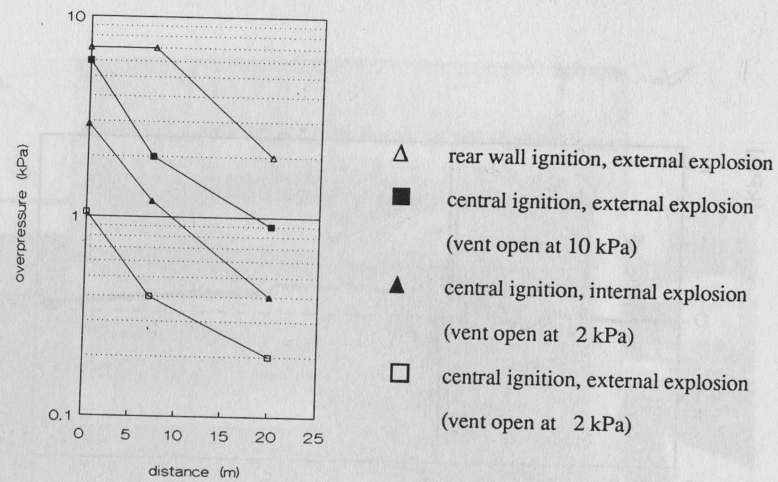

Figure 11 Blast peak overpressures measured as a function of distance for several experiments.

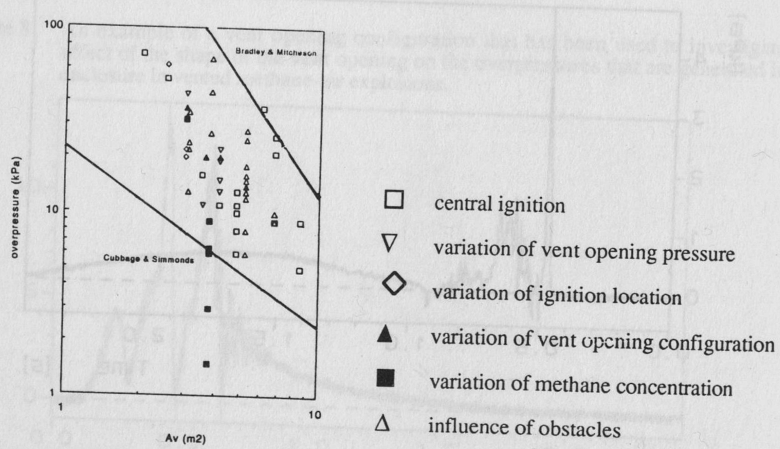

Figure 12 Comparison of vented explosion pressures from all methane-air explosions in the enclosure with the Bradley and Mitcheson criterion for initially covered vents.

CAN WE IDENTIFY POTENTIAL MAJOR HAZARDS?

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This paper discusses a recently developed approach towards the formal identification of major hazards inherent in the design and layout of conceptual and existing offshore installations.

An outline of the methodology and application of the technique is presented, together with a discussion on its possible applicability to new or existing chemical plants.

Keywords: Hazard Identification, Safety Case

1.0 INTRODUCTION

Our inability to comprehensively identify potential major hazards and operability difficulties has been a significant concern with process plant design and operation. Whatever the reasons, there have been many potentially foreseeable incidents which should not have occurred and, in fact, are still occurring.

In the late 1960s, it was recognised by I.C.I. that the identification of hazards and operability difficulties required a detailed, structured and methodical approach. The technique developed to meet these requirements has became known as the Hazard and Operability Study (HAZOP) (Reference 1.)

The HAZOP draws upon the Process and Instrument Diagrams (P & I D) as the basis of the study and is used more as an audit tool when the design is fairly well advanced but when moderate changes to the system can be incorporated without unduly affecting cost or schedule. HAZOP has also been used on existing processes with the objective of identifying latent problems (and often revealing the operators unacceptable methods of overcoming plant operating difficulties). Experience does show that the HAZOP tends to identify fairly basic design and operational flaws and faults with a return period of about 10 to 100 years. However, while it is an invaluable design audit tool, HAZOP was not developed for analysing a new concept in terms of layout or operational interaction.

The identification of major hazards, which will tend to have a return period of more than 100 years can be haphazard and is very much dependent on the experience and background of the design team.

