine, for example, the presence of oxygen could allow bacterial action that would result in spoilage by converting the ethyl alcohol to acetic acid (vinegar).[7] In some locations, wheat and grain are stored with carbon dioxide instead of air, to prevent spoilage and to control insects without the use of chemical fumigants.[8] Microbial spoilage and rancidity in meat products can also be reduced by using inert gas storage and packaging.[9]

IMPLICATIONS

The use of inert atmospheres to control flammability, product quality, and food preservation has been discussed. There are a number of gases and mixtures of gases that can be used for this purpose. However, application of inert gases to these processes requires careful matching of processes and products. In some cases, using an incorrect inert atmosphere may result in an atmosphere that could still react or explode. In addition, some materials, such as unsaturated hydrocarbons, can explosively decompose or react at high temperatures and pressures even if no free oxygen is present.

HAZARDS OF INERT ATMOSPHERES

Confined Space Entry

While inert atmospheres, with low or no oxygen concentrations, are very useful in many industries, as with any useful tool they can be dangerous. There have been numerous fatalities resulting when workers entered a confined space, such as a tank that contained or had contained an inert atmosphere, without performing the proper confined space entry procedures. A worker entering such a space will replace the oxygen in the lungs within one or two breaths, and will be quickly overcome by simple asphyxiation. Often there will be multiple fatalities in this scenario, as one or more other workers enter the space to attempt a rescue. A second scenario can occur when a plant maintains an inert atmosphere through the use of piping to convey the inert atmosphere to the vessels and spaces that use the inert atmosphere. Fatalities have occurred when contract workers attach supplied-air respirators to these lines. In a March 1989 Hazard Information Bulletin,[10] "Use of incompatible nitrogen gas and breathing air supply lines as the cause of employee fatalities." The U.S. Occupational Safety and Health Administration (OSHA) states "Air Line Couplings must be used that operate only on breathing air and not nitrogen, oxygen, or other gas systems." These systems should be constructed with couplings that will not connect to the type used with breathing air systems.

A second cause of fatalities associated with entering a confined space that contains an inert atmosphere can result when the space had contained a flammable liquid.[11] In tank removal operations, it is common to purge such tanks with an inert gas, such as nitrogen or carbon dioxide, to avoid an explosion during removal of the flammable material. The tank is then tested to determine if the atmosphere is less than 10% of the lower explosive limit of the flammable material before a worker would go into the tank. The test is usually conducted with an instrument known as a combustible gas meter. When oxygen concentrations are less than about 10%, these meters can give an incorrect low reading, even if combustible gases still remain. If a worker then enters the space, even with a supplied air respirator, an explosion can occur if a flame or spark is present, such as with welding apparatus.

Toxic Gases
Another hazard that may be associated with the use of inert atmospheres, especially those generated on site through the use of combustion products of natural gas, is exposure to carbon monoxide. In some cases as much as seven or eight percent of carbon monoxide can be present in such atmospheres. Seven percent carbon monoxide is 70,000 parts per million (ppm). Exposure to this concentration of carbon monoxide would be fatal in minutes. Even when diluted to 1,000 ppm, exposure for only two hours could be fatal. Great care must be taken when using inert atmospheres containing carbon monoxide, to insure that employees are not exposed to even dilute concentrations of the atmosphere. If the tank had contained a toxic material, the concentration of this material must also be measured to be sure it is not present at a level that is toxic to workers.

OSHA STANDARDS
Two OSHA Standards that are applicable to workers who are employed in industries that use inert atmospheres are as follows:

1. The "Hazard Communication" Standard[12] requires that employees be informed of the

hazards of chemicals to which they may be exposed in the workplace. OSHA considers inert gases that are present in high enough concentration to present a suffocation hazard to be hazardous chemicals,[13,14] and requirements of the Hazard Communication Standard must be followed, including hazard evaluation, training, and signs and labels.

2. The "Permit-Required Confined Spaces" Standard[15] requires that before workers can enter a space that may contain a hazardous atmosphere, such as an inert atmosphere, a permit must be obtained, and other conditions must be met. Part of the requirement for obtaining the permit is testing the atmosphere to be entered for hazardous gases or vapors, and for oxygen content.

IMPLICATIONS

Inert atmospheres are used in many production processes. Great care must be taken to design and use these systems in such a way that employees are protected from exposure to these atmospheres. In addition, the inert atmosphere used must be consistent with the process with which it is used. Improper selection of the inert atmosphere, or the way it is used, can be harmful or fatal to employees.

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