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INDUSTRIAL SAFETY - PUBLIC DEMAND AND AN ANSWER OF BAM THE FEDERAL GERMAN INSTITUTE FOR MATERIALS RESEARCH AND TESTING

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Review article

Abstract: Safe industrial operation is expected by the public. It contributes to a clean environment, innovation and prosperity. BAM the Federal German Institute for Materials Research and Testing has its responsibility in further developing safety in technology and chemistry by research, testing and expert advice. The basic reasoning for this activity and examples of current work are provided. Particular attention is given to the unique BAM Test site Technical Safety. Acceptance of findings and transfer of results are based on collaboration and exchange of personal. Modes of cooperation are described.

Keywords: Industrial safety, large test facility, structural integrity, dangerous substance.

Introduction

Technologies and industrial development facilitate life and bring comfort, but they are also associated with increased risk of damage and disaster. Recent history has plenty of examples e.g. in chemical industries where we have seen the detonation of ammonium nitrate in Toulouse, France, and West, Texas, U.S.A., derailing of trains as in Eschede, Germany, the collapse of the drilling platform Deep Water Horizon, the failure of the nuclear power plants of Fukushima, Japan, the rupture of the clearing dam of the Baia Mare Gold Mine, Rumania, and subsequent pollution of the rivers Tisza and Danube. Earlier on, in 1852 the derailing of a train carrying the later German Emperor Friedrich III lead to the establishment of the predecessor institution of BAM (Ruske et al, 1996, p. 69 ff). The explosion of ammonium nitrate in Oppau, Germany, in 1921 lead to increased investigations of hazardous substances in industry by the newly established Chemisch-Technische Reichsanstalt, another predecessor of BAM.

Technological development leads to continued research to maintain a high level of safety and adjust it to public demand. Results of the work are taken up in law-making and standardization.

Materials and methods

Public expectation regards to industrial safety

The public expectation to industrial safety is put forward in BAM's statement of its tasks and role: "The citizens right to life and to physical integrity is established in Article 2 of the Constitution of the Federal Republic of Germany, amended by the commitment by property in Article 14 (its use should also serve the public good) and by the protection of the natural living conditions for future generations in Article 20a." (BAM, 2002) This corresponds to the Charter of the European Union which states the right of life and everyone's physical and mental integrity, and security (Articles 2, 3, 6 and 37; European Union, 2012a) and in several articles of the Treaty on the functioning of the European Union (European Union, 2012b).

For the German Federal Government particular responsibility is in appropriate legislation, maintaining surveillance and taking action. The latter two are conveyed to Federal institutions and senior authorities such as BAM, if following to the principle of subsidiarity it cannot be executed by the Federal Länders and assigned to qualified private institutions. The Federal institutions are also responsible for further developing the state of science and technology in their area.

Risk, danger and safety

Safety is not a fixed value but it has to be defined in terms of risk and considering the chances as well as the potential damage that may be associated. Fig. 1 indicates that starting from an unavoidable residual risk risk is increasing and so are the chances for a potentially high gain but also high losses and damage. It is upon the stakeholders to agree on a maximum acceptable risk, which may be loss of life, value or damage to the environment.

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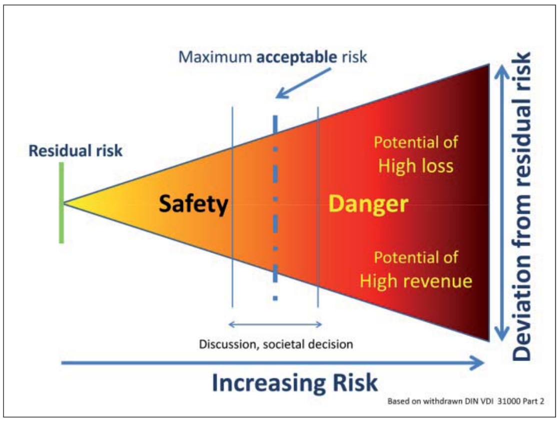

Fig. 1 Safety is defined as a risk that is lower than the maximum acceptable risk

In a technical environment risk (R) may be described in terms of probability of an event leading to damage (P) and expected severity of the damage (D):

$$R = P \cdot D$$

based on withdrawn DIN VDI 31000 part 2. The current discussion follows the lines of deterministic approaches and a quantitative risk analysis (Pfeil, 2012).

Results

BAM's response and on-going research

BAM is the German Federal Institute for Materials Research and Testing. Its mission as a senior authority of the Federal Ministry for Economics and Energy is to further develop safety in technology and chemistry enabling and supporting innovation in industry. Based on its excellent research BAM performs tests, provides expert advice and is active in the transfer of technology.

Industrial safety from small to large dimensions

BAM investigates materials properties and the behavior of parts and systems from the nano scale up to full-scale testing of components and investigation of plants and industrial sites. The range of topics includes:

- Chemical Industries:
  - Explosive, flammable or otherwise dangerously reactive substances,
  - Systems of substances or articles,
  - Pressurized gases,
  - Process Analytical Technology.
- Power Industries:
  - Power plants and materials,
  - Fossil fueled - nuclear - green - storage.
- Food Industries:
  - Contaminants in food.
- Transport Industries:
  - Rail, air, pipelines, power lines, infrastructure.

