# HAZARD IDENTIFICATION METHODS

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epsc

European Process Safety Centre

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IChemE
INSTITUTION OF CHEMICAL ENGINEERS

**Published by**
**Institution of Chemical Engineers (IChemE),**
**Davis Building,**
**165–189 Railway Terrace,**
**Rugby, Warwickshire CV21 3HQ, UK**

IChemE is a Registered Charity
Offices in Rugby (UK), London (UK) and Melbourne (Australia)



ISBN 0 85295 457 3

Printed in the United Kingdom by Antony Rowe Limited, Eastbourne

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# Foreword

Over the last 20 years a great deal of effort has been devoted to the improvement of safety in the process industries, through the efforts of industry, through research projects and through legislation. This has resulted in greatly improved methods for the assessment of the consequences of incidents, for the assessment of the risks involved and for the selection of the most appropriate preventative and protective systems.

Fundamental to the use of these techniques is the need for the thorough and systematic identification of hazards. Without a sound system of hazard identification it is possible for a hazard to be overlooked and so the assessment of risks and the selection of preventative and protective systems may be incomplete or flawed. The importance of this process is recognized in Annexe III of the Seveso II Directive, which calls for the:

> '*adoption and implementation of procedures for systematically identifying major hazards arising from normal and abnormal operation and the assessment of their likelihood and severity*'

To assist in the application of sound techniques for hazard identification, the European Process Safety Centre (EPSC) commissioned a book entitled *HAZOP: Guide to best practice*[7] in 2000. This provided guidance on the first systematic technique of hazard identification to be used within the process industries, a technique that is still used extensively today. Since the first use of HAZOP (hazard and operability) a number of other techniques have been developed, some to address specific problems, others to provide more rapid assessments. The broad range of techniques now available can make it difficult for a manager or a safety specialist to decide which is the most appropriate and effective technique to use in a particular situation.

This book is designed to meet this need. It provides an overview of the techniques currently in use in the process industries together with an assessment of the strengths and limitations of each technique. In order to meet the overall objective of the book, and to keep it to a reasonable size, the book does not attempt to describe the techniques in detail but directs the reader to selected references.

The selection of the techniques covered, their strengths and their limitations is based on the experience of EPSC members. This has been combined with the wide experience of the two authors who worked with EPSC on *HAZOP: Guide to best practice.*

It is the hope of EPSC that this book will make a further contribution to safety in the process industries.

**Robin Turney**
**Technical Director, EPSC**

**Martin Dennehy**
**Manager, Engineering Technology and Process Safety,**
**Air Products Europe**

# Acknowledgements

This guide would not have been possible without the contributions of the following individuals and the support of their companies:

| | |
|---|---|
| Martin Dennehy | Air Products plc |
| Matthias Reichardt | Akros |
| Christophe Daux | Atofina |
| Alain Gayon | Aventis |
| Peter Herreilers | Basell Polyolefins |
| Bernd Ruge | BASF AG |
| Volker Pilz | Bayer AG |
| Keith Ratcliffe | BP Chemicals Ltd |
| Fritz Altorfer | Ciba Specialty Chemicals |
| Klaus-Juergen Niemitz | Clariant International |
| Keith Cassidy | Consultant |
| Karl McManus | European Process Safety Centre |
| Robin Turney | European Process Safety Centre |
| Nigel Bairstow | Exxon Chemical Company |
| Arie Plaisier | Huntsman Polyurethanes |
| Fred Poot | Lyondell Chemical Europe Inc |
| Peter Guldbrandsen | Novartis |
| Ulrich Widmer | Novartis |
| Simberto Senni | Snamprogetti |
| Claude Bartholomé | Solvay SA |
| Richard Gowland | The Dow Chemical Company |
| Veikko Rouhiainen | VTT Industrial Systems |

Whilst all of the above contributed to this book, the authors would like to give special thanks to the following for their suggestions, comments and support: Keith Cassidy, Martin Dennehy, Richard Gowland, Ken Patterson, Robin Turney and Ed Webster.

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Politecnico di Milano, Italy
SAVE Consulting Scientists, The Netherlands
Technical University Delft, The Netherlands
Université de Liège, Belgium
Loughborough University, UK

# Contents

# 1 Introduction

Hazard identification is fundamental to the safe design and operation of any system, be it a process plant or any other facility. The tools used vary according to the situation but they are all rigorous, systematic and depend to a greater or lesser extent on the knowledge of team members that will usually contain some form of expertise.

