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Product Development Process Requirements in Non-electrical Explosion Protection Require Innovations

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Product Development Process Requirements in Non-electrical Explosion Protection Require Innovations

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Abstract

Explosion protection is an important element of our everyday life. Many processes can create explosive atmospheres due to the substances used and the oxygen in the air which, if combined with an ignition source, can lead to a dangerous explosion. Various measures can be taken in the electrical and non-electrical explosion protection field to minimise the risks in the affected areas. Development activities and the deployment of measures are supported by standards and guidelines. In particular, there is a focus on health & safety and the elimination of risks during the product development phase. To guarantee this, designated inspection bodies carry out defined tests as specified in the guidelines. The product weaknesses are highlighted; these may arise due to design faults, a lack of expertise in terms of explosion protection and faulty production procedures. The products need to be optimised using iterative processes in the product development phase, although these do lead to an increase in time and costs. Every weakness that is detected at a later time will lead to higher costs. As a result, special attention must be paid to non-electrical explosion protection. In contrast to electrical explosion protection, this relatively new field requires fewer tools during product development, which is why the goal of this project is to enhance the design method which applies in particular to non-electrical explosion protection to reduce time and costs. Specific and innovative tools need to be developed. To achieve these goals, non-electrical explosion protection must be shown clearly and transparently for the product development process.

Keywords: Design methodology, Explosion protection, Product development.

Introduction

In today's society the factor time has assumed an important role in various areas of our life and work. For instance, news spreads across the world in a matter of minutes, travel time has been reduced from days to just a few hours (Kurpjuweit, 2013) and manufacturers of entertainment electronics reduce the product lifecycle so they can launch new products even more quickly (Scheimann, 2011).

Reduced lifecycles can also be observed for many other products in the consumer and investment goods market because the market entry strategy has a direct impact on the possible sales volume of the product (Meffert et al., 2008, pp. 445-446). However, the success of a product is the result of a number of factors although, in addition to quality and costs, time is one of the main parameters. Consequently, the interplay of these three independent factors needs to be taken into account during the product development process to ensure that the specified goals are reached (Burghardt, 2013, p. 23). In turn, these goals are influenced by technological progress, changing customer needs and international competition (Cooper, 2010, pp. 8-11).

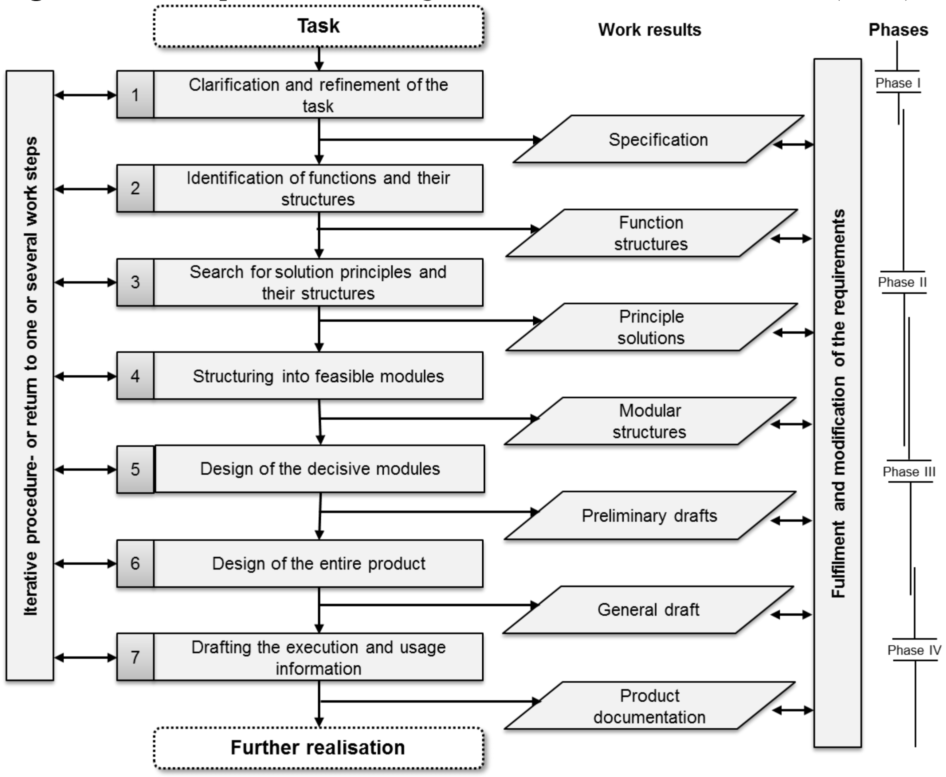
Applying structured product development processes allows the various goals to be addressed and controlled regardless of department or task. Application examples for complex but systematic product development processes can be found in the automotive and IT sector (Braess, 2013; Ruf & Fittkau, 2008). With respect to safety equipment products, there is one special aspect that needs to be paid special attention to during the development, design and production processes, namely: quality. The requirements and standards that need to be fulfilled are demanding; some of these have been anchored in statutory regulations to ensure the safety of humans and machines. In the explosion protection field, which is a sub-area of the safety technology field, compliance with regulations and standards for product development for the market is mandatory. Amongst other things, new parts need to undergo intensive testing by designated testing bodies. These conditions have a fundamental impact on the product development process and the design method, and characterise the cost and time-intensive process through in-depth iterations (Träger et al., 2005).