The CIMAH Regulations (Reference 2) states in schedule 1:

"A manufacturer who has control of an industrial activity to which this Regulation applies should at any time provide evidence including documents to show that he has:

a) *Identified the major accident hazards and;*

b) *Taken definite steps to -*

   i) *Prevent such major accidents and to limit their consequences to persons and this environment.*

   ii) *Provide persons working on the site with the information, training and equipment necessary to ensure their safety.*

In order to satisfy this requirement, some method of Hazard Identification has to be used. It is recognised that a number of companies use a design audit process but this is frequently based on a random checking process rather than a detailed, unit related process. Hazard Identification is a technique which has been developed in the Offshore Industry for both new and existing installations with the objective of making the identification of hazards both more rigorous and thorough. This is achieved through the application of a structured and analytical approach in a technique known as HAZID.

The significant differences between HAZID and other safety audits, corporate or otherwise, is that HAZID does not permit the opinion engineering approach that "It can not happen" but assumes that it will and that the conditions required to make it happen must be investigated. Other audits may consider a few areas of study but HAZID may use of the order of 50 areas and specifically examines the violation of safety objectives. HAZID has been proven to be very flexible and can cover any topic in any depth of detail required, as will be discussed further below.

2.0 DIFFERENCES BETWEEN ONSHORE AND OFFSHORE PRODUCTION PROCESS SYSTEMS

There has long been an illfounded belief, held by many, that the onshore and offshore production processes are so significantly different that the experiences of one do not readily transfer to the other. Hydrocarbons burn as fires or explosions in air whether onshore or offshore. While an offshore production plant will have a different design and layout to an ethylene oxide plant, the principles of safe design and operation are the same. However, there are obvious physical constraints which are apparent off shore. On shore, the production process usually involves a chemical reaction where the final product, or its precursor, is produced. In offshore production plants, the process is essentially one of component separation rather than reaction. There is effectively no chemistry involved. This is the first major difference.

On shore land is comparatively cheap, of the order of £5 per m^2. Offshore, the structure which supports the process plant may cost £100,000,000 resulting in a floor space cost of £2000 per m^2. Furthermore, the geometry of both developments are significantly different. The onshore development extends in a horizontal plane whereas the offshore development extends in a vertical plane. The production plant may be incorporated on up to 6 deck levels. This is the second major difference.

Onshore the production unit is physically distant from any office or residential area, whereas offshore installations might incorporate an hotel, a heliport, a power station and a small oil refinery within its confines.

There may also be a need for a drilling and well workover facility and craneage to handle materials delivered by supply boats. This is the third major difference.

The fourth major difference is the requirement for a supporting structure for the offshore installation. This can be subject to fatigue, corrosion, impact, earthquake and, of course, fire.

The fifth major difference is to be found in the means of escape from a hazard. Onshore, the perimeter fence is accessible and readily found through 360°. Offshore, the installation is bounded by what may often be a hostile sea. The designated safe refuge, lifeboat or other means of escape will also be located in relatively close proximity to the hazard.

3.0 DEVELOPMENT OF HAZID

It is difficult to establish the origins of HAZID. It has been used in one form or other for over 5 years. One of its first uses was on the analyses of the failure modes of oil well casings and completions. HAZID has now been developed to evaluate, from the safety standpoint, the layout and design of new and existing offshore installations, and the operation and interaction of production, drilling and utilities facilities. Whereas HAZOP is based on the examination of P and I Ds, HAZID examines a layout or concept. Looked at another way, the HAZOP examines what is happening "inside the process", the HAZID examines what is happening outside the process and the interactions between different process systems.

HAZID has now been used on a number of projects, including the assessment of a new oil and gas producing installation under design, several existing producing installations and a number of diving support vessels.

4.0 COMPARISONS BETWEEN HAZOP AND HAZID

In a HAZOP study the team is ideally composed of four discipline representatives, a leader and a secretary. The same is true with HAZID. With HAZOP the same participants are often used throughout the study, but with HAZID the team composition is more flexible. Ideally two members other than the leader and secretary should be fixed. The other two may change from one phase of the study to another depending on the subject or area under consideration. This provides for a degree of consistency throughout the study, while at the same time enabling input from those with the most knowledge and experience of a particular discipline, operation or project phase. Ideally, one of the "permanent" members would be an "Operations Man" who is liable to be involved to some degree through many of the construction, commissioning and operational phases.

