# Testing products and processes with regard to electrostatic hazards

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Abstract
In the past few years a rapid development in products intended for use in explosive atmospheres has taken place. More and more products appear on the market which have specially treated surfaces or high-voltage devices coupled to microprocessor control systems. For this reason, methods have been developed which allow virtually every product and/or process to be tested with regard to its electrostatic safety in explosive atmosphere. These methods are based on a charging process under worst case conditions and a subsequent investigation of the resulting provoked discharges either by incendive test gas mixtures or by pure electrical measuring methods. The methods were described and applied to products, processes and the clearing up of explosions which actually occurred within the past year.

Keywords: Electrostatics, testing, products, processes, transferred charge, test gas, accidents

## 1. INTRODUCTION

Some years ago many people described electrostatic hazards as something comparable to “black magic.” Indeed, human beings are unable to detect a hazardous charge accumulation with their normal senses. They are only able to watch a resulting discharge which might ignite an existing explosive atmosphere. Therefore, this discharge appears as a mystery whose timing and incendivity cannot be predicted.

Today, this statement is no longer true. New measuring devices are commercially available which allow not only the amount of charge accumulation to be quantified but are also able to measure which explosive atmosphere can be ignited by a provoked discharge to a measuring electrode from a charged surface. For this reason, the testing of new products and processes with regard to their electrostatic ignition hazards has become possible to a degree which could not be foreseen some years ago. The following section describes a strategy for testing products and processes for verifying explosions caused by electrostatic discharges. All cases described were executed at the PTB within the past year.

2. STRATEGY FOR TESTING THE ELECTROSTATIC SAFETY OF PRODUCTS

Is it really necessary to test products with regard to their electrostatic safety? The answer is clearly “yes.” Some of the accidents having occurred could clearly be attributed to static electricity as this was the only ignition source present (Fig. 1). In the following section a strategy for examining the electrostatic safety of a product will be presented.

*Fig. 1: 1 m³ Container for flammable liquids after an explosion caused by static electricity*

In the first step of the test examination, the product must be checked for insulating conductive parts. If necessary, their capacitance against earth has to be determined with a battery-operated capacitance measuring bridge. The maximum permitted capacity depending on zone and explosive atmosphere is given in CLC TR 50404 [1], the maximum permitted resistance to earth can be taken from the same document [2]. Only products fulfilling these requirements are acceptable for use in explosive atmosphere.

In the second step, the surface resistance of existing plastic parts has to be measured. If this resistance is too high [3] and the area of the plastic part exceeds the values given in [4] for

- the projected area, or
- the thickness (when backed with an earthed conductor), or
- the area framed by earthed conductors,

further experiments are necessary in a third step to prove that the product is suitable for explosive atmosphere.

Today most products have to be examined by such third step experiments. This is due to the fact that increasing low-cost safety measures (e. g. structuring of the surface, corona tips embedded in the material, low break through voltages or increasing the relative humidity) are applied. It is obvious that these safety measures are not covered by the first two tests.

Many new standardization documents allow and describe such third step tests, e.g. [5-11]. The strategy of these tests is quite simple. The product to be tested is charged as highly as possible under most critical conditions, usually in dry climate at 23 °C at a relative humidity of less than 30 %, and a discharge to an electrode of a detector is provoked. This detector may be a gas probe with test gases of different ignitability, or an electrical measuring instrument displaying the transferred charge of the provoked discharge. In the latter case, the measured values are compared to admissible border limits published in the cited documents [5-11].

Suitable gas probes are described in e. g. [10]. They are commercially available and many persons in the Anglo-American countries master this method perfectly.

Suitable coulombmeters are described in [11-14]. This method is based on the experimental result that the incendivity of a discharge is described by its energy density, which corresponds to the transferred charge of a discharge due to Paschen's law. The following types of coulombmeters are distinguished:

1) normal coulombmeters, suitable only for single discharges in the absence of corona discharges from tips on a high potential,
2) coulombmeters with microprocessors which suppress corona discharges and the accumulation of multiple discharges and freeze the correct value,
3) coulombmeters based on a capacitor with parallel resistance coupled to an oscilloscope yielding the same properties as 2),
4) coulombmeters based on high-frequency shunts coupled to rapid oscilloscopes with integration function, which seems to be the most reliable equipment.

Coulombmeters of types 1, 2 and 4 are commercially available (e.g. [15]) and are given preference on the European continent and in Japan. However, the electrical methods have their advantages (e.g. yielding a numeric value) and disadvantages (e.g. indirect method). As comparable tests between gas probes and coulombmeters on the same specimen showed no significant differences in the test results [16-17], both methods seem to be adequate and suitable.

*Fig. 2: Measuring the transferred charge with a coulombmeter in dry climate after charging with electrons spraying from needles on a potential of -70 kV (fakir electrode).*

*Fig. 3: Example of a high-frequency shunt resistance of 0.25 Ohm coupled to an oscilloscope*

The following paragraph gives recommendations for testing a product experimentally with regard to its electrostatic safety with a coulombmeter. The corresponding test by means of a gas probe is executed in a similar way. Explosion groups are according to EN 50014 [18].

