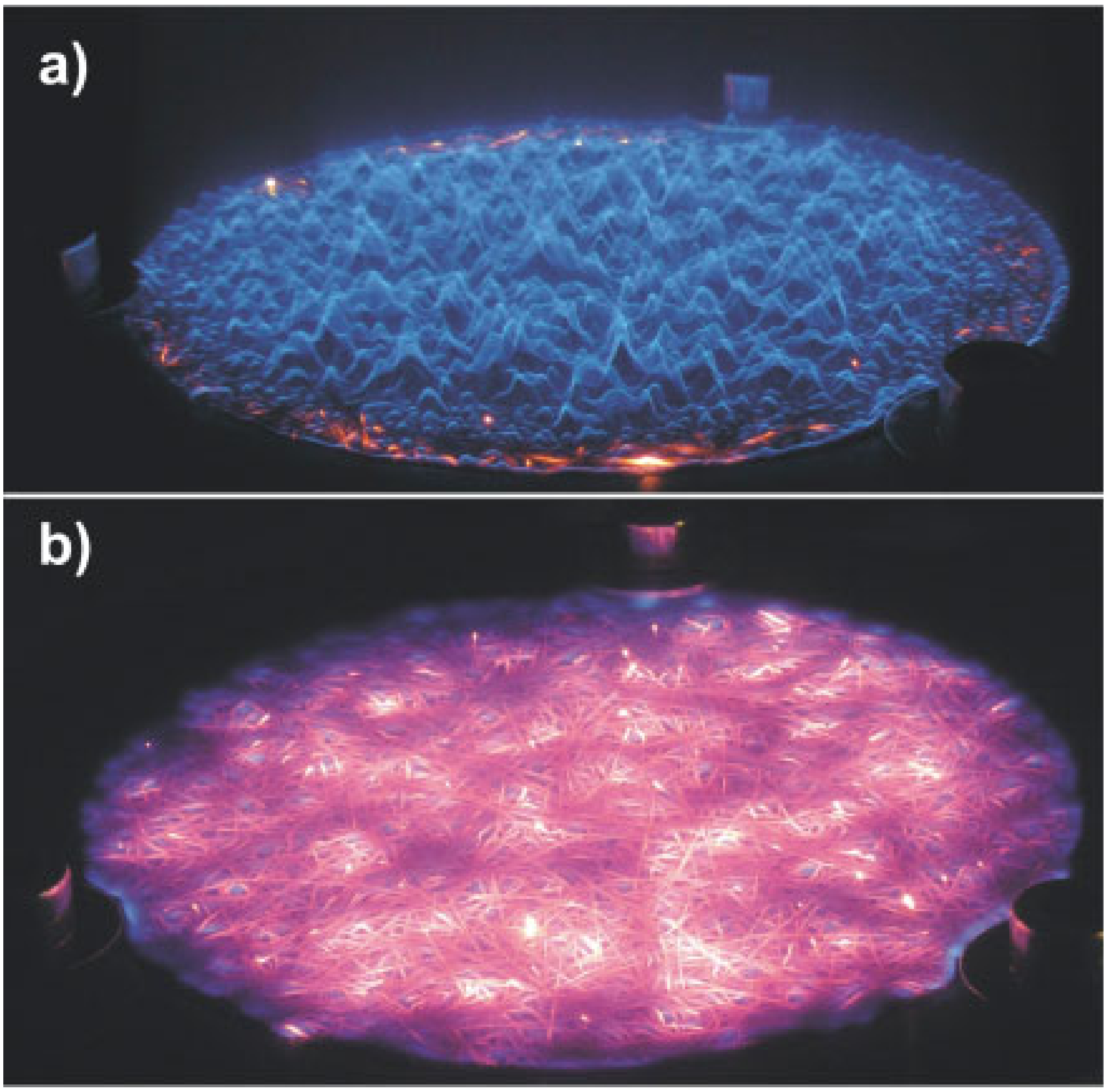
Chemical Physics and Explosion Protection

Reports of the Divisions



Division 3

Chemical Ph
Explosion P

Division 3 "Chemical Physics and Explosion Protection" is concerned with the subjects "Metrology in Chemistry and Material Properties" as well as "Physical Safety Technology and Explosion Protection".

