

AVOIDING EXPLOSIONS BY MEANS OF INERTING SYSTEMS

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The paper discusses the production of a new safety manual on Inerting of potentially flammable atmospheres. The manual was produced for a third party company following a serious explosion at one of their sites. No one was injured, but the failure of the Inerting system led to an explosion heard five kilometres away. The main approach of the new manual is on the management of Inerting systems, as well as design, installation and maintenance.

Keywords: explosion, fire, inert, Inerting, flammable, process, safety, incident, management, process safety management.

INTRODUCTION

It is often the case that an explosion occurs for a readily foreseeable reason. What is often not the case, however, is that a series of bizarre events occur, leading to an explosion, which, though foreseeable with hindsight, may not have been given credence from the unusual series of events necessary that preceded it.

After an explosion had occurred in a major company, and Chilworth Technology had investigated it, a series of failures was found leading back to the most basic design of the process. The pharmaceutical company had a means for drying powders inside a drying ‘oven’, and the drying process consisted of ensuring that all water and solvents present were evaporated and extracted to atmosphere, under an inert gas blanket.

When the explosion occurred, it was heard five kilometres away, but, fortunately, no one was injured.

This paper is not on the cause of the incident, nor on why failures occurred in the installation concerned. What it is concerning, is the lack of suitable guidance preceding their explosion on one particular aspect of safety. That is the topic of Inerting. It was the Inerting system that failed, and had several defects in it, which had accumulated over the years after initial installation, culminating in the explosion.

Whilst, prior to the incident, there were five documents in general use on the topic of Inerting, there was not one which covered the topic of management of an Inerting system, nor which covered maintenance of an Inerting system. Therefore Chilworth Technology, in conjunction with the company concerned, devised a Design Concept to cover such issues for future use by the company.

EXISTING GUIDANCE

There are several existing guidance documents on Inerting. These are:

1. Factory Mutual. Property Loss Prevention Data Sheets. 7-59. 1977, revised 1998. Inerting and Purging of Tanks, Process Vessels and Equipment.

2. VDI 2263 Part 2, 1992. Dust Fires and Dust Explosions: Hazards – Assessment – Protective Measures.

3. Guide to Dust Explosion Prevention and Protection. Part 2 – Ignition Prevention, Containment, Inerting, Suppression and Isolation. C. Schofield and J. A. Abbott. Institution of Chemical Engineers.

4. NFPA 69, 1997. Standard on Explosion Prevention Systems

5. ESCIS Booklet 3, 1994. Inerting. Methods and Measures for the Avoidance of Ignitable Substance-Air Mixtures in Chemical Production Equipment and Plants.

These all cover the establishment of inert atmospheres adequately, so no detailed calculations are given in this paper. Reference to the above documents is recommended.
However, what none of them cover is the Management of Inerting systems.

After the explosion, Chilworth Technology attempted to combine the existing documentation with existing knowledge of safety management systems. This produced a Design Concept, which could then be applied to new or existing Inerting systems to determine whether they are managed appropriately.

What the guidelines tried to produce was a logical means of ensuring that the Inerting system for any hazardous process is designed, installed, maintained and MANAGED to an acceptable level of safety.

The Design Concept, as with all guidance, is open to interpretation and is not rigid. Chilworth Technology personnel created it, and the information it contains is, generally, in the knowledge of Chilworth Technology, even though the company concerned published the document internally. Chilworth Technology cannot offer sight of the document, as it is not their property. However, the following aspects of the lecture will cover how the topic of Inerting is assessed from design, through to commissioning and maintenance, and includes comments on the management of the system. The overall aim is to try to ensure such a major incident does not occur in another company, due to lack of knowledge of the Design Concept.

The Design Concept is intended to ensure that all aspects of design and management are covered, and define certain terms in association with Inerting. This means that certain items, such as Critical Safety Items, are defined, with respect to Inerting. When an item is a Critical Safety Item, it must be suitably assessed to ensure that the Level of Integrity of the item is capable of ensuring that a suitable Basis of Safety exists.

INERT GASES

The guidelines cover different types of gases used for Inerting. Carbon dioxide, nitrogen, noble gases, steam and flue gases, are all types of gases that can be used for Inerting.

The type of gas used should be determined by taking into account the following factors:

Cost;
Availability;
Reliability of supply;
Effects of contamination of product by inert gas, and
Effectiveness in reducing explosibility.

