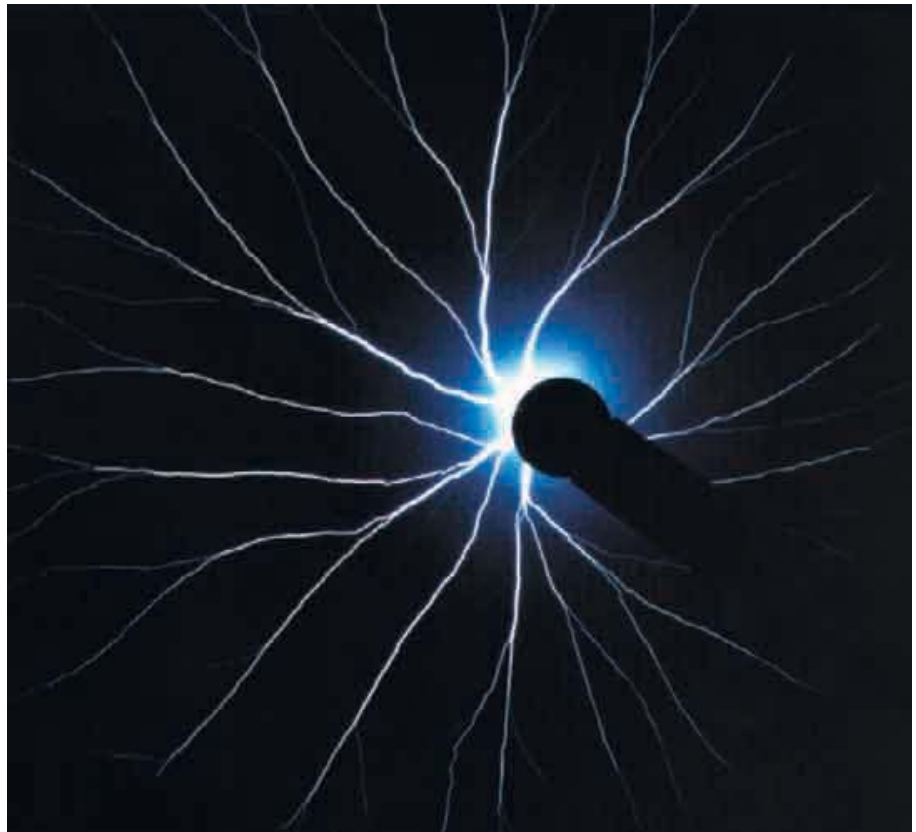




# Physical ignition processes

## Evaluation of the incendivity of electrostatic discharges without ignition tests with combustible gases or dusts

by Ulrich von Pidoll



An electrostatic charge that is generated by disconnection processes or by friction involving insulating surfaces during many production processes can, on discharge, result in the ignition of an explosive atmosphere. That is why measures must be taken to prevent incendive discharges in hazardous areas.

These measures include using high-voltage electrodes with limited discharge energy for electrostatic coating processes, or rendering non-conductive plastic surfaces anti-static by modifying their structure or through

the addition of a conductive material. The effectiveness of these measures must be verified if they are to be applied in hazardous areas (see CENELEC TR 50404:2003, section 4.4.3) [1].

A new method is presented here. This allows the incendivity of electrostatic discharges to be determined without experimental ignition tests with combustible gases or dusts. Already over 100 comparative tests have been carried out on electrostatic hand-held spraying devices, plastic surfaces, textile materials, and in almost every case the results of the new electric test method matched the experimental test method that is currently being used.



Figure 1: Experimental ignition test to verify the effectiveness of anti-ignition measures

### Current test method

The item to be tested is subjected to a test gas, the incendiarity of which corresponds to the explosive atmosphere when the product is used. Discharges to an earthed ball electrode with a diameter of 25 mm are then provoked. The item is considered to have passed the ignition test if no ignition of the test gas occurs within 20 minutes (Figure 1). The disadvantage of this test method is that the test engineer has to work with the test specimen in the gas mixture without having audible feedback and without being able to see clearly or to move freely. This can result in gas leakage. Despite considerable efforts being invested in this experiment, the test result is only a Yes/No decision, which could lead to the opposite assessment when the experiment is repeated. This is unsatisfactory and has led to the development of quantitative electrical measuring methods, the results of which can be compared with a threshold value. →