In addition, Division 3 makes contributions to the cross-sectional area "Flowrate" (see report of Division 1) and to the projects "Avogadro constant" (see report of Division 4) and "Boltzmann constant" (see report of Division 7).

The subject area "Physical Safety Technology and Explosion Protection" is dealt with in the four Departments 3.4 "Fundamentals of Explosion Protection", 3.5 "Flame Transmission Processes", 3.6 "Intrinsic Safety and Safety of Systems" and 3.7 "Prevention of Ignition Sources". This year's report is focused on the developments in explosion protection.

Research and development, testing services and consultancy of PTB in the field of explosion protection are performed in close coordination with the Bundesanstalt für Materialforschung und -prüfung (BAM, Federal Institute for Materials Research and Testing) within the scope of the project "Chemical-physical safety technology".

Cover picture:
Burning on an endurance burning flame arrestor with a flame arrestor element of sintered fibres with different upstream flow velocities (a: 0.73 m/s, b: 0.04 m/s)

Developments in explosion protection

For some time now, the process of the European harmonization of the (national) regulations in explosion protection has already been completed with Directives 94/9/EC and 1999/92/EC. The supporting CEN-CENELEC working programme has been developed almost completely. For electrical equipment, the technical development of standards takes place almost exclusively at IEC level. In the field of today's CEN standards, this international harmonization process has just been started with the foundation of the IEC SC 31 M which will draw up ISO/IEC standards.

For some years, technical regulations have been elaborated which are intended to make the "Betriebssicherheitsverordnung", which implements Directive 1999/92/EC in Germany, more precise.

Also, for the classification and identification of dangerous substances and goods, a worldwide harmonization process is about to be completed. The "Globally Harmonized System of Classification and Labelling of Chemicals" (GHS) is at present being transferred to the European and German area and has, among others, some impact on the classification of flammable liquids.

PTB employees from the four explosion protection departments have participated decisively and - partly - in leading positions in the elaboration of these national, European and international standards and regulations at all levels and in many committees.

Physics and Protection

Support of the economy by application-related research and development

PTB supports the economy with research and development work which allows manufacturers and operators of explosion-protected devices and autonomous protection systems to promptly implement new scientific and technical developments and findings in the field of explosion protection.

Influence of the enclosure on the ignition temperature of flammable liquids

Investigations into the influence of pressure on the ignition temperature have shown that in specific cases, the kind of enclosure of the explosive atmosphere leads to a clear decrease in the ignition temperature compared to the standard ignition temperature even without the existence of a significant increase in the mixture pressure or volume. These findings furnish important indications to the institutions for statutory accident insurance and prevention when assessing the ignition of explosive atmosphere by hot surfaces.

Innovative technology leads to a clear increase in the performance of the type of protection "intrinsic safety"

Compared to other types of protection, the type of protection "intrinsic safety" has many advantages. Due to the principle of the "intrinsic safety" - i.e. the limitation of the available electric power - the available power rarely exceeds 3 W.

The novel, dynamically acting, intrinsically safe energy supply concept DART (Dynamic Arc Recognition and Termination) allows considerably higher power values - up to 50 W - to be achieved, while at the same time the fundamentals of intrinsic safety remain unchanged. The working concept is based on a very fast recognition of failure conditions (e.g. ignition sparks) by the evaluation of the associated (dynamic) current changes and the immediately following transfer of the system into a safe state (e. g. by switch-off). The safety-relevant time-frame for the influencing of the process is furnished by the duration of any possible ignition-capable sparks. Transfer into the safe state is performed so fast that the spark cannot become capable of causing ignition. The spark is, thus, safely limited in time already in its formation phase. As an example, Figure 1 shows a break-spark influenced already in its formation phase by switch-off.

