A RISK ASSESSMENT STANDARD FOR EQUIPMENT FOR USE IN POTENTIALLY EXPLOSIVE ATMOSPHERES: THE RASE PROJECT

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EU Directives 89/392/EC (machinery directive) and 94/9/EC (ATEX 100A) have to be applied by manufacturers of equipment and protective systems intended for use in potentially explosive atmospheres. These Directives include Essential Safety Requirements and place an onus on manufacturers to carry out a risk assessment for the intended use of their equipment. In order to help manufacturers in this task, the European Standards organisation, CEN, is developing a standard on the risk assessment of equipment for use in potentially explosive atmospheres. The RASE project was set up to meet the requirements for developing such a standard as specified in the dedicated call of the European Commission's Standards Measurement and Testing programme concerned with subjects relating to the standardisation activities of CEN - Explosive atmospheres - risk assessment of unit operations and equipment. The project is co-ordinated by INBUREX with the participation of FSA Germany, INERIS France, HSE England, NIRO Denmark and CMR Norway. The project started in Dec 1997 and is due for completion in May 2000. This paper describes the work plan of the project and the results obtained to date. An outline is given of the contents of the methodology that has been developed for the risk assessment of equipment and unit operations for use in potentially explosive atmospheres.

Keywords: risk assessment, explosive atmospheres, equipment

INTRODUCTION

The Essential Safety Requirements relating to EU Directives 89/392/EC[1] (machinery directive) and 94/9/EC[2] (ATEX 100A) are to be applied by manufacturers of equipment and protective systems intended for use in potentially explosive atmospheres. Current standards (e.g. EN1127-1[3]) only consider the basic concepts and methodology dealing with explosion prevention and protection. There is a lack of a common methodology which can be used by manufacturers facing the design of the wide variety of equipment and protective systems (both electrical and non-electrical) intended for use in explosive atmospheres.

CEN/TC305 and its four working groups is currently developing standards in the area of explosive atmospheres to enable manufacturers to comply with the Essential Health and Safety Requirements of the machinery and ATEX 100a Directives. These include standards for test methods to determine the flammable and explosive characteristics of materials, standards for equipment and protective systems for use in explosive atmospheres and a standard on risk assessment. A specific European standard dealing with risk assessment of equipment for use in potentially explosive atmospheres does not currently exist, thus there is an urgent need for such a standard.

In order for manufacturers to meet the Essential Safety Requirements, it is necessary that they carry out a risk assessment of their products including its intended use. Current Risk Assessment Methodology standards, for example EN 1050[4], provide a good general overview of the techniques and the concepts involved for application of the machinery directive. However they need to be extensively and clearly extended to cover the specific situations and problems associated with risk assessment for explosive atmospheres.

A flexible, comprehensive and unified methodology needed to be developed that will assess the process parameters including those of equipment and protective systems, identify the hazardous situations and evaluate the risks. This methodology needs to provide a link between the risk, its severity and probability of occurrence and the consequences whilst allowing the evaluation of mitigating effects arising from both the design and construction of the equipment and also the provision of additional protective systems.

THE 'RASE' PROJECT OBJECTIVES

The RASE project was set up to meet the requirements specified in the dedicated call of the European Commission's Standards Measurement and Testing programme concerned with subjects relating to the standardisation activities of CEN - Explosive atmospheres - risk assessment of unit operations and equipment.

The objective of this project is to develop a comprehensive flexible Risk Assessment Methodology for identifying potential hazardous situations in equipment such as reactors, dryers, mixers, storage systems intended for use in potentially explosive atmospheres in various industries (chemical, oil, food and provender, metallurgy etc.).

The developed Risk Assessment Methodology will help manufacturers of such equipment fulfil their obligations under the ATEX100a (Equipment for use in potentially explosive atmospheres, 94/9/EC) Directive, i.e. it will be related to the equipment groups and categories defined in this Directive and will be produced in a form that can be readily incorporated into a European Standard. The project has been developed to ensure a close relationship with the work performed in CEN/TC305 and CENELEC/TC31, the European Standards bodies.

