A STRUCTURED BRAINSTORMING APPROACH TO THE ASSESSMENT OF EMERGENCY RESPONSE

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This paper looks at the possibility of applying a HAZOP type approach to the assessment of emergency response. It presents two case studies where such an approach was used to identify the potential failures and hazards that could affect the success of the emergency response. In the first case study, it was used to identify any weaknesses that may exist in the emergency response procedures of a nuclear facility. The second case study, commissioned by the Health and Safety Executive (HSE), investigated its applicability to Evacuation, Escape and Rescue (EER) from offshore installations. A hazard identification method was developed and was published by the HSE in the Offshore Technology Report series. The results of these studies show that the HAZOP type approach can greatly benefit the assessment of emergency response by providing a more systematic and comprehensive hazard identification.

Keywords: Emergency response, Hazard identification, HAZOP

INTRODUCTION

An emergency has a number of important features. The first of these is the immediate risks posed by the initiating hazard (e.g. a fire). Normally, they are significantly higher than those in normal operation. The second feature is its rarity. Consequently, those involved often find themselves in a situation with which they are unfamiliar. This could in turn lead to some degree of confusion and uncertainty. Thirdly, there is often a need for the people involved to quickly abandon their normal activities and to take alternative actions, such as to evacuate. Past experience suggests that many are reluctant to do so. The provision of training would help to reduce, but would not eliminate, the second and third problems. Furthermore, training is not practicable in situations where members of the public are involved. Forthly and finally, the people involved, especially those who have to deal with the emergency, would have to process a large amount of information in a short period of time. In the initial stages of the emergency at least, such information is likely to be incomplete. It could also be confusing and even conflicting. Because of the above, things are more likely to go wrong in an emergency than during normal operation. This calls for a thorough and systematic assessment to identify what might go wrong in an emergency.

This paper describes two case studies and looks at how a structured brainstorming approach can be applied to assess emergency response. The methodology in both studies share the same principles with a hazard identification technique called the hazard and operability (HAZOP) study. For the purposes of this paper, it is referred to as the HAZOP type approach.

THE HAZOP APPROACH

HAZOP is designed to encourage imaginative thinking and to ensure that the identification of hazards is as comprehensive as possible. This is done through structured brainstorming sessions by multi-disciplinary teams. The basic concept of a HAZOP study is to take a full description of the process, to question every part of it to discover what hazards or problems might arise and to identify their causes and consequences. Keywords are applied to prompt thinking. Thus, a HAZOP study concerns the following:

- **Intention** - i.e. What is the design intention? What is each part of the process intended to do?
- **Deviation** - i.e. What might go wrong? How might things deviate from the intention?
- **Causes** - i.e. What causes the problem to arise?
- **Consequences** - i.e. Should the problem arise, what effect may it have on the intended operation?

Note that the "intention" may be concerned with physical processes or human activities. HAZOP studies are already applied successfully in a number of industries for the identification of hazards or failures in normal operations. There is scope for expanding the application to the analysis of the emergency response process. In order to achieve this, however, one has to be able (i) to find a way to account for each part of the emergency response process in a structured manner and (ii) to find the suitable keywords to describe all potential deviations. The following case studies demonstrate how these can be done in different industrial contexts.

CASE 1: EMERGENCY RESPONSE IN A NUCLEAR FACILITY

A HAZOP type approach was applied to analyse the emergency response arrangements of a nuclear facility (Au (1)). The aims were to identify any weakness that might exist and to recommend any remedial actions which the facility should consider taking. It covered all stages of the emergency response, from the sounding of the evacuation alarm up to the point when the facility is ready for the resumption of normal operations.

Process Description and Keywords

In order to provide a systematic description, the emergency response process was divided into the following five generic stages. This was done in terms of the different functions which staff in the facility had to perform:

- Set up emergency command/control posts
- Restrict access within and to and from the facility
- Muster and roll call
- Deal with the incident
- Resume normal operations

The success of the emergency response in this case, as in many others, relies heavily on the actions of the people concerned. A task analysis was therefore conducted to describe the tasks or activities staff members in the facility are supposed to carry out at each of the above stages (i.e. the intention). To ensure that the description was sufficiently detailed for the identification of potential deviations, they were broken down into lower level sub-tasks. In this exercise, the Hierarchical Task Analysis (HTA) technique was used so that the tasks and sub-tasks were described in terms of their operating goals. Apart from enabling the production of a full description of the emergency response process, the task analysis also revealed that communication between emergency control staff was vital to the success of the response. A set of information flow diagrams was therefore drawn up to provide a mean for visualizing the communication "network" and to enable the assessors to address in detail the issue of communication during the brainstorming sessions.