Due to the strong mutual dependencies of energy supply, line and consumers (e. g. field devices, solenoid valves) it is - according to today's state of knowledge - only reasonable to certify these units as a total system. The assessment of dynamically acting intrinsically

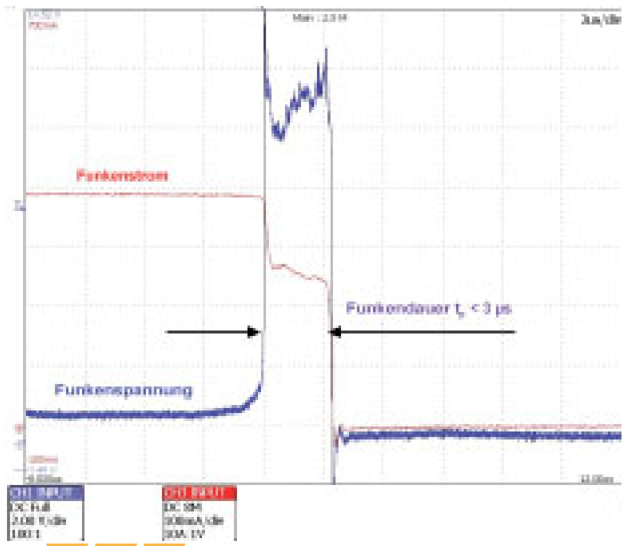


Figure 1: Influencing of a break-spark by rapid switch-off

safe power sources on the basis of the currently valid international standard IEC 60079-11 is not, however, possible, as it does not contain suitable requirements for dynamic, intrinsically safe current circuits. This is why new test methods must be elaborated which can be used as a standard. The investigations required for this purpose have not yet been completed.

The PTB results available so far have been obtained from the projects funded by the Federal Ministry of Economy and Labour (via the Working Group of Industrial Research Associations e. V. - Arbeitsgemeinschaft industrieller Forschungsvereinigungen, AiF) and a German industrial consortium. These projects have led to two DART realization approaches for specific fields of application. The first approach aims at achieving generally applicable, high-power intrinsically safe energy supplies (DART for high-power applications) to provide as high a power as possible in a point-to-point connection. The second approach (DART for field bus applications) is, in contrast to this, optimized for field bus applications with distributed, decentral topology and large cable lengths.

Both concepts were presented at the INTERKAMA 2008 and in "Automatisierungstechnische Praxis" (atp) and were discussed in a PTB workshop. It turned out that German industry is strongly interested in a further advancement of this innovative technology. In this connection, the elaboration of suitable requirements for the international (IEC) standards is of central importance. For industry, PTB's support in the specifying of safety-relevant parameters and the implementation of the respective requirements in standards is especially important.

Use of RFID transponders in potentially explosive atmospheres

Due to the constantly increasing demand for information (e.g. for quality assurance measures and process control), RFID (Radio Frequency Identification) technology is applied in industry to an increasing extent.

An RFID system is composed of a reader (reading device) and a transponder (data store). The operation of a transponder always requires a reader. The energy supply in a system with a working frequency of, for example, 13.56 MHz is performed via the HF field generated by the reader. The transponder is exclusively operated in the magnetic near field (closed coupling) of the reader. A passive transponder is, as a matter of principle, composed of an LC resonance circuit tuned to the working frequency, a rectification with a charging capacitor and a chip with data storage. Active transponders are additionally equipped with a battery to supply the chip. For use in potentially explosive atmospheres (as, for example, in process industry) there are already some type-tested RFID systems, readers and transponders.

For the use of transponders, e.g. as future electronic labels, a constantly increasing production range is available. It is, among others, the aim of the NAMUR Working Group (4.16) to define conditions under which transponders can be used in potentially explosive atmospheres without representing a potential ignition source. In cooperation with PTB it was investigated which ignition sources may become effective in the case of RFID transponders.

For this purpose, conditions had to be defined under which passive RFID transponders do not have to be regarded as potential ignition sources. Transponders are usually encapsulated in plastic materials. Many transponders are too small to cause a hazard due to electrostatic charging. Electrostatic charging must, however, be considered especially in the case of labels (transponders in adhesive labels). When the transponder housing is destructed, electric circuits may be exposed. In conventional transponders with a resonance frequency of 13.56 MHz, reactances are, however, too small to generate ignition-capable sparks. For the investigated transponders, an ignition-capable electromagnetic radiation was not given as they do not represent an independent transmission device. As a main problem, heating of the transponder by the coupled power was investigated. A heating worth mentioning could, however, be observed only when the transponders were triggered with a reader in normal operation (cf. Figure 2).

