VAISALA / APPLICATION NOTE

JUNE 2009

Oxygen measurement in inert applications

Unique solutions for:

- degassing silos
- chemical or pharmaceutical reactors
- centrifuges
- dryers
- mixers
- mills
- any other equipment containing flammable material

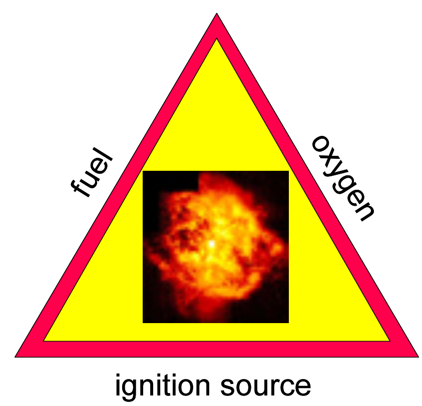

Figure 1. Ignition triangle.

This document provides general information about inerting processes and oxygen measurements in inerting applications.

What is inerting?

Inerting means the reduction of the oxygen (O_2) level inside a confined vessel using a non-reactive (inert) gas. Suitable gases for inerting include nitrogen, carbon dioxide, flue gas and noble gases. The main reason for inerting is fire and explosion prevention, but it can also be applied to prevent product degradation or discoloration or propagation of unwanted chemical reactions.

The target in inerting is either to eliminate oxygen or to reduce its concentration to a safe level. The inert gas is introduced into the vessel in order to displace oxygen. The vessel can be a storage tank or a degassing silo, a chemical or pharmaceutical reactor, a centrifuge, a dryer, a mixer or a mill or any other equipment containing flammable material.

Ignition triangle

Fuel, ignition source, and oxygen are all required for an explosion to occur. This is often presented in the form of an ignition triangle (Figure 1). Explosions can be prevented by elimination of at least one of these components. Inerting is conducted to remove oxygen in processes where fuel is present and ignition sources can't be totally eliminated. The fuel can't ignite if oxygen is excluded, thus explosions are prevented.

The following parameters are critical for fire and explosion prevention:

Lower Flammability Limit (LFL) and Upper Flammability Limit (UFL):

The terms LFL and UFL are used interchangeably with the terms Lower Explosion Limit (LEL) and Upper Explosion Limit (UEL), respectively. LFL and UFL are the lower and upper limits of the fuel concentration range, which supports flame propagation in the air - flame propagation cannot take place under LFL and above UFL.

In practical terms, a mixture below the LFL is too lean to burn or explode, whereas and a mixture above the UFL is too rich. The values for LFL and UFL are typically given in percentage of volume or in g/m^3 units.

LOC (Limiting Oxygen Concentration):

The Limiting Oxygen Concentration (LOC) is the Maximum Oxygen Concentration (MOC) in a mixture of combustible gas, air and inert gas, in which an explosion will not occur. Thus LOC is the lowest oxygen concentration supporting flame propagation.

It is not always possible to reduce the fuel concentration below LFL or keep it above UFL. Effective prevention for flame propagation can be provided by reducing the oxygen concentration below LOC by inerting.

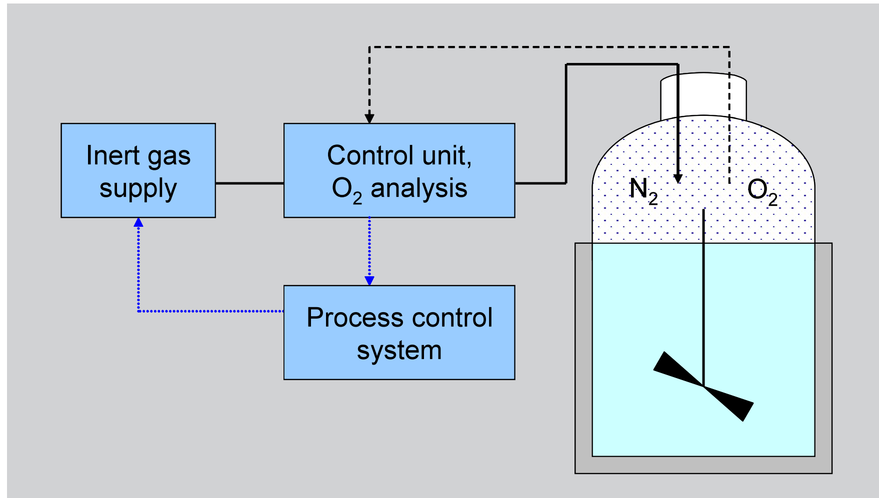

Figure 2. Flow through inerting of a chemical reactor or a storage tank.

Inerting methods

Several methods are applied in inerting:

- Vacuum inerting: A cycle of evacuation and re-pressurization to atmospheric pressure with inert gas is repeated until reaching the desired O_2 concentration.
- Pressure inerting: A cycle of inert gas pressurizing and venting back to atmospheric pressure is repeated until reaching target O_2 concentration.
- Vacuum-pressure inerting: A combination of the vacuum and pressure inerting techniques.
- Flow through inerting: Inert gas is fed into the system from a gas inlet and simultaneously vented at another point (Figure 2).
- Siphon inerting: The vessel is first filled with liquid. The inert gas is fed to the vessel simultaneously with the liquid removal to create an inert atmosphere.
- Displacement inerting: This method is based on density difference between the inert gas and the gas to be displaced, thus the gas in- and outlets are designed accordingly.

Why measure oxygen when inerting?

There are several ways of controlling the inerting process, including pressure, flow and oxygen monitoring. In flow monitoring the flow rate of the inert gas into the vessel is regulated, whereas in pressure monitoring the vessel pressure is controlled. As pressure reduces, more inert gas is fed into the system, whereas a pressure rise results in releasing of inert gas from the system through a vent valve.

Oxygen monitoring is the only one of the previously mentioned methods, where the composition of the inert atmosphere is controlled, see an example in Figure 2. Oxygen measurement enables the adjustment of the oxygen concentration exactly to the required level. Oxygen monitoring provides flexible control of the inerting process: transmitters can be installed in the inert gas generation system, the inert gas stream or the vessel itself or in multiple locations in the process. This is beneficial for the efficient control of the inerting process and for the potential reactive actions needed in process disturbance situations.

The driver for applying oxygen measurement in inerting applications might also be safety. Potential leakage of the inert gas from the confined vessel during operation or maintenance might result in oxygen deficiency and thus induce a risk of asphyxiation. It is worth considering whether oxygen transmitters are also needed outside the confined vessels in occupied areas.

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