Safety technology with a long tradition

A historical survey of the development of explosion protection in Germany

by Wolf Dill

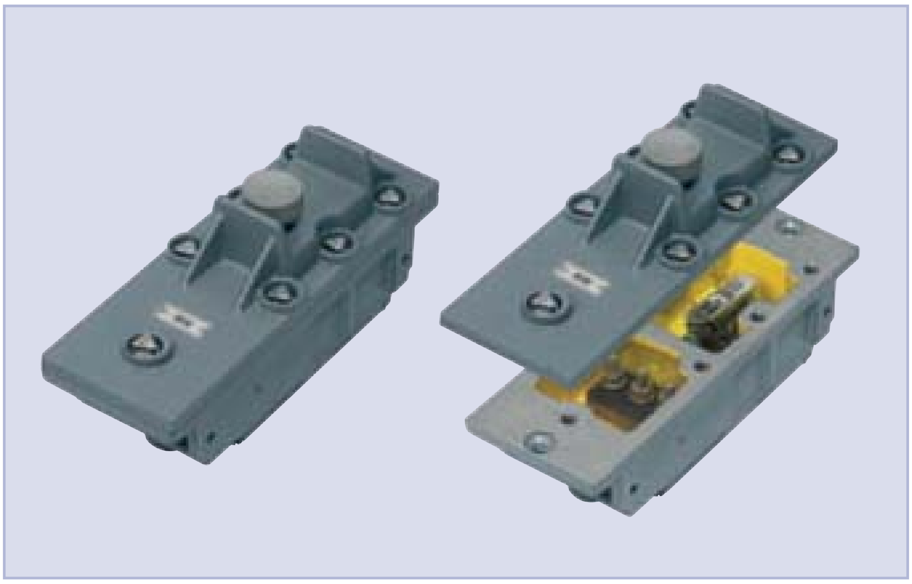

Figure 1: Explosion protected push button in a flameproof enclosure of cast iron manufactured by R. STAHL Maschinenfabrik between: 1930 and 1950

This article was not written with a historian's precision, but rather with the intention of highlighting some milestones as well as a few less well-known details about the technological development of explosion protection, in particular with regard to the constructive measures in avoiding ignition sources. Should any important details be missing, it is because the articles' scope has intentionally been limited.

The driving force behind developing explosion protection technology were the demands from the industrial plant users and the innovative power of the manufacturers. At the same time, the historical development is also a history of the standards, the regulations and laws, the testing laboratories, and the public authorities. The code of the public authorities (commonly based on investigations of testing stations or the resulting developed safety standards) often proved to be the greatest challenge. The general goal of implementing state-of-the-art technology even in areas of potential explosion hazards was a challenge for many developers and inspectors working in the wake of such changes. Germany oftentimes provided significant progress for new developments, which all those involved can be proud of, but from the beginning, the innovation in explosion protection came from the international exchange of information.

Firedamp explosions

Mining was one of the first branches of industry with explosion hazards that was always known and was primarily dealt with through the improvement the mine ventilation. Since open flames were still being used to illuminate the workplace in the 19th century, this ignition source needed to be defused first for firedamp explosions. In England, Davy's invention of the fine mesh wire-gauze protective cylinder that was used as a flame arrester actually marked the first type of protection. The next step was then doubling the wire-mesh cylinder that constituted the principle of the doubled type of protection. This was a considerable improvement, as the miner's lamp was also later used as a gas-measuring device that allowed the Methane content, as low as approximately 0.5 %, in the mine air to be measured by observation of the flame.

With the initial mechanisation of coal mining and the exploitation of deeper mines that proved difficult to ventilate, the number of explosions continued to rise. The ignition source of these explosions was mostly explosives that were used for roadheading and to loosen the rock for coal mining. The explosion risk of coal mining consists of two parts: a methane explosion, whose effects can lead to the death of many workers, generally whirls up the omnipresent coal dust and subsequently ignites a coal dust explosion. With an increase in explosion pressure and flame speed, this explosion spreads further through the dust whirled up by the blast wave throughout the entire mine and at worst, exits the pithead opening. Incidentally, the last such incident in Germany was recorded at the Stolzenbach lignite mine in 1988. The ignition was caused by the use of explosives that were not approved for coal dust.

In most cases, insufficient training combined with negligent supervision and management causes such incidents. Generally speaking, the hazards and methods to avoid these incidents have been known for decades.

Testing stations (›testing galleries‹)

At the end of the 19th century, as the number of firedamp explosions in the Westphalian mining industry reached a quantity (300 explosions in 10 years) that could no longer be considered unavoidable, mine owners saw the need to act. In 1894, the Westphalian mine owners' association fund, the community organisation of the owners Westfälische Berggewerkschaftskasse WBK) that was founded for training and safety, decided to construct a testing gallery. This replica of a typical underground roadway (gallery) was constructed next to the slagheap of the Bismarck mine in Gelsenkirchen-Schalke.

