Journal of Loss Prevention in the Process Industries xxx (2017) 1–6

Contents lists available at ScienceDirect

Journal of Loss Prevention in the Process Industries

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

Pressure testing flameproof equipment intended for extremely low temperatures

Jim Munro [a,*], Kou Xiaoguang [b], Hu Yingzhen [b]

[a] Jim Munro International Compliance Pty Ltd, Blaxland, Australia
[b] Nanyang Explosion Protected Electrical Apparatus Research Institute, Nanyang, PR China

ARTICLE INFO

Article history:
Received 9 December 2016
Received in revised form
28 March 2017
Accepted 29 March 2017
Available online xxx

Keywords:
Flameproof
Pressure determination
Extremely low temperature
Pressure piling
Motors

ABSTRACT

International requirements for flameproof equipment are contained in International Electrotechnical Commission standard IEC 60079-1. An important test for flameproof equipment is the overpressure test. This is normally based on pressure determination tests which involve measuring the maximum pressure from a number of explosions using a representative gas/air mixture. The highest figure pressure obtained is then multiplied by a factor to obtain the pressure figure to be used for the overpressure test. It is known that the pressures obtained during pressure determination tests can be expected to rise as the temperatures drop. If temperatures drop as far as −60 °C this increase becomes significant. The standard provides several options for overpressure testing of equipment that is intended for use in temperatures below −20 °C. But for some equipment, such as motors, where pressure piling is possible, the options are restricted to two. One of the options that can be applied to any equipment is that the reference pressure can be determined at normal ambient temperature using the defined test mixture, but at increased pressure. The absolute pressure of the test mixture (P), in kPa, is calculated by a formula given in the standard. However, there is a lack of published data that supports this approach, in particular where pressure piling might occur. This could particularly be an issue for motors. This paper initially examines data from tests done some years ago with gases at extremely low temperatures. It then reports on recent tests using an enclosure producing pressure piling and the correlation of the pressures produced using the formula and those produced at actual temperatures. The paper concludes with recommendations for the next edition of IEC 60079-1 in regard to the application of this approach for testing equipment intended for extremely low temperatures.

1. Introduction

1.1. Overpressure testing of flameproof equipment

Flameproof enclosures are subject to pressure whenever an explosion occurs inside them. To ensure the enclosures are strong enough to withstand these explosions, they are subjected to an overpressure test during testing and certification. This can be done statically or dynamically. When determining the reference pressure, the enclosure is filled with a representative gas/air mixture at atmospheric pressure and the mixture ignited. The resulting pressure is measured using pressure transducers. The test is repeated a number of times as defined by the relevant standard. The value of the maximum pressure, as a reference pressure, is then multiplied by a factor and the resultant figure is used to apply a static or dynamic pressure test to the enclosure. The most widely used standard for this testing is the international standard IEC 60079-1 which is currently at Edition 7.0 IEC (2014). Most commonly, the factors applied by this standard are 1.5 and 4. The factor of 4 can only be applied for enclosures that do not incorporate welded constructions and the test with this factor exempts the enclosures from routine pressure testing by the manufacturer.

1.2. Pressure piling

The impact of pressure piling has long be recognised as a mechanism that can occur in flameproof enclosures, leading to increased pressures from explosions. Hence the mechanism is briefly examined here to provide some background.

The following is the definition in IEV 60050-426 International

* Corresponding author.
E-mail address: mail@jimmunro.org (J. Munro).

http://dx.doi.org/10.1016/j.jlp.2017.03.028
0950-4230/

Electrotechnical Vocabulary – Part 426: Equipment for explosive atmospheres IEC (2008b).

Pressure piling
results of an ignition, in a compartment or subdivision of an enclosure, of a gas mixture precompressed, for example, due to a primary ignition in another compartment or subdivision

Typically the above situation occurs when there is a restriction between compartments in a flameproof enclosure. The explosion in the first compartment precompresses the gas in the second compartment before the flame from the explosion reaches the second compartment. Thus the pressure of the gas in the second compartment is at a pressure higher than ambient pressure when it is ignited. This leads to higher pressures and faster rise times. A flameproof motor provides a typical example of where this occurs. For a motor the explosion ignited at one end has to pass through the air gap or other connecting paths before reaching the compartment at the other end. Pressure piling can also occur between the motor body and the terminal box if there is a connecting path for the explosive gas. Thus where pressure piling occurs, enclosures need to be stronger to be able to withstand the increased pressure from internal explosions.