This book provides a selection guide that attempts to introduce, describe and illustrate the most commonly used methods, and then to direct the reader to more detailed references where more detailed guidance may be found on the specific method. It does not provide a full listing of all of the available methods. The selection is based on an analysis of the more common methods used by EPSC members. It should be noted that the authors found that a general method might have some very small, industry specific, features or changes and then be known by a different name. The descriptions given here for each method are generic and non-industry specific, so that the methods can be used by different industries with minor, case specific variations. In the descriptions it will be seen that a method may sometimes use an adapted part of another method. This too is to be expected as most will include the best parts of other, tried and tested methods.

The methods selected by the EPSC members include some that are on the boundary between identification and assessment. These include:

- fault tree analysis (FTA);
- event tree analysis (ETA);
- failure modes and effects analysis (FMEA).

These methods can be used both analytically and quantitatively. In the first mode they can be used as an investigative tool but it is in the second mode that they have most use.

Each method is described under the following headings:

- Definition;
- Description;
- Resource requirements (both personnel and documentation);

- Timing (against the process hazard analysis (PHA) time frame—see Figure 2.1, page 5 and reference 1);
- Advantages, disadvantages and uncertainties;
- Applications;
- Illustrated example (if needed).

Hazard identification should be regarded as a set of tools that are used at the appropriate time during a particular project development (see Figure 2.1). The timing of use is not always critical and, other than possibly for HAZOP study, there may by several points in a project where a method can profitably be used. Also it should be recognized that a 'project' could be a maintenance task, a modification or a large construction project. The identification methods can be considered for any of these, the only differences being in the depth, the effort and the recording. The method should always be selected with due thought to the need and the final outcome of the study.

The appendices in this book provide three examples showing which of the methods are most appropriate for those particular projects and when they would be applied. They also give a more detailed illustration of the inter-play of the various methods and show how they can, and often do, interact to produce the best results. Where worked examples are given in the method descriptions in the main text they are intended to help explain the detailed working of that method.

All of the examples are relatively simple, requiring little or no specific prior knowledge and it is intended that they should be easily understood. Full, real examples would be much more complex and detailed and cannot be used in an introductory document such as this.

Table 1.1 shows the usual timings for each of the selected methods based on the standard six stages of a project. As described on page 5, an additional two specialized stages, numbers 0 and 7, have been included. In the table the most likely time of use for a method is shown by an X; a less likely time is shown by (X). Definitions of the abbreviations are given on page 96.

Note that HAZOP is shown as a possibility at project stage 2, as there may be some desire to carry out a 'preliminary' HAZOP on a piping and instrumentation diagram (P&ID) as it is being developed.

No index is provided for this book as a standardized format has been used in the description of each of the selected methods and the parts of each description are fully detailed on the contents pages.

***Table 1.1*** *Hazard identification technique and project phase*

| **Method used** | **Project life cycle stage, 0–7 (See pages 5–9)** | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| Checklists | X | X | X | X | X | X | X | X |
| RR | X | X | (X) | | | | | (X) |
| What-if | X | X | X | | | | | X |
| FTA | | X | X | X | | | (X) | X |
| ETA | | X | X | X | | | (X) | X |
| FMEA | | (X) | X | X | | | (X) | |
| LOPA | | | X | X | | | X | |
| HAZOP | | | (X) | X | | | X | |
| PHR | | | | | | | X | (X) |

# 2 Process hazard analysis

The topic referred to here as process hazard analysis (PHA) has several other names. Common ones include hazard studies 1 to 6, process safety reviews, project hazard studies, and project safety, health and environment reviews. Confusingly, PHA has also been used as an abbreviation for preliminary hazard analysis.

## 2.1 Definition

PHA is a systematic analysis of a project, both process and control, by selected teams of experienced personnel, at defined phases during its development. It ensures that the safety standards in-built into the project satisfy corporate and national standards as well as the project, corporate and national criteria.

