Introduction

When recommending active fire protection systems, such as sprinklers in warehouses and archives or gas extinguishing systems in IT rooms, telecommunication centers, electrical switching and distribution systems, Allianz Risk Consulting (ARC) engineers are sometimes questioned by clients if oxygen reduction systems are an acceptable alternative solution, as suppliers promote them as such. They even indicate that oxygen reduction systems are a substitution to passive fire protection, such as fire walls.

This Tech Talk provides insight into the differences between oxygen reduction systems and inverting or gas extinguishing systems, including the often misused words of prevention versus protection.

In addition, ARC’s position and recommendations are provided for oxygen reduction systems.

Oxygen Reduction, Inerting & Gas Extinguishing Systems

Inerting and oxygen reduction systems add inert gases, such as carbon dioxide, argon and nitrogen, into an enclosure to lower the oxygen concentration. Gas extinguishing systems may use inert gases or so called "chemical" gases, such as clean agents and halon.

Gas extinguishing systems are designed to extinguish fires after they start, therefore, they are protection systems. Inverting systems are designed to prevent the formation of explosive mixtures of gases, vapors or dusts. Oxygen reduction systems are designed to prevent the occurrence or spread of open fires. Therefore, inverting and oxygen reduction systems should not be referred to as protection systems. Some system suppliers and installation standards use “preventive fire or explosion protection” wording for oxygen reduction or inverting systems, but this is contradictory and confusing.

Oxygen reduction, inverting and gas extinguishing all refer to the mechanisms in the following diagram, but with significant differences in the oxygen concentration levels:

The main difference between oxygen reduction systems and inverting or gas extinguishing systems is the required safety margin between the design oxygen concentration (C) and the ignition threshold oxygen concentration (B).

To safely fulfill the objectives of gas extinguishing and inverting systems, the design oxygen concentration has a much higher safety margin with regard to the experimentally determined ignition threshold (which differs for each ignitable / explosible material and may vary for a given material depending on the lab method used) than for oxygen reduction systems.
Therefore, caution is required when determining the design oxygen concentration of oxygen reduction systems, especially for mixed materials storage and for materials containing high air/oxygen concentrations.

For example, a material with an ignition threshold oxygen concentration of 17% would only require a 1% safety margin for oxygen reduction according to VdS 3527en or BSI PAS 95, leading to a design concentration of 16%. For gas extinguishing and inerting, a 10% safety margin is required to provide a design oxygen concentration of 7%. To avoid a smoldering fire, the design oxygen concentration should be reduced to 3 to 4% depending on the type of materials.

In addition, recent semi-industrial scale tests performed in France by CNPP showed that there is not a linear correlation between the development of a fire once the ignition threshold is passed. By contrast, there was an extremely rapid progression of the fire getting out of control only several tenths of a percent above that threshold.

It was also shown that once a fire starts, it will persist at oxygen levels much lower than the ignition threshold, or even the oxygen reduction design threshold, before it auto-extinguishes (sometimes auto-extinguishing oxygen concentrations where as low as 7%). Thus, the installation of a “booster system” activated by fire detection is often recommended by suppliers to lower the oxygen concentration; however, the effectiveness of this additional feature is questionable.

There are also much higher technical requirements for gas extinguishing and inerting systems with regard to monitoring and controlling the actual oxygen concentration in the enclosure to ensure it stays below the design oxygen concentration. This also translates into lower target oxygen concentrations (D) (the target value for the concentration controller) and lower acceptable oxygen fluctuation limits.

Concerns with Oxygen Reduction Systems

Protection of Workers

While outside the scope of property loss prevention, life safety is a serious concern in low oxygen atmospheres. There is ongoing debate and varying administrative approaches in different countries with regard to worker protection regulation.

Globally, Heath & Safety administrations require limited and controlled access to areas with oxygen concentrations below 17%, and a staged approach for the allowable duration of worker presence without self breathing apparatus in such areas according to the oxygen concentration. For example, 4 hours is the maximum duration in an atmosphere between 16 and 17% and 2 hours is the maximum duration in an atmosphere between 13 and 15% according to INRS ED 6126. No permanent workplace is allowed in an area below 13% and access requires wearing self breathing apparatus.

According to feedback from ARC clients, stringent medical surveillance for personnel entering low oxygen atmospheres have led to a permanent deactivation of oxygen reduction systems due to the difficulties to manage these constraints, sometimes increased by workers’ council scrutiny.