The mining testing gallery (Bergbau-Versuchsstrecke, in short BVS) was not the first testing gallery of its kind. It was constructed according to the testing gallery in Neunkirchen on the Saar. Later, there were also occasional testing galleries in Beuthen (Upper Silesia), Freiberg (Saxony) and in Alsdorf near Aachen. Initially, the first and most important activity of the BVS was testing methane and coal dust explosions and their ignition by using explosives.

Development work was carried out to alter explosives and detonators so that at least the methane-air and coal dust-air mixtures no longer ignited when specific precautionary measures were taken. Over the decades, the focus of the development work increasingly shifted more towards the explosives industry, while the BVS engaged in highly-specialised testing laboratory activities. For this reason, they were also expressly authorised by the Explosives Law of the Federal Republic of Germany. Based on the test reports, the Federal Institute for Material Testing (Bundesanstalt für Materialprüfung - BAM) then issued an approval.

With the implementation of the EC Explosives Directive 93/15/EEC in 1998, the German Federal Government also transferred testing operations to the BAM. Despite the additional tasks required for testing equipment and personnel, the government did not want to leave the explosives testing in the hands of a privatised company or individual.

In 1908, the BVS was forced to relocate to Dortmund-Derne, as the Bismarck mine and subsequent the mine Consolidation could no longer supply sufficient quantities of firedamp for experiments. At that time, the Gneisenau mine in Derne had a large supply of firedamp.

The move to Derne was coupled with large-scale expansions of both the test installations and the buildings. A 200-meter long gallery (∅ 2.50 m pipe) was constructed to test coal dust explosions and was put into operation in 1911. During distinct verification procedures within this gallery, it could be proved that coal dust could lead to self-propagating explosions without the involvement of methane, which mine owners vigorously denied.

The gallery is incidentally still used today to test whether specific coal dust (anthracite) can independently cause propagating explosions in roadways. Specific explosion protection measures can be omitted for a corresponding result.

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Glückauf,

Berg- und Hüttenmännische Wochenschrift

Versuche

Figure 2: Publication from 1898 about ignition hazards by electricity. An accepted non-incendive lower limit for the energy of electrical sparks could not be ascertained at that time

Beyling's investigations on firedamp-proof electrical equipment – the beginning of the type of protection flameproof enclosures

Beyling, the active BVS director from 1902 to 1938, who had already significantly contributed to the development of safe explosives, soon moved onto the next potential ignition source: electrical devices that included motors, switchgears, and luminaires that were used underground.

The electrical industry believed that such devices could be built tight enough so that methane could not penetrate them. The BVS experimentally proved that the explosive methane-air mixture quickly penetrated all innovated motor and switch designs and that it ignited with the smallest sparks. The subsequent explosion leads to the destruction of the enclosure and the ignition of the surrounding atmosphere.

The design objective of the following BVS investigations, which were at the time largely supported by the manufacturers Siemens and AEG, was to control the explosion pressures and prevent external ignition. Beyling published the results in 1906. This publication describes all fundamental principles that are relevant for the type of protection Flameproof enclosure ›d‹ and other protection concepts.

Standardisation as the early regulation instrument of explosion protection

The close collaboration with the electrical industry was the impetus behind the idea of not just incorporating technical specifications into the statutory mining regulations, but rather into a VDE regulation (VDE = Verband Deutscher Elektrotechniker – Association of German Electrical Engineers).

VDE regulations for high-power electrical equipment have been around since 1895. The ›Guidelines for designing firedamp-proof devices in electrical machines, transformers and apparatus‹ published by the VDE went into effect on July 1st, 1912. The protection technology referred to as enclosed encapsulation within these principles describes the fundamental principles for the type of protection that were later referred to as flameproof enclosure, and includes the explosion pressure resistant design of components, the flameproof joint and avoids constructions with separated rooms that can lead to pressure piling. Furthermore, the principles of plate protection and woven wire encapsulation (both of which are used today in type of protection Flameproof enclosures ›d‹) are also described. The fundamental principles of improvement of operational non-sparking devices, or devices which do not become hot by using mechanical protection, increasing the dielectric strength, reducing the permitted heating and using secured connections are also defined. This was the preliminary stage of the subsequent type of protection Increased safety ›e‹. In addition to the standardised protection technologies, other protection technologies may also be tested by a recognised mining testing station. This allows the subsequent standard ›special protection‹ (Ex s, Sch s) approach to open the way for new technologies.

This special concept of the VDE guiding principles that was later continued in the national VDE standards is comparable to an EC directive according to the ›New Approach‹. The New Approach entails the general description of potential protection measures and the application of alternative new concepts, as long as they are tested by a ›Notified Body‹.

In the United Kingdom, Professor Wheeler, who worked closely with Beyling, performed corresponding investigations that created the foundation of the British standard BS 229:1926. Beyling's and Wheeler's scientific work was both honoured with a medal from the Royal Society for Institution of Mining and Mechanical Engineers in London in 1938. Looking back at the date, which was just before Hitler's onslaught on neighbouring states, one cannot overlook this remarkable event.

The VDE guiding principles have been revised several times to incorporate new insights.