As a consequence of this scientific objective, the following technical objectives will be achieved:

- harmonisation of the method used to assess hazardous situations by manufacturers, consultants, competent authorities and users. The user will then be able to consider safety under operational conditions on the basis of risk assessment performed at the design stage by the manufacturer.
- estimation of the residual risk (if any)
- improvement of the choice of equipment referring to safe operating conditions
- reduction of production losses during operation of the equipment and total loss of equipment from an accidental explosion
- use of the results of the risk assessment for the training of operators of equipment.

As the proposed project has been planned to be accomplished in close co-operation with CEN/TC305 and CENELEC/TC31, the end result will be a methodology that can be directly incorporated into a standard which will enable manufacturers to simply and quickly assess the risks associated with the intended use of their products, thus contributing to the improvement of Health, Safety and Environment in Europe.

WORK PLAN OF THE PROJECT

The project, which started in December 1997 and will be completed by May 2000, was divided into four discrete work packages as follows.

INQUIRY ON CURRENT EXPERIENCE FROM MANUFACTURERS

The starting point was the existing experience of manufacturers. An inquiry has been carried out through questionnaires. Included in this questionnaire were aspects such as the full range of foreseeable industrial use, the level of training of operators, the degree of automation of the equipment, the choice of safety measures used, the severity of harm, the probability of occurrence of hazardous situations, the reliability data of equipment and safety measures, the efficacy of the safety measures, maintenance, the lessons learnt from accidents, the existing national regulations, standards and codes of practice and safety rules specified in the instructions for use.

Following development of the questionnaire, it was translated and distributed to a wide range of manufacturers of equipment for use in potentially explosive atmospheres throughout Europe The results were then collated and evaluated. The lessons learnt were incorporated into the risk assessment methodology.

DEVELOPMENT OF RISK ASSESSMENT METHODOLOGY

According to the responses to the questionnaires and the types of equipment involved, a review was carried out of existing methodologies for risk assessment which has enabled a methodology to be developed that is flexible enough to be simply applied to the equipment considered but comprehensive enough to deal with the above mentioned aspects. The objective was the development of integrated explosion safety through the choice of reliable and effective safety measures.

The review of existing methodologies considered not only current European standards but also national standards, guidelines and current practices. In addition accident literature was reviewed to ensure that any lessons to be learnt were incorporated in the methodology. The scope of the risk assessment methodology was based on the requirements identified from the reponses to the questionnaire.

APPLICATION OF THE METHODOLOGY FOR VARIOUS TYPES OF EQUIPMENT

The methodology developed was evaluated by carrying out trials in connection with manufacturers of equipment such as reactors, dryers, mixers, grinders, storage vessels etc. The trials ensured that the methodology is simple and coherent to use and that it produces the required results. An appraisal procedure was also developed to allow the assessment of the results of the trials in respect of areas of the methodology which have to be modified.

COMPARISON OF RESULTS, POSSIBLE REVISION OF METHODOLOGY AND FINAL DEFINITION OF THE METHODOLOGY

After close analysis of the results of risk assessments performed in the trials, a revised final document has been written. This incorporates the modifications identified by trials of the draft methodology. The format of final risk assessment methodology is such that it can be readily incorporated into a draft European Standard by the relevant Standards bodies.

STATUS OF THE PROJECT

The project is now nearing completion and has met all of its objectives. The project followed its intended work plan and the results from the individual tasks are summarised below. A draft version of a risk assessment methodology which can be used by manufacturers of equipment designed for use in potentially explosive atmospheres has been produced and the relevant CEN /TC305 working group will progress this to a European Standard.

