Improvement of the hazard identification and assessment in application of the Seveso II Directive

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IMPROVEMENT OF THE HAZARD IDENTIFICATION AND ASSESSMENT IN APPLICATION OF THE SEVESO II DIRECTIVE

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ABSTRACT

The Council Directive 96/82/EC of 9 December 1996 on the control of major-accident hazards involving dangerous substances, known as SEVESO II Directive, aims at the prevention of major accidents and the limitation of their consequences for human beings and environment. Although rules are well established to identify potential risk, there is no method to measure the risk level which takes into account safety devices and safety management systems implemented by operators.

This paper deals with the first stage of a global methodology that aims to better assess benefits form safety devices and safety management systems through accident scenario selection.

1 INTRODUCTION

1.1 Context

In several European countries, risk level is often deducted from effect distances, as results of the evaluation of gravity and likelihood of major accident scenarios. Therefore, the identification of accident scenarios appears as a critical point in the risk analysis process that should take into account measures related to "state of art" and philosophy of the SEVESO II Directive. Typically, risk experts have to answer the following questions :

- Is the reliability of safety devices assured ?
- What is the influence of measures taken at conception level ?
- What are the benefits brought by safety management systems ?

Because of a lack of methodology, it is now particularly difficult to point out the influence of these parameters specially when determining accident scenarios. This difficulty is specially relevant in France where a deterministic approach is adopted [1].

As a matter of fact, effect distances are results of major accident scenarios that are considered independently of their likelihood which is not assessed. The underlying philosophy is based on the idea that measures taken to protect people from worst cases accidents are able to behave similarly with any less serious ones.

However, this conservative and cautious approach may lead to an over-estimation of the risk level [2], that fails to :

- encourage operators to increase risk prevention,
- define a relevant and accurate risk level.

This paper presents the first developments of a method that, in a deterministic context, emphasizes :

- the risk level inherent to an industrial plant, by the definition of Maximum Physically Possible Scenarios (MPPS),
- the influence of inherent or integrated safety rules and regulations, state of art… by the definition of the so-called Reference Accident Scenarios (RAS)
- the benefits brought by safety devices and safety management systems by the definition of Residual Risk Assessment Scenarios (RRAS).

This general method is also divided in three stages, that are illustrated by (Fig 1).

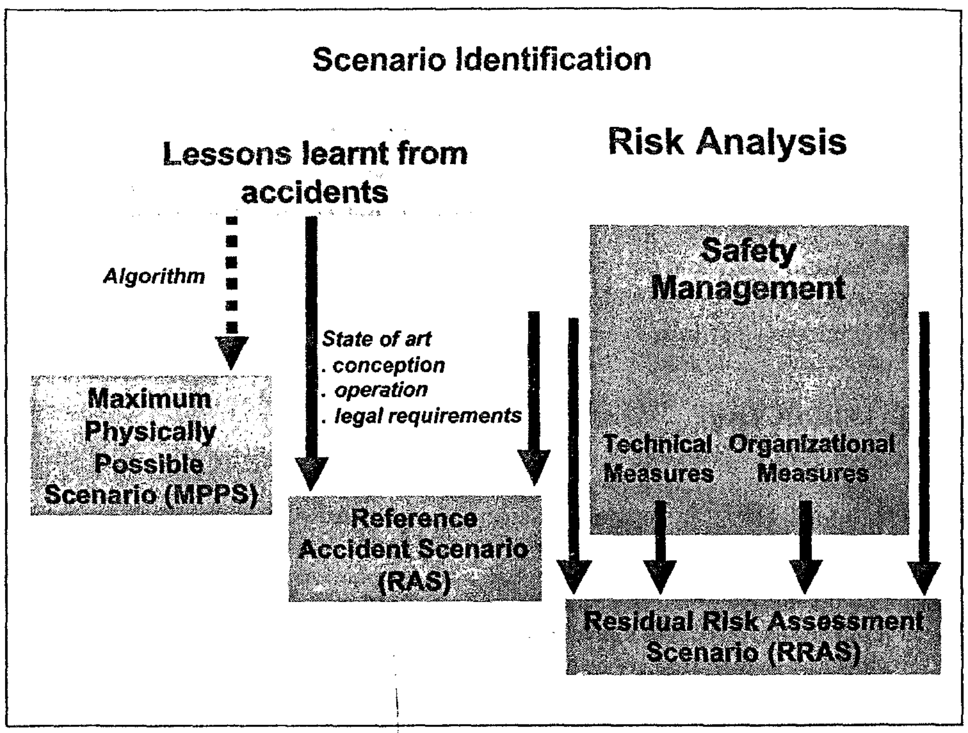

Figure 1 : Scenario Identification

This method is being developed with the French Competent Authorities in charge of the application of the Seveso II Directive.

