

Publications from the PTB

Summaries of the most important investigations – excerpt from the 2002 annual reports

Application of a new method for determining the ignition effectiveness of electrostatic discharges

Technical progress has led to more and more complex products for use in hazardous areas. Even though it was still relatively simple in the past to theoretically assess these products in respect of the danger of ignition resulting from electrostatic discharges, an experimental test is necessary in order to do this in the age of high-tech plastic surfaces and sophisticated control equipment for high-voltage electrodes. However, an ignition test in potentially explosive gas mixtures is dangerous on one hand and provides only an undifferentiated result in the form of 'ignition / non-ignition' on the other.

A purely electrical measuring method (cf. 2001 annual report), which specifies the charge transferred in the discharge operation as a measure of the ignition effectiveness has been developed on the basis of theoretical considerations, which have also been confirmed experimentally. This new measurement method has now been applied to numerous devices and materials subject to the risk of electrostatic ignition, e.g. electrostatic spray apparatus, ionisers and filter systems, in addition to textiles (e.g. for protective suits in hazardous areas), materials for containers for flammable substances (e.g. FIBCs: Flexible Intermediate Bulk Containers, transport containers for dusts, IBCs: Intermediate Bulk Containers, transport containers for fluids). On the basis of the experience gained with these investigations, standardisation proposals have been elaborated for testing electrostatic hand-held spray apparatus, IBCs, FIBCs