1.3. Background on relevant IEC standards

The first international standard relevant to flameproof equipment was IEC Publication 79 IEC (1957), published by the International Electrotechnical Commission. The standard was developed by IEC Technical Committee TC 31. Since then there have been six further editions of the standard, which is now called IEC 60079-1. However, the early editions did not address the impact of low temperatures on the pressures that can occur when an explosion takes place inside the enclosure. This did not occur until the Third Edition of IEC 79-1 IEC (1990). This edition of the standard clarified the applicable ambient range of temperatures as being from "-20 °C to +60 °C for explosive gas atmosphere characteristics" and from "-20 °C to +40 °C for the operation of electrical apparatus". It also noted that for "ambient temperatures below −20 °C, stronger enclosures may be required due the higher pressures generated at low temperatures and the possibility of brittle fracture of the enclosure materials". However, this information was missing from the next edition of the standard.

Edition 5.0 of IEC 60079-1 IEC (2003) introduced significant pressure testing requirements for temperatures below −20 °C. The following requirements were included for pressure determination:

For electrical apparatus intended for use at an ambient temperature below −20 °C, the reference pressure shall be determined at a temperature not higher than the minimum ambient temperature.

As an alternative, for electrical apparatus.

- of Groups I, IIA, or IIB; or
- of Group IIC with internal free volume <2 l, other than rotating electrical machines (such as electric motors, generators and tachometers) that involve simple internal geometry such that pressure piling is not considered likely, the reference pressure may be determined at normal ambient temperature using the defined test mixture(s), but at increased pressure.

The absolute pressure of the test mixture (P), in bar, shall be calculated by the following formula, using $T_{a,\,min}$ in °C:

$$P = [293/(T_{a,min} + 273)]\,\text{bar}$$

It did limit the use of the approach for situations where pressure piling does not occur and for large IIC enclosures. However, things changed with Edition 6.0 of IEC 60079-1 IEC (2007). This edition of the standard introduced more detailed requirements for extremely low temperatures. In addition it changed the applicability of the above formula by allowing it to be used for all equipment. Hence it permitted the use of the approach for equipment where pressure piling might occur. The restriction on only using the approach for Group IIC enclosures with internal free volume <2 l was also removed. It also changed the formula from bars to kPa as follows:

$P = 100[293/(T_{a,min} + 273)]\,\text{kPa}$ (After correction by corrigendum IEC (2008a).

The current edition, Edition 7.0 of IEC 60079–1, has same approach as the previous edition in accepting this method of testing for very low and extremely low temperatures.

It is not clear from published literature what the justification was to initially permit the use of the formula in the standard, even if restricted to equipment with "simple internal geometry", and only for Group IIC enclosures with internal free volume <2 L. Similarly there is also a lack of published literature to support the subsequent broader approach of allowing pressure determination of any equipment to be done using this formula.

1.4. The effect of low temperatures on explosion pressures

The explosion pressures in enclosures increase as temperatures fall. A significant published experiment demonstrating this for a variety of gases used in flameproof testing was done some years ago by George Lobay Lobay (1977). The results are reproduced in Fig. 1.

The formula used in the standard for applying increased initial pressure to simulate very low temperature conditions is based on a common law of physics, Amontons' Law of Pressure-Temperature and also known as Charles'-Guy Lussac's Law. Amontons' Law states that The Pressure of a gas is directly proportional to the Temperature (Kelvin) at constant V and n; where V is the volume and n is the moles of the gas. The formula provided in the standard does not change for different gases, but if can be seen in the results of Lobay that the rate at which explosion pressures increase for lower temperatures varies with different gases.

As noted earlier, there is a lack of published literature to

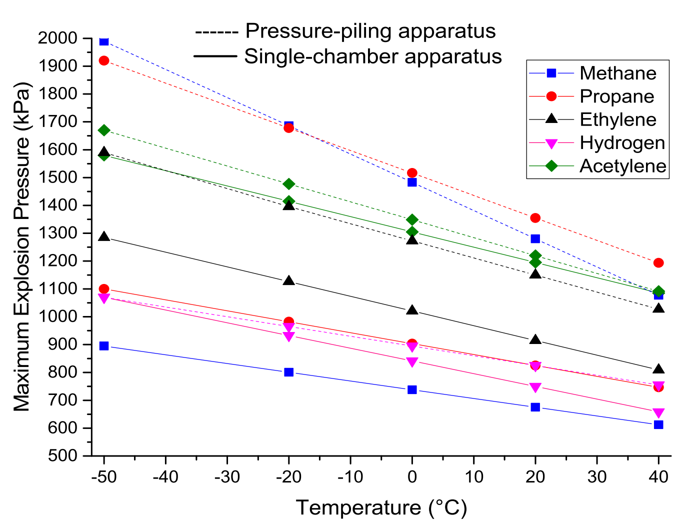

Fig. 1. Pressure figure results from Lobay's report.

Please cite this article in press as: Munro, J., et al., Pressure testing flameproof equipment intended for extremely low temperatures, Journal of Loss Prevention in the Process Industries (2017), http://dx.doi.org/10.1016/j.jlp.2017.03.028