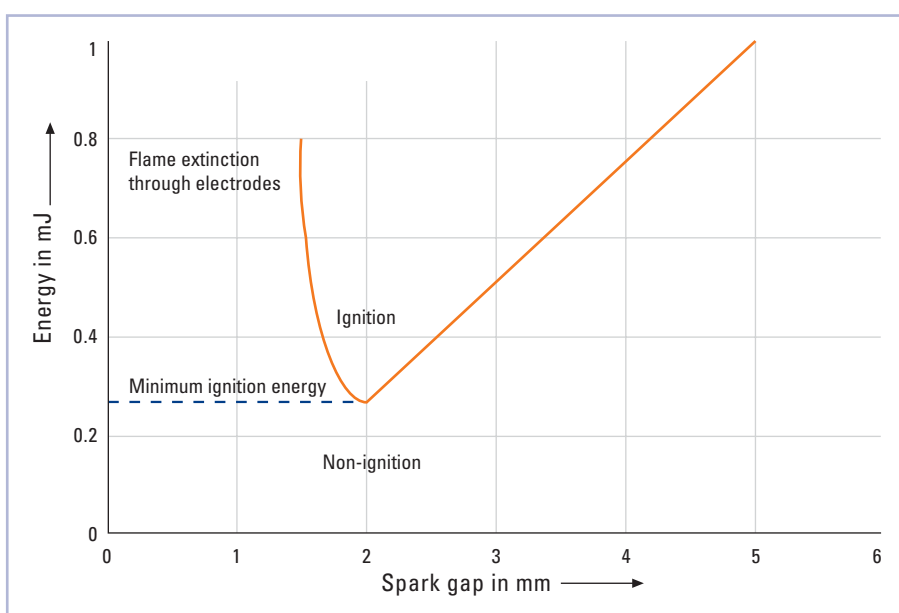


Figure 2: Ignition energy as a function of the spark gap

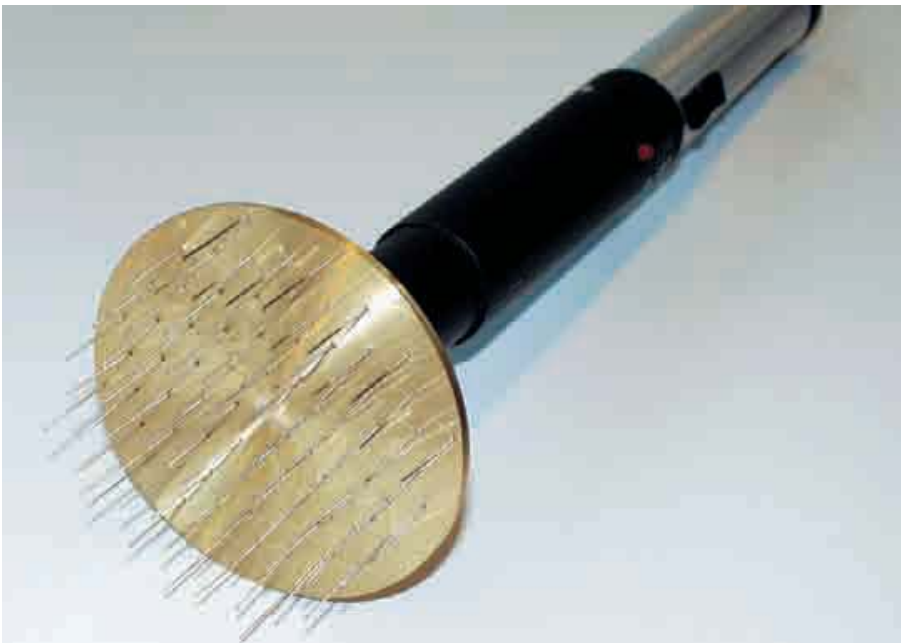


Figure 3: Conventional needle electrode on a high-voltage stick of -70 kV



Figure 4: Applying a charge with a needle electrode and then measuring the transferred charge Q with a coulombmeter