Product Development Process

Definition of Structures and Tools

Since the end of the 19th century attempts have been made to define a structured approach for the development of products. According to various models by Wögerbauer (1943), Kesselring (1954) and Hansen (1965) various authors, including Rodenacker (1970), Hubka (1973/1976), Pahl and Beitz (1977) developed similar views and models for methodical product development in the middle of the 20th century. A general structured product development process that is valid in German-speaking countries is the result of the VDI Standard 2221 'Systematic approach to the development and design of technical systems and products' (VDI Richtlinie 2221, 1986) which takes into account all previous studies (Bender, 2004, pp. 12-47; Pahl et al., 2013, pp. 11-23).

Figure 1. *Development and Design Procedure acc. to VDI 2221 (1993)*



The current valid version of the VDI Standard 2221, 2nd edition from 1993, describes a development and design process with seven work steps, see Figure 1. The individual work steps can be repeated several times by means of iteration as required. It is possible to make adjustments, depending on the industry and company, to ensure that the generally valid production creation process can be applied in practice.

Also, cross-industry methods are listed in the VDI Standard 2221 (1993), VDI Standard 2222 – Sheet 1 (1997) and Sheet 2 (1982) that support the work methods in the various work steps of the process. This also includes predominantly intuitive methods, such as creativeness techniques and predominantly discursive methods, such as design catalogues.

The formation of development and design tools began with deliberations about a structured product development process. From a workshop-oriented design (approx. 1850) through methodical design (approx. 1950), the focus today is on computer-assisted product modelling and virtual product development (Pahl et al., 2013, p. 9).

The Legal Framework for Product Development in Germany

Designers and product developers should be familiar with the legal framework within which they work. Unfortunately, this is often very different in practice. If a company develops a product that causes injury as a result of a fault, this can have legal consequences under civil law, public law, criminal law and labour law.

Amongst other things, private contracts are covered by civil law. If a customer orders a customised product, the head of design is responsible for potential design errors. The damages arising under civilian law may be mitigated by insurance policies. The public law has laid out requirements in guidelines that need to be observed when a product is launched. The public authorities check compliance with the requirements. This field of law is very important with respect to safety equipment. Criminal law is applied when a product fault was the cause of the injury or fatality. The consequences of prosecution must be borne personally and cannot be mitigated by insurance policies. Consequences under labour law are possible in all cases because the employer can sue the liable party (Neudörfer, 2014, pp. 11-12).

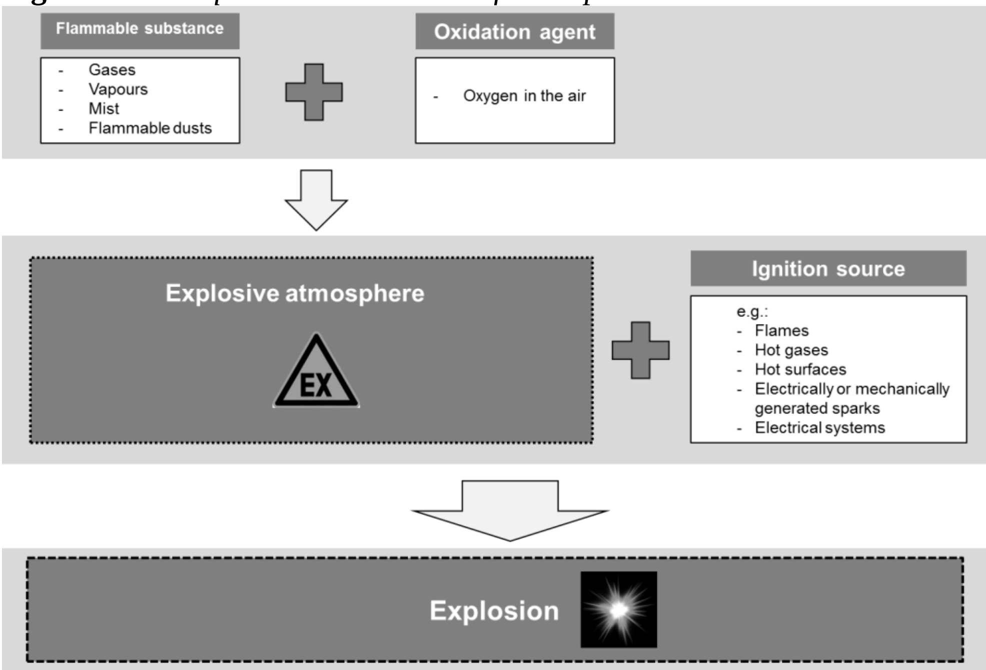
Explosion Protection

Definition

The term 'explosion protection' is often only used in the field of mining and the chemical industry; however, there are a large number of products and processes that also have a connection to explosion protection and need to be taken into account. These include objects used on a daily basis, such as textiles, wooden furniture or baked goods because the released or used materials can create explosive atmospheres which can lead to an explosion if there is an ignition source.

