HAZARD AND OPERABILITY STUDY OF OFFSHORE INSTALLATIONS - A SURVEY OF VARIATIONS IN PRACTICE

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A limited survey has been undertaken of the use of hazard and operability study (HAZOP) in relation to offshore installations. Ten offshore operating companies were involved in the survey. These were selected to reflect the range of company profiles and installation types. Data was collected by interview, by questionnaire and by personal correspondence. The survey revealed substantial divergence from the 'classical' HAZOP technique, even in its application to conventional process systems. The points of divergence are reported in detail.

Key Words HAZOP, Survey, Offshore Safety, Hazard Identification

INTRODUCTION

A limited survey has been undertaken of the use of hazard and operability study (HAZOP) in relation to offshore installations. The survey was part of a feasibility study commissioned by the Health and Safety Executive (HSE) in which the role of HAZOP in Offshore Safety Cases (OSCs), and possible means of HAZOP quality assurance were considered [1].

HAZOP is widely used as one means of hazard identification in the process industries. The technique has strengths in being inter-disciplinary and forward thinking. It complements the use of expert review and codes and standards to assure the acceptability of process designs. More recently it has become common to apply HAZOP retrospectively and also to apply HAZOP style techniques to systems other than conventional process systems.

The HSE feasibility study considered whether HAZOP as applied to offshore systems is achieving the desired objectives. The study was broken into three phases. In the first the framework within which QA of HAZOP would be carried out by HSE was explored. In the second, reported here, the current practices and views of a sample of operating companies were surveyed, and in the third means of HAZOP QA were considered.

HAZARD AND OPERABILITY STUDIES

The basic technique of HAZOP is set out in a Chemical Industries Association booklet [2]. Its use and relationship with hazard analysis is discussed by Kletz [3]. A classic account of its application was given by Lawley [4]. The technique can be applied both to processes in nominal steady condition and to actions carried out to take a plant from one condition to another. A new account of the use of the technique, by one of the authors of the CIA booklet, has recently been published [5].

The classical form of HAZOP is usually carried out when firm engineering line diagrams are available and requires a multi-disciplinary team with an independent leader skilled in the technique itself.

The attention of the HAZOP team is systematically focused on a series of possible deviations from design intent, each deviation being prompted by the association of a guide word with a location or action.

One attractive feature of HAZOP is the high level of completeness of the deviations considered. This leads, potentially, to a high level of completeness of hazards identified. Whether this completeness is achieved in practice depends critically on the skill of the leader and team in interpreting the guide words. Some of the guide words have a catch-all quality which is hard to do justice to and others can be ambiguous when applied to certain plant configurations or actions. Even where a high level of completeness is attained the team may still fail to recognise a potential cause or consequence in relation to one of the posed deviations.

Another striking feature is the number of opportunities which arise within the study to identify the same cause to consequence scenario, in other words the level of redundancy in the technique. This redundancy on the one hand provides strength by permitting *two bites of the cherry*, but on the other hand can bring tedium to the proceedings and lead to reduced interest in proposing candidate causes and consequences.

BACKGROUND TO THE SURVEY

An overall objective of a Safety Case is to demonstrate that risks to personnel are as low as reasonable practicable. This requires that any further sacrifice of time, money and trouble, that would be necessary to improve safety, is grossly disproportionate to the benefit that could be obtained.

In the guide to the Offshore Installations (Safety Case) Regulations 1992 [6] a requirement for hazard identification was set out and HAZOP was an expected choice of tool for partial fulfilment of that requirement. Therefore, HSE required an assessment of the quality of HAZOP used in offshore applications.

A number of variations in the practice of HAZOP were known to exist. This complicates any proposed scheme of quality assessment, since there is only a limited common basis upon which the data to be assessed has been produced. In order to develop an approach to quality assurance of HAZOP it was therefore necessary to investigate the extent of these variations.

Although the motives for the survey were quite narrow, relating to quality assurance, the data obtained will be of wider interest to those involved in application of the HAZOP technique to process systems whether onshore or offshore.