Table 1 shows the keywords used in this study to describe all potential deviations from the expected response. They are based on the keywords designed for the identification of human errors in human operations (Whalley (2)). When applied in this study, these keywords denote the types of failure or the failure modes that could occur when performing an emergency response task. A key benefit of this approach is that they are similar to those used within traditional engineering HAZOP studies and can therefore be easily adopted by safety engineers.

Table 1: Human Failure Keywords Used In The "HAZOP" Type Session

KEYWORDS	DESCRIPTION
Not Done	The task was not attempted.
Part Of	Sub-tasks are missed out.
Less Than	Quantity - The results of the task are less than required.
More Than	Quantity - The results of the task are more than required.
As Well As	An extra task is completed. Can be a completely irrelevant task or the task carried out on an additional item.
Other Than	The wrong task is undertaken.
Sooner Than	The task is completed too early.
Later Than	The task is completed too late.

Analysis of the Emergency Response

The analysis of the emergency response arrangement of the facility was carried out in four half-day HAZOP type brainstorming sessions. Members of the facility's management participated along with the assessors in the brainstorming so that the analysis could draw on a range of experience and could take different views into consideration.

The aim of the session was to identify any deviations from the intended emergency response which could adversely affect its success. This was achieved by considering each activity or task identified in the task analysis. Potential deviations associated with the task were identified by going through the keywords in Table 1 and deciding what failures might occur. The causes and consequences of each failure and the remedial measures were also identified. It is worth noting that the failure cause could be in the form of any combination of human errors, system failures, adverse conditions (e.g. fire, smoke and release of toxic gas) and undesirable circumstances (e.g. staff shortages). Findings of the assessment were recorded in a tabular form.

The outcome of this study suggests that the HAZOP type approach can be successfully applied in the context of emergency response. This particular study served two useful purposes. Firstly, it helped to confirm that the facility's emergency procedures and its emergency control organisation were, in general, adequate. Secondly, it enabled the identification of some specific weaknesses which, in the view of the facility management, might not otherwise be identified. Based on the findings of this study, twenty four recommendations were made. This resulted in changes to certain aspects of the emergency response arrangements. They include the amendment of instructions to various emergency control staff and the installation of extra communication equipments at some parts of the facility.

CASE 2: EVACUATION, ESCAPE AND RESCUE FROM OFFSHORE INSTALLATIONS

The terms Evacuation, Escape and Rescue (EER) are defined in paragraph 20.2 of the Cullen Report on the Piper Alpha Disaster Inquiry (3) as follows:

> *Evacuation refers to the planned method of leaving the installation without directly entering the sea. Successful evacuation results in those on board the installation being transferred to an onshore location or to a safe offshore location or vessel.*
>
> *Escape refers to the process of leaving an offshore installation in the event of part or all of the evacuation system failing, whereby personnel on board* (POB) *make their way into the sea by various means or by jumping.*
>
> *Rescue refers to the process by which escapees and man overboard (MOB) casualties are retrieved to a safe place where medical assistance is available.*

The success of EER from offshore installations depends upon a number of factors:

- Control and mitigation of the initiating hazard
- Appropriate installation design and its integrity in an emergency (e.g. escape routes, muster area)
- The performance and integrity of equipment in an emergency (e.g. alarm systems, fire fighting equipment, survival craft, rescue craft)
- The actions of the personnel concerned (e.g. emergency response team, persons on board)

Beyond the immediate risks posed by the particular initiating hazard, additional risks to personnel can arise from the process of EER itself. An effective assessment of the EER provisions needs to address each of these components and their interactions for each foreseeable emergency scenario. It is therefore important to apply a suitable hazard identification technique to the analysis of the EER that enables full consideration of the range of potential failures and hazards that could arise. This case study summarises a research project commissioned by the Health and Safety Executive (HSE) to investigate the possibility of applying a HAZOP type approach to the assessment of EER (Gould and Au (4) and Gould (5)).

Development of the HAZOP Type Technique for EER

It is a fundamental requirement that the technique should be capable of identifying the full range of significant hazards which might exist during the EER process. To ensure this requirement is fulfilled, a "back-to-front" approach was adopted whereby a comprehensive hazard list was derived and used to develop the HAZOP type technique.

