Risk analysis for equipment and protective systems intended for use in potentially explosive atmospheres

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EU Directives 98/37/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 organization, CEN, TC 305 has mandated its WG 4 (terminology and methodology) to write a standard on the risk assessment of equipment and protective systems intended for use in potentially explosive atmospheres. The RASE project was set up as a prenormative research work to define 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 standardization activities of CEN - Explosive atmospheres - risk assessment of unit operations and equipment. The project (December 1997-May 2000) was co-ordinated by INBUREX with the participation of FSA Germany, INERIS France, HSE England, NIRO Denmark and CMR Norway. Since March 2000, WG 4 (TC 305) is actively involved in preparing the final draft of this standard. This paper describes the objectives and the results obtained to date in RASE project and in WG4. An outline is given of the contents of the standard being developed for the risk assessment of equipment and protection systems intended for use in potentially explosive atmospheres.

Keywords : risk assessment, explosive atmospheres, equipment, protective systems.

INTRODUCTION

The Essential Safety Requirements relating to EU Directives 98/37/EC (machinery directive) and 94/9/EC2 (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) only consider the basic concepts and methodology dealing with explosion prevention and protection for group II equipment. 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 has mandated (December 1994) its working group 4 (terminology and methodology) to write a specific European standard dealing with risk assessment of equipment for use in potentially explosive atmospheres before end 2001. This means that there is an urgent need for a standard on risk assessment.

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, 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 situation and problems associated with risk assessment of equipment and protective systems intended for use in potentially explosive atmospheres.

Thus it is necessary to develop a flexible and comprehensive unified methodology that will assess the process parameters including those of equipment and protective systems to 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 (risk reduction).
the 'RASE' project objectives

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 standardization 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 discussed as an input for 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 concerned with this topic.

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

- harmonization of a comprehensive approach of hazardous situations between manufacturers, consultants, competent authorities and users.
- The user should consider the safety in 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 (including malfunction) of the equipment and total loss of equipment from an accidental explosion
- use of the results of the application 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 used as an input for the work to be performed by CEN/TC305/WG4 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.

The work (WI 00305061) mandated to WG 4 in TC 305 is concerning a methodology for risk assessment of equipment and protective systems for intended use in potentially explosive atmospheres.

The proposed scope is the following :

This standard will give guidance on risk assessment related to dangerous (hazardous) situations arising from potentially explosive atmospheres.

This includes :

- The evaluation of the likelihood and consequences of an explosion
- The mitigation of explosion effects
- The selection of equipment and/or protective systems (including components)
- The information for safe use and maintenance.

I WORK PROGRESS IN RASE PROJECT (December 1999-May 2000)

A draft version of a risk assessment methodology which can be used by manufacturers of equipment designed for use in potentially explosive atmospheres was produced in May 2000. This methodology was established as an end product after completion of four discrete work packages :

- Inquiry on Current Experience from Manufacturers
- Development of Risk assessment methodology
- Application of the methodology for various types of equipment and protective systems
- Final definition of the methodology.
-

I.1 Inquiry on Current Experience from Manufacturers

The starting point has been the existing experience of manufacturers. An inquiry was carried out through questionnaires. Included in this questionnaire were aspects such as the intended 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, the maintenance, the lessons learnt from accidents, the existing national regulations, standards and codes of practice, the safety rules specified in the instructions for use and whether and how manufacturers currently carry out risk assessments.

A questionnaire was also adapted to users.

These 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 customers 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/vapor 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, there were a lot of standards used by manufacturers either related to the equipment in general and 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.

Additionally, incident data have been collected and 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 accidents.

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 is 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 :

- 33-67 % 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 factor, plant design and maintenance and that these factors should be taken into account in the development of the risk assessment methodology.

I.2 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 will enable a methodology to be developed so that it is flexible enough to be simply applied to the equipment considered but comprehensive enough to deal with the above mentioned aspects. The objective is the development of integrated explosion safety through the choice of reliable and effective safety measures.

The review of existing methodologies considers 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 are incorporated in the methodology. The scope of the risk assessment methodology was based on the requirements identified from the responses to the questionnaire.

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 allowed 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 be 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 (i.e. temperatures pressures etc.) levels 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/vapor 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.

I.2.1Contents 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 favorably be applied
Informative Annexes	
Annex I	Equipment characteristics
Annex II	Operational aspects and influences
Annex III	Human factors and organizational 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

1.2.2 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 methodology proposed 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, the decision is made that the risk needs to be reduced 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.