EXTENT OF THE SURVEY

Ten operating companies with fixed installations were invited to participate in the survey and to nominate contacts. They were selected to cover a wide range of activity, or proposed activity, ownership and size. The survey was conducted primarily by face to face interviews, held with seven contacts, but with a follow-up questionnaire to all ten companies and some additional correspondence.

STRUCTURE OF THE SURVEY

The question set, on which this account of the survey is based, developed naturally as the work proceeded. An initial set of talking points which were considered in face-to-face interviews with representatives of some of the companies was eventually extended into a detailed questionnaire.

The questions posed covered, broadly, four areas of interest which can be distinguished as context, policy, practice and assurance. These areas of interest are now defined.

Context

Here, the context for HAZOP of interest is defined in general by its potential role within an OSC. Particular features of this context include the relationship of HAZOP to quantitative risk assessment (QRA) and to other hazard identification tools.

Policy

The policy matters of interest relate to, for example, the existence of a company HAZOP procedure, the mechanism by which a HAZOP procedure is invoked, the range of systems to which HAZOP (or HAZOP style tools) is applied and the retrospective application of the technique (where relevant).

Practice

The details of implementation of the HAZOP procedure and associated administration are the main issues here. Timing, team composition and closure of the HAZOP are some of the important features.

Assurance

Where an operating company had its own mechanisms for auditing or testing the HAZOP procedure, these were also of interest. In a similar vein, it was expected that the operating companies would have experience which would help to identify, for example, those features of HAZOP where scrutiny is important, or particular means for carrying out HAZOP quality assurance.

DEFINITION OF TERMS

For consistency, it is necessary to define certain terms which are not generally agreed upon throughout the industry. These definitions were set out in the pre-amble to the questionnaire.

The unqualified phrase *hazard and operability study* (or *HAZOP*) is used exclusively to refer to a study carried out when engineering line diagrams (ELDs) or piping and instrumentation diagrams (P&IDs) are available. Other techniques from the same root are referred to by qualification such as *HAZOP style approaches*. The phrase *hazard studies* is used as an umbrella term for HAZOP and other hazard identification techniques. The phrase *process related* is used to indicate systems normally considered as relating to the discipline of a process engineer. The term *project holder* is used to mean a person appointed with responsibility for carrying out a project according to project procedures and reporting to a manager. The term *safety arm* is used to mean a line of management within the company with a specialist capability in safety matters and distinct from the hierarchy below a project holder. The term *action* refers to an action arising from a HAZOP meeting.

The term *hazard analysis* has been used broadly here to refer to the activities of identification, probability estimation, consequence estimation and decision making in relation to hazards.

RESPONSE TO THE SURVEY

An account of the data obtained in the survey is given at some length in Table 1. The data is grouped in sections corresponding with the areas of interest specified above. The questions raised and the phrases used to describe the position taken by different respondents are generally drawn from the text of the questionnaire. In order to present the information in a reasonably concise form, some subjective interpretation of the responses has been necessary.

DISCUSSION OF THE PRACTICES IDENTIFIED BY THE SURVEY

The main outcome of the survey was a set of points on which the implementation of HAZOP diverges.

Whilst in some cases a strong argument may be made for reducing the divergence, in others there are quite sensible reasons for a company wishing to act differently due to its own particular circumstances. Further, there are some characteristics which follow from the role which the HAZOP takes within the company's overall approach to hazard identification, for example where a series of studies is performed or where a combination of hazard identification tools is applied. Certainly, it should not be assumed that the prevalence of a particular position is a guide to its desirability.

A statistical analysis of the responses is not appropriate because the number of responses is small and because respondents were chosen to reflect the range of activity and organisation, not as a representative sample.