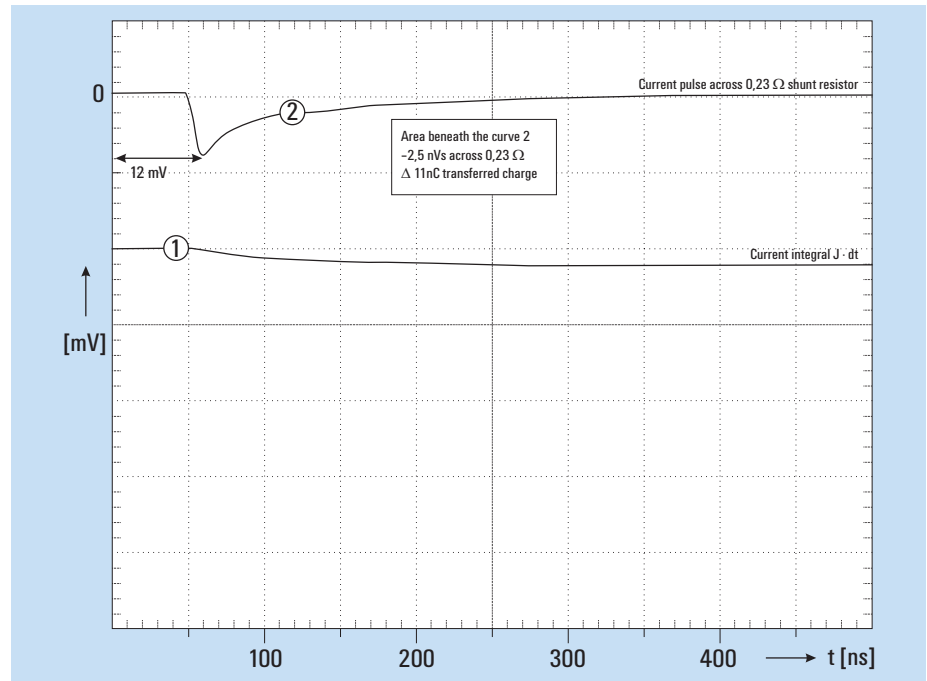


Figure 1: Non-ignition-effective discharge of an FIBC material

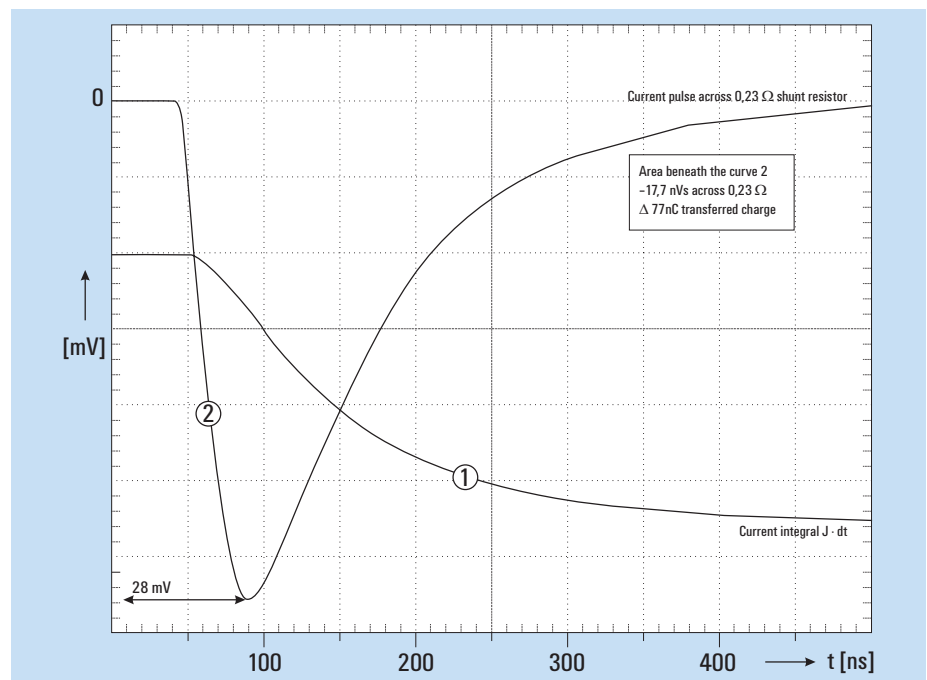


Figure 2: Ignition-effective discharge of an FIBC material

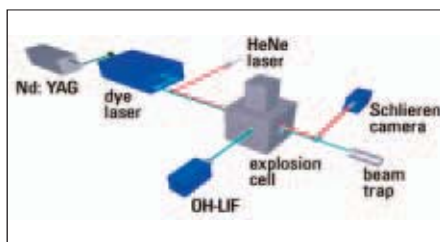


Figure 3: Test stand for independent determination of flow information using the Schlieren method and ignition locations by LIF

and textiles for protective clothing, including the new test method.

Experimental investigation into the ignition of H₂/air mixtures by hot free jets

Ignition processes are of tremendous importance when considering combustion processes, both theoretically and practically. A deeper understanding can therefore make a contribution to avoiding explosions in hazardous areas by taking appropriate measures. Ignition processes in hot, reactive free jets are being investigated in a joint project of the PTB and the Institute for Combustion Technology of the University of Stuttgart. The ignition process is an unsteady and spatially inhomogeneous process. Consequently, measurements, which are discrete both spatially and temporarily are required for investigating the process, and these measurements have had to be conducted in separate series of measurements to date [1].

With the aid of a newly constructed test stand (Figure 3), it is now possible for the first time to combine different measuring techniques simultaneously and plot all required data on a time scale which is short in comparison with the time scale, in which flow and chemical reactions lead to changes. The actual flow process is observed using the Schlieren method. The location of the ignition in a hot free jet is determined using laser-induced fluorescence (LIF) in order to describe the ignition process. The investigations conducted within

the framework of the project make it possible for the first time to determine the precise location of the ignition in free jets while measuring the time sequence of an explosion. A greater understanding of the mixing processes in the shear layers, which are to be investigated in the next phase of the project by LIF using added tracer molecules is required for a more precise description of the ignition process.

Explosion risk in unvented petrol tank vessels

During empty voyages of inland petrol tank vessels, an explosive vapour-air mixture may develop in their tanks, if the tanks have not been degassed (vented) after unloading. On behalf of the Federal Ministry of Transport and traffic authorities in Switzerland and the Netherlands, the PTB investigated the explosion risk in such tanks. For this purpose, a large number of concentration measurements were conducted in the tanks of inland tank vessels.

In conventional unloading of the cargo by sucking in of air, an explosive vapour-air mixture will form in a part of each tank after unloading. The concentration differences within each tank will equalise gradually during the subsequent empty voyage, the resulting fuel concentration being either below or above the upper explosive limit (UEL) (depending on weather conditions and type of fuel). Unloading by sucking in gas from a vapour recovery unit very often leads to concentrations above the UEL throughout the entire tank directly after unloading. Leaving a residual quantity of petrol in the tanks reduces the explosion risk (as a result of transgression of the UEL) only after periods of several hours.

Even if the concentrations have been above the UEL throughout the entire tank, spaces with explosive mixtures may form again, e.g. owing to induction of large quantities of air after a sudden drop in ambient temperature. If diesel fuel is transported as the next cargo in unvented petrol tanks, petrol vapour concen-

trations within the explosion range may still occur for several days in the free space above the fluid.

Even if the danger of explosion exists, only weak explosive effects may often be anticipated, since the explosive atmosphere is present only in parts of the tanks (< 15 % of the volume) or has a fuel concentration near the UEL. However, the possibility of major explosions cannot be completely excluded.

Influence of highly porous materials on flame transmission

In accordance with EN 50018, safe avoidance of flame transmissions on electrical apparatus of type of protection Flameproof enclosure 'd' is ensured by an extensive type examination. The result of this examination cannot be estimated easily in advance owing to the large number of influencing parameters. Measures to reduce the risk of flame transmission during a type examination or even to ensure ignition-proof design of the flameproof enclosure [2] are being investigated within the framework of a 'ProlInno' project, sponsored by the Federation of Industrial Research Facilities (Arbeitsgemeinschaft industrieller Forschungsseinrichtungen 'AiF') in co-operation with the KEK GmbH company.