The great success of the standard version of VDE 0170/0171 from 1943/1944 must be noted. In the meantime, all significant types of protection had been incorporated and it was used for design changes in coal mining equipment with next to no changes made to its original version up until 1988. It remained in effect up until the date when Directive 94/9/EC was implemented.

1935 – 1943

From firedamp protection to general explosion protection

The technological advances made in the industry resulting from armament activities also lead to an increase in the number of plants with hazardous areas. On October 20th, 1938, the VDE published a draft for the standard VDE 0171 that was intended to standardise the corresponding electrical apparatus.

In a letter to the WBK dating back to July 18th, 1939, the Secretary of State for Trade and Industry summoned the BVS to expand its field of activities concerning such tests. At the same time, the Secretary of State for Trade and Industry announced that the commercial department of the ministry was planning to establish a testing facility for explosion-proof electrical motors at the Federal Chemical Technical Institution (Chemisch Technische Reichsanstalt – CTR) in Berlin. In 1940, the Minister summoned the WBK to start constructing the testing facility.

In 1941, the economic group of the electrical industry announced that the CTR was concerned over testing delays during the construction phase of the testing facility, and that the Secretary of State for Trade and Industry was therefore planning to recommend authorising manufacturer's testing facilities. On October 13th, 1943, the Secretary of State for Trade and Industry approved the ›Polizeiverordnung über elektrische Betriebsmittel in explosionsgefährdeten Räumen und Betriebsanlagen sowie in schlagwettergefährdeten Grubenbauten‹ (police regulation on electrical apparatus in hazardous places and installation as well as in mines susceptible to firedamp) that would be published in the same manner as a VDE standard – a unique way of combining technology and law. The CTR, the BVS (to a limited scope) and specially authorised manufacturer's testing facilities were named as testing stations for ›Ex‹ protection. BVS was made solely responsible for firedamp protection (›Sch‹). This specialised field was thoroughly regulated with both the VDE standard VDE 0170/0171 for equipment published in 1943 and the respective VDE installation standards.

The time following the Second World War

The reconstruction and the political division of Germany influenced the post-war period. The pre-war tasks that the Berlin-based CTR took over for explosion protection were transferred to the Physikalisch Technische Bundesanstalt PTB (Federal Physical and Technical Institute) in Brunswick, which emerged from the PTA (Physical and Technical Institute, formerly called the PTR). Thanks to the generous backing provided by the mineral oil industry, the new testing laboratories were excellently equipped.

In 1948, the BVS, which had been classified as a munitions production facility by the allied forces and was completely bombed out, was rebuilt and re-equipped using funds provided by the coal mining industry.

In 1949 in the GDR, the Saxon testing gallery founded in 1928 at the Freiberg Mining Academy became a part of the Institute for Mines Safety (Institut für Bergbausicherheit – IfB) in the areas of fire and explosions. As the GDR Institute for Blasting Technology, Fire and Explosion Protection for Mining and Industry, the IfB also took over the research performed for the fundamentals of the TGL standards, which were in force at that time in the GDR.

The Federal Republic of Germany initially adopted a federalist approach to the explosion and firedamp protection of electrical equipment. The testing stations PTB and BVS issued type test certificates, and based on these, the responsible regional authorities (district presidents, mining inspectorates) made approvals.

The public-authority approvals were first discontinued with the implementation of the Explosion Protection Directive 76/117/EEC by ElexV – Verordnung über elektrische Anlagen in explosionsgefährdeten Anlagen (Regulation concerning electrical installation in hazardous areas) in 1980 and the Firedamp Protection Directive 82/130/EEC by ElZulBergV Elektro Zulassungs Bergverordnung (Mines regulation concerning admission of electrical equipment) in 1984, as the PTB and BVS examination certificates received the status of general approval as well as the certificate of conformity of other EC testing stations.

In 1991, following the reunification, the IfB (Leipzig & Freiberg) was formally dissolved. Thanks to the support provided by the Federal German Ministry of Economy, work at the Freiberg testing gallery in the IBExU-Institut für Sicherheitstechnik GmbH was continued in 1990.