The differences are too numerous to be discussed in detail, although it is hoped that their exposition will provide food for thought for those responsible for implementing HAZOP. A selection of the more significant differences are discussed below. Where appropriate cross references to related questions are given in square brackets

Retrospective HAZOP [Q 9]

The question of the utility of retrospective HAZOP is still contested. Those who have carried it out are generally convinced of its benefits. There is a tendency to regard the application of HAZOP to one of a set of similar installations as sufficient, but differences between installations do not have to be large or obvious to be significant.

HAZOP at design has a *carrot* element, in that commissioning and operating problems, usually high probability and low consequence events, can be avoided and a *stick* element in that hazards, usually low probability but relatively high consequence events, can be protected against. In retrospective HAZOP much of the *carrot* element has been lost, the commissioning and operational problems having been largely overcome through experience.

HAZOP carried out in retrospect can benefit from knowledge of layout, often not finalised at the HAZOP stage of a new design, and from operating experience. The former can improve estimation of escalation and the latter can improve, for example, estimated susceptibility to blockage. Also common cause problems are more likely to be identified with this additional knowledge.

There is a view that retrospective HAZOP does not justify the required resources, when other steps have been taken to identify major hazards and operating experience will have revealed many minor design faults. This case against retrospective HAZOP, is difficult to maintain, especially for offshore installations. Retrospective HAZOP may reveal, for example, that a trip is unacceptable, whereas, because of the low value of the tolerable failure frequency, operating experience is unlikely to reveal such a deficiency. Fifteen or so years of satisfactory operation would not provide sufficient evidence that these problems do not exist.

HAZOP of Modifications [Qs 5,6]

The case for application of HAZOP to new design and major modifications is widely accepted. There is, however, a difficulty in deciding where to draw the line on minor modifications.

It appears that in some cases the need to consider use of HAZOP is not automatically flagged to the project engineer. The reliance on the project engineer, or line management above the project engineer, to identify the need for HAZOP on modifications is undesirable.

There are checklists in use which can be used to aid the decision on whether or not a HAZOP is required on a minor modification. However, this decision should not be under-estimated. There is little evidence of correlation between the scale of a modification, in time or cost or personnel involved, and the scale of the threat to overall integrity that the modification can present.

Modifications to CIA Guidelines [Q 4]

There is a proliferation of customisation of or changes to the CIA guidelines for HAZOP. It is difficult to judge how substantial the changes are and whether improvements have been achieved. There may be some advantage in sharing the thinking that underlies these changes, if a suitable forum can be found.

Documentation [Q 14]

The survey identified three levels of reporting. If reporting of the HAZOP does not include protected hazards then more attention should be paid to the means of design and review of relief, alarm, interlock and other protective measures. Full reporting provides for a cross-check with design of protective systems. Without this cross-check, scenarios which can lead to a demand on the protective systems may be overlooked.

The need for HAZOP documentation to be of a kind that facilitates review and quality assurance may not have been foreseen when the technique was developed. Difficulties, in obtaining quality assurance, naturally arise where the recording has been less than full, but of course there is no simple correspondence between the extent of recording and the effectiveness of the HAZOP. Fuller recording will also be helpful where HAZOP has to be reworked for modifications.

Non-Standard Operating Modes [No specific question]

An area of ambiguity and concern is in the handling of non-standard operating modes. Start-up, shut-down and irregular activities, including alternative operating modes and maintenance, are likely to be distinctly hazardous by comparison with 'normal' operation and therefore warrant special attention.

The extent to which non-standard operating modes are addressed separately from, or subsumed into, the HAZOP of standard operation seems to be variable . In the authors' view some HAZOP procedures are deficient in this respect.

Contribution of Other Disciplines [No specific question]

An interesting point which arose in the survey is that in some disciplines such as electrical and civil engineering, techniques with the rigour of HAZOP are not generally available or applied.

CONCLUSIONS

Companies need to be encouraged to adopt the best practice in relation to HAZOP, bearing in mind that 'best practice' may vary according to a company's particular circumstances, for example, the extent to which the company draws on internal or external resources to support HAZOP.