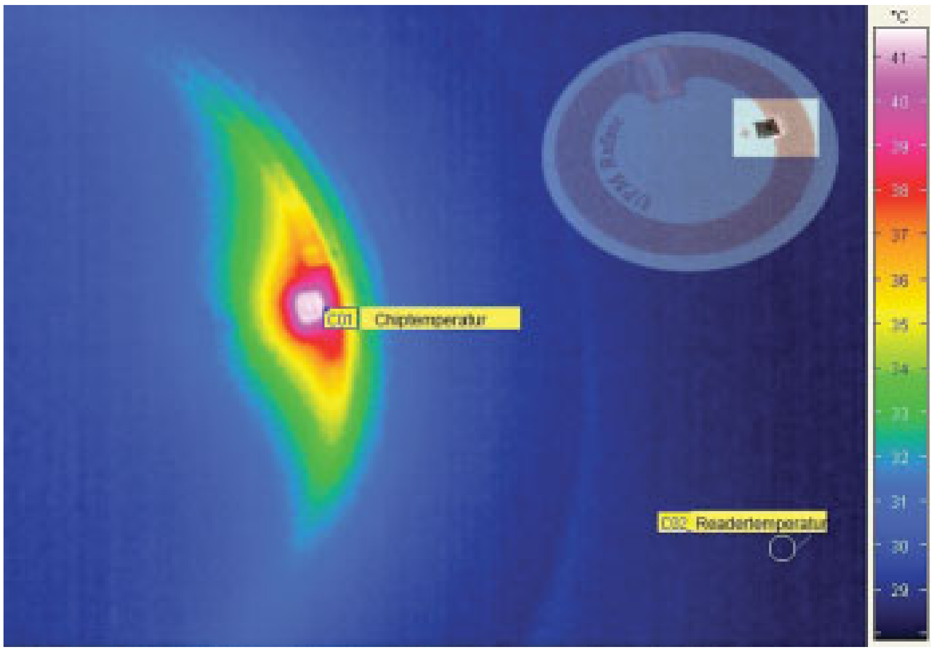


Figure 2: Surface temperature of a passive transponder

This is why specific conditions could be defined for passive transponders with a working frequency of 13.56 MHz to position them without risk in potentially explosive atmospheres. Reader and battery-supplied transponders are, however, generally regarded as potential ignition sources and must, therefore, meet the requirements of explosion protection.

Small hot components as potential ignition sources

The surface temperature required for the ignition of a fuel/air mixture depends strongly on the geometry of the surface. It is, therefore, admissible that the temperature of small components exceeds - under specific conditions - the ignition temperature of the respective explosive atmosphere. Proof of the ignition incapability must be furnished by an ignition test performed on the small components under operating conditions.

Within the scope of a research project, it was investigated systematically - together with a manufacturer of electric devices - how the ignition capability of small hot components with a component surface < 3 mm_ (cf. Figure 3) can be taken into account in the construction of explosion-protected devices. The ignition capability of such components can be prevented if other device parts in their immediate environment prevent transition of the surface reactions in a self-sustaining flame propagation into the test mixture. Here, cooling of the test mixture in the direct environment of the hot component is not the only important aspect, but also the free convection of the gas mixture at the outside of the hot component. When suitable constructive measures are taken and these results are taken into account, the ignition of the test mixture by the small hot components can be safely prevented without influencing the desired function of the electric device.