In nano technology BAM investigates in cooperation with other institutes the synthesis and characterization of nano particles with reproducible properties. The aim is the provisions of mono disperse reference materials which for instance may be used in bio-medical research or as reference for environmental risk assessment (BMUB, 2013).

An outstanding facility is the BAM Test site Technical Safety (BAM TTS, Fig. 2) located some 50 km south of Berlin in a sparsely populated forested area. On the 12 km^2 area a number of unique large scale test equipment were set up. 45 million Euros have been invested and a further investment of 25 million Euros is planned. The facilities may be used in collaborative projects and contracts. Some of the test facilities will be described in greater detail below (clearly the blasting site and technical buildings are to be seen).

Fig. 2 Aerial view of the BAM Test site Technical Safety

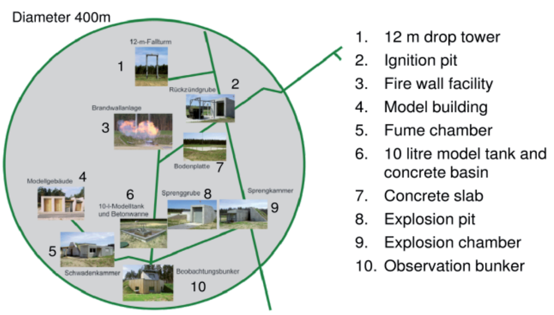

Fig. 3 Instrumentation on the blasting site of BAM TTS

Current Research - Safety of Gases and Gas Installations

Gases take an important role in the chemical, process and energy industries. They include oxygen, hydrogen, acetylene, natural gas, and a wide variety of gaseous compounds.

Fig. 4 Instrumented experimental pipe to investigate detonative properties of gas mixtures. Diameter 200 mm, length 30 m, max. pressure 40 bar

In view of a development to buffer electric energy from wind power and photovoltaic plants by hydrolysis to hydrogen the issue of safety margins and explosion behavior arise again. For the assessment and modeling of safety measures the development of a detonation in a pipe needs to be investigated (Fig. 4). The run-up distance for the deflagration to detonation transition was investigated by BAM researchers (Blanchard et al, 2011).

Prevention of dust explosions

High concentrations of flammable dust may occur under working conditions in saw mills, granaries, and during industrial processes. The introduction of nano sized powders to industry raises the question of transferability of existing data to smaller sized particles (Krietsch, 2014). The on purpose designed 20-liter-sphere for the determination of explosion characteristics is operated in the laboratories of BAM's main site, while the transfer of laboratory results to real size and the verification of models may be achieved in the testing silo on BAM TTS (Fig. 5).

Fig. 5 Dust explosions and devices such as pressure such as pressure relief openings may be investigated in the test silo on BAM TTS. Filling volume 50 m³, pneumatic charging

Safe transport and storage of dangerous goods

Research for the safe transport and storage of dangerous goods is a major task of BAM with activities in materials research, non-destructive evaluation and full scale testing. A number of unique test rigs have been established for this purpose.

Fig 6 Fire test of a dangerous goods container in the fire test rig for destructive testing. The wind shielding plate has been removed for demonstration

Two fire test stands, each of 12 m x 8 m open test space for destructive and non-destructive fire tests and adjustable heat input are in use for the investigation of materials behavior of gas tanks and containers for spent nuclear fuel. Recently, the performance of various fire protection coating systems on dangerous goods tanks in view of BLEVE (Boiling Liquid Expanding Vapor Explosion) have been investigated by Sklorz et al. (Sklorz et al., 2013) with the aim to reduce the risk of a BLEVE. In large scale fire tests these protection coating systems of different manufacturers were used. The aim was to achieve a 90 minute delay before a BLEVE would occur (Fig. 6).

Apart from fire tests drop tests and other investigations, spent nuclear fuel containers have to withstand the fall from 9 m height onto an unyielding fundament. BAM has set up a drop test facility of 36 m height and a basement with a total mass of 2640 tons. It is designed for drop test with real size nuclear containers of 200 tons mass (Fig. 7).

Fig. 7 Drop test facility (200 tons lifting capacity) on BAM TTS

During transport the containers are equipped with shock absorbers. Safety research is associated with the energy absorption capability of the shock absorber materials. In a PhD-Thesis wooden shock absorbers were investigated (Eisenacher, 2014). It was demonstrated that over a wide range of compression the wood requires a steady compressive force; the force strongly depends on the orientation of the fibers.

Safety in high power transmission lines

The increasing installation of renewable energy power plants in Europe - wind energy and photovoltaic - leads to increasing demand for safe high power transmission lines. Learning from failure analysis of mechanically overloaded power lines (Klinger et. al., 2011) and recent research in the MOSYTRAF project on the effects that gale force wind exert on power lines (Mehdianpour et. al., 2014) provides a basis to investigate the mechanical behavior and accordingly configure transnational power lines with increased current rating.

