Journal of Electrostatics xxx (2017) 1–6

Contents lists available at ScienceDirect

Journal of Electrostatics

journal homepage: www.elsevier.com/locate/elstat

Ignition of a cloud of dry powder using super brush discharges

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ARTICLE INFO

Article history:
Received 13 October 2016
Accepted 6 January 2017
Available online xxx

Keywords:
Static electricity discharge
Process safety
Ignition source
Superbrush discharge
Ignition source

ABSTRACT

Ignition of a cloud of dry powder is a major concern in the field of industrial process safety. The different types of discharges are already defined (spark discharges, brush discharges, propagating discharges, cone discharges, corona discharges) such as their ignition properties in a gas or a dust atmosphere. For example, it is known that a classic brush discharge cannot ignite a cloud of dry flammable dust [6,13]. Glor and Schwenzfeuer performed direct ignition tests using brush discharges and defined that even if the energy released by this kind of discharge equaled the one of a spark, the power released by the brush discharge is too low to trigger an ignition.

However, some doubts remained for super brush discharges. A brush discharge as a super brush discharge occurs between a charged insulating object and a conductive electrode. The main difference lies in the surface charge density reached on the insulator that is much higher for a super brush discharge than for a brush discharge. A high charge density can be reached for example using pipes of polyethylene individually charged by tribo-charging piled one above another. Such a configuration was evocated by Lüttgens [12] and tested by Larsen [11] who performed direct ignition tests in oxygen enriched atmospheres.

This study is relevant with the actual safety problems since pharmaceutical and chemical powders are well known to generate electrostatic charges during their transport or handling and since the same configuration of independent polyethylene fibers can be found in flexible bulk containers that are one of the most common solutions to package this kind of powder.

This paper presents the experimental set-up and the results of direct ignition tests performed with a polyethylene wax whose MIE is lower than 1 mJ at ambient conditions. The electric field reached at 1 m and the charge transfer were also registered and are described. Finally, numerical simulations are carried out to define the original surface charge density in order to help to understand the phenomenology of this discharge and its frequency of occurrence in industry.

1. Introduction

Explosion protection is of major concern in the field of process safety and remains an ongoing process. The French office of technological accident feedback took an inventory of 61 explosions in chemical or petrochemical facilities in 2014 [1]. In order to harmonize all the different methods in the different European countries, the so called ATEX legislation was developed and applied in 1999 [3]. Since then, an explosion protection document is required in each plant where a flammable atmosphere is susceptible to appear [7,10]. It aims to define if the frequencies of an explosive atmosphere and of an associated ignition source remain reasonably low enough considering the expected consequences. In Switzerland, two domains are thus defined: a safe one and one where corrective actions should be carried out (Fig. 1). Above those two domains, the consequences of an explosion need to be assessed to really identify the configurations that must be improved as soon as possible. Forestier [4] proposed a method based on the SIL decision tree to rank by priority the different actions to be taken.

The EN 1127-1 [2] states that 19 different ignition sources should be investigated and among them, five are related with static electricity.

1.1. Static electricity hazards in the industry

The hazard of static electricity in the process industry has been widely studied [5,12]. Six types of discharges are identified:

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http://dx.doi.org/10.1016/j.elstat.2017.01.005

