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Partial inerting – A possible means of eliminating the brush-discharge-ignition hazard with explosive gases and vapours?

M.J.H. Henden [a], P. Kosinski [b], B.J. Arntzen [b], W. Olsen [b], R.K. Eckhoff [b,*]

[a] Scandpower AS, Fjøsangerveien 50B, N-5059 Bergen, Norway
[b] University of Bergen, Dept. Physics and Technology, PO Box 7803, N-5020 Bergen, Norway

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ABSTRACT

It was found that the brush discharge ignition hazard with IIA gases/vapours (propane) can be eliminated by reducing the oxygen/nitrogen volume ratio in the atmosphere to the order of 15/85. The condition is that the diameter of the earthed electrode ≤ 40 mm. Published information on whether an oxygen/nitrogen ratio of 15/85 is acceptable as regards the oxygen deficiency hazards is contradictory. With IIB gases/vapours (ethylene) the oxygen/nitrogen ratio must be reduced to at least 10/90 to eliminate the brush-discharge-ignition hazard. Lowering the oxygen/nitrogen ratio to this level will undoubtedly present a substantial oxygen deficiency hazard to humans.

1. Introduction

1.1. Gas explosions – an industrial hazard

Accidental gas/vapour explosions present a potential hazard in all industrial processes where explosive gas/vapour atmospheres can occur. The types of industries of concern include oil and gas production facilities and refineries, petrochemical and chemical process industries, and nuclear industries. In all industries faced with a gas/vapour explosion hazard various methods for preventing and mitigation such explosions are implemented. Fig. 1 shows a typical event tree of an accidental gas explosion following an accidental gas leak.

The various actions normally taken to prevent and mitigate accidental leaks and subsequent accidental gas/vapour explosions are indicated in the rectangular boxes embracing the event tree itself. As Fig. 1 shows one important means of reducing the explosion hazard is to prevent ignition sources.

The present investigation focuses on the ignition hazard by electrostatic brush discharges, i.e. comparatively weak one-electrode discharges between a charged electrically non-conducting object and a conducting earthed electrode. According to Glor [2] brush discharges are likely to occur if the radius of curvature of the tip of the earthed electrode is at least 5 mm. Whereas electrostatic spark discharges between two electrically conduction objects can be effectively prevented by earthing and bonding, it is generally more difficult to prevent brush discharges. It was of interest, therefore, to study whether the ignition hazard by such discharges may be eliminated by partial inerting of the explosive atmosphere.

The explosion hazard presented by the very energetic propagating brush discharges, which are also one-electrode discharges, are not considered in the present paper. If circumstances are such that propagating brush discharges could occur, special actions have to be taken to eliminate this possibility.

1.2. Partial inerting – a means of eliminating the brush-discharge ignition hazard?

The concept of partial inerting was discussed by Eckhoff [3] in relation to dust explosion mitigation. The idea is that both the ignition sensitivity and the explosion violence of explosive fuel/air mixtures are reduced if the explosive cloud is mixed with an inert gas, e.g. nitrogen. However, as can be seen from Fig. 1 neither complete nor partial inerting is included in the classical event tree for accidental gas/vapour explosions. This is because most accidental gas/vapour explosions are initiated and take place outside process equipment, where it would be very difficult and expensive

* Corresponding author. Tel.: +47 5558 2858; fax: +47 5558 9440.
E-mail address: rolf.eckhoff@ift.uib.no (R.K. Eckhoff).

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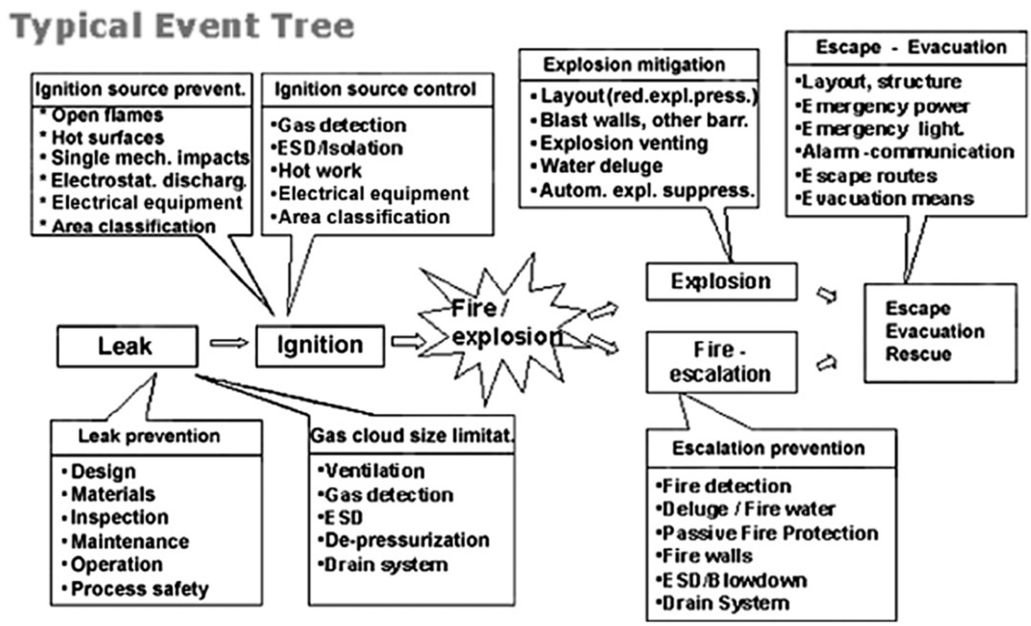