A survey of current practice has revealed much divergence in the application of the HAZOP technique. The more significant points of divergence have been discussed here, in particular relating to retrospective use of HAZOP, its application to modifications, alterations to the CIA approach and details of documentation. These and other points raised should be of interest to those responsible for policy on the use of the HAZOP technique. The need for fullness of reporting to facilitate quality assurance has been highlighted.

The feasibility of HAZOP quality assurance is substantially undermined by some current practices, in particular incomplete recording of the HAZOP meetings.

ACKNOWLEDGMENTS

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Table 1 - Responses to the questions posed in the survey

Explanatory note :

In this table, 'Q' is used to denote a question and 'R 1, R 2 ...' to denote responses. An indication of the number of respondents supporting a particular point of view is given in square brackets with the following key

*	A small minority
**	A minority
***	A majority
****	A large majority

The responses are not necessarily exclusive or exhaustive.

Section 1 *Questions relating to the* ***context*** *within which HAZOP is used*

Q 1 What do you regard as the role of hazard and operability studies (HAZOPs) within an OSC?

R 1 *Evidence of good engineering practice [***]*
R 2 A source of all process related accident scenarios or initiating events for subsequent use in QRA [*]
R 3 A source of some process related accident scenarios or initiating events for subsequent use in QRA [**]
R 4 A source for cross-checking with the output from other tools for generating process related accident scenarios or identifying process related initiating events for subsequent use in QRA [*]

Q 2 What other hazard identification techniques are used by your company to identify process related accident scenarios or initiating events (for subsequent use in QRA or for other purposes in the context of the OSC)? [In each case the respondents were asked to indicate whether the technique is routinely or selectively applied, 'R' and 'S' are used to distinguish the strength of these responses.]

R 1 *What if analysis [R *, S *]*
R 2 Preliminary hazard analysis in the style of HAZOP [R **]
R 3 Preliminary hazard analysis not in the style of HAZOP [R **, S *]
R 4 Failure modes effects (and criticality) analysis [S ***]
R 5 Checklists [R **, S **]
R 6 Fault tree analysis (going beyond generic loss of containment failures to identify root causes) [S ****]
R 7 Event tree analysis (going beyond generic loss of containment failures to identify initiating events) [R *, S ***]
R 8 Human factors analysis [S **]

Q 3 How would you characterise the interface between QRA and HAZOPs?

R 1 Highly integrated [*]
R 2 Some association [***]

R 3 No direct links [*]

Section 2 Questions relating to the **policy** of HAZOP usage

Q 4 What is the basis of the company procedure for HAZOP?

R 1 The procedure follows the Chemical Industries Association (CIA) guidelines without alteration [*]

R 2 The procedure follows the Chemical Industries Association (CIA) guidelines with modifications which are unique to the company (or contractor) [****]

Q 5 Do procedures for process related **design** call for HAZOP?

R 1 In all cases [****]

R 2 At the discretion of the safety arm [*]

Q 6 Do procedures for process related **modification** call for HAZOP?

R 1 For any changes to plant configuration [**]

R 2 For any changes to operating procedures [*]

R 3 At the discretion of the safety arm [**]

R 4 At the discretion of the project holder [**]

Q 7 Do procedures for **non**-process related **design** call for HAZOP-style reviews?

R 1 At the discretion of the safety arm [**]

R 2 At the discretion of the project holder [**]

R 3 According to criteria set out in modification procedures [*]

Q 8 Do procedures for **non**-process related **modification** call for HAZOP-style reviews?

R 1 At the discretion of the safety arm [**]

R 2 At the discretion of the project holder [**]

R 3 According to criteria set out in modification procedures [*]

Q 9 Has retrospective application of HAZOP to process systems been carried out?

R 1 In a majority of cases [*]

R 2 In all cases [*]

R 3 At the discretion of the safety arm [**]

R 4 At the discretion of the plant management [*]

Section 3 Questions relating to **practical points** of HAZOP implementation

Q 10 Is the time used for HAZOP controlled to guard against fatigue?