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01.01.1883	Berlin	›Verordnung über das gewerbsmäßige Verkaufen und Feilhalten von Petroleum‹ (statute regarding commercial sales and the offering of kerosene for sale) took effect.
1884	Aachen	First investigations of ignition hazards caused by electricity by Professors Wüllner and Lehmann (Technical University Aachen) as commissioned by the Prussian firedamp commission.
07.11.1887	Hameln	Explosion of the Werder mill with 10 dead – reportedly the first dust explosion in Europe. The investigations of the Brunswick engineer C. Arndt led to safety regulations by the occupational Employes' Liability Insurance Association of milles.
22.01.1893	Berlin	Foundation of the VDE (Verbandes Deutscher Elektrotechniker – Association of German Electrical Engineers).
1894	Gelsenkirchen-Schalke	Establishment of a testing gallery (›Bergbau-Versuchsstrecke‹ – BVS) by the Westphalian mine owners'association fund (Westfälische Berggewerkschaftskasse WBK).
23.11.1895	Eisenach	The commission of the VDE issues the ›Safety regulations for electrical power systems‹, for installations of up to 250 V; underground or electrochemical installations are excluded.
1898	Essen	Heise and Thieme publish their results ›Versuche betreffend die Entzündlichkeit von Schlagwettergemischen und Kohlestaubaufwirbelungen durch die Wirkung der Elektrizität‹ (Experiments relating to ignition of firedamp mixtures and clouds of coal dust by the effects of electricity). An accepted non-incendive lower limit for the energy of electrical sparks cannot be ascertained; every spark is to be considered potentially capable of ignition.
12.12.1900	Dortmund	Mining regulations regarding the ventilation of coal mines. If the firedamp content cannot be held under 1 pCt, then the operation is to be shut down.
1903	Berlin	VDE 100 ›Errichtungsbestimmungen für elektrische Anlagen bis 1000 V‹ (Installation of power systems and equipment with nominal voltages up to 1,000 V) with first mining regulations.
1906	Essen	C. Beyling (Director of the BVS since 1902) publishes the investigative results fundamentally describing the principles of flameproof enclosures and other protection techniques (oil immersion, plate protection, increased safety).
01.04.1910	Rhine river	The European federal states and nations with direct access to the Rhine (Baden, Bavaria, Alsace-Lorraine, Hesse, Prussia, the Netherlands) issued the ›Vorschriften über die Beförderung von Petroleum und dessen Destillationsprodukten in Kastenschiffen auf dem Rhein‹ (regulations regarding the transportation of petroleum and petroleum distillation products in tanker ships on the Rhine river) as a replacement for the ordinance from 1905. This forerunner of the European directives contains detailed primary and secondary explosion protection measures, e.g. for the ignition systems of engines and the limitation of exhaust temperature to 80 °C. According to the ordinance ›Ordnung über die Untersuchung der Rheinschiffe‹ (ordinance regarding the examination of Rhine ships), which was issued by the same European states and nations likewise in 1905, the containment tanks that were limited to 150 m^3 capacity must be vented. The ventilation openings were to be covered with ›Davy gauze‹, a type of wire mesh construction designed to inhibit transmission of internal ignition.
1911	Dortmund-Derne	The BVS puts the 200 m coal dust explosion testing gallery in operation. Proof can be furnished that coal dust explosions can be autonomously propagated by swirling of dust deposits.
01.07.1912	Berlin	Published by the VDE, the ›VDE-Leitsätze für die Ausführung von Schlagwetterschutzvorrichtungen an elektrischen Maschinen, Transformatoren und Apparaten‹ (VDE-guiding principles for designing firedamp-proof devices on electrical machines, transformers and apparatus) takes effect.
14.10.1913	Wales, United Kingdom	Explosion at the Senghenydd mine triggered by a signalling device that was considered non-incendive; 439 people were killed. Prof. Wheeler begins the thorough investigation of the ignition risk in electrical sparks. The results formed the first fundamentals of the type of protection ›Intrinsic safety‹ that was standardised in 1945 in BS 1259.
21.09.1921	Oppau	A silo with ammonia sulfa-nitrate explodes, resulting in 561 dead.
03.12.1927	Berlin	Professor W. Philippi from the Siemens-Schuckert company after a visit to Belgian mines and the testing gallery in Frameries, proposes to align the Belgian and German electro-technical specifications for mining. The harmonisation of these standards is finally completed in 1977.
1935	Berlin	VDE 0165 ›Leitsätze für die Errichtung elektrischer Anlagen in explosionsgefährdeten Betriebsstätten und Lagerräumen‹ (Guiding principles for installation of electrical systems and equipment in workplaces and storage rooms with explosion hazard).
1938	Berlin	VDE 0171/Draft ›Vorschriften für die Ausführung explosionsgeschützter elektrischer Maschinen, Transformatoren und Geräte‹ (Regulation for the design of explosion protected, electrical motors, transformers and electrical apparatus).
1938	London	Beyling's and Wheeler's scientific work was honoured with a medal from the Royal Society for Institution of Mining and Mechanical Engineers.
13.10.1943	London	Adoption of ›Polizeiverordnung über elektrische Betriebsmittel in explosionsgefährdeten Räumen und Betriebsanlagen sowie in schlagwettergefährdeten Grubenbauen‹ (police regulation on electrical apparatus in hazardous areas and workplaces as well as in mines susceptible to firedamp) by the Secretary of State for Trade and Industry.
1945	Great Britain	BS 1259:1945 is the first standard in which the testing of intrinsically safe circuits with spark testing equipment (Breakflash No. 3) is described.