QUESTIONNAIRE ON CURRENT EXPERIENCE FROM MANUFACTURERS

In order to determine the current status of risk assessment in the field of equipment intended for use in potentially explosive atmospheres, two questionnaires were developed - one for manufacturers and one for users of such equipment. The questionnaires covered aspects such as the range of industrial use of the equipment, the choice of safety measures used, and whether and how manufacturers currently carry out risk assessments. Questions were also included to determine which standards or regulations were currently used by the firms.

The questionnaires were translated into French, German, Danish and Norwegian and sent to firms in England, Ireland, France, Belgium, Germany, Switzerland, Austria, Denmark, Sweden and Norway. The distribution was mainly to manufacturers (mainly non-electrical but also some electrical) as well as to some users of equipment for use in both gas and dust explosive atmospheres. Both large and small companies were approached as well as Engineering Contractors. Unfortunately due the time constraints of the project, it was not possible to cover Southern European countries.

Approximately 200 responses were received and the results reported using an Excel spread sheet specially developed to aid with the evaluation of the results. The main conclusions that can be drawn from this survey were:

- Most respondees have little awareness of the European Directives themselves, however the majority are aware of national legislation in this field.
- In many instances, manufacturers do not consider that it is their responsibility to define hazardous zones and assess risks, however, customer's specifications are taken into account. They do not seem to use the results of any risk assessment which would appear to contradict the response that the majority consider 'intended use'.
- The risk of occurrence of explosive atmospheres are assessed by Users with a large diversity of methods. Both potential gas/vapour and dust explosive atmospheres are taken into account. For this risk assessment, topics such as flammability and explosivity characteristics of products, hazardous areas classification, protective and preventive methods are considered.
- 1/3 of manufacturers are aware of accidental explosions involving their equipment.
- 1/2 of users had had explosions in their plant - protective systems were present in the majority of these incidents.
- A large variety of safety measures were used by users, however, surprisingly, such safety measures were chosen as a result of a risk assessment in only 50% of the cases.
- With respect to efficacy, a lot of standards were used by manufacturers either related to the equipment in general or for specific protective measures but only 50% of the users said that they received such information.
- Ca. 85% of the users consider reliability of equipment and protective systems as a part of their risk assessment whereas only ca. 50% of manufacturers consider this aspect.

The questionnaires identified that both manufacturers and users are still looking for suitable tools to use for risk assessment.

REVIEW OF INCIDENT DATA

Incident data has been collected and has been evaluated to determine relevant aspects which would have a bearing on the proposed risk assessment methodology. The review included approximately 750 dust explosion accidents and 20 gas explosion incidents. The investigation revealed the following with respect to the cause and effects of dust explosions:

- 26 % of the accidents are caused by human action (based on German records, UK records indicate that only 7 % of the accidents are caused by human action)
- 28 % of the accidents are caused by poor design
- 12-14 % of the accidents are caused by poor maintenance
- 2-7 % of the consequences of the accidents were worsened due to human action
- in 19-21 % of the accidents poor design can be pointed out as a factor for worsening the effects

It was found that in almost all cases knowledge of ignition properties of the respective dusts would not have been able to prevent the accidents from happening. Explosion protection was

applied in many cases but worked satisfactory in only a fraction of the cases that it was applied.
With respect to the causes of gas explosions it was found that:

- 33% and 67 % of the accidents can be attributed to human action (respectively offshore and onshore)
- both offshore and onshore design errors are responsible for approximately 33 % of the accidents
- poor maintenance appears to be responsible for 11 and 17 % of the accidents occurring offshore and onshore respectively however, 46 % of the accidents concerned mechanical failure.

In all investigated gas explosion accidents the design was too poor to withstand the gas explosion effects. Overall the review showed that important issues in risk analysis are: human factors, plant design and maintenance and that these factors should be taken into account in the development of the risk assessment methodology.

REVIEW OF EXISTING RISK ASSESSMENT METHODOLOGIES

A review of existing risk assessment methodologies has been carried out to determine which aspects are applicable for the special situation of equipment for use in potentially explosive atmospheres. The underlying philosophy for conducting risk assessments was identified and can be summarised as an estimation of the explosion risks and their reduction to acceptable levels. Four basic steps were identified:- hazard identification, risk assessment, risk evaluation and risk reduction. It was identified that a critical and often overlooked aspect of risk assessment was the accurate definition of the function of the machine / system to be assessed.