Another significant difference is that HAZOP is often <u>cause</u> driven while HAZID is <u>effect</u> driven. In a HAZOP, the structure and execution of the study is quite rigid, the cause of an untoward effect in the process is itemised and its effect recorded.

In HAZID, the effect or possible consequences of an untoward incident is itemised and the possible causes, if any, are rooted out and recorded. In this way HAZOP is a vertical thought process with only one or two simultaneous failures, but HAZID is a lateral thought process which can result from a number of simultaneous failures.

Experience has shown that the lateral thought process can identify the very low probability (10,000 year return) events which would not be recognised by the HAZOP process, and that it can be used for concept evaluation as well as assessing an existing facility.

As an illustration of the differences it is worth considering an example of a HAZOP and HAZID analysis.

The analysis of a car's brake hydraulics lines in a HAZOP would note:

Objective: To convey high pressure fluid from the master cylinder to the brakes:

The layout of the records sheet would then be as follows:

Guideword	Deviation	Cause	Effect	Consequence	Action
Pressure	None	Line Leaking	No brakes	Car crash	Consider fitting a redundant system (diagonal breaking)

The logical end point of this analysis is that the braking system should be <u>totally</u> redundant.

In the case of HAZID, the analysis would be more like:

Objective: To stop the car in a controlled manner

The layout of the record sheet would then be as follows:

Guideword	Event Nature	Cause	Consequence /Escalation	Control or Mitigating Factors	Hazard Index		Action Required/ Comments
					Cons	Freq	
Failure (Brakes)	Leaking Master Cylinder	Seal failure	Loss of brakes - car crash and injury	Likely to be progressive if corrosion	H	L	Review the reliability of the seal specified
Failure (Brakes)	Leaking Hydraulic Line	Corrosion or impact	Loss of brakes - car crash and injury	Could use hand brake	H	M-H	Consider fitting a segregated braking system

The logical end point of this analysis is the desireability of a diagonal braking system as fitted on most, if not all, modern cars.

The differences between HAZOP and HAZID are quite clear in this example, HAZOP has examined the "process" or the internal problem but HAZID has examined the external route to the hazard. Furthermore, HAZOP does not pre-suppose that a hazard can occur whereas HAZID assumes it will occur and asks what are the events which may cause it, however unlikely.

The fact that there may be several contributory events, each of which must be identified, is central to the HAZID principle. This incidentally is why the hazards or end events often detected have a very low associated probability.

5.0 PREPARATION FOR AND EXECUTION OF A HAZID STUDY

5.1 Preparation for the HAZID Study

Prior to commencing a HAZID study, and committing a number of (busy) personnel to it, a degree of preparation is required in order that when the sessions do take place, they are conducted in an efficient and methodical manner, in terms of time, resources and subjects covered. Some of the main areas of preparation, such as development of objectives and guidewords, selection of team members and availability of equipment layout drawings, study documents and other relevant documentation, are considered below.

5.2 Development of Objectives and Guidewords

First it is necessary to define those clear safety objectives which have to be achieved and those effects which may compromise the attainment of the objectives. This is usually achieved by a series of one or two half day meetings with the client who should have a good all round knowledge and experience of the particular process. During these meetings, the leader will use his experience to clarify the safety objectives for the process.

There are obviously a number of objectives which are universally required, such as the availability of evacuation and escape provisions in the event of an incident. However, some may be less obvious, or may only be specific to a particular area or system, such as maintaining a breathable atmosphere in a safe haven. These need to be identified up-front so that they can be considered fully in the HAZID study sessions.

The guidewords can, in general, be compiled from standard "checklist" hazards, such as "loss of containment", "fire", "explosion", etc. However, specific guidewords which are thought applicable to a particular system, process or area can be added. As an example, when considering drilling facilities and operations "shallow gas" might be added as a guideword. A suitable set of guidewords which might be developed for a reactor in a chemical plant might be as follows:

Reactor

Exotherms
Endotherms
Catalyst Activity / Regeneration
Flammability Envelope
Mixing
Stability / Control / Kill

Byproducts

Toxicity
Foulant
Carry over
Disposal

Operation / Start Up/ Shut Down

Reactivity
Turn down
Replacement / Recharge
Cleaning / Inspection

Base Design

Intensification
Attenuation
Modification

The list of guidewords could extend to two pages, depending on the process itself. At this point the guidewords may appear somewhat random but the significance will be more obvious as the paper is developed.