OPERATIONAL OXYGEN LEVEL DETERMINATION

There are four stages to be taken into account when considering oxygen levels in an inerted atmosphere. These are:

Limiting oxygen concentration;

Maximum permissible oxygen concentration;

First alarm level, and

Normal operating conditions.

The Limiting Oxygen Concentration (LOC) is the level applicable at the operating temperature and pressure. The value determined in/by the laboratory may not be directly applicable if the operating temperature or pressure is different, or if the experimental gas was different – obvious, but sometimes overlooked.

But this level has no safety margins, and is therefore a level at which any increase in oxygen leads to a flammable atmosphere.

Hence, a lower value, known as the Maximum Permissible Oxygen Concentration (MPOC) is used to obtain a safety margin. This is the safety shutdown level, and if the oxygen level is monitored and allowed to reach this level, the plant should shut down in a safe condition.

The MPOC is generally accepted as being two percentage points below the LOC, but this depends on factors such as how quickly the oxygen concentration can rise in case of failure of the Inerting system.

Below the MPOC is the maximum set point - normal alarm level. This is a level at which plant alarms sound, and which the operator can take reasonable action to try to recover the situation, prior to the oxygen level reaching plant shutdown. This should be set at a suitable level below the MPOC, and would depend upon the sensitivity of the equipment used to detect the oxygen levels.

Below the maximum set point is the set point – normal operating conditions. This is the level to which the plant is normally controlled.

It is apparent that if the LOC is not known for the chemical being inerted, then the MPOC cannot be set. If the MPOC cannot be set, then the normal operating conditions cannot be fully listed. Hence, for any plant relying on Inerting as a Basis of Safety, the LOC, MPOC, Maximum Set Point and Normal Operating Conditions must be listed and recorded. It is only when the plant is operated outside these figures, or with materials irrelevant to the recorded figures, that incidents can occur.

In other words, we start to see the beginnings of the requirements for managing the Inerting systems.

METHODS OF INERTING

The method of *Inerting* chosen will depend upon several factors, as follows:

1. The process itself, continuous or batch (or simple storage);

2. The design pressure of the equipment, i.e. its suitability to withstand pressure or vacuum;

3. The financial implications of the various types of *Inerting*: demand, price, type of generation, constant flow or intermittent flow, etc.

4. Health and ecological considerations.

In addition, there are several different types of inert gases available, for instance carbon dioxide and nitrogen, which are the usual gases, but also on-site exothermic gas generators, endothermic gas generators, noble gases, steam and flue gases from boilers, furnaces etc.

They all have different characteristics, but the choice of inert gas is usually led by (a) availability of supply, and (b) the phrase 'everyone uses nitrogen'.

It is usual to use nitrogen, but it must be realised it is not the only gas available, and others may be more obscure, but, for given functions, may be more desirable.

The purpose of the choice of inert gas is to satisfactorily ensure that the concentration of oxygen in the atmosphere never reaches the level at which an explosion can be supported. In order to ensure this aim is achieved, the Inerting system must be appropriately designed.

DESIGN

The atmosphere in the plant item should never reach a higher level than the MPOC. This concentration is determined by applying several safety factors to the LOC.

However, before the MPOC can be calculated, the LOC must be determined. This can be from such sources as Material Safety Data Sheet (MSDS) Lists, from the lists given at the end of the manual, or from test data. Tests should be carried out by laboratories experienced in this field, such as Chilworth Technology.

The method for determining the MPOC takes into account the following factors. (An example of MPOC determination is given in section 4.1.)

a) A correction for any difference in temperature and pressure for the determined value of the LOC and the operating conditions.

b) A margin which will allow for oxygen concentrations, safety measurement delays, instrument errors and lags, and alarm delays. It is usual to subtract a figure of 2 percentage points to give this margin, although occasionally this margin may need to be increased.

The MPOC can be considered an automatic shut down level. Below this are two other levels, ‘first alarm level’ and ‘normal operating conditions’. These are determined from the following:

c) A margin to ensure spurious (false) alarms do not occur – this would depend on the reliability and time lag in the instrumentation utilised.

d) Where the Limiting Oxygen Concentration is below 5 per cent, and the plant is continuously monitored, the plant shall not operate at any level higher than 60 % of that Limiting Oxygen Concentration.

e) Where the plant is NOT continuously monitored, the plant shall not operate at any level higher than 60 % of that Limiting Oxygen Concentration. If the Limiting Oxygen Concentration is below 5 per cent, the plant shall not operate above 40 % of that Limiting Oxygen Concentration.