A model enclosure with which practically orientated explosion sequences can be simulated was developed within the framework of →

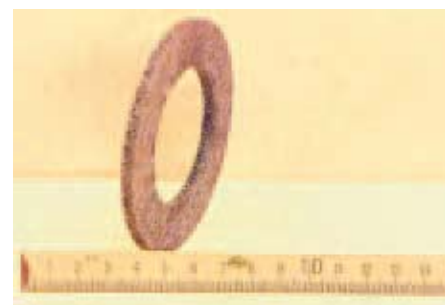


Figure 4: Flame transmission-preventive structure consisting of sintered metal fibres for use in a commercially available electrical motor

→ the project. On this enclosure, it is possible to assess the effectiveness of various measures by varying the gap. The investigations indicated that cooling of the escaping hot gas can reliably prevent a flame transmission by using appropriate components in the flow path. The components must have a suitable flow resistance and may not be attacked by the hot exhaust gases despite having a large internal surface area. The best results to date were achieved by using sintered elements made of high temperature-resistant metal fibres. The components are to be investigated for effectiveness on commercial explosion protected electrical equipment in the current phase of the project.

Calculation of explosion limits with detailed reaction kinetics

The lower and upper explosion limits restrict the range of concentration in which a fuel gas-oxidant mixture can be ignited. The experimental determination of explosion limits implies extensive tests, particularly if fuel mixtures and/or inert gas mixtures are used. Consequently, options are being sought to calculate the unknown explosion limits of mixtures. The explosion limits of various fuel/air/inert mixtures were determined numerically in cooperation with the Institute for Combustion Technology (Institut für technische Verbrennung) of the University of Stuttgart. The model used describes the effect of heat losses in the form of radiation on laminar premixing flames. If the energy losses from the flame front predominate over heat release as the result of the chemical reactions, the flame is extinguished. Investigations with the model used thus allow fundamental statements to be made in relation to the combustion processes near to the explosion limits.

The model used was validated by a comparison of the calculated explosion limits with values determined experimentally in accordance with DIN 51649. This indicated a

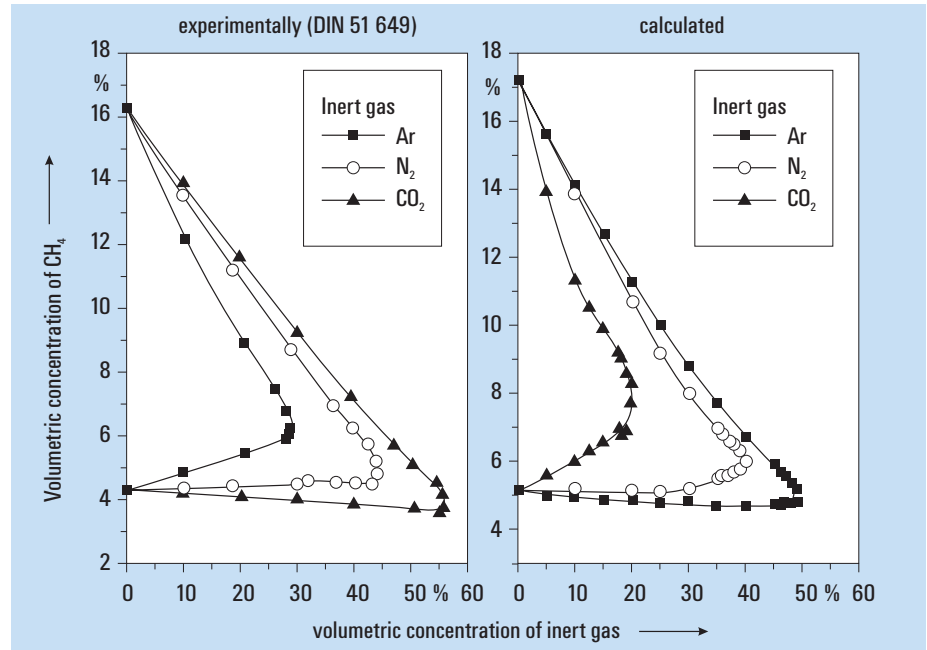


Figure 5: Comparison of experimentally determined and calculated explosion limits of methane-air-inert gas mixtures (T = 293 K, p = 1 bar) [3]

very good correspondence of the results (Figure 5), particularly in the range of the lower explosion limits of hydrocarbon-air mixtures. The influence of temperature, pressure and inert gas addition on the explosion area is also reflected satisfactorily by the calculation.

Literature

- [1] Beyer, M.: Über den Zünddurchschlag explodierender Gasgemische an Gehäusen der Zündschutzart ‚Druckfeste Kapselung‘. Dissertation, Technische Universität Braunschweig (1997).
- [2] Deutsches Patent DE 198 26 911, Verfahren zur Führung von im Innern eines Gehäuses gebildeten Explosionsgasen durch zünddurchschlagsicher ausgebildete Spalte und explosionsgeschützte Gehäuse. Deutsches Patent- und Markenamt, 09.03.2000
- [3] Markus, D. und Maas, U.: Die Berechnung von Explosionsgrenzen mit detaillierter Reaktionskinetik. In: Dechema-Fachtreffen Sicherheitstechnik und 9. BAM/PTB-Kolloquium zur chemischen und physikalischen Sicherheitstechnik, Bothe, H. und Stolz, T., (Hrsg.) (2001) S. 89-98