DEVELOPMENT OF A RISK ASSESSMENT METHODOLOGY FOR EQUIPMENT

The results of the review of existing methodologies for risk assessment together with the responses from the questionnaire and the review of gas and dust explosion incidents that have occurred, has been used to develop a methodology which is flexible enough to be simply applied to the equipment considered but comprehensive enough to cover all aspects required by the Directives.

The scope of the methodology has been extensively discussed by the project partners. In particular, the intended breadth of application of the methodology i.e. whether it is intended just for simple pieces of equipment or also for more complex assemblies of apparatus was a difficult point to resolve. On the one hand limiting the scope of application to simple single items of equipment has the advantage that the resulting methodology would be relatively simple to describe, however, this is unlikely to meet the requirements of the project which specifically states that the methodology should be applicable to all equipment and unit operations which fall under the ATEX 100A Directive. At present the methodology attempts to cover all equipment covered by the ATEX 100A Directive. It is primarily targeted at manufacturers, however, it also covers aspects of use to ensure a common format/language between the two aspects. Often the severity/consequences of an incident can only be defined by the user and a link is needed between these aspects.

The methodology concentrates on risk analysis i.e. hazard identification, risk estimation and risk evaluation. and also includes details of the relevant tools/techniques which can be used. In addition, ways to identify possible deviations have also be included. Risk reduction, which is not a part of risk assessment has not been included, however, a section on risk reduction options analysis has been included to ensure that the risk assessment considers the effect of any risk reduction measures that were taken. An extensive list of existing risk assessment techniques has been included with a short description of each and reference to more detailed information.

It became apparent that a critical stage in the process of risk assessment was the definition of the scope of the intended use of the equipment being studied. The methodology includes a novel procedure for the preparation of an 'Equipment/Process Flow Diagram' to ensure that the intended use of the equipment is correctly defined. This procedure helps specify the conditions within the equipment during its use by the inclusion of energy levels (i.e. temperatures, pressures etc.) for each phase of the equipment's operation which are then used to consider/define the status of the materials being handled and the equipment itself. Such a flow diagram not only helps to define the intended use but is also used as the key part of the iterative risk assessment process.

A large amount of effort has been expended in trying to achieve both a clear logic flow through the risk assessment procedure and also the arrangement of information in a structured way. Logic diagrams have been included to make the methodology more useable. Flow charts for deciding which data/tests are required for gas/vapour flammability properties and for the explosibility of dusts have been developed and included.

The methodology provides ways to consider the risk of damage to people, the environment and property and a separate section has been included discussing residual risk. In order to help the user of the methodology, tables with a prescribed format have been included for recording the results of the hazard identification step and also the new 'Function/State Analysis' step. These also help achieve one of the aims of the methodology i.e. transparency between manufacturer and user. Although quality assurance is not felt to be a part of the methodology, the specific requirements for documentation which have been included would allow an audit of the results to be carried out where necessary.

It is intended that the final document will contain examples of the use of the methodology and will include information to help manufacturers classify their equipment as defined in the Directive.

TRIALS OF THE RISK ASSESSMENT METHODOLOGY

A dry run of the methodology equipment has been carried out by the project partners using data on two types of equipment, namely a spray drying plant and an oil seed extraction plant. The application of the risk assessment methodology to these examples identified that the initial data available is often insufficient to carry out a risk assessment.

Trials of the methodology have been carried out with manufacturers of equipment for use in potentially explosive atmospheres. The critical aspects which need to be considered in evaluating the trials of the methodology were included in an appraisal procedure. This included questions about the efficiency of the methodology in achieving the various goals of risk assessment and was completed for each trial to aid with the evaluation stage of the project. Further details on the results of the trials of the methodology will be given in a separate paper in this conference.