## 2.2 Description

The most common set of studies, carried out as appropriate during the project life cycle are:

1) conceptual design
2) front end engineering design (FEED) – process development
3) detailed engineering design
4) construction/design verification
5) pre-commissioning safety review
6) post start-up

The numbers are those referred to in the traditional 'safety studies', as first developed by ICI (see Swann[2]) and adapted by many other companies. The composition of the team and the documentation changes from study to study as the project develops and the detail becomes more fixed. Descriptions of studies 1 to 6 have been given in the literature[3,4], with one account going in to some depth although specifically for the pharmaceutical industry[5].

In recent years it has been customary to add two extra studies. These, numbered to leave the traditional study numbers 1 to 6 unchanged, are:

0) inherently safer/less harmful to the environment
7) decommissioning and demolition

It is important to recognize that these studies form a continuum and, to a degree, flow into one another. Each looks back at the outcomes of the preceding study and feeds into the following study. The timing is important so that each analysis is in place for the correct phase of the project but is not carried out too early, when the definition may still be incomplete, or too late, when the options for change may be limited. The timing of stages 1 to 6 in a normal project life cycle is shown in Figure 2.1.

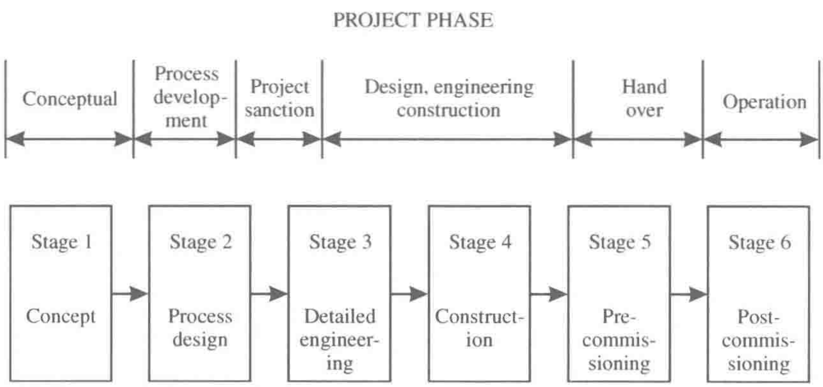


***Figure 2.1*** *Relationship of six-stage process study system to project life-cycle (Source: EPSC, 1994, Safety management systems (IChemE, UK))*[1]

## Study 0 – inherent safety

This study is carried out as the design options are being identified; its aim is to examine and to apply where possible the principles of inherently safe design[6] including environmental impact. The team is small and the study only lasts about one day. Members include a project representative together with a process engineer, chemist, safety engineer and a technology expert. Ideally there is a careful review of the history of that type of process including a search of accident databases.

## Study 1 – concept stage hazard review

In this study the basic safety, health and environment (SHE) data for the operation should be reviewed and SHE criteria set. This study identifies what further information is needed, and defines the programme of studies required to ensure that all safety, health and environmental issues can be adequately addressed during the project. It also checks if there are any fundamental issues that might stop project development. Typical issues include:

- properties of the feed stock, product and by-products, toxicology and handling;
- operating/start-up conditions;
- reaction kinetics/reactor control;
- special construction considerations;
- containment integrity;
- environmental impact;
- storage and transport;
- off-site services.

In addition, any constraints due to relevant legislation should be identified. A decision may be taken on which of the remaining hazard studies (2 to 6) should also be undertaken. Efforts to apply the principles of inherent safety should continue, including minimization of inventories of hazardous substances.

On occasion there may be important location-specific issues that must be identified. There would, for example, be some very different issues with a greenfield, joint-venture site in a remote, developing country compared to those at an established, wholly-owned site in a developed country.

The team required for this type of study has a similar composition to that of study 0 but the work may extend over a number of days. The results of the study may lead to the project being delayed or even abandoned if there are major concerns about SHE issues.

### Study 2 – FEED/process definition

This study is carried out as the design option is being developed to the point where detailed design is beginning. It typically covers hazard identification and risk assessment, and considers the operability and control features that must be built into the detailed design to manage these risks. The study looks for any residual concerns that might delay the design of the project. Typical issues include:

- establishing the project safety criteria;
- carrying out the start-up/shut-down analysis;
- carrying out the preliminary risk assessments (loss of containment);
- carrying out the over/under pressure analysis;
- carrying out the preliminary assessment of the performance of the shut-down system, for example by layer of protection analysis (LOPA);