5.3 Selection of Team Members

The team members selected must be fully knowledgable of the technical and operational aspects of the particular process or system under consideration. The balance may have to be adjusted when specialised members are co-opted. As with a HAZOP study, the best result is obviously achieved when the balance is correct. The core of the team should be four - the leader, the secretary, one of the client's safety group and a reasonably senior Operations Man who has a broad overview of the process or system.

As the study develops it will be necessary to co-opt several additional members such as Process Engineer, Machinery Engineer, Mechanical Engineer or Construction Engineer. Ideally, the team should not change too often as this could disrupt the continuity of the study and be counter-productive.

For a HAZID study of an offshore installation, the list of co-opted members might include a Drilling Engineer, Pipeline Engineer, Structural Engineer, or Diving Representative.

5.4 Availability of Drawings, Process Information and Other Useful Documentation

Just as a HAZOP study uses a P and I D, the HAZID study uses Layout Drawings (both plan and elevations) so that the interaction between equipment and systems can be assessed.

The drawings should be in sufficient detail that they can show all major pieces of equipment, escape routes and the location of safety features such as lifeboats or fire fighting stations.

Supporting documentation might also include a Process Flow Diagram, Main Piping Track details and the location of Emergency Shut Down Valves and Relief Valves if known.

The quality and detail of the drawings is not paramount to the HAZID study. Obviously gross errors are not tolerable but block layout drawings are just as useful as fully developed drawings.

Issues raised in the HAZID which cannot be answered, due to a lack of available detail or documentation, can always be recorded and addressed at a later date. It is essential that the drawings can be marked up during the study by participants to visually describe the origins or development of a hazard which may be under consideration.

6.0 EXECUTION OF THE HAZID STUDY

As with the HAZOP study, the HAZID is mentally tiring and so should be carried out in 3 hour sessions, ideally two per day in blocks of 3 days. The duration will depend upon the overall complexity of the process but typically the study would be in the range of 6 to 20 days in total.

The team is convened and the overall objectives of the study are outlined by the leader. The team members then explain their discipline and expertise so that the team as a whole is aware of the experience and knowledge at hand.

The senior client representative then gives an overview of the whole process from start to finish and a broad outline of the objectives of each system and the likely interaction. This would be a fairly high level overview, but should outline any significant interactions by reference to the layout diagrams.

The study is then focused closer on each major item of process within the area concerned is described in terms of objective, capacity and potential for hazards.

This process may take about one hour as the picture is slowly developed for the team, and the members begin to understand the potential for hazard and for interaction.

The leader then uses the guide words to develop concepts whereby the safety objectives may be violated. This is very much a lateral thought process which must be flexible and will only be productive if responded to by the team members. By means of the guide words, the leader encourages the team to consider potential hazards and how these may occur.

In the HAZOP study the leader will direct the team through a strict schedule (vertical thought) but in HAZID the objective is to direct the thought process along a more creative and enquiring route. In this way the leader takes on what is very much an active role. He must strike the balance between keeping the discussion to the subject in hand whilst not stifling free ranging and creative thought. Typically, the learning process can take an hour and it is not unusual for the first session to be relatively unproductive.

However, the team will then be in a position where they can better understand the potential for hazards and interactions which may not be immediately apparent. This process can be viewed as focusing the mind on the potential problems.

The leader must stimulate and encourage creative thought among the team by emphasising the fact that low frequency/high consequence hazards are rarely obvious and are often the interplay of a number of potential causes. Therefore, the questioning must not stop at the obvious, but extend to "then what happens?".

The thinking process is more intense than that of a HAZOP and the leader has to be alert to the setting in of mental fatigue. The task of the secretary is then to convert the ideas and concepts discussed into a more objective statement which can be reviewed and addressed by others outside the HAZID study.

The main record of the proceedings would be contained in HAZID record sheets, similar in format to the table shown in Section 4.

The principle steps of the HAZID technique are represented in the Flowchart shown in Figure 1. These steps are followed through in a "worked example" given in Figure 2.