1.2.3 Determination of intended use (Functional / State-Analysis)

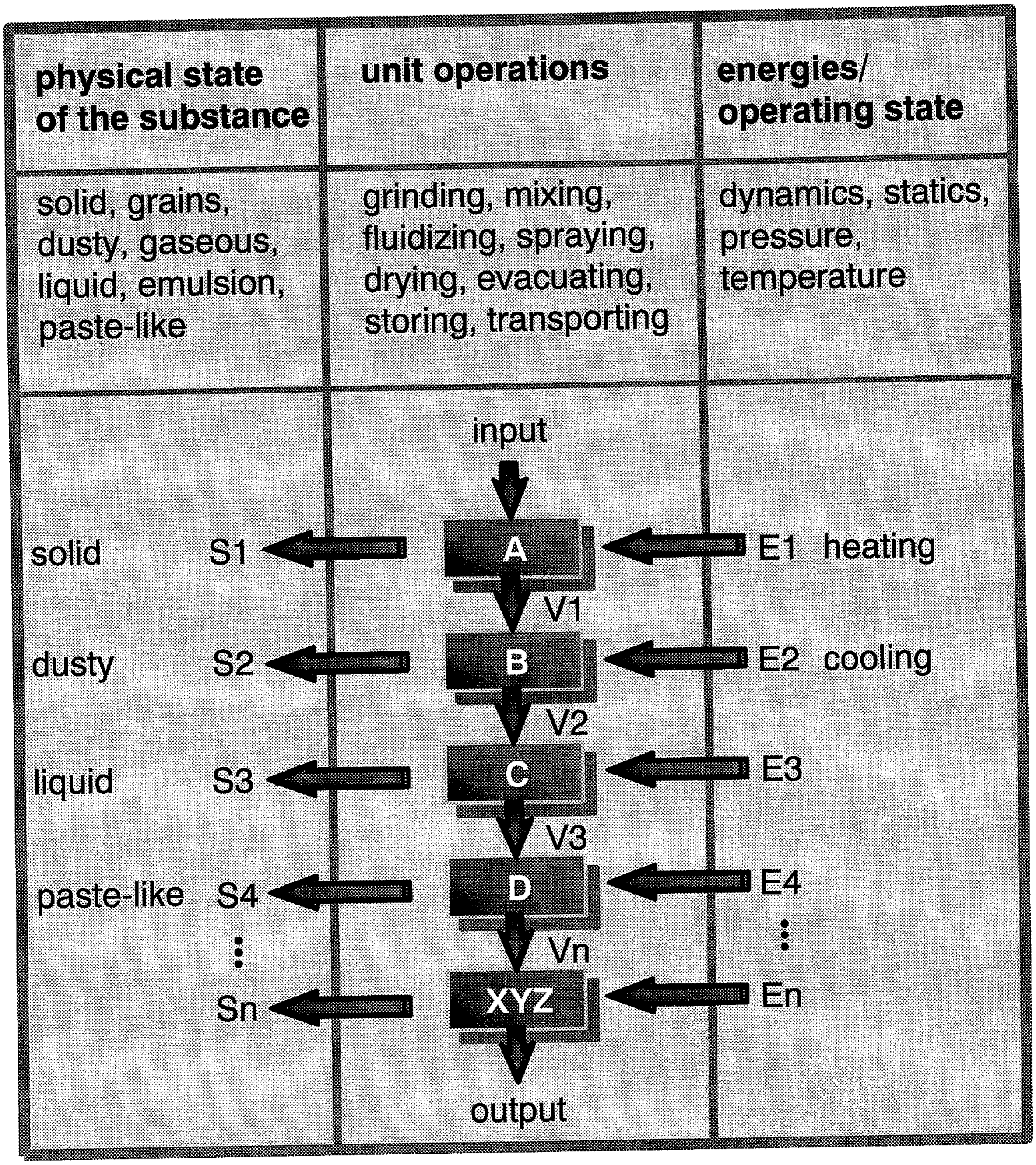
As mentioned above, the trials of the methodology with manufacturers showed that this aspect was often poorly defined particularly in terms of nature of the explosive atmosphere that may be present. A functional state analysis procedure has therefore been developed by the project team and included in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

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...



S: physical state of the substance   A...XYZ: unit operations
E: energy/operating state
V: linkage (depending on function/depending on effect)

Figure 1: Functional Analysis of Unit Operations

I.2.4 Identification of hazards, hazardous situations and hazardous 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 organization in which safety is not given priority.

In many ways, hazard identification is the most important part of any risk assessment. In order to successfully carry out this step the previous step must have accurately defined the equipment in sufficient detail. Once a hazard has been identified, the design can be changed to minimize it, even though the degree of risk may not have been estimated, however unless the hazard is recognized it cannot be addressed during the design phase. A full understanding of the equipment 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 standard, for example, for flammability limits or relevant data characterizing the behavior of the explosive atmosphere, and for the exclusion of ignition sources.