The following paragraphs only deal with a method to identify Maximum Physically Possible Scenario (MPPS) in a deterministic way.

1.2 MPPS : Definitions and Hypothesis

As stated in the introduction, Maximum Physically Possible Scenarios characterize the risk level inherent to high-risk establishments. In a simpler way, it can be noticed that these scenarios determine the worst situations that could physically occur.

Generally, a scenario is assimilated as a succession of events presented in (Fig 2), which inspired from the bow-tie approach presented in [3].

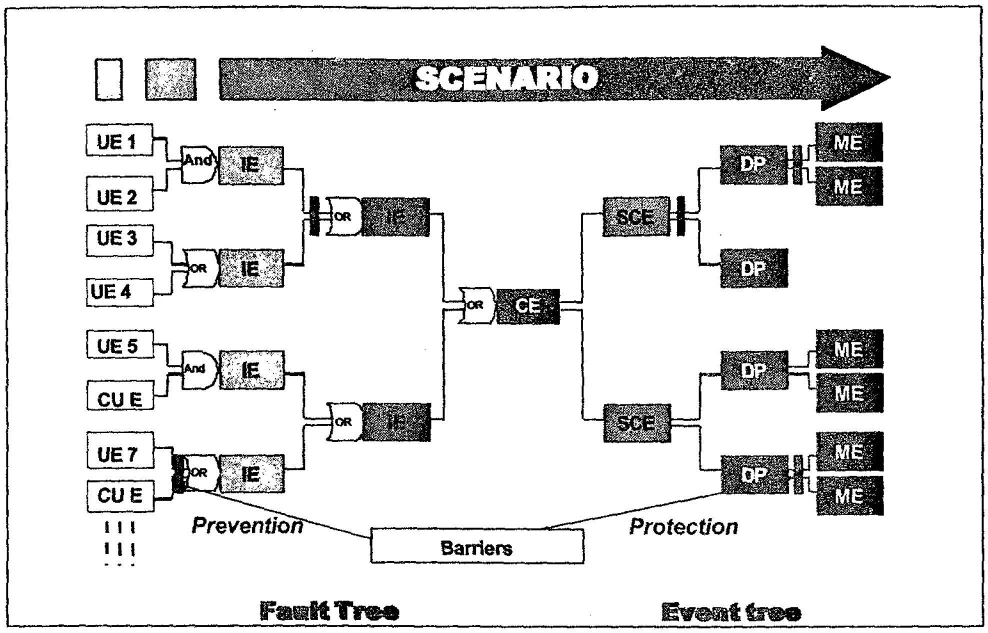

Figure 2 : Accident Scenario Identification

Fault Tree

The origin of the fault tree is determined by :

- Undesirable Events (U E), which are supposed to occur exceptionally in the usual conditions of operation
- Current Events (Cu E), which occur more or less frequently and that are in a certain way, foreseeable.

The combination of Undesirable and Current Events may lead, according to the influence of prevention barriers, to an Initiating Event (I E). An Initiating Event is defined as the step that precedes the occurrence of the Critical Event (C E). The Critical Event is generally defined as a Loss of Containment (LOC).

Event tree

The characteristics of the Critical Event pointed out by the fault tree analysis may be determined by the Secondary Critical Events (SCE), taking into account protection barriers. (formation of a pool, puff, gaseous release…).

The secondary Events may lead to Dangerous Phenomena (DP) such as fire, Vapor Cloud Explosion (VCE), BLEVE, toxic gas dispersion…

At last, Major Events (ME) are defined as the exposition of targets (human beings, structure, environment…) to a significant effect from the identified Dangerous Phenomena.

As previously shown, an accident scenario mainly depends on :

- the nature and the characteristics of the Initiating Events,
- the nature and properties of the substance handled,
- the characteristics of the equipment (vessel, process unit, pipe..;) involved,
- the possible action of prevention and protection barriers.

At this stage, the methodology will allow to quantify the potential hazards of a unit by the definition of Maximum Physically Possible Scenarios (MPPS). For this purpose, it is important to identify the worst cases that could possibly occur, regardless of any probabilistic matters. In consequence, the following hypothesis can be reasonably made to determine MPPS :

- the eventual prevention and protection barriers are supposed to be inoperative,
- there is no need to determine the possible causes of the accident for a MPPS must be representative of the worst cases. As a matter of fact, such scenarios are most of the time justified by external aggressions such as natural catastrophes (seisms,…) or domino effects.

