PROCESS SAFETY ANALYSIS: IDENTIFICATION OF INHERENT PROCESS-HAZARDS

C.A.W.A. Husmann, T. van de Putte*

SUMMARY

The concept of process safety analysis is introduced as the particular safety study which looks into the potential hazards inherent specifically to the (chemical, physical and/or mechanical) process and the chemicals involved. It is defined as the systematic investigation of inherent, acute hazards of a process, under normal operating conditions as well as under reasonably foreseeable abnormal conditions. The objective of the analysis is to determine the safe limits of the process-parameters and to appreciate the effects when the process-parameters are going outside these limits. In the analysis the process is studied as such, apart from the containment and the lay-out of the installation. The main part of the analysis is to be carried out during the research and development work. The results are used for the detailed process-design and lay-out.

INTRODUCTION

Incidents in the process-industry have shown that sometimes hazards, inherent to the process itself, are not fully understood and/or recognized. This situation is becoming ever more alarming since the development of chemistry and chemical technology has resulted in increasingly sophisticated and complex processes. Besides this, the production-installations for the manufacturing of chemicals in large quantities, have grown in size. It has worried the public opinion because of its potential for major hazards and therefore, in view of the above, it is advisable to execute a systematic safety study before an industrial activity is started. In this study the analysis of the hazards inherent to the process and its process-chemicals should be done separately. This part of the study is called process safety analysis.
At this moment a working party of Rivepro (1) consisting of experts from the industry and governmental agencies in Holland, is preparing a report about this subject (2).

*Ministry of Social Affairs and Employment, Directorate General of Labour, The Hague, Holland.

SCOPE OF THE PROCESS SAFETY ANALYSIS

Definition

The process safety analysis is defined as the systematic investigation of inherent, acute hazards of a process, under normal operating conditions as well as under reasonably foreseeable abnormal conditions. In the analysis the process is studied as such, apart from the containment and the lay-out of the installation. In order to identify the inherent hazards, the properties of all chemicals involved as well as the characteristics of the process must be studied.

The objective of the analysis is to determine the safe limits of the process-parameters and to appreciate the effects when the process-parameters are going outside these limits.

According to figure 1, a systematic safety study of an industrial activity consists of different sub-studies with different objectives. Process safety analysis is part of the first sub-study, which is focussing on the identification of unwanted events. In the identification, the process safety analysis is meant to give full understanding of the basic potential hazards of a process, which may (or may not) lead to unwanted events. The possible unwanted events,as such, are being traced by the second part of this sub-study, i.e. the hazard and operability study (3).

Timing

In the course of a project for a new industrial activity a number of stages can be distinguished

- research
- process development
- plant design and detailed engineering
- construction
- commissioning

Since the process safety analysis is looking into the inherent hazards of the process itself, no detailed plant design is required sofar, in contrast with the Hazop-study. Generally, the analysis should be carried out in the research and process development-stage and concluded before detailed engineering is started. Its greatest effects have to be expected in these early stages. By systematically studying and exposing inherent process hazards, the potential hazards are recognized early and so, research and development programs can be adjusted without or with minimum effort and costs in order to look for safer process-routing and/or process-conditions.

The results of the analysis provides the design engineer with basic information about process-(un)safety aspects of the process itself and indicate the necessary reliability of the instrumentation controlling the process as well as the necessary reliability of the containment and other apparatus.

The relation between process safety analysis and the other techniques in the sub-study of identification of unwanted events on one side and between process safety analysis and the different project-stages of a planned industrial activity on the other side is given in figure 2.

CONTENT

Because of the wide variety of processes, including chemical, physical and mechanical processes, the aspects to be considered can differ considerably. Each specific analysis will have its own parameters and items to be studied. This paper will be limited to a survey of the three main parts of the analysis, i.e. the study about the hazards of the process-substances, of the process itself and about the interaction between process and containment. The different aspects are covered with somewhat more detail in the report to be published by the Directorate General of Labour.

Process-substances

In this context process-substances are all substances, directly or indirectly involved in the process, not only reactants and products but also catalysts, intermediate- and byproducts, coolants, heating agents,lubrificants, cleaning agents, id.

Properties. Chemicals participating in the process can be hazardous depending on their properties and the process conditions. Physical, chemical and toxicological properties of all substances have to be considered. Process-unsafety may be calamitous directly, by the release of a chemical in the atmosphere or indirectly, by introducing a hazardous situation, because of the instability and/or reactivity of the chemicals. So, not only the flammability, the explosivity and the toxicological effects are relevant, but also aspects like the disintegration and polymerisation of the chemicals due to storage-time, temperature, contact with certain construction-materials, UV-light, id.
The reactivity of process-chemicals can be characterized by some indices. The Gibbs-formation-energy, H_f can be used as indication of the energy-content of the chemical and gives valuable information about possible process-unsafety aspects. Also the reactivity hazard index, RHI, and even the index-system of the National Fire Protection Agency can be applied and give additional information.