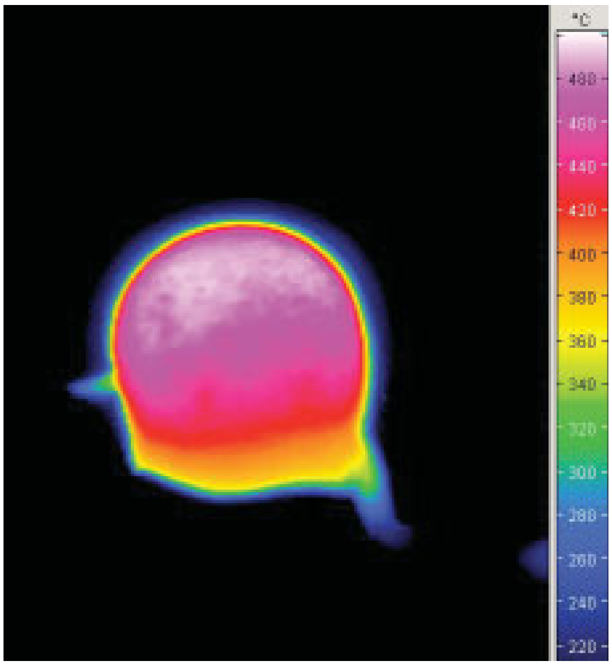


Figure 3: Thermograph of a small hot component (surface = 2.7 mm2)

New explosion protection concept for converter-fed motor units of the type of protection "increased safety“

Compared to mains-operated motors, frequency-converter-fed motor units have considerable advantages, such as large energy savings in the case of fluid flow engines, an increase in the product quality by optimization of the production process, a prolongation of the service life of the facility, a decrease in the circuit feedback by voltage sags during the run-up of larger motors, as well as savings by the frequently possibly omittance of a gear.

It is also desired to use frequency-converter-fed motor units flexibly and cost-effectively in potentially explosive atmospheres of chemical and petrochemical facilities. The test and certification concept for the type of protection "increased safety" applied so far has only required concerted testing of the motor together with the converter type with which the motor will later be operated. This has led, among other things, to the actually unnecessary exchange of the motor when the converter is defective and a converter of the same construction is no longer available. This is why new facilities often do without converter operation although this is not expedient for reasons of energy efficiency. Instead, the discharge capacity is - for example in the case of a pump - adjusted by means of a bypass line with very low system efficiencies. Figure 4 shows a comparison of the two variants.

The new test and certification concept which has been developed at PTB and honoured in 2008 with the Adolf Martens Prize, deregulates the necessity of solid coupling of the motor to the converter without lowering the safety level. This was facilitated by an observation of the single frequency converter output parameters in view of additional losses in the machine which allowed an interface between motor and converter to be defined. For the safe operation of the motor, limiting values of the interface parameters are determined. Parallel to this it is required to assess the cooling of the motor with respect to the current speed.