CONTENTS OF THE PROPOSED STANDARD

The proposed methodology has been written in the format of a standard and its contents are shown in Table 1.

The Introduction outlines the requirements of both the Machinery and ATEX100a Directives in terms of producing a safe machine and describes the applicability of each Directive. Thus in order to comply with the Essential Health and Safety Requirement of the Machinery Directive, it is necessary to comply with the ATEX Directive. If there is an explosion risk which is outside of the scope of the ATEX Directive then the original

Machinery Directive will apply. Following a brief description of explosion risk and the influencing factors in section 4, the main body of the proposed standard is contained in section 5 which describes the proposed risk assessment methodology.

0	Introduction
1	Scope
2	Normative references
3	Definitions
4	Aspects on how to influence explosion risks
5	Risk assessment procedure
5.1	Determination of intended use (Functional / State-Analysis)
5.2	Hazard Identification
5.3	Risk Estimation
5.4	Risk Evaluation
5.5	Risk Reduction Option Analysis
6	Methods and/or techniques that could favourably be applied
Informative Annexes	
Annex I	Equipment characteristics
Annex II	Operational aspects and influences
Annex III	Human factors and organisational aspects
Annex IV	Risk estimation and evaluation
Annex V	List of risk assessment techniques
Annex VI	Examples: Application of risk assessment methods

Table 1. Contents of Proposed Standard on Risk Assessment of Equipment

RISK ASSESSMENT PROCEDURE

A risk assessment methodology needs to consider all risk factors including unexpected parameters. The methodology needs to answer the following basic questions:

- What do we know? What is the risk?
- Do we have an incident waiting to happen?
- What action can we take?
- What can go wrong? What are the potential consequences?
- How likely is it to happen?
- What is the chain of events which could lead to harm?
- Can we tolerate the potential consequences at the estimated likelihood?
- What are the benefits and costs of alternative technologies?

For the purpose of the proposed standard, risk assessment comprises in principle four steps following the determination of intended use and the proposed methodology follows this sequential approach::

- Determination of intended use (Functional / State-Analysis)
- Identification of hazards, hazardous situations and hazardous events
- Risk estimation of consequences / likelihood
- Risk evaluation
- Risk reduction option analysis

The first three steps of risk assessment (determination, identification, estimation) are often referred to collectively as risk analysis. Risk assessment is an iterative process. If, after risk has been evaluated a decision is made that the risk needs to be reduced, then it is necessary to re-estimate the risk. A decision can then be made as to whether the measures taken have reduced the risk to an acceptable level. It is also essential to check that the measures used to reduce risk have not themselves introduced any new hazards. Therefore a feedback loop from Risk Reduction Option Analysis to Hazard Identification has to be made.

DETERMINATION OF INTENDED USE (FUNCTIONAL / STATE-ANALYSIS)

As mentioned above, the trials of the methodology with manufacturers showed that this aspect was often poorly defined particularly in terms of nature of the explosive atmosphere that may be present. A functional state analysis procedure has therefore been developed by the project team and included in the proposed methodology.

In this respect it is an advantage to establish an Equipment / Process Flow Diagram in the light of a Functional / State-Analysis with the inclusion of energy levels (i.e. temperatures, pressures etc.) for each phase of the equipment's operation. Such a diagram helps the assessor to consider and/or to define the status of the materials being handled and the status of equipment itself, see Figure 1.