Define the activities involved in the EER process In order to identify the hazards associated with a process, it is necessary to define the process itself. The first step in deriving the EER hazard list was therefore to develop a general reference model of the EER process. This was done based on the description of the EER process by Haddock (6), illustrated by Figure 1, and the human factors analysis of EER by Kennedy (7). The objective of the model was to define all the activities that may take place during the EER process. As in the first case study, the HTA technique was used to achieve this objective. The EER model is essentially a series of HTA trees. Figure 2 shows the top level tree which covers the seven main stages of EER. The activities that may occur during each of the stages were identified and, where necessary, were broken down further.

Identify all potential hazards Using the EER model as a basis, criterion hazard lists were derived for each EER stage using the following definition of a "hazard":

> *Any item, action or procedure which may prevent or delay the EER process, or cause additional danger to personnel during EER.*

The hazards were listed under the following three categories: physical; command and control; and behavioural. "Physical" hazards are those due to equipment (design, malfunction or failure) and physical conditions (e.g. environment, fire, smoke, etc.). These hazards were identified by detailed knowledge of offshore installations, the layout of typical installations and of the predicted causes and consequences of major emergency scenarios. Installation specific hazards were identified by examination of typical plot plans of a number of different types of installation. "Command and control" hazards are those due to poor procedures, inadequate safety management systems and breakdown of communications. They were identified using knowledge of the safety management system, examination of operation manuals and from human error analyses. "Behavioural" hazards are those due to human errors and undesirable behaviour. They were identified through human error analyses.

Develop HAZOP type keywords Based on the criterion hazard lists, the development of the HAZOP type technique was performed by a team of specialists within a workshop. The team included offshore risk assessment and human factors specialists in order to cover all aspects of EER from offshore installation. They also possessed considerable HAZOP experience in a range of applications. The criterion hazard lists were, first of all, reviewed by the team and were revised accordingly. The team then developed two sets of keywords to match the hazards identified in the criterion lists. The first set consists of forty "property words" which define the activities and the property of the EER process. As shown in Table 2, the number of property words for each EER stage ranges from three to eight. The second set consists of eight guidewords which describes how the "property" might deviate from the intended response. They are shown in Table 3. The property words and the guidewords were tested within the workshop by performance a trial HAZOP study on an example installation for the first three EER stages (i.e. "Alarm", "Access" and "Muster").

Table 2: EER HAZOP Guidewords

Failed
Impaired/Damaged
Fails During
Not Done
Inadequate/Insufficient
Incorrect/Inappropriate
Too Late/Soon
Congested/Overloaded

Table 3 : EER HAZOP Property Words

EER STAGE		PROPERTY WORD
1.	ALARM	Alarm_System (System, Information) Response Communication (System, Information)
2.	ACCESS	Escape_Route Decision Movement
3.	MUSTER	Muster_Point Communication (System, Information) Registration Survival_Equipment (Equipment, Use of)
4.	EGRESS	Escape_Route Decision Movement
5.	EVACUATION - BY BRIDGE LINK	Escape_Route Decision Movement
6.	EVACUATION - BY HELICOPTER	Availability Approach Landing Take_Off Helideck Boarding Communication (System, Information) Equipment (Equipment, Use of)
7.	EVACUATION/ESCAPE - BY BOAT	Boat (Availability, Passive, Active) Launch System (System, Procedure) Crew Communication (System, Information) Navigation Drop_Zone Survival_Equipment (Equipment, Use of)

Table 3 : EER HAZOP Property Words (cont.)

EER STAGE		PROPERTY WORD
8.	ESCAPE - DIRECTLY INTO SEA	Escape Devices (Devices, Use of) Decision Movement Survival_Equipment (Equipment, Use of) Drop_Zone
9.	RESCUE - BY VESSEL OR CRAFT	Availability Search Recover Sustain_Life

The outcomes The workshop sessions demonstrated that it is feasible to apply the HAZOP type technique to the analysis of EER. It did pull out human factors elements quite successfully as well as the "physical" hazards. As with any HAZOP, a successful outcome is dependent on the lead given by the person chairing the session, the expertise and range of knowledge of the design and procedures of the team members and the quality of the information available.

It is worth noting, however, that this technique has only been considered in a fairly generic manner to date and it is recognised that further development work is required. In particular, it needs to be tested on a real installation design as part of a live project. Interest in this direction is currently being pursued.