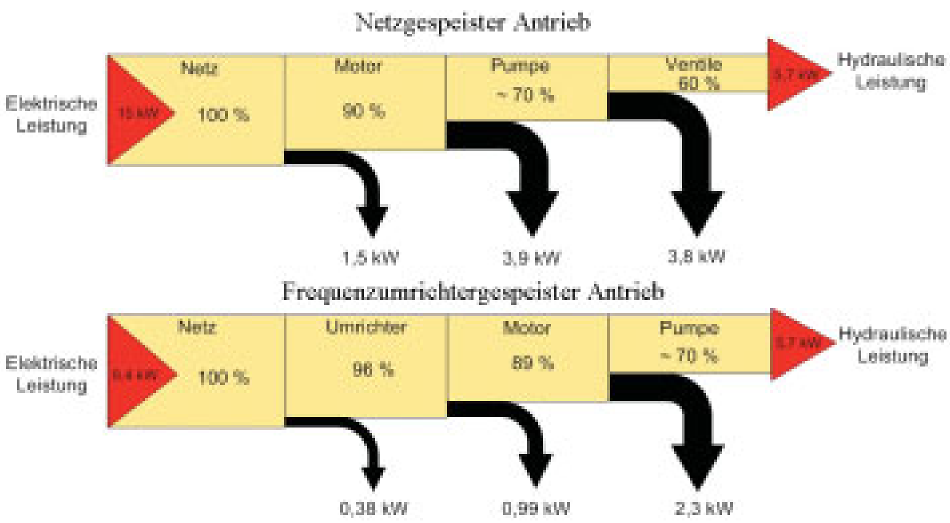


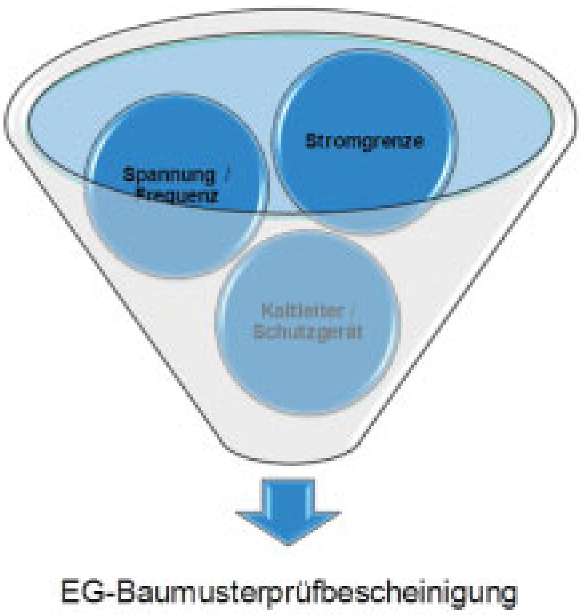
Figure 4: Loss distribution of mains-operated and frequency-converter-fed pump drives

The additional harmonic losses in the machine caused by the frequency converter normally lie in the range of up to five percent of the fundamental losses, provided the permissible interface parameters of the motors are complied with so that no inadmissible heating is to be expected here.

However, the interface parameters do not only relate to the harmonics load, but also to the value of the fundamental. If the rated voltage is not reached, e.g. by voltage drops on converter and lines, this may lead to an inadmissibly large machine slip and very high temperatures, above all in the rotor of the machine.

The new test and certification concept considers all these conditions by a speed-variable current limitation which must be implemented in the converter as a function. The converter itself is not certified. This is why direct temperature control via PTC thermistors by means of a monitoring device which has been tested for correct functioning must be provided as an additional element of the new test and certification concept. The EC type-examination certificate for the motor, therefore, contains specifications regarding the permissible harmonics and electric pulse strength of the motors, the speed-variable current limitation and the thermal machine protection, Figure 5.

Figure 5: Parameters specified in the EC type-examination certificate



The experience gathered so far with the new test and certification concept is extremely positive. It is to be expected that it will make the frequency-converter-fed motor unit also more attractive for potentially explosive atmospheres and that it will open up very large energy saving potentials. Figure 6 shows the cost development for the mains-operated and the converter-fed variant of a pump drive with a rated output of 18 kW.

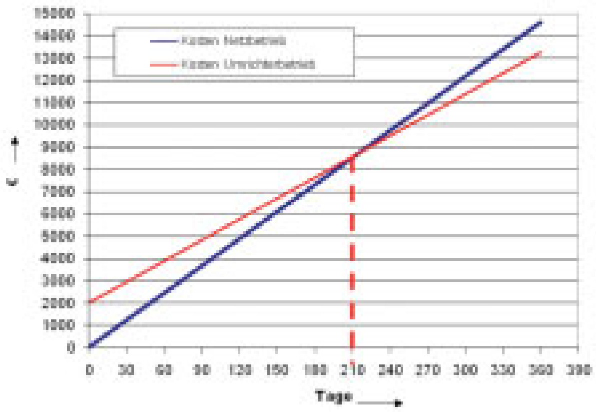


Figure 6: Energy cost developments for the mains-operated pump drive and for a converter-fed pump drive. Here, the converter costs of ¤2000 have amortized after 210 days.

Explosion pressure in small volumes

Housings of devices of the type of protection "flameproof enclosure" must safely withstand the pressure of an explosion in the interior of the device. The explosion pressure depends, among other things, on the free internal volume of the housing. Proof of this compressive strength must be furnished by a test. For this purpose, the maximum explosion pressure (the so-called reference pressure) is determined which, for housing volumes of less than 2 cm_, can be determined only with high experimental outlay. It was, therefore, investigated whether a limiting value of the maximum reference pressure can be determined for small volumes to simplify the test procedure.