20.02.1946	Bergkamen	Firedamp explosion at the Grimberg mine, 405 dead.
1947	Brunswick	Construction of an explosion protection laboratory in the PTA (Physikalisch-Technische Anstalt) Physical and Technical Institute, (formerly called the PTR) by Nabert.
28.07.1948	Ludwigshafen	A bogie tank wagon loaded with diethyl ether explodes, resulting in 207 dead and 3818 injured.
25.03.1957	Rom	Signing of the Treaty of Rome – establishment of the EEC.
1957	Berlin	K. Müller submits his dissertation ›Die Zündung von explosiblen Methan-Luft-Gemischen durch elektrische Schaltfunken‹ (The ignition of explosive methane-air mixtures by electrical switching sparks) at the Technical University in Charlottenburg.
1957	Prag	IEC committee meeting of SC 31-G. The results of many comparative tests with the various intrinsic safety test apparatus used in the various countries (e.g. UK / Breakflash No. 3, FR / Eclateur Rapide, DE: the device from Müller / Siemens). The instrument developed in Germany by the Siemens Company was selected and standardised worldwide in IEC 79-3.
15.08.1963	Bonn	›Verordnung über elektrische Anlagen in explosionsgefährdeten Räumen, Explosionsschutzverordnung, ExVO‹ (Regulation concerning electrical installation in explosion hazardous places).
1965	Frankfurt	VDE 0170/0171/d adopts the intrinsic safety test apparatus stipulated in IEC 79-3.
1969	Brüssel	1969 Brussels: CENELCOM begins harmonisation of the electro-technical standards in the EEC (six members).
05.05.1969	Brunswick	1st International Work Conference for testing stations for explosion protected electrical apparatus.
1970	Brussels	Beginning of exchange of experiences between the bodies notified to the EC Commission. During consultation regarding subsequent Directive 76/117/EWG, a memorandum in the Council protocol initiated the establishment of Working Group HOTL (Heads of Testing Laboratories). Initially, the group included the testing authorities INIEX (BE), BVS and PTB (DE), CERCHAR and LCIE (FR), CESI (IT) and BASEEFA (UK).
1973	Brussels	CENELCOM receives EFTA members and becomes CENELEC.
18.12.1975	Brussels	Directive 76/117/EEC regulates the free trade of electrical equipment for Zone 1.
1977	Brussels	EN 50014 – 50020 were published as the first generation of European standards for electrical apparatus for potentially explosive atmospheres (explosion protection + firedamp protection). The marking EEx is intended to signal ›European explosion protection‹.
06.02.1979	Brussels	Directive 79/196/EEC harmonises the standards EN 50014-50020 for Group II. The ›Distinctive Community Mark‹ Ex originally symbolised the six founding member states of the EEC.
09.02.1979	Bremen	Flour dust explosion in Bremen's Roland Mill (14 dead, 14 injured).
01.07.1980	Bonn	Verordnung über elektrische Anlagen in explosionsgefährdeten Räumen, ElexV, (Regulation concerning electrical installation in explosion hazardous places) takes effect starting 27 Feb. 1980. It implements Directives 76/117/EEC and 79/196/EEC for Zone 1 equipment. The particularly nationally oriented obligation to test electrical apparatus for Zone 0 (PTB) and Zone 10 apparatus (BVS) are stipulated and set in writing. The approval of the type of construction by regional authorities is omitted; certificates of conformity of the bodies notified to the EC Commission for Zone 1 devices get the status of an approval.
1982	Brussels	Directive 82/130/EEC harmonises the standards EN 50014-50020 for firedamp. However, some portions of the standards are modified and the Directive introduces in the appendix its own standard for intrinsically safe systems, which deviates from the CENELEC draft EN 50039.
1984	Bonn	The ›Elektro-Zulassungs-Bergverordnung (ElZulBergV)‹ (Mine regulation concerning admission of electrical equipment) puts Directive 82/130/EEC into practice in the German legal sphere.
01.06.1988	Borken	Lignite dust explosion at the Stolzenbach mine with 51 dead and 8 injured.
05.05.1993	Mannheim	1. Meeting of CEN TC 305 ›Potentially Explosive Atmospheres – Explosion Prevention and Protection‹.
1994	Brussels	Directive 94/9/EC extensively regulates free trade of equipment, protective systems and components for all areas of explosion protection (gas, dust, firedamp-electrical and non-electrical equipment, all zones).
1997	Brussels	CEN publishes EN 1127-1, the first fundamental standard dealing with explosion protection as per Directive 94/9/EC. While still in CEN TC 114, it was developed on the basis of the Ex-RL (explosion protection rules of the BG Chemie).
1999	Luxembourg	Directive 1999/92/EC approves minimum requirements for improving the safety and health protection of workers in the workplace as well as equipment usage in accordance with 94/9/EC. In the Appendix, the Zones 0, 1, 2 (gas) and 20, 21, 22 (dust) are defined.
2002	Brussels	EN 13980 was jointly developed by CEN and CENELEC and defines requirements for quality assurance used by manufacturers of equipment, if required monitored by the ›notified bodies‹ in accordance with Directive 94/9/EG.