### New test method

Initial experiments on the incendiarity of high-voltage discharges conducted at the end of the 19th century already showed that the energy density of the spark, i.e. the energy  $[0.5 \times C \times U^2]$  per spark gap  $l$ , describes its incendiarity. Furthermore, according to Paschen's law,  $U$  is proportional to  $l$ . The following result is obtained by combining both equations:

$$\text{Incendiarity} = \text{const} \cdot C \cdot U = \text{const} \cdot Q = \text{const} \cdot \int I dt$$

where  $C$  is the capacitance of the discharge circuit,  $U$  is the voltage at the discharge circuit,  $Q$  is the charge transferred by the discharge and  $I$  is the discharge current.  $C$ ,  $U$  and  $\text{const}$  can be derived from the minimum ignition energy measurements already published (Figure 2). The following threshold values for the charge were stipulated in CENELEC TR 50404, EN 13463 [2] and for the various explosion groups in IEC/EN 60079-0 [3]:

- > I: 60 nC
- > IIA: 60 nC
- > IIB: 30 nC
- > IIC: 10 nC

These threshold values make it possible for the electrical measurement of the charge transferred by the discharge to be used instead of an experiment using a test gas mixture. This even revealed that, in the case of gases and vapours, the ignition limit is not dependent of the type of discharge.

### Measurement using the coulombmeter

Before the measurement is carried out, the test specimen is conditioned in a dry atmosphere (23 °C, < 30 % relative humidity). The test specimen is then charged using three different methods: e.g. rubbing with a felt cloth, hitting with a leather glove and spraying electrons onto it. The last-mentioned method must not be used with an un-earthed, conductive plastic, with a plastic material that has a conductive backing, and with test specimens that are highly concave (e.g. inside of pipes, inside of sealing caps). An appropriate device with a needle plate and 100 needles is commercially available (Figure 3). The needle plate is simply placed on the test specimen, a high voltage of -70 kV is applied, and the device is removed from the test specimens after a few seconds of being switched on.

The coulombmeter's ball electrode is then moved towards the surface that has been charged as highly as possible by friction or high voltage, until a single, audible brush discharge occurs. The coulombmeter is then removed from the remaining electric field, the reading is taken in nC and compared with the allowable threshold values. This procedure is required to offset any interference from the voltage induced in the ball (Figure 4). This is no longer necessary when using modern coulombmeters with an integrated microprocessor, as these instruments automatically display and freeze the correct measured value.

It is advisable to carry out a parallel test using a PTFE disk with a defined area (e.g. 100 cm<sup>2</sup>) so that any systematic measuring errors (e.g. caused by incorrect →



Figure 5: Ball electrode with connected coaxial 0.25 Ohm shunt resistor, attached to the input channel of an oscilloscope



Figure 6: Spark-over from an electrostatic hand-held spray device to the test electrode

conditioning) can be identified. It should be remembered that certain plastic materials onto which the electrons are sprayed lose their chargeability over time.

### Measurement using the oscilloscope

The described method of measurement using a coulombmeter has only limited suitability with regards to the assessment of textile fibres. This is because multiple discharges may occur here, and these make the measured transferred charge appear incorrect. Furthermore, the coulombmeter measurement is not suitable for evaluating discharges from a high-voltage electrode, since this may also give rise to multiple discharges.

In such cases the method should be modified so that a ball electrode (Figures 5 and 6) with an integral shunt (resistance approx. 0.25 Ohm, cut-off frequency greater than 500 MHz) and connected to an oscilloscope (at least 1 gigasample/s, min. 300 MHz bandwidth, 50 Ohm input, mathematical function ›integral input‹) via a high-quality 50 Ohm cable is used instead of the coulombmeter. In this case the mathematical function is programmed so that the oscilloscope directly displays the measured result

$$\frac{1}{R} \cdot \int I dt$$

(R = shunt resistance in Ohm), i.e. the transferred charge in nC. This also allows conclusions about the type of discharge to be drawn from the current flow. Figures 7 to 10 show the relevant current flow curves for different types of discharge.