Ref	Explosive atmos-phere	Frequency of Release	Location of Explosive atmos-phere	Potential of Ignition source	Occur-rence of Ignition sources	Probabi-lity of Ignition sources	Effective-ness of ignition sources
1	**Mixture with air of flam-mable gas**	**for a short period only**	**outside filling part**	**stirrer motor surface**	**during malfunc-tion (overload)**	**likely to occur during malfunc-tion**	**High, as surface temperat ure > ignition temperat ure**
2	**Cloud of combus-tible dust**	**Present frequen-tly in normal operation**	**inside elevator housing**	**Friction sparks in bucket elevator**	**buckets rubbing on housing**	**likely to occur occasio-nally in normal operation**	**Low, due to slow bucket speed**

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.

I.2.5 Risk Estimation

In principle, Risk Estimation shall be carried out for each explosion hazard or every hazard 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 characterized 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.
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:

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

I.2.6 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, organizational 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.

I.2.7 Risk Reduction Option Analysis

Risk can seldom in practice 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.

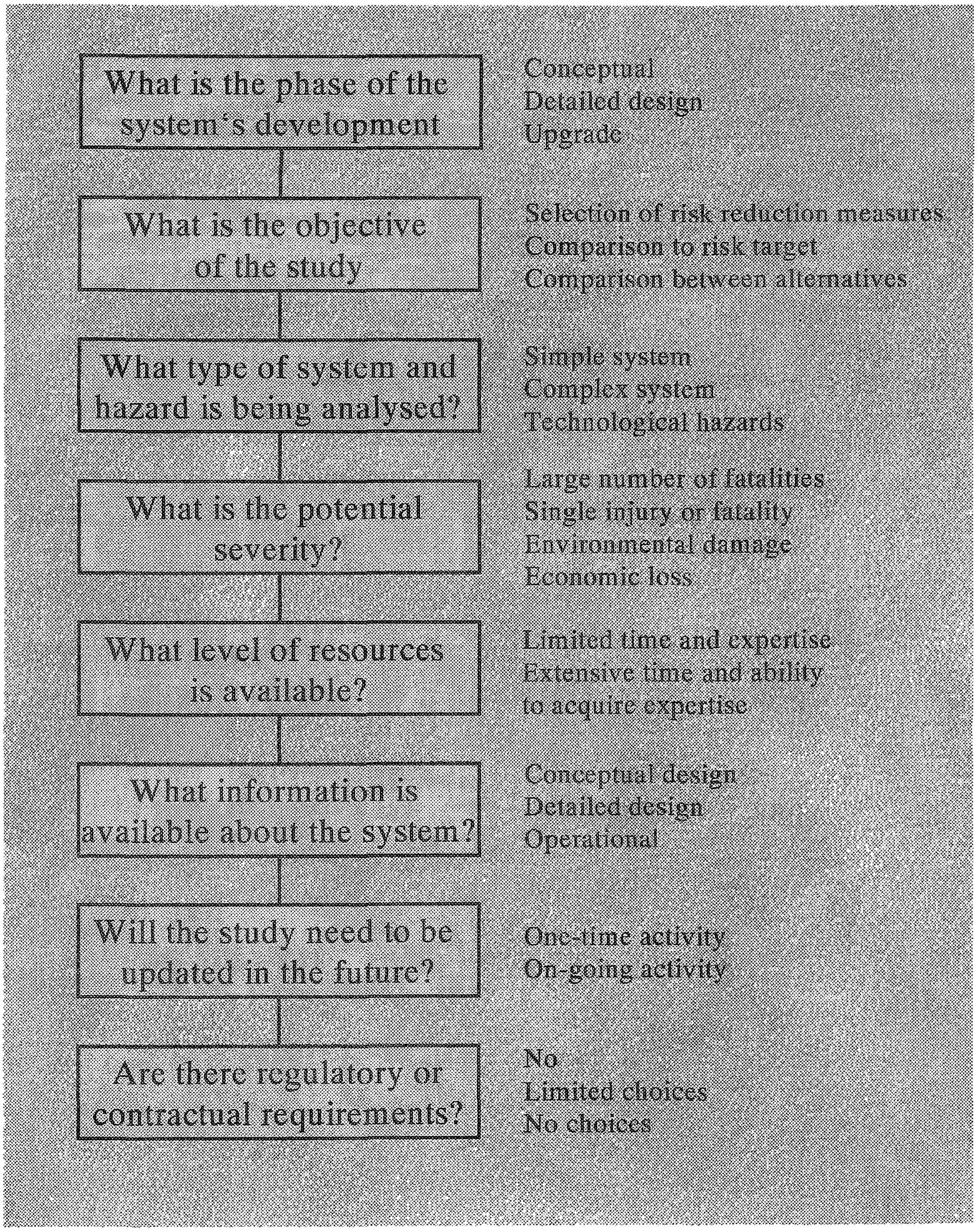
The user of the equipment must be informed about residual risks. Instructions and warnings, for example, prescribe the operating modes and procedures to overcome the relevant hazards.