Therefore, if a plant uses a continuously sampling oxygen analyser, (a), (b) and (c), above, hold. If the Limiting Oxygen Concentration of the material is below 5 %, then (d) has an effect and the set point must be less than 60 % of the Limiting Oxygen Concentration.

If a plant does not use a continuously-sampling analyser, or does not use an analyser at all, then (a), (b) and (c) hold in conjunction with a limit on the operating level of no higher than 60 % of the Limiting Oxygen Concentration. If the Limiting Oxygen Concentration is below 5 %, then (e) applies and the plant cannot have an operating level greater than 40 % of the Limiting Oxygen Concentration.

Hence, the four levels of oxygen concentration applicable to each inerted atmosphere should be recorded for every system that relies on inert gas Inerting as its Basis of Safety.

If the LOC for any of the flammable materials in the plant is not known, then the above cannot be completed correctly. Thus, the Limiting Oxygen Concentration must be known for every flammable material for which Inerting is to be the Basis of Safety.

In the case of flammable gases or vapours and dusts occurring together, the lowest Limiting Oxygen Concentration should be used, if no specific data for the hybrid mixture have been determined. The Limiting Oxygen Concentration of the flammable hybrid mixture will not be lower than the lowest value.

There are several ways of designing a process to operate with an inert atmosphere in them. But, however they are designed, all such plants should have a suitable way of ensuring the inert atmosphere is present prior to the flammable material being introduced.

A brief summary of each is as follows.

PRESSURE-SWING INERTING

In this method, the plant atmosphere is pressurised with inert gas, and then depressurised. This continues for a calculated number of cycles, whereby the oxygen concentration will have been reduced to a known concentration.

FLOW-THROUGH INERTING

Flow through Inerting is undertaken when the plant cannot stand increased pressure. In this case, inert gas is allowed to pass through the plant, displacing oxygen (air) in its path. This method, like above, can give calculable results, but on the often incorrect assumption that perfect mixing is taking place throughout the plant, and that there are no dead spots.

Whilst a pipeline can be adequately purged with flow-through Inerting, the same cannot always be said for industrial plant. If the system is complex, involving side branches through which adequate circulation cannot be established, this method may be impractical and one of the other methods may be more suitable.

VACUUM PURGING.

This method is useful if the plant to be inerted can withstand a vacuum. The plant pressure is reduced to a low internal pressure, and then the vacuum is broken with an inert gas. If necessary, the vacuum/break cycle can be repeated a number of times to reach the desired oxygen concentration.

SIPHON PURGING.

This is similar to vacuum Purging. However, the plant (more appropriately a storage tank) is filled with an inert liquid (say water), then as the liquid is drained out of the tank, inert gas is allowed to replace it.

The benefit of this method is that the required volume of inert gas is exactly equal to that of the vessel being inerted. It also requires only one cycle.

Whilst the above is a suitable method for Inerting vessels that have an outlet at high level, it is obviously not suitable for any item of equipment where air might be trapped inside a void. Additionally, it may not be suitable where the vapour pressure of the inert liquid is high enough to prevent all the vapour space being replaced by inert gas.

The important point to be made is that the flow dynamics have to be checked if dead spaces can occur.

RECORDING

For each plant one of the above methods should be documented as the Inerting method. The operational parameters should be recorded; e.g. length of time of purge, or number of pressure (or vacuum) /relief cycles. This, again, becomes a part of the documented Basis of Safety for the plant.

It would be useful at this stage to also include any calculations undertaken to show how the time or number of cycles was determined. Then, in the future, operational changes can readily be recalculated.

VERIFICATION

Once an inert atmosphere has been established, its presence needs to be verified before any flammable materials are admitted. There is the possibility of stratification with flow through Inerting, and air ingress with all methods of creating the inert atmosphere. Hence, the *Basis of Safety* has to be assured before flammable materials can be admitted. In fact, the admittance of the flammable materials can, in itself, allow air into the plant.

This may be due, for instance, to air being added with powders (bulk powders can contain up to 50 % of their volume as air), or air being pumped in from a nearly-empty drum.