A Brief Guide to an EER HAZOP Type Study

The timing of the EER HAZOP type study, information requirements and study team composition are very similar to those of a traditional engineering HAZOP study. For a new installation, a study can be carried out during detailed design. It should commence when the relevant drawings and documents are sufficiently complete. For existing installations, a study should be carried out if the EER provisions have not been assessed systematically or if there are developments which suggest that the existing EER assessment may no longer be valid (e.g. a significant change to the installation or the operational procedures, the detection of a significant problem or the occurrence of a major incident or potentially serious near miss which could have some implications on the existing EER provisions). The typical information that would be required for the study is as follows:

- Installation general details: size, POB, operating pressure, facilities installed, etc.
- Installation layout drawings showing for example escape routes, muster points and location of EER equipment
- A summary of platform safety systems
- The EER provisions and the basis for selection (e.g. muster/evacuation times)
- The emergency response procedures
- A list of major hazard scenarios
- A summary of hazardous event consequences

The study team should, between them, have a detailed knowledge of the installation and how the EER provisions are intended to work. Therefore, apart from the Chairperson and the Secretary who play a structuring and supporting role, the team might also include the services of the following:

- Project engineer
- Installation design engineer
- Process engineer
- Operation personnel
- Safety personnel (including risk assessment specialist)
- Human factors specialists
- Other appropriate specialists (e.g. survival)

The EER HAZOP type study procedure Figure 3 gives an overview of how an EER HAZOP type study would normally proceed. The first step of the study is to ensure that all members of the study team are aware of the objectives and scope of the study. The study can then be carried out on each of the seven EER stages in turn (see Figure 1). Appropriate property words and guidewords (see Tables 2 and 3 respectively) can be applied to identify any deviations from the design and operating intentions in each EER stage. For each deviation identified, the study team will have to consider the following:

- Is the deviation possible?
- If so, what are the causes?
- What are the potential consequences of this deviation?
- Could it lead to additional danger to POB or prevent or delay the EER process?

If the deviation is identified as a safety problem, the HAZOP team should consider what mitigating measures are in place and whether any changes to the EER provisions are required. Necessary actions are assigned to appropriate individuals or departments. The findings of the study should be recorded. Figure 4 shows an example record sheet.

CONCLUSIONS

The two case studies presented in this paper have demonstrated that the HAZOP type approach can be applied to analyse emergency response. It retains much of the benefit offered by the traditional HAZOP: i.e., it provides a systematic and comprehensive hazard identification, provides an open discussion between specialists of different disciplines and encourages imaginative thinking. Both the facility management in the first case study and the independent specialists involved in the second case study believed this to be an useful approach which enables the identification of hazards which might otherwise be missed. Furthermore, during the workshop in the second case study, a brief comparison with the checklist approach was made. It was generally felt that the HAZOP type approach has a number of advantages over the checklist approach. A summary of the comparison can be found in Offshore Technology Report OTH 95 466 (4).

The authors have so far applied the HAZOP type approach to the analysis of emergency response in two specific industrial contexts. However, providing the process involved can be clearly defined and suitable keywords can be found to describe all potential deviations, the authors believe that such an approach could also be applied to analyse emergency response in other contexts.

REFERENCES

1. Au, S.Y.Z., 1995, RMC confidential report for client on the analysis of the organisation of emergency response, RMC document ref: R95-88(N).

2. Whalley, S.P., 1987, Factors Affecting Human Reliability in the Chemical Process Industry, Ph.D. thesis, Aston University, November 1987.

3. Cullen, The Hon Lord, 1990, The Public Inquiry into the Piper Alpha Disaster, Department of Energy, London: HMSO.

4. Gould, G.W. and Au, S.Y.Z., 1995, A Methodology for Hazard Identification on EER Assessment, Offshore Technology Report OTH 95 466, London: HMSO.

5. Gould, G.W., 1996, The Application of a HAZOP Type Technique to EER Analysis, Paper presented at: Improving Risk Management Offshore Using QRA to Support the Management Process, 30-31 January 1996, Aberdeen, UK.

6. Haddock, S.R., 1993, Note on Planning and Coordination of the EER Process, HSE OSD Technology Branch, Paper to EERTAG P/25 July 1993.

7. Kennedy, B., 1993, A Human Factors Analysis of Evacuation, Escape and Rescue from Offshore Installations, Offshore Technology Report OTH 93 994, London: HMSO.