For all above reasons, in a deterministic approach, a MPPS depends only on the nature and the properties of the dangerous substance and the characteristics of the equipment involved. Therefore, MPPS is fully determined by the following triplet :

- the Critical Event (CE), which is determined by the physical state of the substance handled,
- the Secondary Critical Events (SCE), that can be completely defined by the type of equipment and the conditions of use of the substance,
- the Dangerous Phenomena (DP), that are linked to the physical state and the hazards of the substance, regardless of the type of equipment involved.

2 METHODOLOGY FOR MPPS IDENTIFICATION

This description of the methodology is illustrated by a practical example considering a pressurised vessel of liquid chlorine at ambient temperature. These elements of illustration are located in the text by the symbol "✂".

2.1 First step : Definition of Critical Events and Secondary Critical Events

The first step of the methodology consists in determining the Critical Event. Clearly, this Critical Event is closely linked to the physical state of the substance involved. If this substance is handled in a fluid phase, the Critical Event is a Loss of Containment. If the substance handled is a solid, we would rather talk about Loss of Physical Integrity.

✂ *For a pressure vessel of chlorine, the Critical Event is a loss of containment.*

Once the critical event is characterised, it is possible to deduce the possible Secondary Events from the type of equipment.

We introduce here a classification of industrial equipments, based upon the work performed by the Major Risk Research Center (Faculté Polytechnique de Mons, Belgium) on domino effects [4, 5]. Nine general categories have thus been identified :

- Mass storage (essentially powder),
- Solid storage in small conditionings,
- Pressure storage,
- Atmospheric storage,
- Cryogenic storage (with cooling system),
- Liquid or gas storage in small conditionings,
- Process equipment (reactor, condenser, distillation column...)
- Loading and unloading equipments,
- Pipeline networks.

These nine categories allow to define a majority of equipments that may be found in high-risk establishments. In a deterministic and simplified approach, it is then possible to define a finite number of Secondary Critical Events (SCE), for each category of equipment, depending on the conditions of use of the hazardous substance.

Practically, a matrix, called SCE matrix, is available for each equipment category and defines the Secondary Critical Events, according to the conditions of use of the hazardous substance.

The methodology warns risk analysts that the conditions of occurrence of the accident and more specially domino effects could possibly change the normal conditions of use of the hazardous substance (for example, radiative heat impact due to pool or jet fires). In such cases, analysts are advised to consider the most appropriate category of equipment allowing to take into account these particular effects, after an adequate analysis. For example, a cryogenic storage might be then considered as a pressure storage in case of failure of the cooling system.

✂ *For a pressure vessel, the SCE matrix is assumed to be as followed :*

Table 2 : SCE Matrix for Pressure vessels

SCE / Conditions of use	Catastrophic rupture			Breach or pipe rupture		
	Gas puff	Puff (including aerosols)	Missiles + overpressure	Gas release	Two-phase release (jet)	Pool formation
⇨ Substance handled under pressure above boiling point (two-phase equilibrium)		X	X	X	X	X
Substance handled below boiling point with inert gas (liquid state)			X			X
Substance handled in a purely gaseous state	X		X	X		

2.2 Second step: Definition of Dangerous Phenomena (DP)

To complete the definition of Maximum Physically Possible Scenarios, the Dangerous Phenomena (D P) must be identified. For example, if the SCE is a gas release, the D P for a substance that is known toxic by inhalation will be a toxic gas dispersion, whereas, if the hazardous substance is considered flammable, the D P will be a vapor cloud explosion or a flash fire.

In a similar way as in step 1, the definition of the Dangerous Phenomena is realised, regardless of the type of equipment, considering only the properties of the substances (hazards and physical state).

To classify the hazardous substances, the methodology relies on the Council Directive 67/548/EC on the classification, labelling and packaging of dangerous substances, and more precisely, on the definition of the risk phrases. The reasons of this choice are highly intelligible :

- The council Directive 67/548/EC is the basis for all rules and regulations linked to the classification of dangerous hazards at the European level (ex. Council Directive 96/82/CE),
- The use of risk phrases limits the confusion between labelling and classification,
- Risk phrases are easily available,
- Risk phrases sometimes introduce elements relative to physical properties of the dangerous substance (flash point, boiling point), that can be helpful for the analysis.