Air can also access the plant if the inert atmosphere fails or is displaced, for whatever reason. These could be because of:

- Convection
- Density differences – air to inert gas
- Diffusion
- Manholes and other charging operations
- Leaks
- Negative operating pressure compared to ambient (i.e. operating under vacuum)
- Temperature
- Operating errors
- Pumping air, not liquid, when the tank is virtually empty
- Air entering when discharging liquids from the plant.

There are several methods of undertaking verification. The preferable one being, simply, measuring the oxygen concentration within the plant. Another is by ensuring inert gas keeps flowing into the plant, or the plant remains under a positive pressure. A few are discussed below.

OXYGEN ANALYSIS

In general, if an oxygen analyser is used, the oxygen concentration can be monitored continuously, cyclically or at random. If the system is totally self-contained, or is operating under slight negative pressure, then continuous monitoring is required. Conversely, monitoring at random assumes good working knowledge of the plant, and what the likely failure scenarios are. This information may have been obtained by continuous monitoring over a period of time, before the conscious decision was taken to reduce the sampling intervals.

The requirement for continuous monitoring on systems working under negative pressure applies only to those systems that rely on Inerting as a Basis of Safety. If a system is operating under near full vacuum, the Basis of Safety is then the presence of the vacuum, not inert gas Inerting.

The oxygen analyser should preferably sample from multiple parts of the plant. These points should not be close to an inert gas inlet, or to an outlet. In the former situation, this is to prevent sampling the inert gas, and not the actual contents. In the latter case this is because there is the chance of the flow-through gas bypassing most of the plant, and exiting directly through the vent.

The oxygen analyser must be capable of giving an alarm in the event of lack of flow into the analyser, reduced flow, or any other parameter that could indicate potential problems. If the situation becomes unsafe, and there is the possibility of the oxygen level increasing beyond the safe operational envelope (i.e. the MPOC), the plant should go to immediate automatic shutdown.

It may be difficult to determine what the possible alarm situations could be, and what effect they could have on the integrity of the plant. It is therefore useful at this stage for a competent Instrument Engineer to draw up a Cause and Effect Table. This is a table of identifiable failures of the instrument, and the outputs (or lack of them) that would result. As an example, power failure to the instrument may cause the visual gauge to drop to Zero. This would then indicate a situation in which there was no oxygen in the plant, and hence the plant was safe. This is obviously not the case, so appropriate alarms would be necessary to identify these situations.

Whatever system is used it must:

- be capable of analysing a representative sample of the contents of the plant;
- responding to alterations in the oxygen content of the plant with reasonable rapidity;
- be capable of raising a first-stage alarm;
- be capable of causing an emergency shut down automatically, or, at the very least, raising an alarm which instigates a shut down procedure;
- be repeatable and verifiable;
- be installed in accordance with the manufacturer's instructions;
- be maintained in accordance with the manufacturer's instructions;
- not be altered in any way without the manufacturer's agreement, or a suitable Management of Change procedure being carried out;
- not be capable of indicating a fault condition that is not readily detectable by alarms, indicators etc., e.g. zero or full scale deflection.

PRESSURE INDICATION

Whilst pressure indication on the plant can assure the operator that the plant is operating at too high a pressure to allow air in, it does not confirm that the atmosphere inside is actually inerted. Nor does it ensure that air is not admitted through powder admission or manhole activities etc. Pressure indication alone is therefore not considered to be suitable as verification.

VACUUM INDICATION

As was stated earlier, any system that operates under negative pressure should have the oxygen content monitored constantly. This is to ensure that leaks of air into the system do not occur without being readily detected.

This requirement does not extend to those systems that are operating at less than 100 mbar absolute. At this pressure, an explosion would not increase the system pressure greater than ambient. Also, any system that operates below 50 mbar absolute is incapable of supporting an explosion.

Hence, a system that operates below 100 mbar absolute has the presence of the vacuum as its Basis of Safety, and does not use Inerting as a means of explosion prevention. Thus the requirement for the constant analysis of oxygen is removed.

Failure of the vacuum system could easily lead to a dangerous situation, hence, this needs special consideration as a Safety Critical Item, but this is beyond this paper.

FLOW INDICATION

The flow of inert gas into the plant could be indicative of maintenance of a suitable inert atmosphere. However, the following points would also need to be addressed.

- Is there the possibility of the inert gas leaking from the supply pipe, but beyond the meter? This would show inert gas flowing into the plant, when actually it was leaking to atmosphere. If this is a possibility, this system in conjunction with pressure indication could suffice.