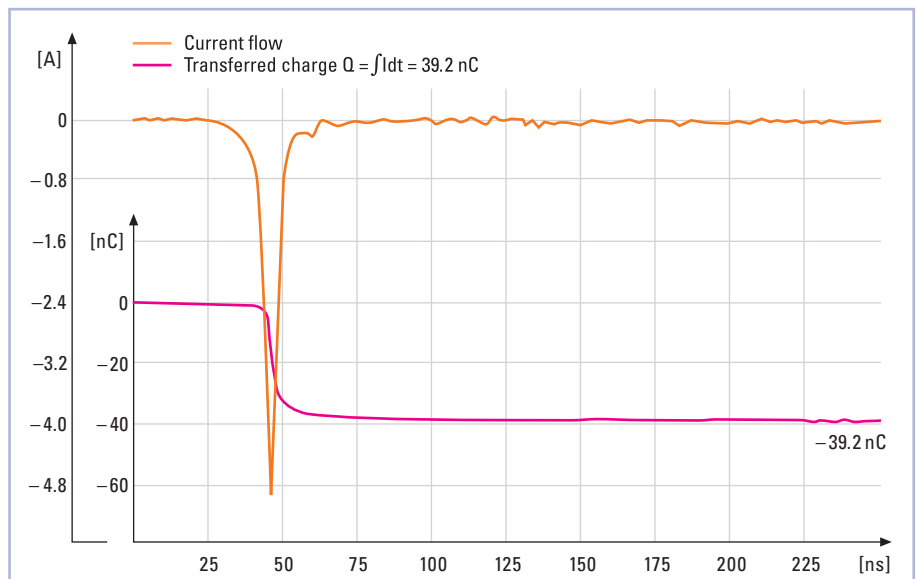


Figure 7: Current flow for a spark discharge from a small, non-inductive capacitance