Physical state of substance	**Unit operations**	**Energies / operating states**
E.g. solid, grains, dusty, gaseous, liquid, emulsion, paste-like etc.	E.g. grinding, mixing, fluidising, spraying, drying, evacuating, storing, transport etc.	E.g. dynamics, static's, pressure, temperature, concentrations etc.
	Input	
Solid S1	**A**	E1 Heating
Dusty S2	**B**	E2 Cooling
.... S3	**C**	E3 ....
	Output	
S: substance physical state	A-C: unit operations	E: energy/operating state

Figure 1: Functional Analysis of Unit Operations

In addition, such a flow diagram not only helps to define the intended use but also can be used as the key part of the iterative risk assessment process. It refers the ATEX product characteristics to energies involved and/or the operating state as well as the physical state of the substance. Thus the analyst is able to determine what, why and how things can happen, especially when dealing with complete machines or more complex products. The diagram is based on the fact that any ATEX product has limits to its functionality and to its use, especially the intended use, its lifetime and space it occupies (configuration). These limits form part of constituent elements or parameters which need to be taken into account in any phase of the Functional/State-Analysis. These constituent elements could serve as a screen to register, for example,

- phases of equipment life
- limits in terms of use, time, space
- accurate definition of the function
- selection of material used to construct
- combustion properties

When defining those limits, the following items have an important impact, for example, in terms of use, time and space:

- intended use:
    - product, capacity, load rate of utilisation, foreseeable misuse
- life time:
    - abrasion, corrosion, parameters of process like ageing by temperature, pressure, vibration, characteristics of substances, maintenance, change of use, change of environment;
- configuration:
    - range of movement, space requirement, location, volume, confinement, weight, kind of interconnections, etc

IDENTIFICATION OF HAZARDS, HAZARDOUS SITUATIONS AND EVENTS

There is rarely, if ever, a single cause of a hazardous situation or hazardous event. Although the immediate cause may be a simple hardware failure or operator error, other events will have also occurred which contribute to the development of the accident. Such events include undetected failure of protective systems, ergonomic problems or an organisation in which safety is not given priority.

In many ways, hazard identification is the most important part of any risk assessment. In order to carry this out successfully the previous step must have accurately defined the equipment in sufficient detail. Once a hazard has been identified, the design can be changed to minimise it, even though the degree of risk may not have been estimated, however, unless the hazard is recognised it cannot be addressed during the design phase. A full understanding of the machines intended use and foreseeable misuse is of prime importance during this step.

A project or a process has an acceptable safety design when one judges that adequate preventive or protective measures have been taken. The term “adequate measures”, refers to generally accepted safety, engineering, scientific, production, operational, and maintenance procedures with view to the location in which the risk might occur.

The main aim of hazard identification is that all possible hazards are found and none are missed. This may be facilitated by the use of more than one method and/or technique. The main output from the hazard identification stage is a numbered listing of hazardous events recorded as in Figure 2, which could result from the unit operations and equipment involved and is used as an input to the risk estimation stage.

Hazard identification can also produce subsidiary outputs, for example, a list of possible protective measures against the hazards which have been identified. Such lists can then be used in the risk evaluation and risk reduction steps of the risk assessment.

In the assessment of the combustion properties and the likelihood of occurrence of a hazardous explosive atmosphere, logic diagrams are useful tools and several have been included in the proposed methodology, for example, for flammability limits or relevant data characterising the behaviour of the explosive atmosphere, and for the exclusion of ignition sources.

	Explosive Atmosphere			**Ignition Source**			
Ref.	Type	Frequency of occurrence or release	Location	Type	Cause	Likelihood	Effectiveness of ignition sources
1	Mixture with air of flammable gas	For a short period only	Outside filling part	Stirrer motor surface	Overload of the motor	During malfunction	High; as surface temperature > ignition temperature
2	Cloud of combustible dust	Present frequently in normal operation	Inside elevator housing	Friction sparks in bucket elevator	Buckets rubbing on housing	Occasionally in normal operation	Low; due to slow bucket speed
Etc.							

Figure 2: Example of Hazard Identification Record Form

The ignition capability of the ignition sources should be compared with the ignition properties of the flammable substances. The likelihood of occurrence of the effective ignition sources is assessed following EN 1127-1 taking into account those that can be introduced e.g. by maintenance and cleaning activities,

RISK ESTIMATION

In principle, Risk Estimation should be carried out for each explosion hazard or every hazardous event in turn by determining the elements of risk after Hazard Identification. The risk associated with a complete machine or process is derived from a combination of these individual risks. Risk in terms of explosion safety is fundamentally made up of two elements: the severity of the possible harm and the probability of occurrence of that harm.