Table 1: Historical dates relevant to explosion protection in Germany

Figure 3: Socket for three phase current type of protection ex d C3 (Marking according to VDE 0171/I.44 V, C = ignition temperature >175 °C, 3 = gap of the joint 0.5 mm; C_2 excluded CS_2), enclosure of bakelite, connection chamber ›Ex e‹, flame transmission resistant rotary switch with a ceramic bushing; manufactured by Stotz Kontakt before 1957

Additional developments in types of protection

The developments that have been incorporated into EN and IEC standards will be described in detail in the following section. Neither all types of protection nor all technological aspects will be addressed here.

Intrinsic safety (›i‹)

In general terms, this type of protection was already outlined in VDE 0170/1934, but there were still no standardised testing methods.

Once again, it was an explosion that echoed the need for standardised testing methods: in 1913, an explosion shook the foundations of safety awareness at the Senghenydd mine in Wales (UK). The explosion was caused by a signalling device that was considered non-incendive and 439 lives were lost.

Professor Wheeler began a thorough investigation of the ignition risk of electrical sparks. The results formed the first fundamentals of the intrinsically safe protection type that was standardised in 1945 in BS 1259.

Due to the increase in equipment that implemented measuring and control circuits and those used for communication, the interest in intrinsic safety rapidly grew worldwide. The British, Germans, French, and Russians all developed separate testing equipment. A competition was held for the IEC standardisation. The decision on which of the different nation's proposed spark test apparatus was to be internationally standardised was made during the IEC committee session SC 31G in Prague in 1957.

The apparatus developed in Germany by the Siemens Company was selected. The protocols of this committee session contain a note explaining that the amperages were limited for use in this apparatus so as to take into account the influences, which were not known at that time, of cable and lines on the ignition risk in electrical sparks. The German national standard VDE 0170/0171d/2.65 was created using the knowledge available at that point in time and did not apply to cables and lines.

Additional milestones regarding the development of intrinsic safety include the experimental work on special effects of spark ignition, the influence of cables and lines, and the ignition caused by hot small components or high frequencies.

Increased safety (›e‹)

After the Second World War, PTB performed thorough investigations to further develop the type of protection concepts, which were already verbally revised in the first VDE standards, on preventing sparks or (excessively) high temperatures by using especially secure attachments, enlarged clearances and creepage distances, high-quality insulating materials, and temperature monitoring and limiting. The emphasis here was placed on electrical motors. Such endeavours remained a German speciality for a long time to come. The German initial letter became an international code but was not particularly accepted or only accepted to a very limited capacity in non-European countries (USA, USSR, Asia).

As equipment in type of protection Increased safety ›e‹ cannot not be immediately distinguished from normal industrial technology and equipment for Zone 2, a great deal of convincing was required in both the standardisation in which German manufacturers and the PTB were actively engaged for decades and with the foreign authorities and operators.

This type of protection received international recognition with the first edition of the IEC 79-7 in 1969. The work at CENELEC (started already in the previous organisation CENELCOM) began in 1974 with the first meeting of the SC 31-4 that Germany chaired in May of 1974 in London.

Encapsulation (›m‹ – moulding)

Encapsulation was also used for quite some time before it was standardised into an independent European standard. Originally, there was in-house testing specifications for the testing stations that were incorporated in the CENELEC committee discussions via the EN 50028 (first edition 1988).

Most importantly, this standardisation brought about particularly detailed test specifications for the thermal and mechanical resistance, as plastic was introduced into enclosure material for explosion protection.

Powder filling (›q‹ – quartz)

In the 1930s, a replacement for flammable oil, which would be used as a spark-extinguishing medium in mining switchgear in France, was being sought. The fire load resulting from the use of combustible oil was viewed as an excessively high risk. After thorough experiments, dried silica sand was selected. The experiments proved that the transmission of an internal ignition of methane could be prevented with just one 10-mm layer of silica sand (grain size approx. 0.7 mm). Experiments conducted with arcs up to 36 kA proved that a grain depth of up to 10 cm is required to prevent a transmission of an internal ignition of arc in the surrounding atmosphere. The results were incorporated into the standards IEC 79-5 (1967) and EN 50017 (1977). The meeting reports at the IEC state an interesting spin off: since the sand fillings prevent or strongly delay explosion processes, they can be used to reduce the excess pressure in enclosures that is caused by the explosion as well as to reduce the required wall thickness.

Technical applications of protection principles were exceedingly rare in the 60s.

In 1956, W. Bartknecht, a BVS employee presented his tests on the transmission of internal ignition on glass sphere fillings at an international mining safety conference. A densely packed 1-mm layer is completely capable of preventing a transmission of internal ignition of methane. 30 mm are sufficient for a hydrogen-air mixture.

This concept was first used as an alternative to type of protection encapsulation ›m‹ back in the 1980s. Using the glass particle fillings, the encapsulated enclosures could be reopened to repair expensive electronics. Encapsulated instruments are disposable.

The required revision of EN 50017 was completed in 1983 and was entirely discontinued for applications with high-energy switching arcs. The standard was written for operational non-sparking electronics and adopted approaches from EN 50028.

Pressurized enclosures (›p‹ – pressurization)

The initial stages of the pressurized enclosure can also be traced back to the 1930s. The VDE 0170/0171:1943 already described the type of protection ›Fremdbelüftung‹ (forced air ventilation) that contains the fundamental principles of today's pressurized enclosure.