1) The test sample is air-conditioned in dry climate (about 23°C at a relative humidity of 30% or less) for at least 24 h.
2) The air-conditioned test sample is then charged as highly as possible by rubbing it with an animal hair cloth. To avoid charge-binding effects from table surfaces it is necessary to lift the charged test sample carefully from the table before the measuring procedure is started.
3) The ball electrode (about 25 mm in diameter) of the coulombmeter is approached until a discharge occurs. It is very important that only one single discharge occurs. This, however, does not apply to coulombmeters based on oscilloscopes or multiprocessors which suppress the accumulation of multiple discharges. If discharge gaps of less than 2 mm (for explosion group I and IIA), 1 mm (for group IIB) and 0.5 mm (for group IIC) are observed, the resulting transferred charge may have a reduced incendivity due to electrode quenching effects.
4) After the discharge has taken place, the ball electrode is removed immediately from the remaining electric field of the test sample and the display is read off straight away (due to decay effects the displayed value decreases with time). This statement does not apply to coulombmeters based on oscilloscopes or multiprocessors which freeze the correct value.
5) Steps (2) to (4) are repeated ten times, provided the threshold limit $Q_{max}$ (60 nC for explosion groups I and IIA, 30 nC for explosion group IIB and 10 nC for explosion group IIC, see [5-8]) is not exceeded.
6) Steps (2) to (5) are repeated with a second charging method (e.g. rubbing with nylon cloth, hitting with leather gloves).
7) Steps (2) to (5) are repeated, but this time charging is achieved by spraying electrons from metal tips on a potential higher than -50 kV, e.g. the fakir electrode (Fig. 2). This step will be omitted if one of the following conditions applies:
   - the specimen is backed with a conductor, or
   - the specimen is dissipative, or
   - the specimen has a distinct concave shape, or
   - the chargeable area is not accessible by rubbing.

The test has been passed if in none of the discharges the threshold level $Q_{max}$ is reached. It is a good idea to verify this method from time to time with a reference plastic sample to make sure that no experimental errors occur. More details can be found elsewhere [14].

The method of charging a product as highly as possible and examining the incendivity of a provoked discharge is universally applicable. It may be used for virtually every product intended for use in explosive atmosphere, e. g. antistatic foils, antistatic resins, coated metals, or products made from these materials - such as containers for flammable powders and liquids, sensors, mobile phones, tank systems, clothing, cabins for electrostatic paint spraying, high-voltage devices (ionisers, electrostatic spraying devices, electrostatic filters), or for testing the effectiveness of an antistatic protection measure.

## 3. STRATEGY FOR TESTING THE ELECTROSTATIC SAFETY OF PROCESSES

In principle, processes were examined in the same way as products. The occurring process is watched and possible critical situations are identified. Test samples were taken and checked with regard to their electrostatical ignition hazard. A field mill is quite suitable to identify highly-charged objects. Special care must be taken to identify insulated conductors, e.g. ungrounded workers. The following examples give some advice.

### *3.1 Is there a danger of incendive electrostatic discharges in a coal mine with a guaranteed relative humidity of more than 60 % at 25 °C?*

The following facts were observed underground:

1. plastic bottles with drinking liquids were rubbing at the clothes of the workers;
2. large plastic signs, coated with coal dust, were hanging from the ceiling;
3. materials packed in 100 l paper bags, wrapped in a transparent plastic foil, were delivered (Fig. 4). The foil is usually covered with condensed water droplets;
4. some working tools were made of plastics;
5. some large cardboard signs were sealed with plastics;
6. some holes with areas of some square meters were closed by plastic foils;
7. waste boxes with plastic bags were used;
8. some workers brought private plastic bags underground;
9. all workers wore antistatic shoes;
10. all other equipment was properly explosion-protected.

The respective items (plastic bottles, working clothes, plastic signs, working tools, foils etc.) were brought to the laboratory and checked with regard to their electrostatic safety in a climate of worst case, in this example at a relative humidity of 60 % at 25 °C. It was found out by experiments that only hazards exist which are due to plastic foils (items 3 - only when dry -, 6, 7, 8). As a consequence, private plastic bags were forbidden, holes and waste boxes were equipped with antistatic foils and it has to be ensured that the foil for protecting products against moisture is always wet at the outside. In addition, the security supervisor underground was charged with the observation of these regulations.

*Fig. 4: Normally, products wrapped in plastic foil create electrostatic hazards in explosive atmosphere. Therefore, it has to be ensured by appropriate measures that the foil is always wet*

*3.2 Why do some car batteries explode when touched by charged persons and others do not?*

To clarify this question, dry car batteries were filled with water and approached in dry climate (less than 30 % relative humidity) by highly charged persons. It showed that with some batteries, sparks occurred from the person's finger through a stopper of the battery to the battery liquid (Fig. 5). Such sparks did not occur in the case of car batteries which until then had not shown an explosion of this type. We therefore recommend measures which prevent such sparks.