The severity or consequence of an explosion can often be adequately characterised, however, the probability of its occurrence is usually more difficult to quantify.

Risk is usually expressed in one of 3 ways:

- Qualitatively for example as high, medium, low, tolerable, intolerable, acceptable;
- Quantitatively by calculating the frequency or probability of some determined event occurring;
- Semi-quantitatively where elements of risk such as consequence, exposure and likelihood are given a numerical score which are then combined in some way to give a pseudo-quantitative value of risk which allows risks to be ranked one against another.

In many situations it is not possible to exactly determine all the factors that effect risk, in particular those which contribute to the likelihood of a specified event occurring. Thus risk is often expressed in a qualitative rather than a quantitative way.

Severity can be expressed as defined levels, one or more of which can result from each hazardous event. Thus in terms of injuries, damage to health or system damage severity can be expressed as shown in Table 2:

SEVERITY LEVELS	DEFINITION
CATASTROPHIC	Death or system loss.
MAJOR	Severe injury, severe occupational illness, or major system damage.
MINOR	Minor injury, minor occupational illness, or minor system damage.
NEGLIGIBLE	Less than minor injury, occupational illness, or system damage.

Table 2: Definition of severity levels

In order to estimate the frequency of each severity level a screening technique can first be applied to determine the probability of each hazardous event in terms of both the occurrence of an ignition source and the explosive atmosphere. The frequency of occurrence can be qualitatively expressed as shown in Table 3:

FREQUENCY	Specific Individual Item (ignition source)	Inventory (explosive atmosphere)
FREQUENT	Likely to occur frequently	Continuously present
PROBABLE	Will occur several times in life of an item	Will occur frequently
OCCASIONAL	Likely to occur sometime in life of an item	Will occur several times
REMOTE	Unlikely but possible to occur in life of an item	Unlikely but can reasonably be expected to occur
IMPROBABLE	So unlikely, it can be assumed occurrence will not be experienced	Unlikely to occur, but possible

Table 3: Qualitative description of Frequency

The risk levels represent a ranking of the risk which enables an evaluation of what further actions are needed if any. Four risk levels are used ranging from 'A' representing a high risk level to 'D' a low risk level. The matrix linking frequency and severity is shown in Table 4:

Frequency of Occurrence	Severity			
	Catastrophic	**Major**	**Minor**	**Negligible**
Frequent	A	A	A	C
Probable	A	A	B	C
Occasional	A	B	B	D
Remote	A	B	C	D
Improbable	B	C	C	D

Table 4: Frequency-Severity Matrix relating to risk levels

RISK EVALUATION

Following the estimation of the risk, Risk Evaluation is carried out to determine if Risk Reduction is required or whether the required degree of safety has been achieved. It is evident that if the risk estimation results in a risk level of A, the risk is so high as to be intolerable and additional risk reduction measures are required. Similarly a risk level of D can be considered to be acceptable and no further risk reduction is required. Thus the risk can be described either as 'Intolerable' - if the risk falls into this ranking then appropriate safety measures must be taken to reduce the risk, or as 'Acceptable' - if the risk falls into this category then no Risk Reduction is required and the Risk Assessment is complete.

Risk levels B and C are intermediate levels and will normally require some form of risk reduction measures to make the risk acceptable. However, the degree of these measures will be smaller and in the case of a risk level C, organisational risk reduction measures will often be sufficient.

Alternatively the process of Risk Evaluation can be carried out by comparing the explosion risks associated with equipment and unit operations with those of similar equipment. In this case it is essential that the following are comparable:

- hazards and elements of risk
- type of equipment, its technology and operational limits
- intended use and the conditions of use

The application of the comparison method does not preclude the need for conducting a Risk Assessment for the specific conditions of use.