It should be noted that no major hazard which has been identified as being possible, can be eliminated without some degree of quantification. This would normally be done outwith the study. In general, there is approximately half an hour of quantification required for every hour of study. The assessment of consequence and frequency are then recorded for comparison with criteria tables.
The actual analysis is slightly less arduous than a Risk Analysis as the sequence of events have already been defined during the study itself. The consequence and frequency analysis would normally be the responsibility of the leader and secretary.

7.0 USES OF HAZID IN PRACTICE

The HAZID process is ideally developed for the analyses of a new concept design where there is scope for changes to the process, the equipment or the layout. In this role, HAZID can integrate and optimise safety and loss control with process and layout design, and will go a long way towards eliminating the "add ons" inherent in the HAZOP process (Reference 3).

Therefore, the study can be used to eliminate hazards at the concept or design phase and add structure and objectivity to any future safety studies. It then becomes a very proactive tool.

The HAZID process is also ideally suited to the structuring of the Safety Case for both on and offshore developments. It identifies the hazards in a structured format and allows the client to carry out his own safety assessment against a clear objective.

8.0 CONCLUSION

In 6 major HAZID studies, it has been possible to identify about 100 major events per study with most having return frequencies of 1,000 to 100,000 years.

Whilst not all of these have been acted upon, there have been many which have been recognised as of significantly high concern to require further detailed assessment and or design modification.

The HAZID study can be a powerful tool in the development of the design and layout of a new facility, and the production of Safety Cases. It is therefore an ideal tool for analysing concepts and auditing the design as it develops.

References

1 "A Guide to Hazard and Operability Studies". Chemical Institute Association.

2 "Control of Major Accident Hazards Regulations, 1984". SI1984 No 1902. HMSO.

3 "Cheaper, Safer Plants or Wealth and Safety at Work". TA Kletz, 1985. Institute of Chemical Engineers.

Figure 1: Flowchart Representation of the HAZID Technique

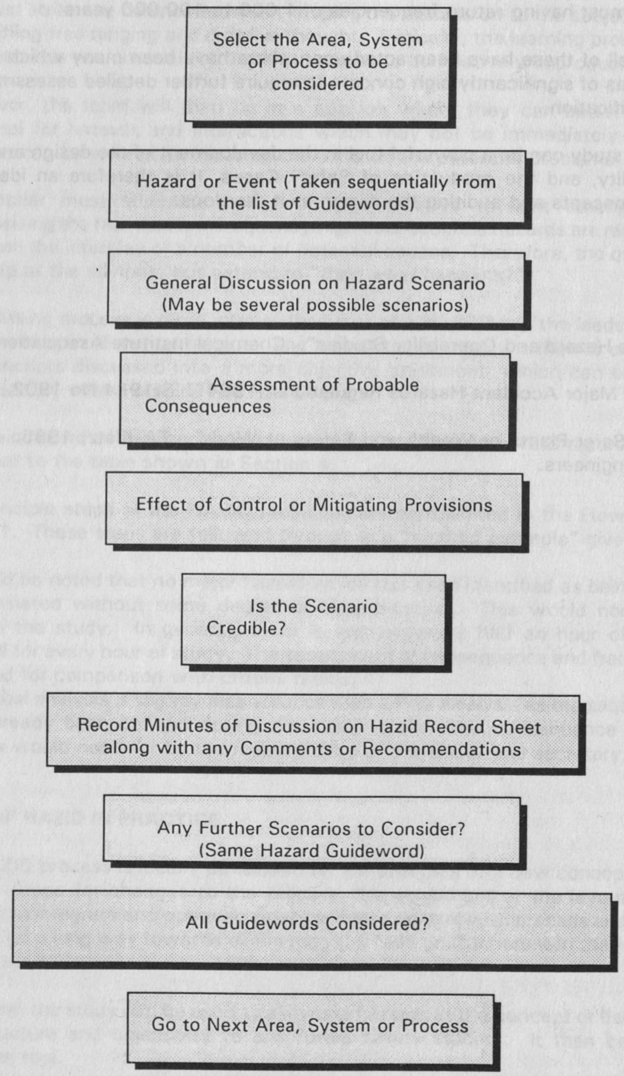

Figure 2: Worked Example of the HAZID Technique