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.

I.2.8 Methods and/or techniques that could favorably be applied

The proposed standard also includes a section describing the different methods that are available for risk assessment and their applicability to different situations. There is no golden rule as to which method and / or technique ought to be adopted. Figure 3 gives some typical consideration in selecting type of analysis and depth of the study.

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


What is the phase of the system's development
Conceptual
Detailed design
Upgrade
What is the objective of the study
Selection of risk reduction measures
Comparison to risk target
Comparison between alternatives
What type of system and hazard is being analysed?
Simple system
Complex system
Technological hazards
What is the potential severity?
Large number of fatalities
Single injury or fatality
Environmental damage
Economic loss
What level of resources is available?
Limited time and expertise
Extensive time and ability to acquire expertise
What information is available about the system?
Conceptual design
Detailed design
Operational
Will the study need to be updated in the future?
One-time activity
On-going activity
Are there regulatory or contractual requirements?
No
Limited choices
No choices

I.3 APPLICATION OF THE METHODOLOGY FOR VARIOUS TYPES OF EQUIPMENT AND PROTECTIVE SYSTEMS

Six examples were extensively developed :

- exhaust system of gas engine
- paint spray booth
- oil seed extraction unit
- protective system : an explosion venting door.
- pneumatic powder transfer system
- spray Dryer for milk.

During these trials many manufacturers found that the document contains a great deal of useful information but from a practical point of view it was difficult to navigate. It was not easy to read, too extensive, doesn't spell out in word of one syllable what manufacturers have to do, what is link between methodology and directives etc. In applying the methodology it was found that the sections on risk estimation and evaluation were not consistent and required further development.

However following the application of the methodology with the help of the project partners, it was found that the use of the proposed proformas helped to clearly summarize the results. Similarly, the methodology provided a good framework to pull together existing safety studies forcing the consideration of the intended use / limitations of the machines.

It was clear from the trials that had been carried out that most manufacturers found the methodology difficult to use. This in part reflects the complexity of the subject but also because the manufacturers have little idea what is involved in carrying out a risk assessment and what they have to do to meet the requirements of the Directive. When guided through the process by a project participants - it was clear that the methodology produced a satisfactory risk assessment with the advantage of the results being transparent.

I.4 COMPARISON OF RESULTS, REVISION OF METHODOLOGY AND FINAL DEFINITION

The above mentioned trials have shown that the basic framework of the developed methodology is suitable and that when the suggested proformas are used for recording the results, the risk assessment which has been carried out can be clearly followed. However it is clear from the trials that manufacturers have extreme difficulty in applying the methodology. This is partly to be expected as the subject of risk assessment is extremely complex and it is unlikely that someone without experience in the field can simply take the proposed draft and directly apply it to their problem.

In order to improve the 'usability' of the methodology the project team has decided to develop and include a 'User-Guide' which will contain detailed examples of the use of the methodology for assessing the risk associated with different types of equipment and unit operations. Once this is completed, the revised draft will be considered as the input for CEN TC305.

II WORK PROGRESS ON RISK ASSESSMENT METHODOLOGY IN CEN TC 305, WG4

After a call for experts through national standardization bodies, three meetings were held until now with the active participation of representatives of the following countries : France, Germany, Sweden, United Kingdom, after a call for experts. Unfortunately, with the exception of one expert, members of the RASE project were unable to attend the meetings of working group four.

A rearrangement of the existing RASE project was proposed by experts to have the basic methodology as one part and examples and users guide as a second part.

The existing document should be adapted to be aligned with ISO/IEC guide N 51 " Safety aspects. Guidelines for their inclusion in standards.

The standard will follow the iterative process of risk assessment as given in EN 1050 used for the requirements of machinery directive (and used in the RASE project).

Revisions of the various parts were proposed and are to be discussed on the basis of an existing document in a meeting to be held in London on October 23 and 24th 2001.

III CONCLUSIONS

The RASE project is finished since May 2000 and has successfully achieved its objectives. A methodology for the risk assessment of equipment and unit operations intended 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 is now an input for the work under progress by CEN/TC305/WG4 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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- by the members of CEN,TC 305WG4/subgroup 3

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