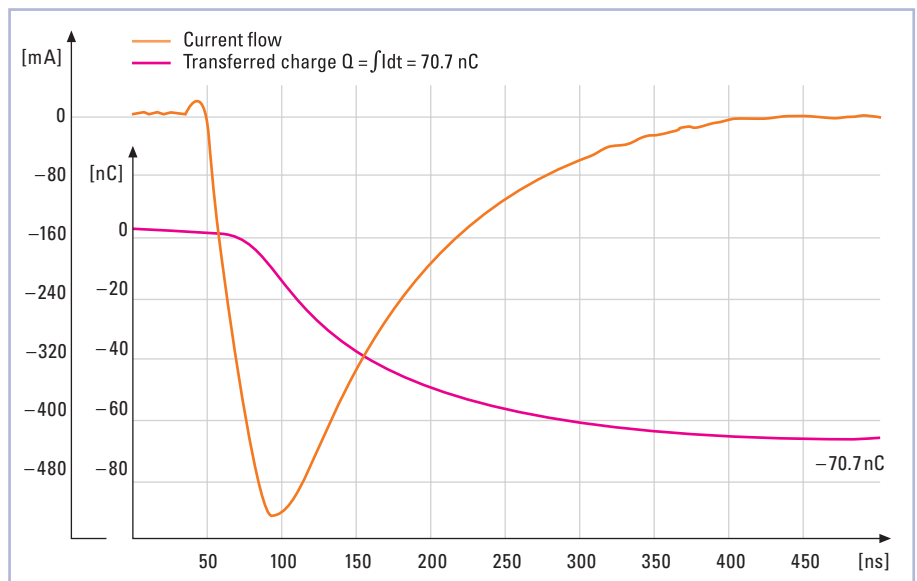


Figure 8: Current flow for a brush discharge from an insulating plastic surface

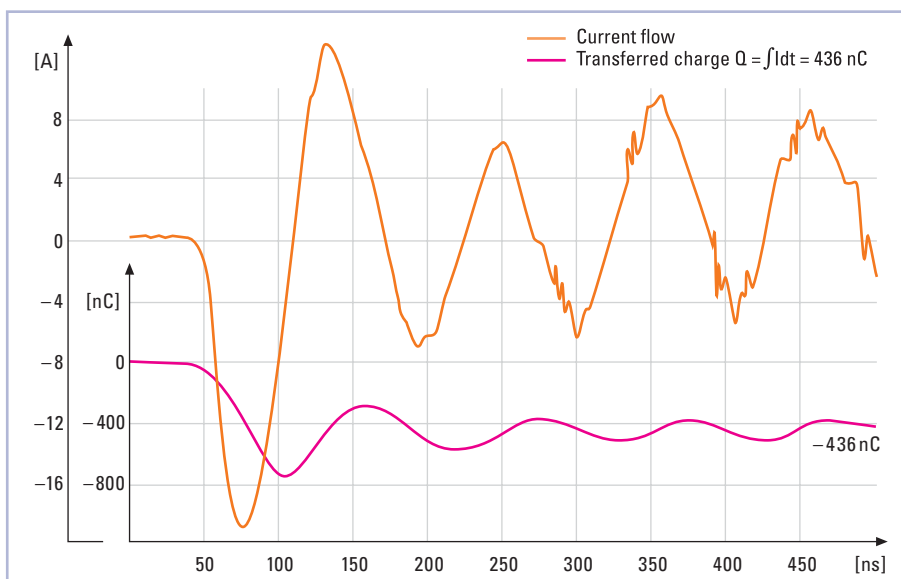


Figure 9: Current flow for a discharge from a wound capacitor

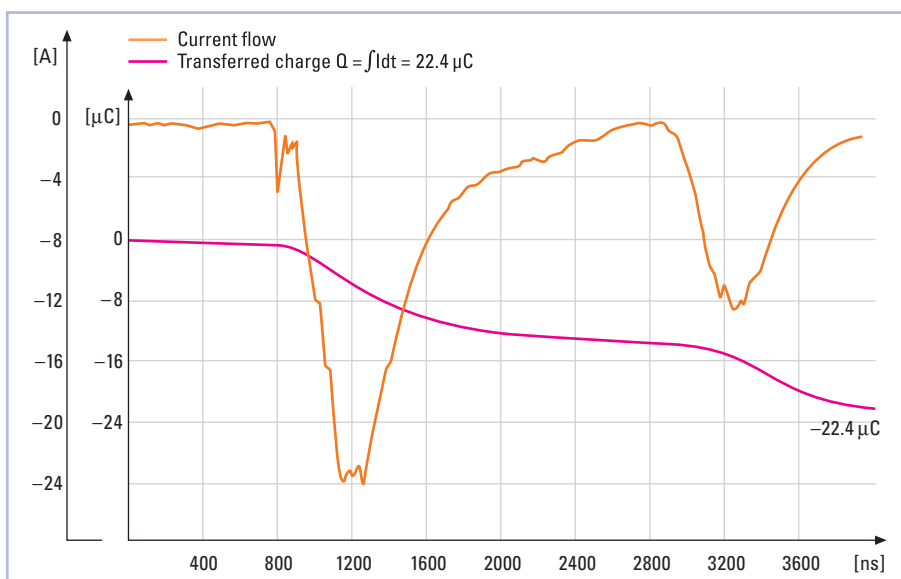


Figure 10: Current flow for a propagating brush discharge  
The actual charge is higher, since there are further discharges outside the oscilloscope display

#### References

- [1] CLC TR 50404:2003  
Electrostatics – Code of practice for the avoidance of hazards due to static electricity
- [2] EN 13463-1 2002.04  
Non-electrical apparatus for use in potentially explosive atmospheres – Part 1: Basic principles and requirements
- [3] IEC/EN 70069-0:2003  
Electrical apparatus for explosive gas atmospheres  
Part 0: General requirements
- [4] U. von Pidoll  
Testing products and processes with regard to electrostatic hazards. Proceedings IEJ/ESA Joint Symposium on Electrostatics, Tokyo 7. –10. Nov. 2004, 245–254
- [5] U. von Pidoll, E. Brzostek and H.-R. Fröchtenigt:  
Determining the incendivity of electrostatic discharges without explosive gas mixtures. IEEE Transactions on Industry [A] Applications, 40 (2004), 1467–1475
- [6] U. von Pidoll  
The ignition of clouds of sprays, powders and fibers by flames and electric sparks. Journal of loss prevention in the process industries, 14 (2001), 103–109