Obviously, all risk phrases defined in the Council Directive 67/548/EC are not of major accident concern. Moreover, some risk phrases point out hazards that need an accurate analysis, and in consequence do not fit the overall methodology presented in this paper.

The methodology argues that risk phrases may not always be sufficient to determine the nature of Dangerous Phenomena. For example, a substance known "Highly Flammable" (R11) may behave like an "Extremely flammable" substance (R12) in particular conditions of pressure and temperature.

After an adequate analysis, the risk assessor is invited to choose the risk phrase that fits the best the possible conditions of use or accidents (domino effects).

✂ *Chlorine is classified as a toxic substance (risk phrase : R23).*
The only Dangerous Phenomenon to consider is then a toxic gas dispersion.

2.3 Third step: Checking the consistence between DP and SCE

Finally, it is necessary to ensure that SCE identified may actually lead to the DP considered. For this purpose, the methodology suggests the use of a matrix, called the SCE/DP matrix.

In most cases, the consistence between SCE and DP is immediate. However, if consistence problems appear, the analyst is invited to:

- check the physical phase of the substance considered in step 1 : "Identification of SCE" and in step 2: "Identification of DP"
- then, check whether the case requires a particular analysis that an overall approach fails to proceed.

✂ *In the practical case of a pressurised chlorine vessel, the consistence of SCE and DP is clear. It is now possible to completely define the MPPS in order to build the following tree.*

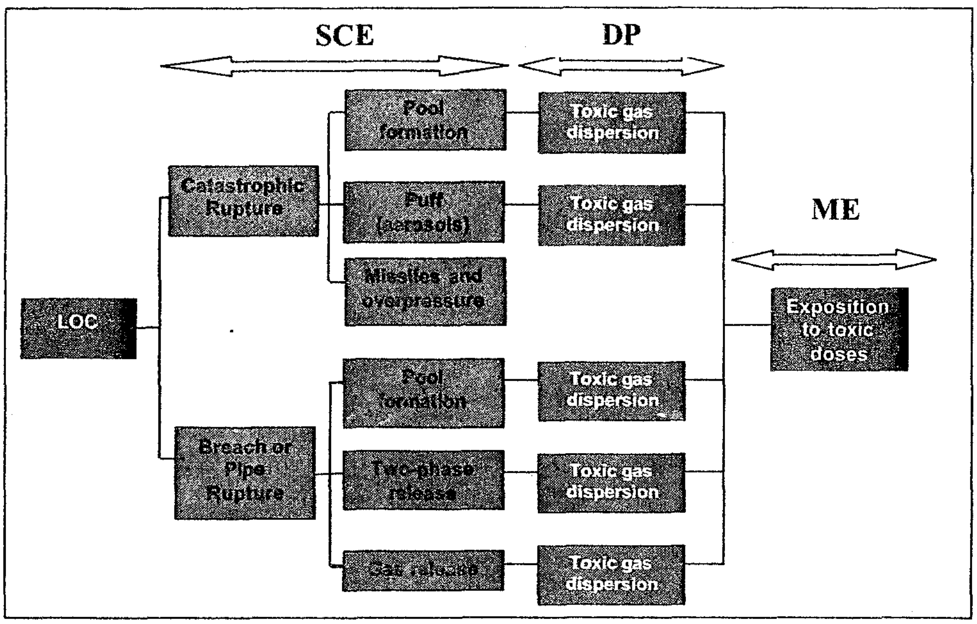

Figure 3 : MPPS for a pressurised vessel of chlorine

3 CONCLUSIONS

The methodology presented in this paper allows risk analysts and competent authorities to identify systematically Maximum Physically Possible Scenarios (MPPS). This method applies to most frequently met cases in high risk industries and follows a deterministic approach.

It is clear that, in some cases, MPPS selection may lead to results that seem obvious to risk experts. However, the benefits of this approach are related to its methodical aspects. MPPS identification should not be considered as a final goal but as an attempt to quantity maximum risk level in industrial establishments. This method is indeed the first stage of an overall approach in order to better assess benefits from safety devices and safety management systems thanks to more detailed analysis.

The second step of the methodology aims to integrate current practices, legal and normative requirements and lessons learnt from experience in the definition of Reference Accident Scenarios (RAS).

The final stage of the methodology tend to taking into account specific technical and organisational measures for prevention and protection of major accidents, in the definition of Residual Risk Assessment Scenarios (RRAS).

In France, there is a need of objective criteria to assess reliability of preventing and protecting measures, either technical or organisational, without using any probabilistic methods. These criteria should help stakeholders in their decision-making process to evaluate the control of major hazard accidents.

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