- Is the inert gas fed into suitable inlet locations? Admitting inert gas at the incorrect locations may lead to a false sense of security. The inert gas feed must be capable of maintaining a suitable sweep of any air admitted into the system, for instance at powder addition locations.

TIME

The parameter of time can be used, for instance, once the purge duration has been calculated, a valve can be opened for a set period of time. This will then allow the calculated amount of inert gas through, which will then inert the atmosphere as calculated.

Obviously, this will not always be the case, and no system is perfect. Therefore the system of Inerting has to be suitably managed.

MANAGEMENT

The purpose of the manual is to try to establish safe operational parameters for the Inerting system under consideration. In order to be 'safe', it is essential that the numbers of levels of safety are commensurate with the risk and the consequences of an incident.

Whilst the greater the levels of safety that are provided, the safer the system is, it can still be perfectly justified to allow a single Safety Critical Item to manage the safety of a large, dangerous, process. However, this is only if the Level of Integrity of that item is suitable.

It is more than likely to be common place that extra levels of safety are required to supplement any Safety Critical Items identified. Similarly, the extra costs incurred in ensuring that the integrity of any remaining Safety Critical Item is suitable, are liable to be prohibitively expensive compared to duplication or triplication of the item.

When Low Probability High Consequence events are considered, it is unlikely that any Safety Critical Items can be tolerated at all. In fact, it is probable that the items under consideration should be duplicated, or even triplicated by equipment that is not subject to Common Mode Failure. Hence, it would not be necessary to examine the hazardous situations caused by failure of a single item, but rather, to consider the implications of failure of any common denominators in the control or operational systems involved.

NOTE. The guideline comments on two independent means of identifying the presence of an inert atmosphere, and two independent means of ensuring it is present at all times a potentially-flammable atmosphere is present. However, when referring to redundancy, this is applied to each of the parameters, and not to the number of parameters chosen. Thus each of two independent means may, in themselves, be triplicated, if necessary.

But this analysis only supports the philosophy behind the manual. A low risk low consequence system can have one or more Safety Critical Items throughout the process; a high-risk high consequence system cannot have any Safety Critical Items. In between, the process must be subject to a standard risk assessment.

Maintenance becomes a crucial part of the Basis of Safety when two or more systems are installed to prevent either being a Safety Critical Item. For, if one of the items fail, the other, by definition, then becomes a Safety Critical Item. Hence, whilst there is a back up, neither can be called safety critical, but if maintenance of one lapses, the integrity of the other becomes more crucial.

CHANGE

The operational parameters, settings and alarm levels should not be changed without a full Change Assessment. This should cover the implications for start-up, shutdown, normal, abnormal and emergency operations. It may be suitable to re-visit the Hazard and Operability Study, or other documentation.

The above paragraph also applies when there is a change to any of the chemicals and equipment used in the plant. For instance, a replacement solvent, a different grade of material, etc.

Change is defined as any 'changes to process chemicals, technology, equipment, and procedures, and changes to facilities that affect a highly hazardous process.' There should be adequate procedures to address the principle of change, and the following should be given adequate consideration:

- the technical basis for change;
- impact of change on safety and health;
- modifications to operating procedures;
- necessary time period for the change; and
- authorisation requirements for the proposed change.

If the change results in modifications to Standard Operating Procedures (SOPs), Piping and Instrumentation Diagrams (P&IDs) or any other Process Safety Management (PSM) information associated with the highly hazardous process, this information must be updated accordingly. All employees who may be affected by a change in the process must be informed of, and trained on, the change before start-up. This requirement includes contractors.

BASIS OF SAFETY FILE

All the documentation produced by the above should be kept in, for example, a Basis of Safety File for the plant concerned. Then, in the future, the method of establishment and maintenance of the Basis of Safety will be readily to hand.