Performance and Maintenance

Building tightness is a key performance issue of oxygen reduction systems. Existing planning/installation standards, such as VdS 3527en, require a door fan pressurization test to verify the building enclosure is adequately sealed to prevent leakage. While a door fan test is feasible for small enclosures, such as IT server rooms (as would be for a gas extinguishing system), applicability of such a test to warehouses is highly questionable today.

Maintaining building tightness over time is already a big challenge for smaller rooms and it is even more difficult for warehouses given that initial tightness had been achieved during the construction phase. Client experience indicates installations of an oxygen reduction system in an existing warehouse regularly fail because sufficient building tightness cannot be achieved. This lack of tightness leads to either the inability to reach the required design oxygen concentration or the need to inject additional inert gas into the building on a permanent basis to make up for the leaks, which dramatically increases operating costs. Several systems have been shut down for this reason.

Oxygen Reduction System Standards

While Germany has been the front runner with regard to issuing an oxygen reduction system standard (VdS 3527en) other countries are catching up, such as the UK (BSI : PAS 95), and international organizations like CEN (European Standardization Organization) are now taking action to develop such a standard.
The challenge with international standards is that they face the necessity to find compromises that generally decrease the requirement level. An example for this situation is the current discussion by CEN to decrease or even eliminate the safety margin between ignition threshold and design concentration of oxygen reduction systems. While some local organizations, such as VdS, have withdrawn from the CEN works, others share their knowledge and findings with CEN, such as the recent semi-industrial scale tests performed by CNPP in France, to prevent unsound decision making.

But even “advanced” standards like VdS 3527en leave sufficient room for interpretation to require caution. For example, while stating the required location, number and type of measuring points for oxygen reduction systems shall be determined by hazard and inert gas, VdS 3527en also states at least two independent measuring points be provided. As a result, some suppliers install only two measuring points even for a warehouse of several tens of thousands of square meters floor area and still claim compliance with VdS 3527en.

**ARC Position and Recommendations**

ARC does not typically consider oxygen reduction systems alone as an alternative solution to active or passive fire protection systems. To consider the oxygen reduction fire prevention concept (also called hypoxic air fire prevention concept as indicated in the figure to the right), it must provide additional benefit to either an active fire protection system or a protection concept combining early fire detection, alarm transmission, manual fire extinguishing supported by an adequate fire water supply, and fire walls.

The added benefit, such as the delayed fire spread due to hypoxic air conditions, needs to be balanced against possible negative aspects with regard to accessibility (need for self breathing apparatus for the fire fighters) or disruption of hypoxic air conditions by permanent openings created by the fire fighters (either access doors or airlocks blocked open to lay fire hoses or even holes created in outer walls of the hypoxic air space to grant access in case doors are blocked or inaccessible).
Before planning to install an oxygen reduction system, please contact ARC to discuss the proposed application. In addition, the following should be thoroughly considered:

1. Top management should conduct a feasibility study to check / validate all potential consequences with respect to health & safety of personnel in all foreseeable situations (i.e. permanent workplace, maintenance work, emergency intervention, etc.) and evaluate all administrative requirements (i.e. legal, workers’ council, etc.) in this respect. Note that compromising on design oxygen concentrations or even target oxygen concentrations for personnel safety reasons is not an acceptable option.

2. Estimated operating costs should be scrutinized, especially with regard to maintenance costs, including foreseeable leakage in building / room tightness over time.

3. Proposed “booster systems”, either for personnel safety reasons or for enhanced hypoxic action in case of fire detection, should be challenged for real efficiency and added costs.

4. Qualified personnel should be available on site for permanent process control, maintenance and inspection of oxygen reduction systems. As with gas extinguishing and inerting systems, oxygen reduction systems have higher technical requirements in regard to monitoring and controlling real oxygen concentration in the enclosure to ensure it remains below the design oxygen concentration. This is crucial, especially for high volume hypoxic air spaces like warehouses.

References

(Germany) VdS 3527en : 2007-01 Inerting and Oxygen Reduction Systems, Planning and Installation

(UK) BSI : PAS 95:2011 Hypoxic air fire prevention systems. Specification

(France) INRS ED 6126 : Working in a low oxygen atmosphere – Recommendations for the protection of the workers and prevention aspects (document in French)

(France) CNPP EP 09-03 : Study of the system efficiency of oxygen reduction prevention systems (report in French ; synthesis of the study available in English)

Questions or comments? Please contact:
Christian Gissler
Technical Manager
ARC France
+33.1.58.85.58.52
christian.gissler@allianz.com