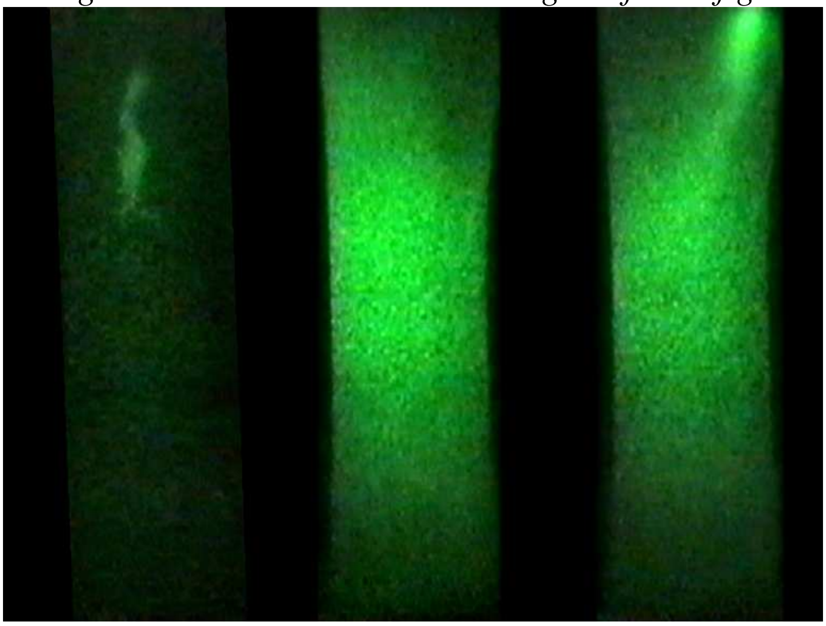
*Fig. 5: Discharge from a highly charged person through the stopper of a car battery*

*3.3 Why did a metal-wrapped plastic container filled with n-dibutyl ether and other organic solvents explode after having been emptied via the bottom valve (Fig. 1)?*

A literature study yielded that no chemical processes occur inside the container due to the presence of n-dibutyl ether (explosion group IIB) and other organic solvents. Hence, the only possible ignition source seems to be static electricity. To verify this, the metal-wrapped plastic container was opened on one side and the plastic inside was rubbed with a cloth in dry climate. It showed that the plastic bubble was pressed close to the metal wrapping and then moved back after stopping the rubbing process. As the charge-binding effect of metal diminishes with distance, charges are set free when the bubble moves away from the metal wrapping. Discharges are therefore possible between higher and lower charged areas. In experiments these discharges turned out to be clearly incendive for substances of explosion group IIB, but not for substances of the explosion group IIA. The most promising explanation is therefore that the bubble was first pressed to the metal wrapping by the weight of the liquid inside. After emptying, this pressure has disappeared and the bubble has moved away from the shielding wrapping and an incendive discharge has taken place. We therefore recommend to use IBC made of antistatic plastic for such applications.

*3.4 Why did explosions occur inside the plastic fill pipes of filling stations after they had been disconnected subsequent to the filling process with gasoline fuel by a road tank car?*

*Fig. 6: Three discharges inside a vertical tube during the flow of gasoline*



At normal temperatures, gasoline vapours are too rich for ignition. For this reason, there is no ignition hazard during the filling process when the pipe is nearly filled with gasoline. However, after disconnecting the filling road tank car from the pipe system, air is sucked in due to gasoline still streaming upstream the pipe system and creating a vacuum behind. In addition, experiments with transparent tubes, with fuel running through, show strong, clearly incendive discharges inside the pipe from highly charged areas to lower or oppositely charged areas (Fig. 6). We therefore recommend to mount a valve at the beginning of the filling pipe of the filling station and to close this valve after each filling process to avoid air intake in the charged filling pipe system.

## 4. CONCLUSIONS

The rapid development of products intended for use in explosive atmospheres and the need for experiments aimed at reconstructing the ignition source of an explosion has led to the development of direct test methods. In these tests, the specimen is charged as highly as possible under worst case conditions and then a discharge to a test probe is provoked, e.g. with an escaping flammable test gas or a connected coulombmeter. The test probe allows the incendivity of the provoked discharge to be determined either by the use of different incendive test gases or by the method of transferred charge. The latter method is especially suitable for quality assurance measures of manufacturers.

However, safe products alone do not assure a risk-free work in hazardous areas. It is also necessary that these products are only handled by workers who are specially trained for this purpose. When examining processes in factories we found out that this is not always the case and that some improvement on this topic is necessary in order to reduce the number of fires and explosions.

References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3) same as 1), but section 4.2
4) same as 1), but sections 4.4.3 to 4.4.5.
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