According to the definition of the standard ISO 8421 Part 1 (1987), an explosion is a sudden oxidation or decomposition reaction during which there is an increase in the temperature, the pressure or both at the same time. Three factors are required for this reaction: a flammable substance, an oxidation agent and an ignition source (Greiner, 2006, p. 51). The flammable substance, which needs to exit in a defined concentration, creates an explosive atmosphere when combined with the oxidation agent. This mixture combusts suddenly, if there is an ignition source thereby causing an explosion. Figure 2 shows these reaction sequences.

Figure 2. *Prerequisite and Creation of an Explosion*



Explosion protection aims to avoid or minimise the risks connected to an explosion. The protection is split into various levels: primary, secondary and tertiary explosion protection. Primary explosion protection ensures safety by preventing the creation of an explosive atmosphere. Secondary explosion protection focuses on measures to render potential ignition sources ineffective. Tertiary explosion protection looks at limiting the consequences of an explosion. In general, primary explosion protection is always preferential because this offers the greatest level of safety; however, these levels and their definitions are the subject of many discussions among experts (Gohm, 2016, pp. 39-47)

Legal Framework for Explosion Protection in Europe

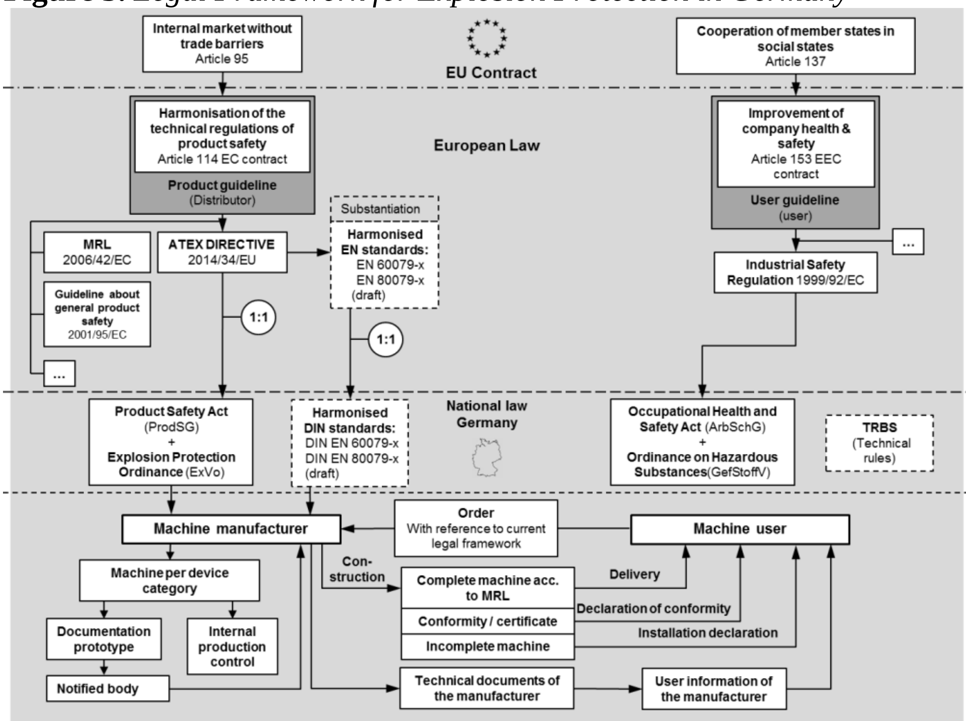
A further possibility to systemise explosion protection is to differentiate between electrical and non-electrical explosion protection. As the names suggest, the focus in these areas is on electrical and non-electrical devices or components. The reason for this distinction lies in the history of this field of expertise.

Explosion protection originated from the mining sector. Due to the fact that there were frequent explosions resulting from pit lamps, the first explosion-protected device was the ignition-safe Davy lamp in year 1815 (Von Pidoll, 2015, p. 7). With the industrial revolution and the onset of the use of electrical motors, examinations were conducted to find causes and possible protection measures to prevent explosions (Von Pidoll, 2015, pp. 9-10). To guarantee safety, the 'Police Regulations on Electrical Equipment in Hazardous Areas and Operating Systems' were adopted in 1943 (Gohm, 2016, p. 18). These made the operator fully responsible for protecting his employees.

The requirements relating to explosion-protected electrical products and their handling were governed by various guidelines and standards. From the middle of the 20th century onwards, standards were harmonised throughout Europe; the insights into the field of explosion protection gained in Germany were highly significant. (Gohm, 2016, pp. 17-20)

Following the introduction of the solely valid EC Directive 'Atmosphères Explosibles', the so-called ATEX guidelines, essential amendments to the European explosion protection legal framework, were implemented in 2003. To further reduce the risk of explosion in the affected areas, there are now two sets of guidelines. First the EC Directive 94/9/EC (ATEX 95) as a guideline for manufacturers and second the EC Directive 1999/92/EC (ATEX 137) as a guideline for operators. Accordingly, the scopes and responsibilities between the product manufacturers and the users of explosion-protected devices were clearly defined. A further fundamental change is the inclusion of non-electrical devices in explosion protection for the first time. The requirements of the Directive must be implemented into national laws. As the EC Directive 94/9/EC was replaced by the EU Directive 2014/34/EU on 20.04.2016, the current legal framework is as follows as shown in Figure 3.

