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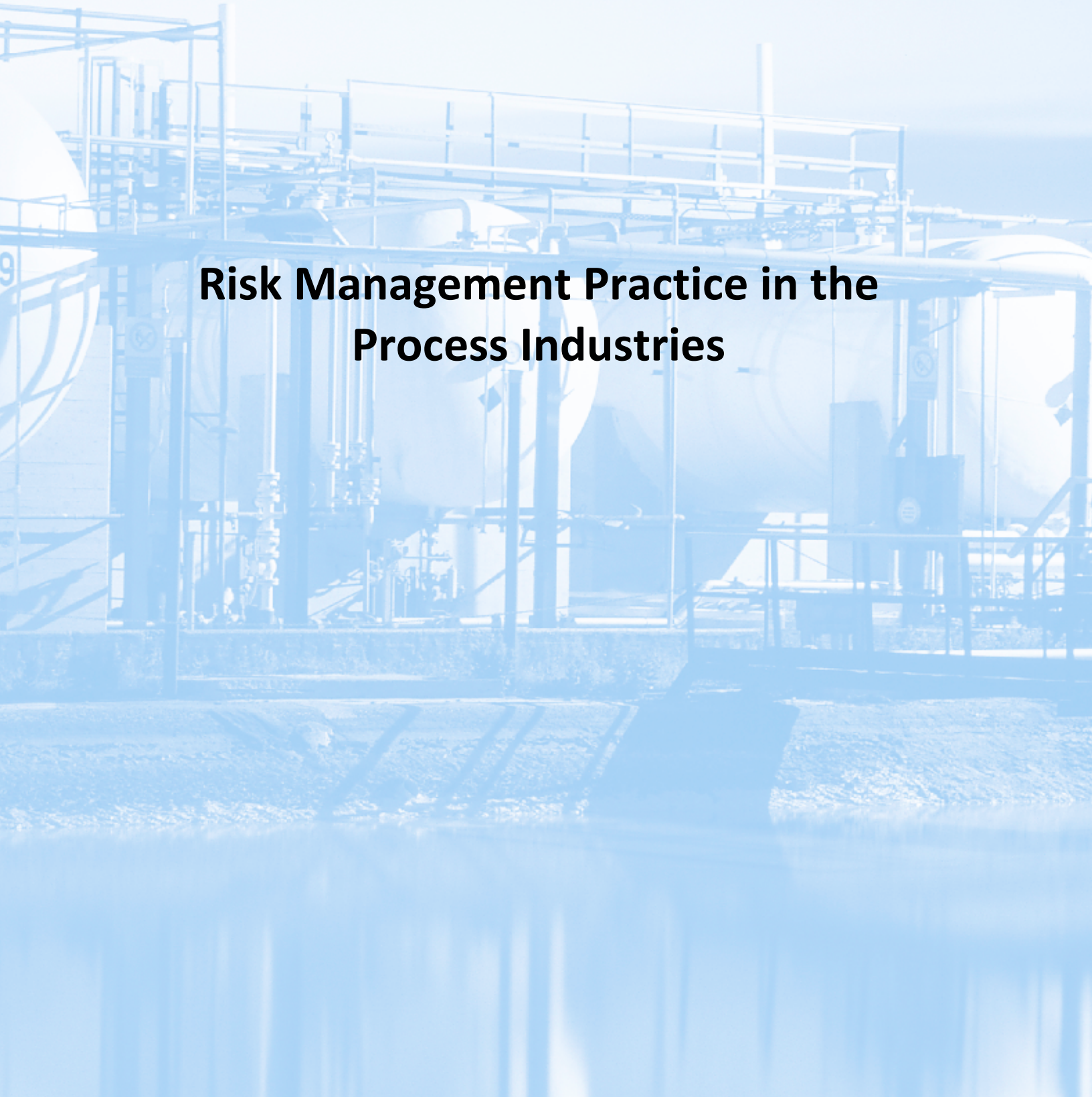
Report Number 18



Risk Management Practice in the Process Industries

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Report prepared by J L Hawksley for the EPSC Safety Management Systems Sub-committee

Any enquiries about this report, or other EPSC matters, should be addressed to Mr Lee Allford, Manager – EPSC Operations

Objectives of the European Process Safety Centre

1. Information

To provide advice on how to access safety information and whom to consult, what process safety databases exist and what information on current acceptable practices is available.

2. Research and Development

To collect European research and development needs and activities in the safety and loss prevention field, to inform members accordingly, to act as a catalyst in stimulating the required R&D and to provide independent advice to funding agencies priorities. "R&D" here includes experimental research and the development and review of models, techniques and software.

3. Legislation and Regulations

To provide technical and scientific background information in connection with European safety legislation and regulations, eg to legislative bodies and competent authorities.

4. Know How Exchange

To provide a platform for development of process safety knowledge for its members and to act as a focal point for dissemination of that knowledge to the European process safety community. Involvement in the Centre's groups gives organisations and individuals the opportunity to meet safety professionals from other companies to discuss areas of common interest and to share knowledge and experience, thus enabling informed comparisons of safety management systems and practice.

Benefits of Membership

- Improved cross-European co-ordination on safety standards
- Identification of areas where manuals and guidelines could be produced
- Improved co-ordination of safety R&D and handling of complex technical research programmes
- Stimulation of R&D in areas where there are gaps in knowledge
- Transfer of knowledge from elsewhere to Europe and between European countries.
- Technical input to legislators and standard makers to ensure more realistic legislation
- Sharing and dissemination of information on safety technology and accident prevention
- Access to information from a single source

Foreword

This report is primarily about the risk management practices necessary to ensure safety of people and the environment when there are potential risks associated with the loss of control of chemical processes or the significant loss of containment of chemicals in storage or transport. It does not cover the management of risks from the physical hazards of industrial activities although the generics of risk management are essentially the same whatever the risks to be managed.