R 1 No [*]

R 2 A maximum number of hours per HAZOP session is mandated [*]
R 3 A maximum number of hours per HAZOP session is advised [**]
R 4 A maximum number of HAZOP sessions per week is advised [*]
R 5 The HAZOP leader exercises discretion [*]

Q 11 Do you include contract staff in your HAZOPs?

R 1 HAZOP team may includes contract design staff [****]
R 2 HAZOP team may include contract secretarial staff [***]
R 3 HAZOP team may include contract team leader [****]

Q 12 How is the HAZOP team leader appointed?

R 1 Any contracted team leader is vetted by company [****]
R 2 The choice of team leader is restricted to a list of named individuals [**]

Q 13 Who has responsibility for closing the HAZOP and its associated actions

R 1 HAZOP activity is closed by safety arm [*]
R 2 HAZOP activity is closed by operating arm or project engineer [****]
with verification by a second party [*]
with verification by the safety arm [*]
R 3 HAZOP activity is closed by the contracted, HAZOP leading, company [*]

Q 14 What philosophy is adopted in making records of the HAZOP meeting?

R 1 Reporting is complete with respect to actions (i.e. action provoking items only) [*]
R 2 Reporting is complete with respect to hazards (i.e. action provoking items are recorded, along with hazards which are identified but which were already catered for within the given design) [**]
R 3 Reporting is complete with respect to guide words (i.e. an entry is made for every guide word even if no hazard is identified) [**]
R 4 Mixed [*]

Q 15 What is the predominant character of the actions arising from HAZOP?

R 1 Teams are encouraged to recommend investigation and checking actions [**]
R 2 Teams are encouraged to recommend investigation and checking actions but sometimes recommend alterations for consideration [***]
R 3 Teams are encouraged to recommend alterations for consideration but often recommend investigation and checking actions [*]

Q 16 Do you use checklists (i.e. lists of prompts for each guide word) in support of the HAZOP?

R 1 No [*]
R 2 A published checklist is used [*]
R 3 An internally developed checklist is used [***]

Q 17 How are drawings arranged for the HAZOP?

R 1 A single copy of each drawing is used [*]
R 2 Each team member is supplied with drawings [****]

Q 18 How are computers used in association with HAZOP? [In responding to this question, most respondents reported that the use of computers varied substantially due to personal preferences of the people involved.]

R 1 A commercial secretarial tool is used in the meetings [****]
R 2 An in-house secretarial tool is used in the meetings [*]
R 3 HAZOP reports are word-processed after the meetings [****]
R 4 A database is used for storing and tracking actions [***]

Section 4 Questions relating to **quality assurance** of HAZOP

Note that no pre-determined responses were offered in this sections, so pre-dominance of responses is not significant.

Q 19 Do you have your own mechanisms for auditing or testing the HAZOP procedure?

R 1 No [**]
R 2 Review of output by experienced person [***]
R 3 Assessment of team leader [*]
R 4 Tracking of follow-up [*]
R 5 Observer sits in on meetings [*]

Q 20 Can you identify features of HAZOP where you believe scrutiny is especially important?

R 1 Team selection [*]
R 2 Information provision [*]
R 3 Follow-up of actions [**]
R 4 Clarity of output [*]
R 5 Post-HAZOP control of drawings [*]
R 6 Completeness of reporting [*]
R 7 *Calibre of leader* [*]
R 8 Inclusion of members who are independent of the design function [*]

Q 21 Can you suggest possible means for achieving HAZOP QA?

R 1 Occasional observation of meetings by independent expert practitioner [*]
R 2 Clarity of procedures [*]
R 3 Clarity of roles of personnel involved [*]
R 4 Database control of actions [*]
R 5 Review of responses to actions [*]

Section 5 Scope

Q 22 What is the scope of your response?

R 1 The answers given reflect the activity throughout the company [***]
R 2 The answers given reflect the activity in one part of the company [*]
R 3 The answers relate to current practice [****]