Figure 3. *Legal Framework for Explosion Protection in Germany*



Requirements for the Non-Electrical Explosion Protection

Influencing Parameters

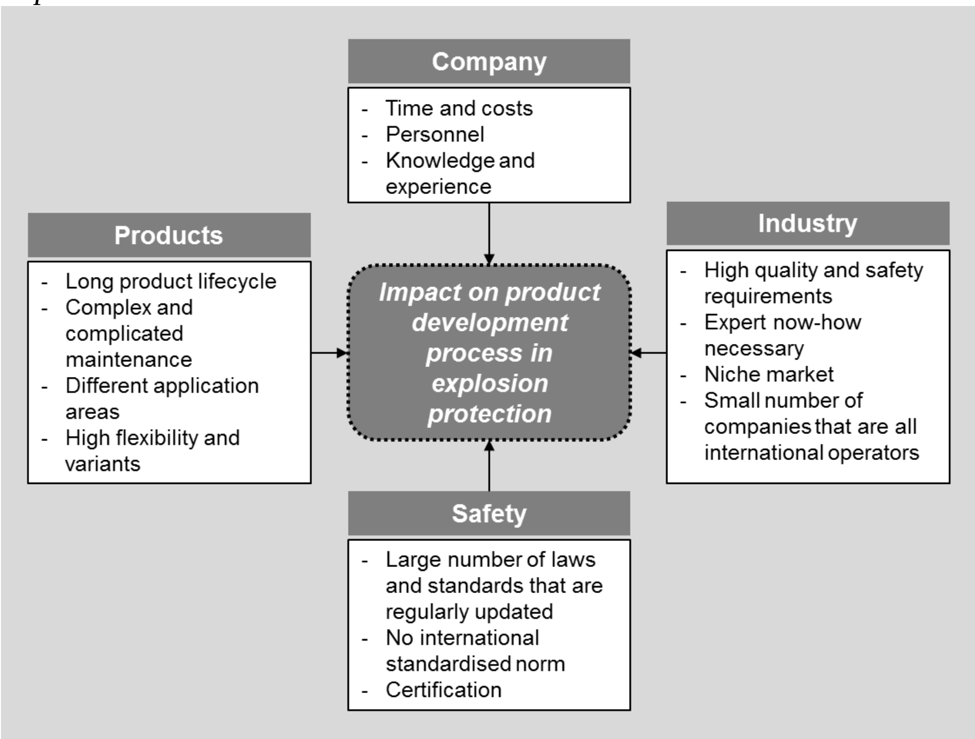
The complexity of the guidelines and standards shows that the legislator sees the absence of risk and occupational safety as the top priority for explosion protection. Therefore, the development work and the choice of measures must comply with these requirements (Nolan, 2014). To guarantee this, defined tests need to be carried out by testing bodies named in the guidelines. The product weaknesses are highlighted; these may arise due to design faults, a lack of expertise in terms of explosion protection and faulty production procedures (Engelmann et al., 2005). The products need to be optimised using iterative processes in the product development, although these do lead to an increase in time and costs. Every weakness that is detected at a later time will have an exponential effect on the costs (Benes & Groh, 2014, pp. 32-34).

The product development process must take into account the requirements of the customer, the operator and the own company. Firstly versatile products with a large range of models need to be developed that have long service lives even under extreme climatic conditions, and need to be serviced in difficult conditions. Secondly, steps must be taken to ensure that the required quality is supplied in compliance with a wealth of standards and regulations that are regularly updated. This requirement profile is determined by application conditions such as:

- use in various areas
- use in climatic conditions – from rough industrial surroundings to maritime environments, through to clean rooms and in the pharmaceutical industry
- use in under extreme ambient conditions – arctic cold in Siberia and sand storms in the Middle East
- explosion pressure resistant design
- flameproof joint depending on explosion group, gap form and casing volume (length and width)
- compliance with maximum surface temperatures
- use of suitable cable openings, plugs and cables
- other requirements relating to specific openings (e.g. shafts, bearings, breathing and draining fixtures, connecting elements)
- deviating requirements regarding parts made of non-metallic materials (e.g. sight glasses) and
- differentiated standards, usually several solutions are necessary (Europe – EN; US – FM, ISA; RU – GOST R; …).

Therefore, the process is generalised according to different parameters of the products, the industry, the safety and the individual companies, see Figure 4. Companies can only guarantee success in this niche by means of personnel, methods and experience.

Figure 4. *Influencing Parameters of the Product Development Processes in Explosion Protection*



Existing Support Methods and Tools

<u>Product Development Process</u>

The application of methods and tools is, however, very minimalistic. A process specially generated for product development in the explosion protection field is only hinted at in the literature, standards and laws. The laws and standards primarily look at product requirements. The product development process and the supporting methods outlined in the VDI Standards can only be applied in part to the explosion protection field due to the above-mentioned influences. Full integration of the standards and the certification process is not possible and leads to a significant increase in costs.

Based on the history, it has been possible to gain lots of experience in handling standards and the product development process in the field of electrical explosion protection. Accordingly, there are many supporting works that offer help to designers when developing parts. This kind of know-how and support is not available for non-electrical explosion protection. Non-electrical devices have been used for explosion protection for 150 years (Gohm, 2016, p. 199) however this field has only been characterised by defined requirements in guidelines and standards for the past 20 years or so.

One series of standards that is important for non-electrical explosion protection is the DIN EN 13463 Non-electrical devices for use in explosive areas. The separate standards show the specific ignition protection types and the ignition hazard assessment. This series of standards currently applies throughout Europe. The drafts of the standards DIN EN ISO 80079-36 and 80079-37, which contain the analogue content of the DIN EN 13463, indicate that the stated topics will be applied internationally in the near future.

Ignition Protection Types

Non-electrical explosion protection is an important part of secondary explosion protection. The use of an ignition protection type can prevent an explosive atmosphere from igniting. According to DIN EN 13463-1, an ignition protection type refers to measures defined in relevant standards which contain the respective requirements and information about ignition protection compatible design.

The following ignition protection types currently exist for non-electrical explosion protection:

- Constructional safety
- Control of ignition source
- Liquid immersion
- Pressurised enclosure
- Protection by enclosure
- Flow-restricting enclosure
- Flameproof enclosure

The various ignition protection types are selected depending on the protection goal. In a first step, attempts should always be made to prevent the creation of an ignition source by means of constructional safety. If this is not possible, control of ignition source measures can be applied to prevent an ignition source becoming effective. It may not be possible to implement this option in some designs. In this case, it is necessary to isolate the potential ignition source. Installing various ignition protection types can prevent contact between the explosive atmosphere and the ignition sources. If none of the previously mentioned measures can be realised, the possible impact of an explosion must be reduced. Figure 5 shows these situations.

Figure 5. *Ignition Protection Types for Non-electrical Explosion Protection*

Preventing activation of the source of ignition	**Constructional safety "c"** – DIN EN 13463-5 (in future - ISO 80079-37)
Preventing activiation of the source of ignition	**Control of ignition source"b"** – DIN EN 13463-6 (in future - ISO 80079-37)
Preventing the ingress of explosive atmosphere into an ignition source	**Liquid immersion "k"** – DIN EN 13463-8 (in future - ISO 80079-37)
	Pressurised enclosure "p" – IEC 60079-2
	Protection by enclosure "t" – IEC 60079-31
	Flow restricting enclosure "fr" – DIN EN 13463-2
Reduction of the impact of an explosion	**Flameproof enclosure "d"** – DIN EN 13463-3 (in future - IEC 60079-1)

Ignition Source Assessment

In addition to ignition source types, the ignition hazard assessment according to DIN EN 13643 is decisive for non-electrical explosion protection. This method is used to analyse and assess a design draft in terms of the ignition sources (Beyer, 2005; Hawksworth et al., 2004).

The following five steps are taken when assessing ignition hazards:

1. Identification of the ignition hazards and their causes
2. Initial ignition hazard rating (with regard to the frequency of occurrence without any additional measures) and assessment
3. Definition of measures to reduce the probability of an ignition hazard from step 2 (preventive and/or protective measures)
4. Final ignition hazard assessment and categorisation (assessment of the ignition hazards with regard to the frequency of occurrence including the measures defined in step 3)
5. Definition of the unit category

The standard DIN EN 13463-1 recommends conducting the ignition hazard assessment using a tabular reporting scheme (see table 1) to ensure transparency.

If, for instance, a conventional high-pressure centrifugal pump is to be used in the explosive area, secondary explosion protection is applied. Electrical components that are approved for the risk area are used. Also, there are many ignition sources that are assigned to the non-electrical area. These are analysed via the ignition hazard assessment.

In step 1 the developed high-pressure centrifugal pump is examined with regard to all possible ignition sources that exist generally (see DIN EN 1127-1). The result is the identification of all unit-related ignition sources which then need to be analysed in terms of ignition capability to identify and assess the potential ignition sources (step 2). Figure 6 shows the potential ignition sources of the high-pressure centrifugal pump.

Table 1. *Reporting Scheme for Ignition Hazard Assessment acc. to DIN EN 13643-1*

Product name																
	1		2					3			4					
	Ignition hazard analysis		Assessment of the frequency of occurrence without application of an additional measure					Measures applied to prevent the ignition source becoming effective			Frequency of occurrence, including all measures					
	a	b	a	b	c	d	e	a	b	c	a	b	c	d	e	f
Seq. no.	Potential ignition source	Description of the basic cause (Which conditions originate the ignition hazard?)	during normal operation	during foreseeable malfunction	during rare malfunction	Not relevant	Reasons for the assessment	Description of the measure	References (standards, technical rules, experimental results known from literature)	Technical documentation (evidence including relevant features listed in column 3 a)	during normal operation	during anticipated malfunction	during rare malfunction	No need for further consideration	Resulting EPL in respect of this ignition hazard	Necessary restrictions
Resulting equipment category / EPL regarding this source of ignition:																

Step 3 aims to prevent the effectiveness of potential ignition sources by using selected measures. Then the final ignition hazard assessments are carried out and a final device classification is defined. Table 2 shows steps 1 to 4 of the ignition hazard assessment based on three potential ignition sources of the high-pressure centrifugal pump.

Figure 6. *Possible Ignition Sources on a High-pressure Centrifugal Pump*

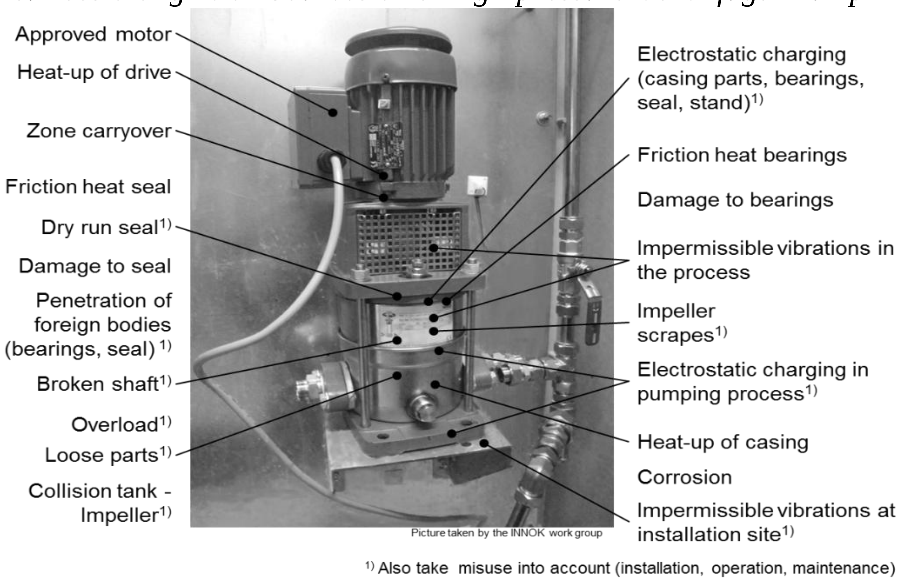


Table 2. *Examples for Steps 1 to 4 of the Ignition Hazard Assessment*

No.	1		2					3			4					
	Ignition hazard analysis		Evaluation of the frequency of occurrence without using an additional measure					Measures used for preventing of taking effect			Frequency of occurrence Incl. all measures					
	a	b	a	b	c	d	e	a	b	c	a	b	c	d	e	f
	Potential ignition source	Primary cause	In normal operations	In case of expected malf.	Infrequent malfunctions	n/a	Reasons for assessment	Description of the measure	References (norms, technical rules, exper. results)	Technical documentation (certificates)	In normal operations	In case of expected malf.	Infrequent malfunctions	n/a	Resulting device category/ EPL	Necessary restrictions
3	Hot surface	Relative movements of pump parts, e.g. on bearings or seals	x				Heat building up during normal operations caused by part friction	Therm. test acc. to 8.2, limitation of maximum surface temperature under the most unfavourable conditions and taking into account the previous misuse, integration of a temperature monitoring and limitation system (IPL 1; ignition protection type „b1“)	DIN EN 13463-1:2009 Section 8.2 *(E DIN EN ISO 80079-36:2014, Section 8.2)*	- Test report no.: . … via thermal type testing -Note in operating manual			x		2G *(Gb)*	T4
9	Electrostatic discharging	Pumping a non-conductive fluid	x				Electrostatic charging in normal operations	Restriction of intended use to fluids with high conductivity (>1 000 pS/m)	CLC/TR 50404:2003, A.1.7.4 *(IEC 60079-32-1)*	- User manual Chapter …, Section …: - Restriction of intended use				x	1G *(Ga)*	
16	Mechanically generated sparks	Damaged bearings on the shaft opening			x		Damaged bearings is seen as a rare malfunction	The bearing calculation is carried out acc. to ISO 28, design acc. to usage period - a malfunction in these conditions is generally seen as a rare malfunction; notes in the maintenance and lubrication plan	DIN EN 13463-1:2009, *Section* 5 and DIN EN 13463-5:2011, *Section* 6 *(E DIN EN ISO 80079-36:2014, Section 5 and E DIN EN ISO 80079-37:2014 "c")*	– Description and calculation No. … drawing No. … via the design - Maintenance and lubrication plan			x		2G *(Gb)*	

Ignition Protection Type ' Constructional Safety

In non-electrical explosion protection, the ignition protection type 'constructional safety' is the primary approach for explosion-protected designs. This ignition protection type is an inexpensive and simple way of preventing potential ignition sources from becoming effective, or at least keeping this risk to a reasonable minimum.

For instance, when designing roller bearings, a modification of the requisite reliability can guarantee the constructive safety. Potential ignition sources in bearings are hot surfaces, electrostatic charging and mechanical sparks that are often created as a result of damage to the bearings or failures, or secondary flows through connection constructions. As a general rule, mechanical engineers should take the following procedure into account when dimensioning a bearing:

1. Analysis of the effective loads on the bearing
2. Specification of the bearings that are to be used and their arrangement
3. Identification of the allowed form and position deviations of the bearing and definition of the required installation tolerances
4. Selection of suitable lubricants and seals
5. Design of the connection construction (e.g. avoidance of shaft bending or twisting)
6. Lifecycle calculation (static or dynamic carrying capacity)

In general, dimensioning is carried out according to the fundamental requirements relating to the reduction of the selection probability by the careful design of the bearings according to the state of the art in compliance with all operating and ambient conditions, as well as correct manufacture and assembly. However there are also other factors that need to be taken into account in an explosion-protected design, e.g. the avoidance of current passages (sparks) and electrostatic charging, guaranteeing necessary lubrication and the specific maintenance instructions for safe operation.

For example, the requisite reliability of roller bearings is increased from 90% to 99% for explosion-protected versions. This reduces the lifecycle coefficient in the lifecycle calculation from 1.00 to 0.16 (DIN ISO 281). A consequence of the safety-related adjustment is an extreme increase in the maintenance interval.

As the example of the roller bearing shows, the selection of this ignition protection type is not without dispute or some doubt. There are various machine elements and designs. However, there are no clear indications and tools for explosion-protected dimensioning and design.

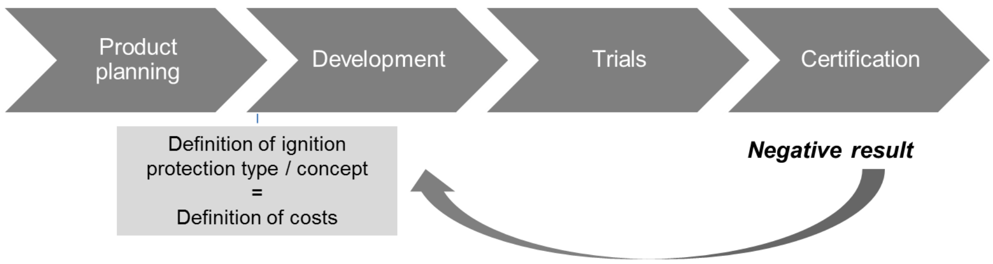
Optimisation Potential

The ignition hazard assessment and the implementation of an ignition protection type only takes place after the design has been completed. In contrast, the ignition protection type decision is taken at a very early stage of the product development process. This decision means that the indirect and direct costs for the entire remaining product development process are defined because this is a result of the specific test and certification process of the ignition protection type. Also, selecting an ignition protection type does not necessarily guarantee successful approval.

A further criterion is the partially unknown loads caused by possible explosions e.g. for the ignition protection type 'flameproof enclosure' which is often used in non-electrical explosion protection in addition to constructional safety. The chemical and physical processes of a gas explosion were examined in simple models, e.g. for explosions in cubic rooms or flow behaviour in nozzles. However these principles cannot be used to derive precise loads for the material in the case of complicated geometries because the processes are so complex and depend on so many underlying conditions that they cannot be calculated. Due to the fact that these simplified models, upon which the real operating equipment originates, form the basis for the design, the result is often so-called 'over-engineering' or 'under-engineering'. These are designs that are over-dimensioned or under-dimensioned and cause avoidable additional costs. For example, the legislator only provides very rough reference values for the design in the valid standard EN 60 079 Part 1; this only encourages these kinds of design errors, and often the impact of these errors can be considerable.

In addition to these factors, one major problem is that designers developing products for non-electrical explosion protection need to choose an ignition protection concept at a very early stage in the development process which means they have a major impact on all direct and indirect follow-up costs for the product. Also, opting for one ignition protection type is no guarantee that the product will be approved. In addition to the costs, the time factor is a significant problem. If the product does not satisfy the specified and, usually very time-consuming, tests, it can often take more than a year until the necessary product optimisations have been approved. If it is not possible to optimise the selected operating principles, and e.g. another ignition protection concept needs to be used, the timeframe may be even longer. In many cases, the product development is terminated due to the seriously delayed market launch. Figure 7 shows these processes.

Figure 7. *Simplified Product Development Process in Non-electrical Explosion Protection*

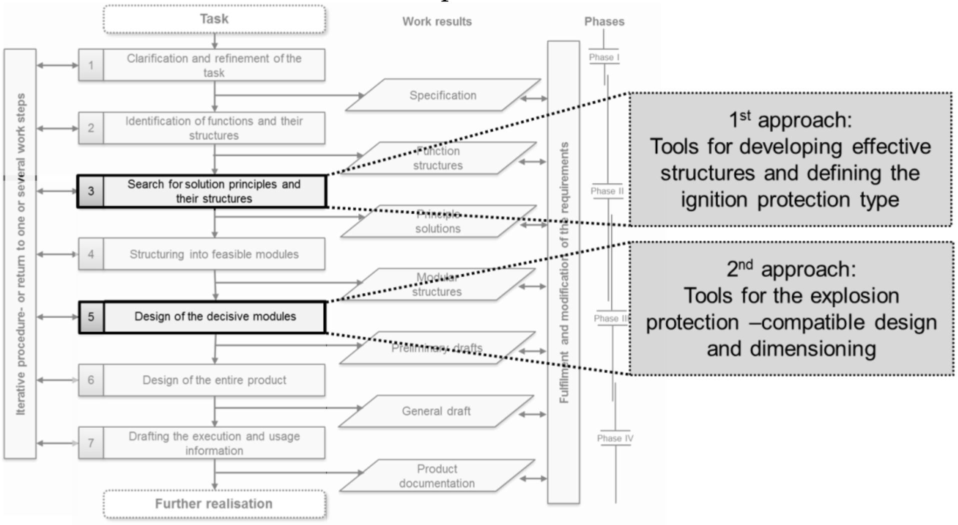


The consequences of general non-transparency are concept errors, design errors and ignorance that lead to a repetition of the certification procedure. Development obstacles arise for innovations in the longer term because there is a higher risk of additional costs.

Possible Solutions

The objective of this project is to adjust the design methods, in particular so that it can be used for non-electrical explosion protection to reduce time and costs in the product development process and to ensure development security. An analysis of non-electrical explosion protection leads to two potential solutions for optimising the product development process. Firstly, tools need to be created that help to develop effective structures and make a decision about the ignition protection type. Secondly, methods and tools are required for the explosion protection-compatible design and dimensioning. Figure 8 shows the process-side classification of the possible solutions in the product development process acc. to VDI Standard 2221.

Figure 8. *Possible Solutions for Optimising the Product Development Processes in the Non-electrical Explosion Protection*

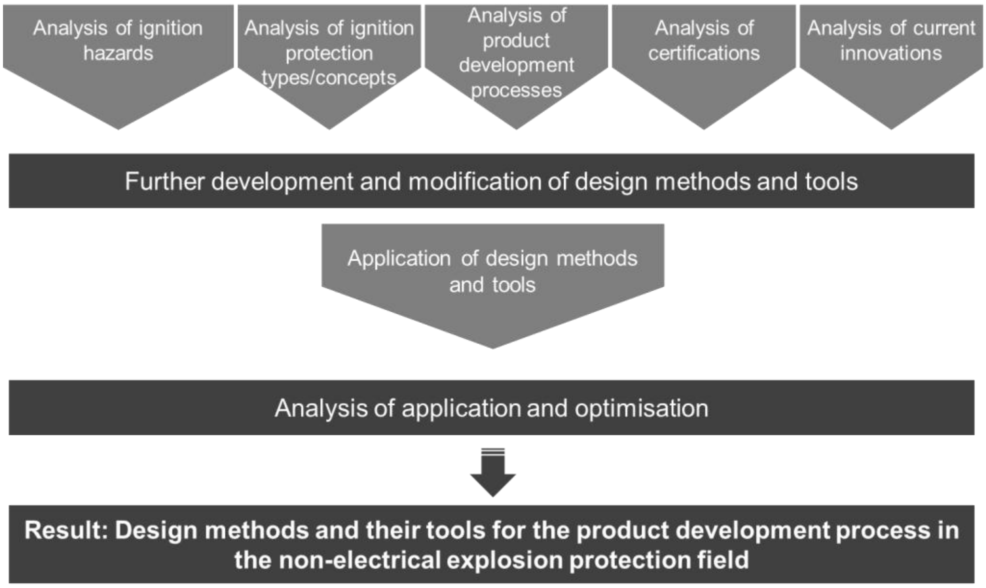


Special checklists are a good tool at the beginning because they ensure a methodical and structured approach. Selected questions and points help the designer to identify the ignition protection type that is best suited for his/her product idea in terms of the technology and efficiency and based on the current standards.

In the product design phase (the second possible solution), design catalogues with selected examples can help when dimensioning the units for use in explosive areas. Each designer is always in a position to design his/her parts according to the state of the art and the application conditions. The next hurdle is the final explosion-protected version. Malfunctions and risks must be avoided in both variants. In the non-electrical explosion protection field, the probability of a risk of this kind must be kept as low as possible, which is why collections of examples of safety factors may be a useful tool. Also, the requirements of the standards must be shown in a transparent manner.

In general, the product development process should be adapted for the non-electrical explosion protection field according to VDI Standard 2221. The objective should be to develop a design method using the named tools to create an integrated and transparent process that is anchored into an expert database. Cooperation with the named offices is especially important here, for example DekraExam or PTB. Figure 9 shows a flowchart of the planned procedure for processing the project.

Figure 9. *Procedure for Adapting the Design Method*



Summary and Outlook

The named goals can significantly optimise the activities in the product development process. Integrated progress in the non-electrical explosion protection sector is possible. The primary goal is to give the designer the practical tools and equipment he needs to achieve a high level of development security; this in turn leads to a plannable product development process. The factors time, cost and quality can be estimated and the possible deviations can be countered by means of specific measures. It may be possible to make use of advantages with respect to the time of the market launch, and also to achieve corporate goals. Furthermore, designers that have little experience in the explosion protection field are able to integrate themselves in this new field more effectively and efficiently. Implementation of the selected solutions opens up a wealth of benefits.

In addition to the presented topics, the latest research approaches in the explosion protection field e.g. the use of lightweight construction methods, should also be taken into account for all aspects and sub-goals. Accordingly, innovations from other mechanical engineering areas also need to be monitored if it is feasible that they could be used in the explosion protection field.

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