This file (or other such documentation) should contain the following information:

1. Material being protected;
2. Limiting Oxygen Concentration;
3. Maximum Permissible Oxygen Concentration;
4. Process Safety Matrix category;
5. System shut down alarm setting;
6. Operational alarm setting;
7. Method of Inerting;
8. Time (or volumetric) purge parameter;
9. Pressure of vacuum levels;
10. Number of pressure or vacuum cycles;
11. Verification system utilised;
12. Verification measurement parameter;
13. Maintenance schedule for measuring equipment;
14. Manufacturer's recommended spares holding for the same;
15. Manufacturer's operating instructions for the measuring equipment;
16. Trip schedule;
17. List of any Safety Critical Items;

18. HAZOP, Computer Hazard and Operability Studies (CHAZOP) and Hazard Analysis (HAZAN) undertaken on the system, as appropriate;
19. An appropriate flow diagram;
20. Piping and Instrumentation Diagram;
21. List of ignition sources identified and methods of control;
22. Brief justification for the Level of Integrity afforded by the control system;
23. A statement justifying the decisions made in arriving at the Level of Integrity afforded the control system. This is recommended for all cases, but is considered mandatory for all systems which have a Safety Critical Item that creates the inerted atmosphere, or have a Safety Critical Item confirm its presence.

PROCEDURES

Once the Inerting system has been designed, installed and verified, it is possible for it to operate unsupervised. However, the Inerting system has been designed and installed as the sole Basis of Safety, and cannot be allowed to deteriorate.

The duty of management in this situation is to ensure that the system continues to operate within the boundaries that were determined when it was originally installed. Any modifications to the system should go through a Management of Change Procedure, which should compare the proposed modifications with the Basis of Safety File. This will establish whether it is foreseeable that the Basis of Safety can be negated by the proposed changes.

Similarly, if it is decided that maintenance intervals should be lengthened, then the equipment will not receive the same amount of preventive maintenance that the Basis of Safety depends on. This again would need formal managerial review and consideration.

Hence, it is suggested that, if they do not already exist, the following systems for the management and maintenance of Inerting systems be established.

1. Management of Change Procedure.
2. HAZOP, CHAZOP and HAZAN of systems.
3. Permit to Work and Vessel Entry procedures;
4. A procedure for identifying repetitive failure of Safety Critical Items.
5. A procedure to ensure that regular calibration occurs for all instrumentation on which establishment of the inert atmosphere depends and on which verification of the establishment of the inert atmosphere depends. Also, procedures should exist for instrument technicians to draw attention to any deviation from ‘normal’ readings.
6. A system for obtaining the Limiting Oxygen Concentration of any new materials to be processed. A written procedure should exist for determining what the Maximum Permissible Oxygen Concentration, alarm level and operating level should be for that new material, and for ensuring it is implemented.
7. A system to provide full traceability of all change of operational parameters (which would usually not be considered in a Management of Change analysis).
8. The SOPs should include the principles of control and verification of the inert atmosphere.
9. Control and alarm settings should be recorded in the trip schedule, a copy of which is retained in the Basis of Safety file.

10. Procedures should be established for validation of the inert atmosphere during pre-commissioning, possibly via independent (possibly manual) sample checks to ensure that the control settings (i.e. time, flow, pressure and oxygen levels) are correct to ensure a safe oxygen level is achieved.
11. Maintenance procedures for Safety Critical Items should ensure that such work is carried out on a mandatory basis.
12. Procedures should exist to ensure that breakdown of Safety Critical Items is monitored as a high priority, and necessary actions are then taken to ensure the integrity of the Inerting system is maintained at all times.
13. Procedures should be set up to ensure that re-validation and calibration of the control instrumentation is carried out at defined, predetermined intervals.
14. A procedure should ensure that testing of the inerted system includes the entire system, as well as individual unit operations.
15. A procedure should ensure that the Basis of Safety file, and its contents, is reviewed in the light of new information or new Standards.

The requirements for the design and installation of Inerting systems are contained within the manual. However, management of the system, once installed, is outside the scope of this document. Nevertheless, there should be systems for identification of unsafe conditions, potentially unsafe conditions and unusual conditions. The systems should then ensure that these conditions are drawn to the attention of an appropriate person, who can ascertain whether action is required, or not. These systems are a part of the maintenance of the Basis of Safety, and should therefore be referred to in the Basis of Safety File.

If the structure of the document is followed, the design, assessment, maintenance and management of the Inerting systems should be to a standard that is as safe as is reasonably practicable.

The whole intention of the document is to ensure that the Basis of Safety is formally identified and managed. In essence the manual is attempting to follow the logic of:

a) What is the Limiting Oxygen Concentration?
b) How is the Inerting carried out to ensure that the oxygen level never exceeds the Limiting Oxygen Concentration of the materials being processed?
c) How is the system managed?

Provided the above three points are addressed correctly, a flammable mixture should be prevented from forming, and the system will be running at a level of risk that is as low as is reasonably practicable.

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