Fig. 1. Event tree for an accidental gas explosion following an accidental gas leak. From Eckhoff [1] with kind permission from Gulf Publishing Co., TX, USA.

to maintain a fully or partially inerted atmosphere. Therefore, the applicability of partial inerting seems to be limited to fully or nearly fully confined spaces, e.g. storage rooms.

The specific question addressed in the present investigation is this: Can minimum electric spark ignition energies (MIEs) of air/IIA gases/vapours (propane) and possibly also air/IIB gases/vapours (ethylene) in air be raised to above the "equivalent energy" of electrostatic brush discharges by controlled advance mixing of nitrogen into the air, without the reduced oxygen concentration imposing unacceptable oxygen deficiency hazards to humans?

1.3. Effects on humans of reduced oxygen content in the atmosphere

Table 1 summarizes some data from Marshall [4] and Jefferson Lab. [5]. The data from Marshall [4] only covers the range of oxygen concentrations from 12 to 14 vol.% and downwards, and even at the highest concentrations of 12–14 vol.% the oxygen deficiency effects are quite serious and clearly unacceptable for normal working atmospheres. The data from Jefferson Lab. [5] also covers the range of higher oxygen concentrations. The effects described by the two sources with 15 resp. 12–14 vol.% oxygen correspond quite well.

Jefferson Lab. [5] adopted a rather restrictive policy as to the minimum acceptable oxygen concentration in working atmospheres. Their minimum value is 19.5 vol.% and they claim that even at this concentration the atmosphere has to be considered as oxygen deficient. In any case they do not allow personnel in their plants to enter or occupy areas where the oxygen concentration is <19.5 vol.%.

Unlike these views, Hypoxic Technologies [6] claim that people without any heart or lung problems will be able to breathe safely for up to 6 h in an atmosphere containing as little as 15 vol.% oxygen. However, if physically demanding work is to be carried out in this atmosphere, or the people concerned suffer from heart or lung problems, a health check has to be undertaken. In the worst case breathing in this kind of atmosphere can cause temporary headache and nausea, which disappear when returning to breathing in normal air.

Minimum permissible oxygen concentrations in industrial atmospheres as regards threats to humans will depend on the specific prevailing circumstances. It may seem reasonable to anticipate that the minimum acceptable limit has to be quite high in normal working atmospheres, whereas somewhat lower limits may be acceptable in atmospheres which are only visited by people infrequently and for short periods.

2. "Equivalent energy" of brush discharges

The concept of "equivalent energy" of electrostatic brush discharges was probably first introduced by Gibson and Lloyd [7]. It is defined as the minimum electric spark energy (MIE), using electric spark discharges between two electrically conducting electrodes, of an explosive gas mixture that can just barely be ignited by a brush discharge. Lüttgens and Wilson [8] stated that brush discharges may be assigned equivalent MIEs in the range 1–4 mJ. According to Krämer and Glor [9] equivalent energies of brush discharges are in the range of a few mJ. Lüttgens et al. [10] were more specific and suggested a value of 3 mJ. However, none of these statements were accompanied by any specification of the method(s) used to determine the MIEs on the basis of which the statements were made.

Glor [11] carried out a series of important experiments to determine the equivalent energies of brush discharges. He concluded that about 3.5 mJ is a sufficiently conservative estimate of the upper limit. Glor's experiments are of prime interest in the present context, not least because he used mixtures of propane, air and nitrogen to determine his equivalent energies.

Hence, in the first part of his work he determined MIEs of propane/air/nitrogen mixtures as a function of added fraction of nitrogen. However, he did not provide any details of the method used for determining the MIEs, but, as will be discussed in Section 5 below, it appears from his results that the method used for deriving MIEs from the primary ignition data was at least as conservative as the method used by Lewis and von Elbe [12]. This means that it produced significantly lower MIEs for the propane/air/nitrogen mixtures tested than the values that would result from the Moorhouse et al. [13] method used in the present study. A possible reason for this discrepancy was discussed by Eckhoff, Ngo and Olsen [14].