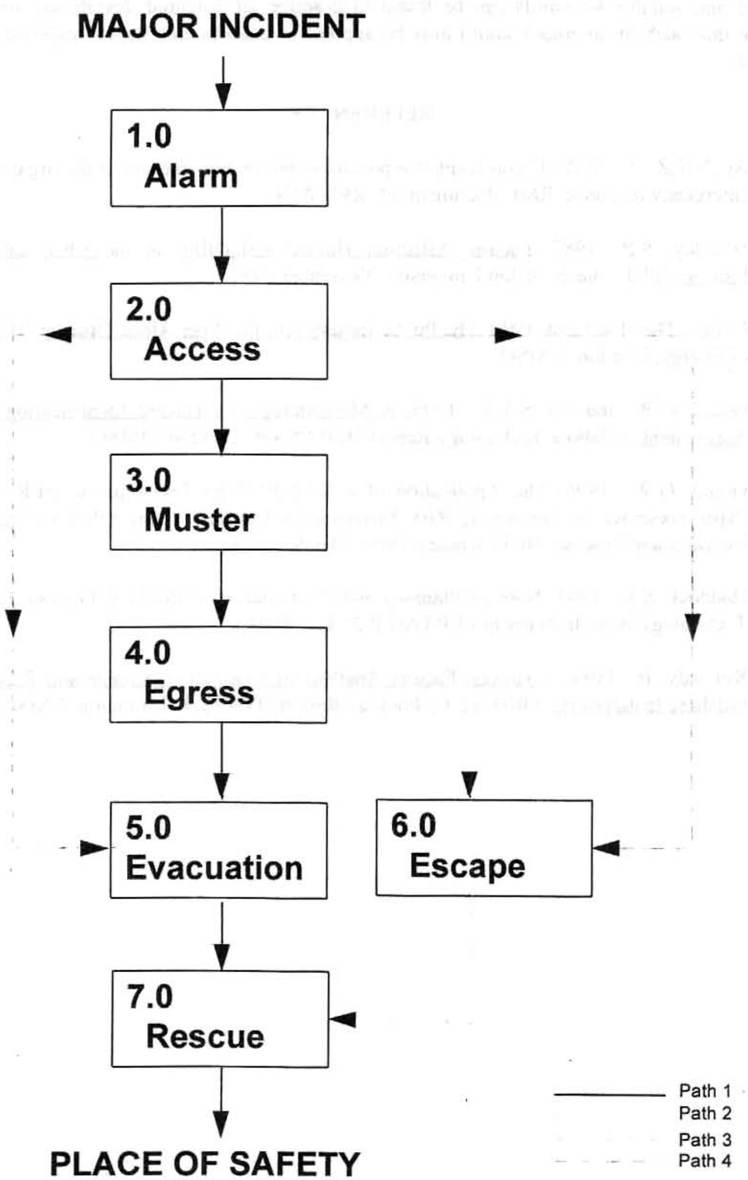

Figure 1: Overview of the EER Process

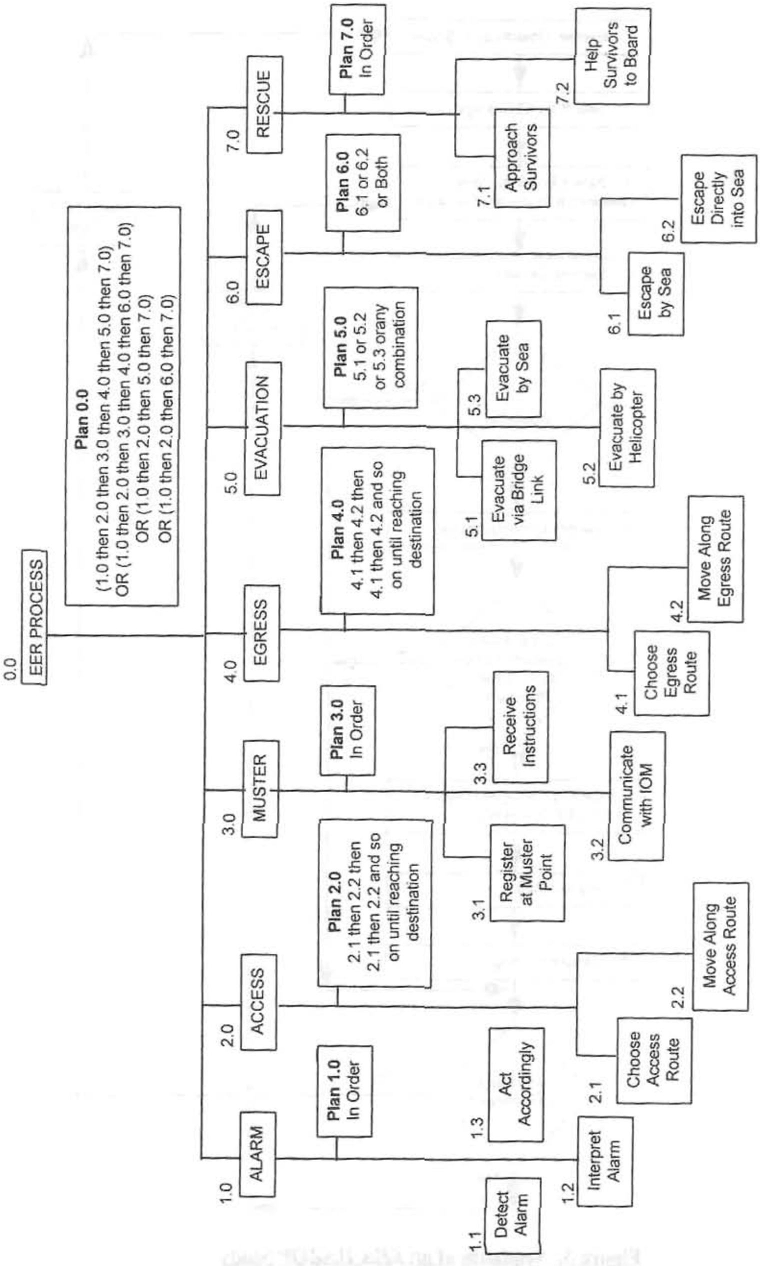

Figure 2: Top Level HTA Tree

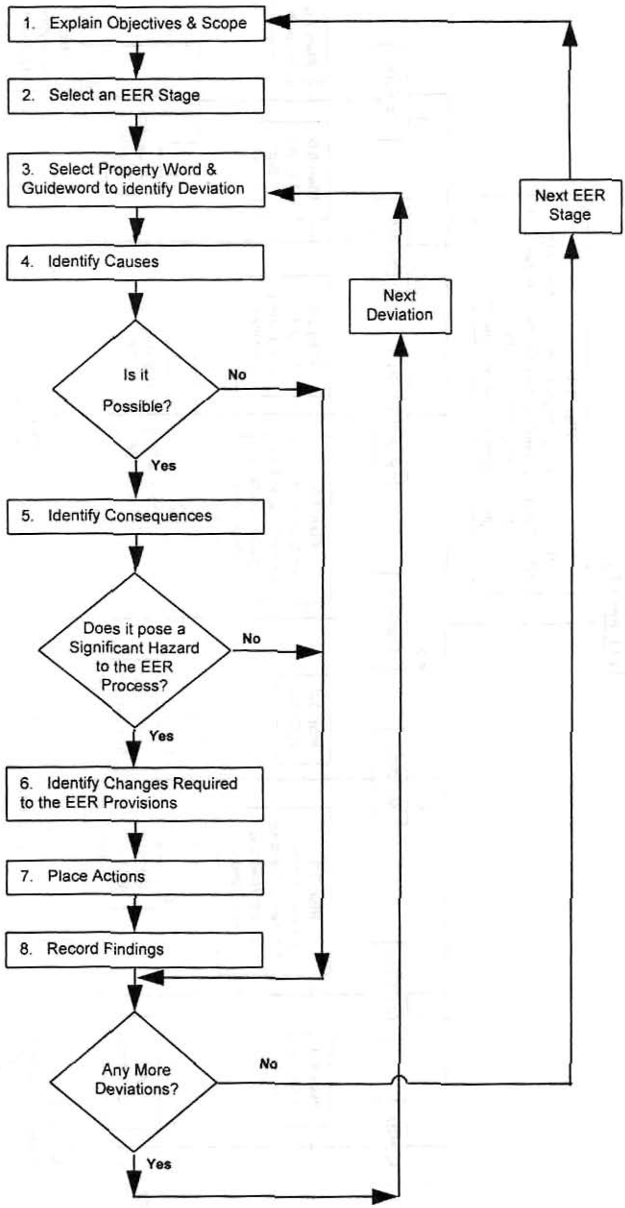

Figure 3: Sequence of an EER HAZOP Study

EER HAZOP RECORD SHEET (Example)

Meeting Ref No: ________

EER Stage : Alarm

Page of

Property Word	Guideword	Causes	Consequences	Action	Comments
Alarm-System (System)	Failed	• Random failure • Siren, Cable, etc. badly maintained	• Some POB not altered • Delay in detecting alarm	• Mr X to look into the possibility of more frequent testing/regular maintenance	*Low risk level due to monthly testing of alarm system and regular maintenance*

Figure 4: An Example EER HAZOP Record Sheet