Interactions. Unwanted interactions between substances may cause unsafe situations and/or introduce process hazards. Possible interactions under normal operating conditions as well as under reasonably foreseeable abnormal conditions should be studied. Attention must be paid to include all chemicals, involved in the process, even those which are not directly and/or regularly in contact with each other. The formation of undesirable by-products may entail a process hazard and result in an accident if it happens unforeseen and/or uncontrolled.
The formation and subsequently release of TCDD during the manufacturing of the insecticide 2,4,5-T at Seveso (Italy) is such an illustration.

Process itself

In a process, chemical and physical aspects can generally be distinguished. Parallel with this, the process safety analysis can be subdivided according to these two aspects.

Chemical aspects. Exothermic reactions can release considerable quantities of energy in a short period of time under certain specific circumstances. The phenomenon of run-away-reactions and thermal explosions is, generally well known but still quite often not recognized in time.

In the very early stage of research and development, when all physical and chemical aspects of the process have not yet been studied, thermodynamic calculations may be very useful. The driving force, G_r, can be calculated from thermodynamic data of the participating chemicals. This figure together with the calculated heateffect, H_r, gives a good indication of the possible hazards of the chemical reactions. Generally, exothermic reactions need attention with respect to the possibility of excessive release of energy.

The microkinetics are not always relevant in the identification of process-hazards. However, often the reaction-rate is limited because of physical barriers such as poor homogenization, physical mass-transport-limitations between chemicals. So, also the macrokinetics and the several aspects of transport-phenomena have to be taken in consideration.

Side reactions. Apart from the main reaction possible side-reactions must be checked, with parameters like temperature, pressure, concentration, inside as well as outside the set limits. Accumulation of one of the reactants can cause process-unsafety and has been a contributory cause of many incidents.

Physical aspects. Process-unsafety can also be caused by physical phenomena. Roll-over in a LNG-tank filled with liquids of slightly different composition is an example. In this phenomenon large quantities of gas may be generated in a short time. Turning over of two phases in a phase-separator because of change in temperature or pressure is a less known hazard but has caused many unsafe situations. The hazardous aspects of explosive vaporization must also be considered. The incidental mixing of water with molten metal is a relatively simple case. More complex is the case where superheated liquids are mixed and azeotropic effects are concerned. This type of process-unsafety may have been involved in the Flixborough-incident(4)
Other subjects to be considered are electrostatic charging, dust-formation and explosion, adiabatic compression, bump boiling, cryogenic effects, id.

Interaction between process and containment.

Depending on the function of the containment it can be divided in apparatus as such, apparatus for heat-transfer and apparatus for mechanical energy-transfer. Each of these apparatus may have its influence on the safety of the process.
Corrosion, catalytic activity of corrosion-products, erosion have to be considered. In case of heat-transfer, aspects like hot-spots, fouling and possible interaction of coolants or heating agents are to be checked. In apparatus, with mechanical energy-transfer, aspects of mixing, layering, transport-velocities, dustformation, plugging, need attention.

It is clear that with respect to these aspects the limitation of process safety analysis is somewhat arbitrary and artificial.

CONCLUDING REMARKS

Summarizing the aspects about the scope and the content of process safety analysis it is clear that it is one more tool with respect to the safety approach in the process-industry. Its emphasis lies in the implementation of safety considerations in the very early stage of research and process development.

In order to carry out the analysis , no standard procedure can be given. Many

specialities, such as thermodynamics, kinetics, process-dynamica, transport-phenomena, chemistry, toxicology and metallurgy are involved. Besides, the analysis will cover a long period of time. All these aspects make it necessary to have the concept of process safety analysis incorporated in the company policy with respect to safety.

The intermediate and final results of the analysis can be used for several purposes. The information, especially in the early stages of research and development, can be used in early decisions about tolerability and profitability of the planned activity and to direct further necessary R en D-activities. In the design-stage information about the safe limits of the process-parameters and the subsequently required availability and reliability of instruments and apparatus can be derived from the analysis. In a later stage, during production, modifications of the process and/or the lay-out are often made. The results of the process safety analysis can be used in the study about the possibility of introduction of a hazardous situation.

Quite often, several items of process safety analysis are already included in standard safety procedures. Nonetheless, a separate study of inherent process hazards may contribute to overview systematically the potential process-(un) safety aspects and may result in an inherent safe design.