The volume dependence of the maximum explosion pressure was investigated for the test gas mixtures of propane, ethene, ethine and hydrogen stated in EN 60079-1. The volume range covered 0.1 cm_ to 33 cm_. The influence of the volume on the maximum explosion pressure depends on the burning velocity of the combustible matter. In the case of propane, for example, a significant decrease already occurs at 10 cm_, whereas in the case of hydrogen this can be detected only in the case of very small volumes (cf. Figure 7). The results do not lead to any suitable simplification of the test, as a resulting conservative limiting value would lead to unnecessarily high requirements for the routine test of the devices. It will, therefore, be reasonable also in the future to determine the reference pressure in small volumes by experiment.

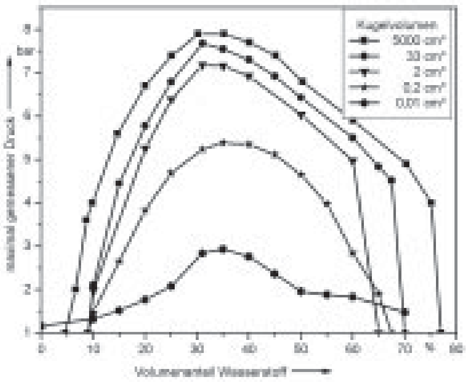


Figure 7: Maximally measured pressure after ignition of hydrogen/air mixtures in different sphere volumes. In the case of a sphere volume of 0.1 cm3, a pressure increase due to the electric ignition spark can be seen.

Flame arrestor elements of sintered fibre structures

In the case of an explosion, endurance burning flame arrestors must withstand a stationary fire on their surface. For the testing of these fittings, a critical volume flow of a characteristic fuel/air mixture is led through the flame arrestor and ignited on the surface. The flame stabilizing on the flame arrestor introduces thermal energy into the system. If the endurance burning flame arrestor is not in a position to discharge this heat to the environment by transport processes, the flame enters the flame arrestor and will - after some time - ignite the gas mixture on the protected side. Within the framework of a research project funded by the AiF within the scope of the ProInno-II programme, the use of flame arrestors made of high-temperature-resistant sintered fibre structures was investigated in endurance burning flame arrestors.

Due to their manufacturing process, sintered fibre structures show a considerably smaller thermal conduction in the axial direction than in the radial direction. Due to this anisotropy, the heat released by the chemical reactions is preferably transported outwards to the housing wall, where it can be released - mainly by convection - to the environment. The transport in the axial direction is, however, much smaller so that the temperature on the lower side of a flame arrestor element of sintered fibre structures is increased only slightly. This detailed investigation of the heat transmission processes allows the advantages and disadvantages of these novel flame arrestor elements to be determined compared to classical flame arrestors using crimped ribbon devices. In connection with a construction-systematic approach it is, thus, possible to design novel products with a calculable chance of success beyond known solutions.

Alternative fuels and combustibles

The introduction of petrol with a high ethanol fraction ("E85") made a new assessment of the safety measures at petrol stations necessary. Detailed investigations of the characteristic safety data of these fuels (also of those with a very high ethanol fraction) were used as the basis for a regulation of the federal states, the publication LV47 "Requirements for facilities for fuels containing bioethanol" of the Federal States Committee for Labour Protection and Safety Technology (LASI). The lower vapour pressure, the higher flash point and the upper explosion point as well as the smaller maximum experimental safe gap of these fuels lead - for some aspects of the explosion protection concept of petrol stations - to higher requirements.

Headlines: News from the Division

(This news and other reports are to be found in detail in the online annual report at www.ptb.de)

Fundamentals of Metrology

Determination of growth hormones in serum

Measurement of the water density at temperatures between 30 °C and 90 °C

Volume and density of spheres of isotopically enriched silicon

Metrology for Society

"Finger prints" of phosphor fertilizers

Measurement of density and of the thermal expansion coefficients of mixtures composed of fossil fuels and biofuels

New release: Safety Characteristic Data / Volume 1: Flammable Liquids and Gases

Determination of the mixture fraction in non-reactive free jets

Metrological characterization of electrostatic discharges

Formation of ignition sources during tribological processes

PTB Testing Instructions for explosion-protected electrical drive systems

New explosion protection concept for frequency-converter-fed drives of the type of protection "increased safety"

Modelling of the ignition source "hot surface"

Metrology for Economy

Conductivity as a quality parameter in the production of car paint

Measurements of the extreme trace humidity successfully completed