RISK REDUCTION OPTION ANALYSIS

In practice, risk can seldom be reduced to zero except by eliminating the activities, however, risks can often be further reduced. Options which address the hazardous events that make the greatest contributions to the total risk have the greatest potential to reduce risk. Effectiveness in reducing risk always starts with changes to the design concept, i.e. an inherently safe design.

Once the risk has been estimated and evaluated, the risk reduction option analysis leads to the final decision as to whether or not the solution found reduces the risk to an acceptable level. This decision includes both the technological and economical point of view based on an appropriate classification of equipment category. If not, the iterative process has to repeated after amending the safety concept. It is necessary to deal with residual risks after all measures have been taken to reduce the probability and consequence of a specific hazardous event. The residual risks are those against which risk reduction by design and safeguarding techniques are not, or not totally, effective.

The user of the equipment must be informed about residual risks. Instructions and warnings, for example, prescribe the operating modes and procedures to overcome the relevant hazards.

In many cases, it is unlikely that any one risk reduction option will be a complete solution for a particular problem. Often Risk Assessment of Unit Operations and Equipment will benefit substantially by a combination of options.

METHODS AND/OR TECHNIQUES THAT COULD FAVOURABLY BE APPLIED

The proposed methodology also includes a section describing the different techniques that are available for risk assessment and their applicability to different situations. There are many possible methods and/or techniques for risk assessment, especially for hazard identification, however, there is no golden rule as to which method and / or technique ought to be adopted. A good hazard identification technique has the attributes that it is systematic, i. e. it guides the users so that all parts of the system, all phases of use and all possible hazards are considered and that it employs brainstorming.

In principle, the identification techniques fit into three categories:

- comparative methodology, e. g. checklists, codes
- fundamental approach, e. g. HAZOP, FMEA
- failure logic diagrams, e. g. Fault Tree Analysis, Event Tree Analysis

The comparative methodology relies on experience, whereas the fundamental methodology aims to discover all possible conditions and deviations in order to identify those which may be hazardous. The failure logic diagram approach identifies and structures combinations or sequences of occurrences with accident potential.

In general, methods or techniques for risk assessment can be classified as:

<u>Qualitative</u>: Both the input to the risk estimation in terms of categories for each unit operation and equipment and the output in terms of risk all consist of qualitative phrases such

as "hazardous event is likely to occur", "severe injuries", "unacceptable risk", "high risk", "low risk" and so on.

Quantitative: The incident scenario is modelled in detail, for example using fault tree analysis and event tree analysis, so that risk estimates can be made of all possible events which affect the overall frequency of a defined hazardous event or consequence. This uses any available data or experience of the frequency or probability the events. The results can be directly compared with accident statistics in order to either validate the method, or to make decisions as to whether the risk is acceptable.

Semi-Quantitative: Input categories are combined numerical or diagrammatically to obtain a numerical (pseudo-quantitative) value of risk. These values are often then banded into categories which are defined qualitatively.

By using more than one technique the possibility of overlooking any relevant hazard is minimised. However, the additional time employed in using more than one technique needs to be balanced against the increased confidence in the results.

CONCLUSIONS

The RASE project is nearing completion and has successfully achieved its objectives. A methodology for the risk assessment of equipment and unit operations for use in potentially explosive atmospheres has been developed. It is based on the results of a review of existing methodologies for risk assessment together with the responses from a questionnaire of manufacturers and users on their current experiences and a review of gas and dust explosion incidents that have occurred. The draft methodology has been tested with selected manufacturers of equipment and the results from these trials have been used to produce a methodology which is flexible enough to be simply applied to the equipment considered but comprehensive enough to cover all aspects required by the Directives. As the project is being carried out in close co-operation with CEN/TC305 and CENELEC/TC31, the end methodology should be able to be directly incorporated in a standard which will enable manufacturers to simply and quickly assess the risks associated with the intended use of their products, thus contributing to the improvement of Health, Safety and Environment in Europe.

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