REFERENCES

1. Directorate General of Labour, "checklist, guide lines for safe design of process plants, first edition 1974.

2. Directorate General of Labour, "Procesveiligheidsanalyse", to be published.

3. Directorate General of Labour, "Hazard and operability study. Why? When? How?" first edition 1979, R no. 3E.

4. R.W. King, Process Engineering, February 69, 1975.

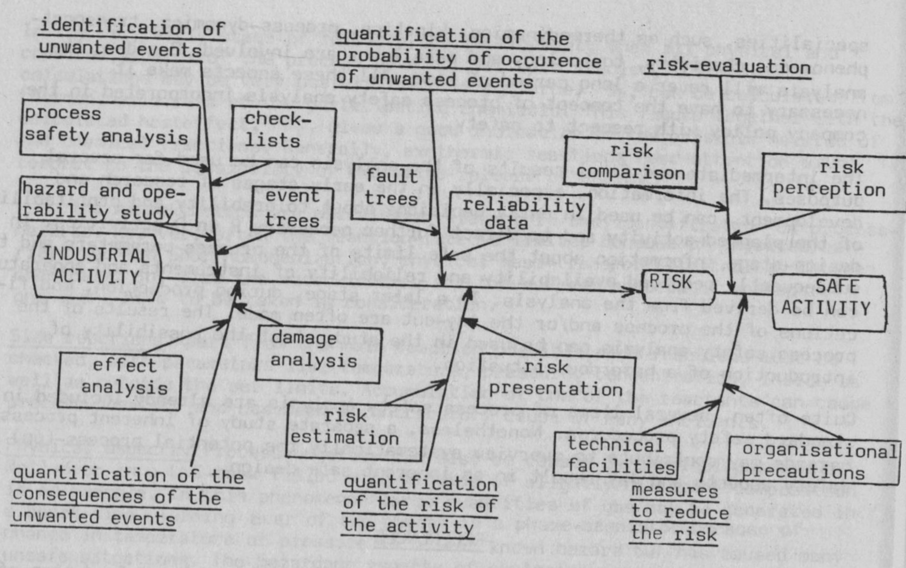

Figure 1 Review of a safety study

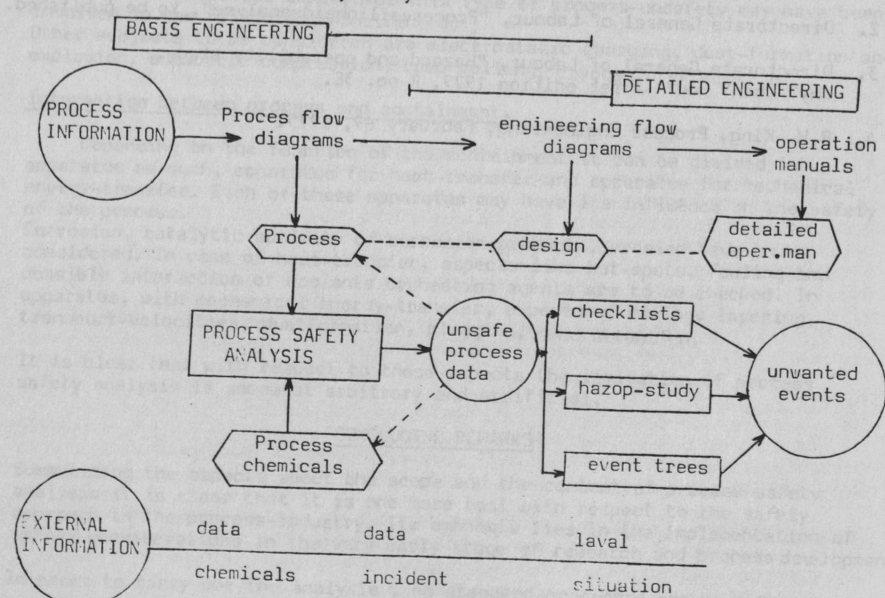

Figure 2 Relation between process safety analysis and the project-stages of a planned industrial activity

BULK STORAGE OF LPG - FACTORS AFFECTING OFFSITE RISK

M Considine, G C Grint, P L Holden*

Refrigerated storage of LPG is usually considered to be less hazardous than pressurised storage. In this paper the offsite risks posed by a 3000Te butane storage facility are examined. This quantity is such that either storage mode could be economically viable. Refrigerated storage in a single tank and pressurised storage in two equal capacity spheres are considered. Individual and societal risks are estimated for an urban site, with population encroaching to within 100m of the site boundary, and for a remote site, with population excluded from within 1km of the storage facility.

INTRODUCTION

It is often thought that the bulk storage of LPG in the refrigerated state poses less of a risk to members of the general public than were it to be stored at ambient temperature under pressure.

In order to examine this concept the offsite risks will be evaluated for a 1 x 3000 te refrigerated butane tank and for 2 x 1500 te pressurised butane spheres on an urban and a remote site. Whilst it is recognised that factors other than offsite risk play a major role in the choice of storage facilities these will not be considered further here although the quantity of 3000 te is such that neither method of storage would necessarily be precluded solely on economic grounds.

DESCRIPTION OF SITES AND FACILITIES

Site Locations and Descriptions

The hypothetical sites for the storage facilities are depicted in Figure 1.

Both sites have been taken as a square of side 500m with the storage facility located at the North West corner. The urban site is surrounded by a population of density 4000 per km^2 and housing encroaches to a distance of 100m from the boundary fence. For the remote site an exclusion distance for dwellings of 1 km centred on the storage tanks has been assumed.

*Safety and Reliability Directorate UKAEA, Culcheth, Warrington WA3 4NE.