The enormous zeppelins that up until 1937 flew from Germany to the USA represented a previously vaguely known area of explosion protection. Using hydrogen as a lifting gas provided a good lifting force, but also carried with it enormous explosion and fire risks. The safety concept not only included attaching the motor turrets away from the flammable gas, but also, for example, prohibited people from wearing shoes containing iron nails in the soles. The ignition risk of mechanical sparks between aluminium (which the supporting skeleton was made of) and rusted iron was known. At higher levels of mechanical energy, the corresponding sparks could even ignite methane.

Pressurized enclosed rooms were designed for the smoking passengers and for the radio transmitter stations. Fresh air drawn in from the outside prevented any hydrogen from entering these chambers.

The accident at Lakehurst in 1937, whose cause has now been clarified, occurred in a situation involving a classic ignition risk. During the landing descent, the zeppelin had to discharge hydrogen on the top to reduce the lift. Both the entire body (earth-insulated capacitance) as well as the rubberized textile hydrogen tanks could be electrostatically charged.

The charging of the (highly flammable) zeppelin coating caused by the atmospheric charges via electrostatic induction is certainly a possible cause for ignition. Sparks that could ignite a hydrogen-air mixture have such a low level of energy that even in the dark they are invisible to the naked eye. However, the cause of the accident was the actual burning of the highly flammable coating combined with the combustion of the hydrogen, not an explosion.

Dust explosion protection

Dust explosion protection also originated in the 19th century. Following the investigation of the flour dust explosion of 1887, which claimed 10 lives in the Hamelin Werder mill, the Employers' Liability Insurance Association (Berufsgenossenschaft, BG) of the mills demanded fundamental safety measures, such as avoiding ignition sources and the accumulation of dust. The increasing levels of processing, transport and storage of powdered, combustible raw materials in the food industry (in addition to flour and sugar, cocoa and maltodextrin, to name a few), in the pharmaceutical industry, and for metal-cutting manufacturing processes in mechanical engineering led to an increase in the number of explosions, and thus triggered a need for regulatory measures.

The explicit obligation to test electrical apparatus for Zone 10 (today: Zone 20) was laid down in the ElexV dating back to 1980. The first German standard for this area (VDE 0170/0171 Part 13) initially went into effect in 1986 after a long drafting process. Some neighbouring countries adopted part of its contents or at least used the standard.

In Germany and Great Britain , the customary classification of the areas into two zones (Zone 10 and 11 or Zone X and Y) were not directly comparable and were different from the classification system in North America (Division 1 and 2).

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All attempts to standardise the definition at an international level were rendered invalid by the European directives. While the Directives 94/9/EC and 1999/92/EC were being drafted, the experts in Europe decided to introduce three zones for the dust. This was the first step of many towards assimilation of the technical requirements for gas and dust devices. In the meantime, this step has been accepted worldwide. The next generation of IEC standards for explosion protection will comprise integrating the standards for gas and dust that have, up until now, been separated.

Electrostatics

Electrostatics as a potential source of ignition has been gaining in importance with the increasing use of plastic enclosures, containers, pipes and packaging in the Ex area. Although since 1982, the limitation of the isolated capacitances and the conducting surfaces in the EN 50014 were considered to have solved certain problems, other detailed variants long remained in the regulations of the Employers' Liability Insurance Association (Berufsgenossenschaften, BG) or in the testing laboratories.

More efforts were made to summarise the specialist knowledge for the entire topic into a single European standard. For formal reasons, the CENELEC committee TC 31 gave the second draft only the status of a technical report, which among experts is a synonym for a first-class burial of a draft standard. In reality, this document (TR 50404) is a recognised instrument throughout all of Europe, which used to assess electrostatics as a potential source of ignition.

In recent years, another procedure, which was already being used by the BVS for measuring the charge that can be generated on an electrostatically charged object, was incorporated into the EN and IEC standards as an ignition hazard measure. The PTB succeeded in determining the exact scientific correlation between the removed charge quantity and the ignition energy, which thus allowed the procedure to be used in the standard.

Gas measuring technology

The development of gas measuring technology is another area that has been so profoundly described throughout the course of explosion protection history that it will not be addressed in detail within this document.

Since practically all gas measuring devices that were developed after the miner's safety lamp require electricity to some extent, there was also a close interface with electrical types of protection. The safety aspect for these devices is of particular importance, as only after taking a measurement, can you be certain of whether or not an explosion hazard exists.

The second fundamental safety aspect of these devices is measurement accuracy and reliability. These aspects were always a focus for the technological development as well as the regulations stipulated by the supervisory authorities in Germany. Nevertheless, it took until 1991 for standards to be implemented at the European level as a unified instrument with the introduction of EN 50054-058. Until then, the technical requirements for reliability and accuracy were stipulated in Employers' Liability Insurance Association's regulations (ZH 1/8) or statutory mining regulations.