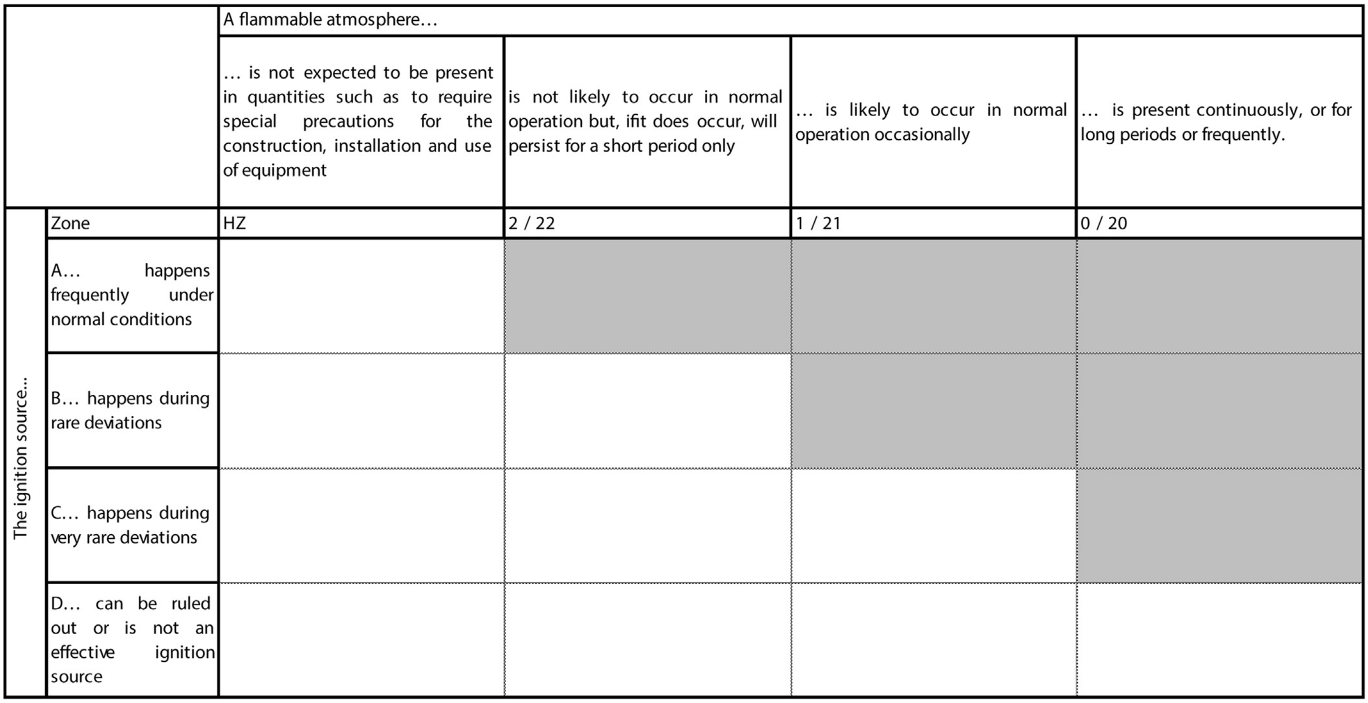

Fig. 1. Hazard matrix, the configuration in the grey area must be improved.

- The sparks: A spark discharge occurs between two conductive parts whose at least one of them is not grounded. This discharge is a capacitive discharge and the released energy can be computed by the following equation:

$$E = \frac{1}{2}CU^2 \quad (1a)$$

And since

$$Q = C \times U \quad (1b)$$

Eq (1a) can be written as

$$E = \frac{1}{2}\frac{Q^2}{C} \quad (1c)$$

Where E is the released energy (J), Q is the amount of charges (C), C is the capacitance of the system (F) and U the potential different between the two armatures of the capacitance (V).

A spark discharge can ignite a flammable atmosphere made of gas or made of dust.

- The brush discharge: A brush discharge occurs between a charged insulating surface and a conductive electrode. This discharge is a so called one electrode discharge. Extensive researches were carried out to define whether or not such a discharge could ignite a cloud of dry powder. Glor [6,13] carried out ignition testing and showed that even if the energy of a brush discharge could be of the same magnitude of a weak spark, it could not ignite a cloud of powder. Schwenzfeuer concluded that the powder of the discharge is too low to do so. To the authors' knowledge, there is no explicit expression of the energy released by a brush discharge. The only approximation would be to use Eq (1c) if the amount of charges transferred is known under the assumption of a capacitive discharge.
- The propagating brush discharge: A propagating brush discharge is a surface discharge and only appear under specific conditions involving a continuous rubbing against an insulating surface. This kind of discharge occurs if the potential difference across the thickness of the material exceeds its breakdown voltage or if a grounded electrode approaches the charged surface. Propagating brush discharges are very energetic and can ignite gas or dust explosive atmospheres. Some preventive measures can be put in place in order to avoid this discharge: for instance conveying the products in grounded conductive pipes or using insulating pipes thicker than 8 mm [9].
- The cone discharge: a cone discharge occurs when handling a bulk powder in large capacities such as a silo, or a tank. This discharge can ignite a gas or dust explosive atmosphere
- The corona discharge: a corona discharge is too weak to ignite most of the flammable gas. This discharge is hazardous only in presence of IIC gases [9].

The thunder-like discharge is also mentioned but was never observed in the process industry.

1.2. Super brush discharges

Super brush discharges were firstly defined by Lüttgens [5]. A superbrush discharge is similar to a brush discharge in various ways: both of them are a one-electrode-discharge. They differ by their surface charge density. Superbrush discharges requires a much higher surface charge density that a brush discharge. Lüttgens states that this point can be achieved by using multiple pipes, individually charging them and superimposing them. Each pipe should be rubbed using a cat fur. In that way, all the pipes are carrying charges of the same polarity.

Glor [5] noticed a similar configuration in industry during the filling of large capacities such as silos or FIBCs. The high charge density would be reached by the compaction of the product being charged.

Two opposite actions take place simultaneously: