

KNOWLEDGE-BASED APPROACH FOR THE IDENTIFICATION AND ASSESSMENT OF HAZARDS DUE TO STATIC ELECTRICITY

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ABSTRACT
To improve the identification of hazards due to static electricity in process plants the use of a knowledge-based system is suggested. The identification and the assessment of electrostatic hazards is carried out by using a systematic safety assessment methodology. Thus a thorough analysis of plants is comprehensively assisted. This facilitates process engineers with special knowledge about the examined process or experts in the field of static electricity to apply the system.

A systematic approach is necessary due to the large amount of knowledge in this field. The CENELEC-Report R044-001 (February 1999) „Guidance and recommendations for the avoidance of hazards due to static electricity“ serves as a basis for the knowledge-based decision system. To validate the decisions of the system the results of the generated safety report are compared with expert opinions. Case histories about explosion accidents caused by static electricity are used to carry out the validation of the system.

The assessment of hazards due to static electricity will be done by linking information about the apparatus and the materials. Special processing situations are also recognised. Starting from that suitable safety measures can be selected. In demanding cases the need for further expert advice is indicated to avoid misjudgements. But the strong point of the system is that every part of the equipment will be checked in view of electrostatic hazards and the results are listed thus generating a safety report.

INTRODUCTION
In order to be able to assess the hazards caused by electrostatic discharges, extensive knowledge is required from the fields of electrostatic, chemistry and process engineering. The comprehensive knowledge on electrostatic charging currently available is therefore concentrated on only a few experts mainly in the big companies of the chemical industry.

The application of knowledge as given by guidelines e.g. the CENELEC Report R044-001 “Guidance and recommendations for the avoidance of hazards due to static electricity” and other publications on a concrete processing situation is often not possible for a non-expert in the field of hazards caused by electrostatic discharges due to a lack of practical experience. To enable an active access to the experiences about detecting and preventing potential hazards, it is a necessity for the knowledge-based system to offer a systematic procedure to identify and assess hazards that is close to industrial practice.

To improve the acceptance of the knowledge-based system the validation of the implemented knowledge is done with case histories descriptions.

EXPERT SYSTEMS

Algorithmic programming languages like FORTRAN and PASCAL are not sufficient for an efficient knowledge representation in the field of safety science. Especially to appropriately describe expert knowledge in the field of electrostatic discharges and explosion protection, it is necessary to have tools that provide object- and rule-structures and offer suitable inference strategies.

In the past most of the available expert systems were not able to fulfil the high expectations they were faced to. These expectations were forced not at least because of terms like "artificial intelligence" which are used with the development of expert systems. A less demanding - but simplifying- definition for knowledge-based systems could be:

Knowledge-based systems are computer-based decision tools that store and save the knowledge of experts by means of special knowledge representation forms, like "If-Then-Rules" and "Class/Object-Structures", to put this competence at the user's disposal.

After the conceptional phase the knowledge acquisition and modelling forms an important step in expert system development. During this step the knowledge model is formulated in co-operation of the domain experts and the knowledge engineers. The implementation of the knowledge model has to be independent from the used tools and should be carried out with adequate software-tools.

HAZARDS CAUSED BY ELECTROSTATIC DISCHARGES

Electrostatic discharges are a potential ignition source for explosive atmospheres. They can become effective as an ignition source for gas/air-, vapour/air- (above flammable liquids) and dust/air-mixtures. Plant components as well as products might cause electrostatic charging and give rise to the possibility of a discharge which may ignite an explosive atmosphere.

Charging of products or plant components occurs when surfaces are separated from each other. Surface in this connection stands for the phase boundary of solids or liquids. Charging arises only when one of the materials involved in the separation process is not conductive (insulator). Therefore charge relaxation is not possible because of too high separating velocities [1].

There are several kinds of electrostatic discharges: spark discharges, brush discharges, propagative brush discharges, cone or bulking discharges, corona discharges, lightening like discharges, super brush discharges. The occurrence of these gas discharges can be determined by the properties of the involved materials. Furthermore one also has to pay attention to the processing variables.

When reaching a sufficiently high charging, ignition effective discharges may occur [2]:

- between an isolated or grounded conductive object and a charged isolated conductive object as well as
- between an isolated or grounded conductive and a charged non-conductive material.

DANGEROUS PROCESSING SITUATIONS CAUSED BY ELECTROSTATIC DISCHARGES

The following examples for dangerous processing situations caused by ESD show the great variety of ways of looking at a problem and the various variables that have to be taken into account. These parameters are a result of the various process sequences that lead to electrostatic charging. During practical safety assessments in the field of electrostatic discharges the following processing situations may occur:

- A dust is poured out of a non-conductive bag.
  Because of the separation of dust and bag, both, the product and the container are charged.
- A powder is filled into an agitated vessel.
  The product as well as the non-conductive container can be charged because of the separation process. Therefore gas discharges could occur. These may ignite a vapour-air-mixture which is present over a flammable liquid in the vessel.
- A surface of a flammable, non-conductive, charged liquid gets close to grounded conductive installations.
  Because the non-conductive surface of the liquid gets very close to grounded installations of the apparatus, brush discharges may occur. They could ignite a vapour-air-mixture over the flammable liquid.
- A non-conductive liquid flows through a fine filter.
  Due to the large surface area between the solid and the non-conductive liquid inside the fine filter, the liquid could be charged up very high.

SYSTEMATIC PROCEDURE WHILE SAFETY ASSESSMENT

The aim of the systematic safety assessment with the help of the knowledge-based system is to detect and assess hazards caused by electrostatic discharges. As a consequence adequate safety measures can be chosen to achieve a reliable and safe plant operation. These safety measures are based on guidelines or regulations e.g. [2].

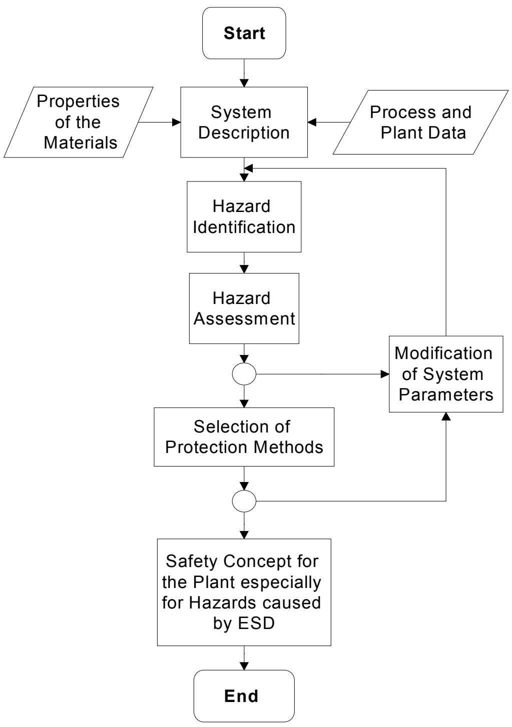

Fig. 1: Proceeding of the knowledge-based system during the systematic safety assessment of hazards caused by electrostatic discharges

To attain a systematic proceeding of the system the following concepts have been developed and implemented into the knowledge-based system. The first concept in Fig. 1 shows the basic structure of the procedure while safety assessment of hazards caused by electrostatic discharges. The procedure should ensure the inclusion of all aspects that have to be taken into account.

The data about the plant and processed material which is necessary for the safety assessment is provided by the user. An examined process is described by its safety characteristics, electrical properties, process parameters and also plant data.

The goal of the hazard identification is to determine the occurrence of explosive atmosphere inside the plant and in the surroundings of the plant. Therefore qualitative and quantitative safety characteristics are valued first of all independently from potential ignition sources [3]. In this way it is possible to identify dangers caused by the properties of the products. The assessment of the occurrence of explosive atmospheres is described with safety characteristics which are dependent from the state of matter. Also, process parameters like e.g. an increased temperature have an influence on the hazard identification process.

If the formation of an explosive atmosphere is possible a systematic hazard assessment is carried out with respect to the occurrence of ignition sources and the incenditivity of them for an existing fuel/air-mixture. The plant and its surroundings are divided into zones, which distinguish the probability of the occurrence of explosive atmospheres.

At the end of the examination the system chooses suitable safety measures. The result of the hazard evaluation is the basis for the development of a safety concept for one apparatus but also for the whole plant. The plant periphery as well as moveable objects should be taken into account. Safety measures have to be determined according to the zone assignment.

By modifying different system properties their influence on the result of the safety assessment can be examined.

MODELLING OF THE PROCESS STRUCTURE FOR COMPUTER-BASED ASSESSMENT

Another important step for the computer-based hazard assessment is the representation of the examined process by a model. The assessment of hazards caused by electrostatic discharges requires the information about the links between several parts of a process plant (e.g. pipes or apparatus). The different parts of the process plant can be represented by objects. The links between these objects represent the electric connections.

Based on this model of the process plant the safety assessment is carried out. The procedure during the assessment of hazards caused by electrostatic discharges invokes the graphical user interface to ask the user for unknown properties. The model of the process forms the basis for the graphical user dialogue which is described in connection with the examples given below.

ASSESSMENT OF IGNITION SOURCES CAUSED BY ELECTROSTATIC DISCHARGES

During the safety assessment, a detailed analysis of the hazards caused by electrostatic discharges is carried out. The structure of the evaluation is shown in Fig. 2.

At first materials are analysed which are involved in the process. Products, plant equipment as well as persons in the surroundings of the analysed part of the plant have to be examined. At this point of the assessment one can decide which kinds of discharges may principally occur. After this, the operating and plant parameters have to be taken into account to be able to analyse the occurrence of possible discharges in detail. This includes parameters which are connected with the process mode e.g. the flow velocity or the surface area between the filter and the fluid during microfiltration. Furthermore the surroundings of the analysed process have to be taken into account. For the evaluation of the different kinds of discharges the occurrence of these discharges is not proved. If the prerequisites for the occurrence of a discharge are given, then the ignition source is regarded as potentially existing. Afterwards the effectiveness of the possible ignition source for the existing explosive atmosphere is assessed. The list of ignition sources and their incendivities given in Fig. 2 is not complete but they represent the valid valuation of the incendivities.

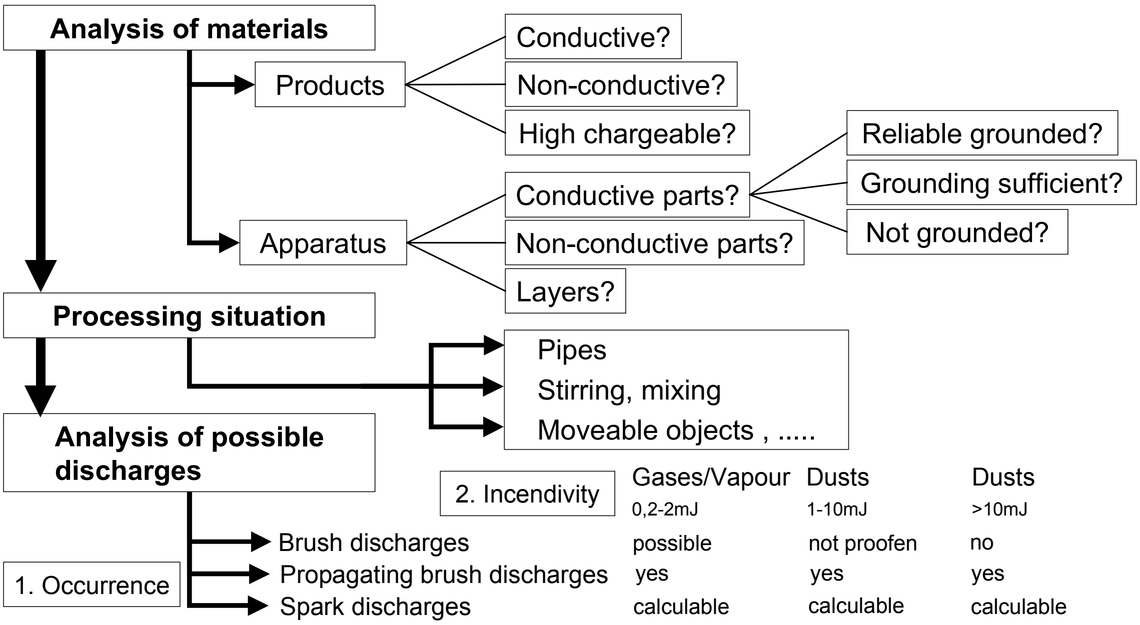

Fig. 2: Procedure during hazard evaluation of ignition sources caused by electrostatic charging.

This procedure constitutes the second, more detailed concept to achieve a systematic assessment of the examined processing situation. The following chapter describes exemplary the necessary steps to be taken when analysing spark discharges.

APPLICATION OF THE GENERAL PROCEDURE

The analysis of different process modes is explained by an example which shows the difficulties of applying the general structure as given in Fig. 2. But, nevertheless, this structure is necessary to ensure that all details for a complete assessment are included.

The first example discussed is a filter which is cleaned in situ by using pulses of pressurised air. This example is given as a case history by Lüttgens and Wilson [4]. The filter bag is supported by a metal basket. Electrostatic charging seems to be not a problem because of the lack of moving parts inside the system. But an ungrounded metal basket could get highly charged because of the separation between filter bag and the basket during a pulse with pressurised air.

During the assessment the user dialogue of the knowledge-based system has to point out to the user that the conductive metal basket could get charged if it is not reliably grounded. Therefore it is necessary to implement knowledge about the structure of this part of the plant. These rules have to transform the input of the user into a form that can be evaluated according to the structure given in Fig. 2.

The application of the procedure described in Fig. 2 for practical cases shows the difficulties for a user with basic knowledge in explosion protection. This user can not take an evaluation of the dangerous situation with common terms like „conductive material“ or „sufficient grounding“.

The following example discusses the problems which occur while applying the practical experiences in the assessment procedure within a computer-based system.

The filling process is shown in Fig. 3 as part of a flowchart. The non-conductive, chargeable dust is conveyed out of the silo into a metal drum, which is weighed during filling. During this operation near the drum and inside the hose an explosive atmosphere occurs. The dust is charged during the conveyance out of the silo.

Spark discharges may occur, if conductive parts of the plant are not grounded. In the example spark discharges can occur by charging the metal drum, the scale or the supporting rings of the hose.

In the evaluated process only the metal drum can be charged up so highly that incendiary discharges may occur. The grounding of the conductive drum has to be examined.

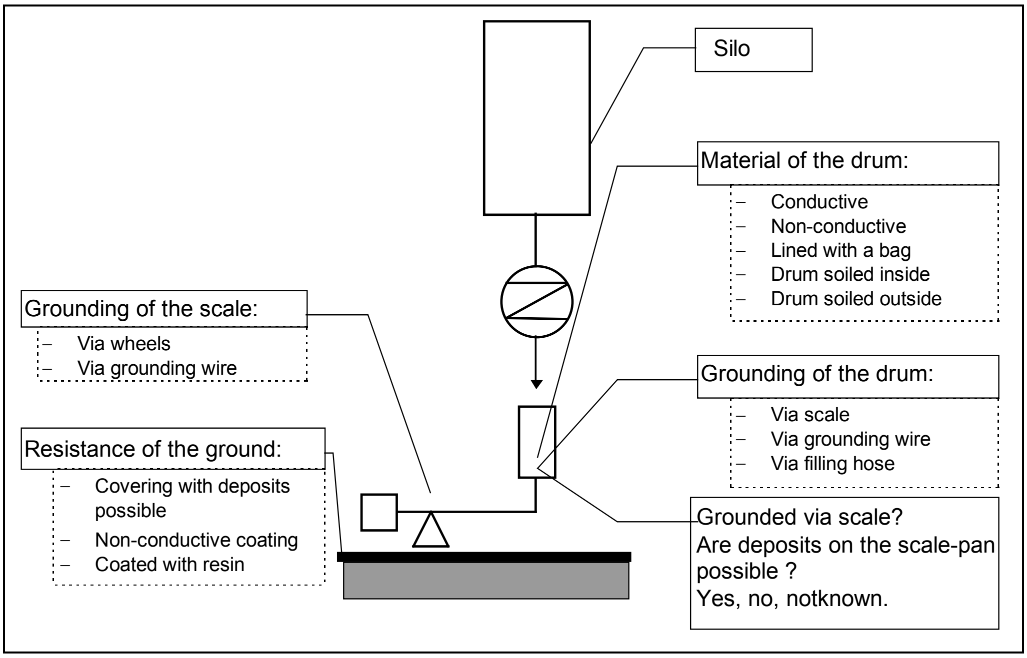

Fig. 3: Drums are filled with dust out of a silo. The drums stand on a moveable scale. Example for the graphical user dialogue with pull-down-menus which allow the specification of the examined process by the user.

The grounding of the drum is a necessary safety measure. A reliable grounding can be achieved by different measures. The drum can be grounded via the scale or via a grounding wire which is connected to the drum before the filling. If the grounding is done via the scale, which is required for an automatic filling process, it must be guaranteed that the scale is grounded and that the scale-pan is not soiled or covered with non-conductive material. The scale itself must be reliably grounded too.

In the given example propagating brush discharges can be excluded due to the fact, that there is no strong charging mechanism like pneumatic conveying. Conveying the powder by gravity does not lead to the necessary high charging for propagating brush discharges. There are also no non-conductive areas in the examined plant which could get charged.

Brush discharges as well as corona discharges cannot be avoided when handling large amounts of medium or non-conductive powders [2]. In the presented case the dust/air-mixture has a minimum ignition energy (MIE) of higher then 5 mJ. The brush discharges cannot ignite this dust/air-mixture. Problems with brush discharges from charged dusts may occur if occasionally a flammable mixture with a lower MIE (e.g. explosive solvent/air-mixture) is present where the brush discharges take place. This indicates that every change in the order of events of the process has to be examined very carefully not to overlook important details.

The examples shows that it is necessary to take into account many details of the concrete process. Therefore it is not possible to describe for example the spark discharges only in general terms. For a computer-based hazard assessment it is necessary to register all details. The user's attention should be drawn to hazardous situations which are relevant in practice. That is why many cases must be analysed during the development of the expert system. From these examples one can derive the parameters to describe specific hazard situations.

The general, systematic procedure derived from the examination of the case histories can be validated with a set of case histories which can be found e.g. in [4].

The user dialogue is supported by a graphical dialogue in which the details of the process are shown. The user has to specify the process to be analysed via pull-down menus. The inputs are evaluated by the expert system and hence included in the assessment of hazards which might be detected.

APPLICATION OF THE EXPERT SYSTEM IN INDUSTRIAL PRACTICE

Different applications of the expert system are possible. While planning a plant, the expert system can give safety advice to avoid hazards caused by electrostatic discharges. The expert system could be used by plant managers to recognize hazards which have been overlooked during the safety assessment in a working plant. Furthermore a repetition of the assessment is necessary, if a process is going to be modified. Safety engineers with practical experience in explosion protection can use this tool to assess potential hazards caused by electrostatic discharges.

The practical application of the expert system facilitates the identification of possible hazards. The results given by the system indicate the necessity for further examinations by experts.

SUMMARY

With the presented knowledge-based system possible hazards caused by electrostatic discharges can be detected and assessed. The system provides a detailed assessment of different processing situations with proposals for safety measures. Potential hazards in explosive atmospheres of dusts, gases and liquids are examined.

The first part during the development of the knowledge-based system is the systematic structuring of the knowledge. The result is a comprehensive and structured summary of the knowledge in this field, that allows hazard assessments independently from the development of the knowledge-based system. This method is the prerequisite to easily extend, validate and maintain the knowledge-based system.

The second part of the development consists of the implementation of the knowledge in the knowledge-based system. To emphasize potentially dangerous operations a graphical user interface has been introduced.

In the result of the safety assessment the knowledge-based system gives references to guidelines and regulations, and the necessity for further examinations by experts is indicated.

LITERATURE

[1] Lüttgens, G., Glor, M.: Understanding and controlling static electricity, Ehningen, Expert-Verlag (1989).

[2] European Committee for Electrotechnical Standardization: CENELEC-Report R044-001, Safety of machinery - Guidance and recommendations for the avoidance of hazards due to static electricity (1999).

[3] Hauptverband der gewerblichen Berufsgenossenschaften: Richtlinien für die Vermeidung der Gefahren durch explosionsfähige Atmosphäre mit Beispielsammlung - Explosionsschutzrichtlinien (EX-RL), Carl Heymanns Verlag, ZH 1/10, (1996).

[4] Lüttgens, G., Wilson, N.: Electrostatic hazards, Butterworth-Heinemann (1997).