Marking and logos – a popular topic, even in explosion protection

With the VDE regulations the EX symbol in a circle became the binding label for explosion protection as did the Sch symbol in a circle for firedamp protection. Similar to a logo, they became a trademark over the course of time for explosion protection from Germany.

In 1977, the label EEx was created for European explosion protection along with the European standard EN 50014-50020. However, the Ex, the ›Distinctive Community Mark‹ associated with Directive 79/196/EC, unwillingly provoked quite a sensation. It became known throughout the world and to some legitimate extent, turned into a mark for explosion protection from Europe, sometimes de facto accepted as approval.

For the parties concerned, the Ex had such a significant marketing factor that it was integrated into the marking scheme in accordance with Directive 94/9/EC. This was an important step as the EU commission highly restricted making additions to the CE marking.

The success of the Ex finally became so big that the manufacturers took the initiative and suggested that the European certification system should be placed at the global IEC level. In the meantime, the global IECEx scheme has become tightly intertwined with the European structures, in particular with the testing authorities and by the standards. For some time now, CENELEC has adopted almost only IEC standards for the explosion protection of electrical apparatus. Thus, the effort exerted for testing global manufacturers has been greatly reduced, as even more countries are adopting the IEC standards.

At this point, a small anecdote involving real people seems more than appropriate:

At the time, some very well-known CENELEC TC31 delegates were represented with anagrams of their surnames within the section of the marking of EN 50014 or 60079-0. Ms. Debelle (Belgium), Mr. Ruchatz (Germany), Mr. Tretjakow (France) and Mr. Heatherington (Great Britain).

The reverberations caused by European Community Directive 94/9/EC

The ramifications of Directive 94/9/EC, or as it is better known, the often-apostrophized francophone term ›ATEX‹-Directive, were more extensive than many of the involved parties had anticipated.

Even the electrical engineers dealing with explosion protection had to adapt. The correlation between apparatus categories and zones took some time to adjust to, but after the industry came to terms with the changes they quickly took up the task of moving up into the global IEC level.

In the non-electrical equipment sector, the requirements accompanying the changeover were enormous as previously there were practically no standards, but rather mostly technical specifications such as, rules of the Employers' Liability Insurance Association, guidelines of the VDI (Association of German Engineers), and Codes of Working Practice from the VDMA (Association of German Machine Manufacturers). The standardisation for explosion protection of non-electrical equipment had already begun under the mandate of Machinery Directive in CEN TC 114 (Safety of Machinery). Around the same time as the creation of the ATEX Directive, the CEN Committee TC 305 (1st session in 1993) was formed. Since then, it has been responsible for bringing a multitude of fundamental standards into existence. To name just a few of the most important norms: EN 1127-1 and 1127-2 serve as basic standards for the entire field. EN 1127 was at first drafted upon the basis of the Ex-Rules (Explosionsschutz Regeln ExRL) explosion protection rules of the Employers' Liability Insurance Association of the chemical industry.

EN 13980 was jointly developed by CEN and CENELEC and defines requirements for the ›notified bodies‹ responsible for assessing quality assurance practices used by manufacturers of equipment in accordance with Directive 94/9/EG.

A particularly demanding and interesting field for standardisation are the various so-called protective systems. A cornucopia of expertise flows into the uniform requirements for explosion doors and bursting discs, quick acting valves as well as rotary valves, explosion isolation systems and explosion suppression systems. Within the general trend of the safety technology branch, the latter systems are under special influence by one specific field whose relevance for explosion protection is continually growing. The functional safety and reliable performance of measurement and control equipment requires uniform assessment criteria. For explosion protection, the spectrum ranges from protective relays for ›Ex-e‹ motors up to measured data processing in explosion suppression systems. The general foundation stones are embodied in the machinery directive standards and IEC standards such as IEC 61508. The consistent application of these basics for explosion protection apparatus has not yet been incorporated in adequate measure into the ›ATEX‹ standards.

Outlook

In the future, existential technical problems will play an ever smaller and less frequent role, in contrast to the strategies of the ›stakeholders‹ of the regional markets. The globalisation of standardisation in the explosion protection sector is practically complete within the electro-technical branch.

The non-electrical area, whose market volume in terms of sales is less substantial, may prove ever more interesting during the transition from European CEN norms to global ISO standardisation. This is due to several segments thereof that are deeply rooted in the German mechanical engineering industry. The potential for problems that could materialize because of extra-European interests should not be underestimated; the engagement of manufacturers and user industry in the standardisation process is the corner stone for market entry without any unpleasant surprises.

Literature

[1] H.Dreier, K.-H. Gehm, 40 years explosion protection of electrical equipment in the Physikalisch -Technische Bundesanstalt (PTB), Ex-Magazine No.13, 1987

[2] H. Wehinger, 50 Years Explosion Protection with the PTB, Ex-Magazine No. 26, 2000

[3] W. G. Dill, 100 Years of the Explosion Test Station ›BVS‹ – 100 Years of Explosion Protection, Ex-Magazine No. 21, 1995

[4] M. Wittler, EXAM a new name but a great tradition, Ex-Magazine No. 31, 2005