A mechanical overload occurred end of November 2005 when heavy snowfall at temperatures around freezing point led to the accretion of ice rolls on the cables and finally the collapse of one transmission tower. In a domino effect another eighty one transmission towers failed (Fig. 8).

Materials investigations showed that for towers built in the 1960es Thomas steel was used. Fractographical analysis demonstrated that during aging of the steel iron nitride had formed which led to brittle fracture. Further mechanical investigations of samples from transmission towers and modeling of the forces on the geometry of the towers pointed to deficiencies in standards according to which the power transmission lines had been built.

The MOSYTRAF project followed three lines of action: continuous measurement on pylons and cables and monitoring of climate action, wind tunnel tests, and numerical modeling. For these first time ever investigations on a real power transmission line a section of a transmission line in the north of Germany near the city of Rostock was used.

Fig. 8 Collapsed power line transmission tower, due to weather induced mechanical overload

Twelve spacers between the cables at heights between 30 and 50 meters were equipped with sensors; another sensor was attached to a pylon. Additional sensors monitored the structural response

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of the towers and mounting suspensions. The section was monitored by an on-line video system.

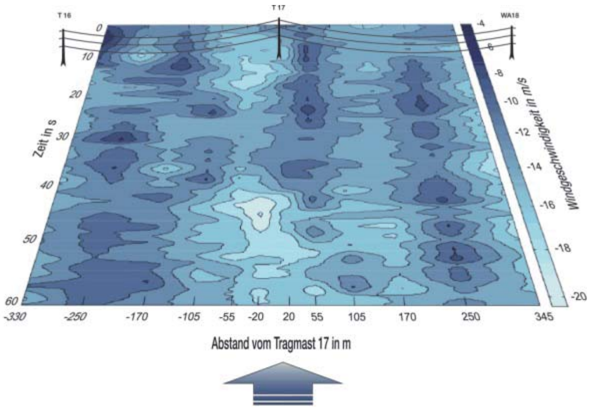

Fig. 9 Visualization of wind velocities during a 60 seconds interval at heights from 30 m to 50 m between three transmission towers

The blue color shades from dark to bright indicate wind velocities varying from 4 to 20 m/s. The results, gained in cooperation with the Technical University Braunschweig and the net provider demonstrated that wind gusts are varying between the pylons. They are distinctly different from the values measured on ground. Evidently, modeling and planning of power lines and relevant standards need to be adjusted.

Fire safety

Fire safety is a multifaceted activity at BAM. There is a long tradition in civil engineering to investigate fire protection of buildings, the effects materials, structures and how they develop to fire scenarios. Recent research extends fire retardancy of polymers and parts apart from civil engineering.

Fiber reinforced polymers are used in many safety relevant applications as aviation, ferries and cars. Knowledge and subsequent standardized characterization procedures will be part of the innovation process. Carbon fiber reinforced polymers is one of the targeted materials groups. A test set-up in an intermediate scale was conceived to investigate the structural integrity of materials under fire (Hörold et al., 2013).

Roads to networking

Sharing knowledge and specialized experimental equipment is essential to achieve best scientific results and economic use of resources. BAM works with researchers from research institutes, academia and industry in collaborative projects funded from various national and European sources. BAM receives researchers in various financial modes. Foreign scientists with excellent academic credentials and outstanding references may be selected for an Adolf Martens Fellowship (BAM, 2014), provided the Ph.D. was obtained no more than three years before. The proposed research has to fit to BAM's strategically important thematic areas and topics. Potential applicants should therefore contact experts in the selected division or department of BAM. Similarly, researchers interested in temporary research at BAM should contact BAM experts in order to identify other sources of funding or do the work on their own funds.

Another essential route for mutual exchange of knowledge and creating innovative power is cooperation in relevant interest groups. The cross European technology platform initiative on industrial Safety (ETPIS) is such a group. It stands for assessing research needs in industrial safety as voiced by industry and other stakeholders such as industrially oriented European technology platforms. From these activities originated SAF€RA the ERA-NET project entitled 'Coordination of European Research on Industrial Safety towards Smart and Sustainable Growth' funded for three years by the European Commission in the 7th Framework Program. SAF€RA coordinates the funding in industrial safety research of 21 leading European public agencies, ministries and research funding organizations, among them BAM as an institutional funding organization. The first call for research projects attracted 53 applications, and 12 of them receive funding. Upon the second call 42 pre-proposals have been received requesting funding of approximately 8 million Euros. For 21 of these pre-proposals it has been asked to prepare full proposals (SAF€RA, 2014). The success of SAF€RA indicates the need for continued cooperation and soliciting for funding in industrial safety.

Conclusion

BAM fulfils its legally based tasks to further develop safety in chemistry and technology by research in its laboratories and the Test site Technical Safety, by collaboration with partners from industry and research institutes and providing advice to regulatory bodies from government and standardization.

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