The report is not a textbook on risk management. Rather it is a reminder of the key principles of risk management and illustrates how the principles can be put into practice by describing and, where appropriate, contrasting the 'how to' approaches taken by various companies. It is based on the practical experience of risk management systems shared by members of the EPSC Safety Management Systems Sub-committee.

The risk management practices adopted by different companies often vary considerably in their degree of formality. The variations reflect the type of organisation and the hazards to be managed.

Companies represented on the EPSC Safety Management Systems Sub-committee were:

Exxon Chemical
BASF
Bayer
DuPont
Rohm and Haas
Snamprogetti
TNO
Air Products
Akcros Chemicals
Borealis
BP Chemicals
Clariant
DNV
Dow Chemical Co
DSM
Hoechst Marion Roussel
ICI
Novartis
Shell International Chemicals
VTT

Presentations on risk management which, together with the consequent discussions, provided the material for this report were made by: R Read* (BP), B Fröhlich (Exxon), J L Hawksley* (ICI), W Kolk (DuPont), P van de Want (Shell), G Suter (Clariant), U Widmer (Novartis), G Caputo* (Rohm and Haas), H Dreher and K Jorg (BASF), S Senni (Snamprogetti)

* Now retired or moved from those companies.

Contents

1. ‘The Fundamentals of Risk Management’

1.1 The need for risk management

Many activities in the process industries involve handling hazardous chemicals, some of which are major hazards. Incidents in which there is loss of containment of such chemicals can have consequences which are potentially harmful to people and the environment. Hence there is the possibility of some risk to people and the environment on or around certain process industry activities. The same sort of incidents can also put business at risk.

Remember the distinction between hazard - the potential for harm – and risk – the probability of harm arising. Risk arises if someone or something vulnerable is exposed to a hazardous event or condition (eg a release of a harmful substance). Only if either hazard or exposure is not present can there truly be zero risk; wherever there is some hazard and some exposure there is a finite level of risk and ‘risk management’ is about ensuring that that finite risk is very small.

To ensure the necessary health and safety of people and the environment, there must be proper management of the risk. So risk management is not optional. It really is obligatory, for moral and legal reasons, and to maintain a company’s reputation and ‘licence to operate’. But it is also necessary to safeguard the business; good risk management is good business. It ensures that the potential safety, health and environmental risks to the business are understood and dealt with in a positive way, by prioritising actions for risk reduction and control and maximising the effective use of financial and other resources.

Benefits to be gained from special attention to ensure good risk management. include, for example:

- Implementation of the most cost effective means of controlling risk.
- Possible justification for lower cost safeguards
- Reducing the negative impacts on business
- Reduced attention from regulator. (e.g. less frequent ‘Seveso II’ inspections)
- Readily obtained permission for extensions.
- Clear demonstration of improvements made.

Key objectives of risk management are:

- elimination of risk where reasonably practicable
- reduction and control of remaining risk to levels as low as reasonably practicable (i.e. the ALARP principle).

Figure 1-1, sometimes referred to as the 'bow-tie' diagram, is a useful way of highlighting some of the key objectives. Various causes give rise to incidents which can lead to a range of consequences. A prime focus of risk management is on the prevention of incidents by the introduction of appropriate layers of preventative control measures (barriers). A secondary focus is on the provision of other barriers to mitigate consequences should an incident occur.

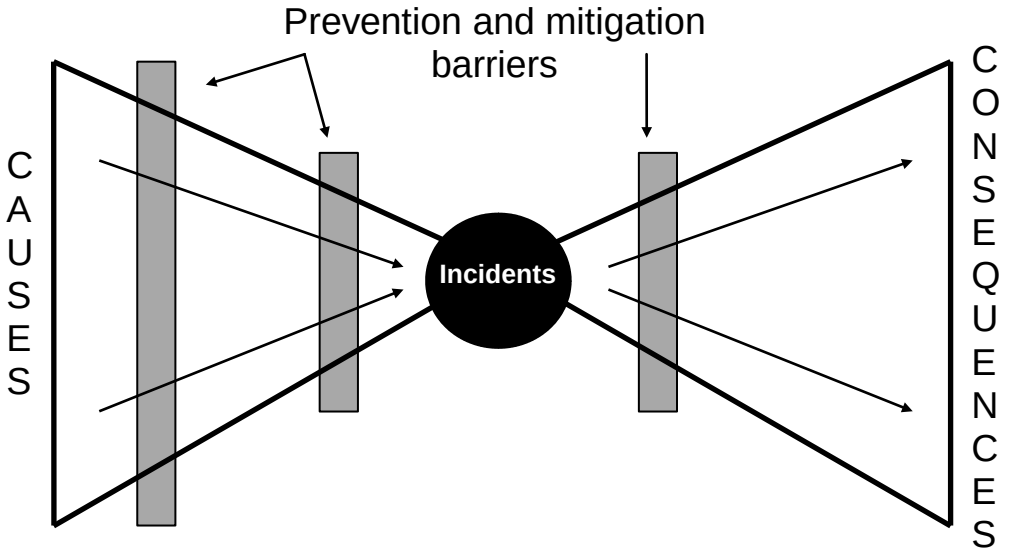


Figure 1-1: The cause/incident/consequence 'bow-tie' diagram

1.2 Responsibility for risk management

The business and operating management which have the responsibility for an activity, should take the responsibility for applying risk management. A fundamental maxim is:

> ***The hazards of an activity must be recognised and the worst foreseeable consequences that could result must be properly understood by the management responsible for the activity.***

The executive business management need an overall understanding, the management directly in control of day-to day operations need a detailed understanding. Without a proper understanding the appropriate measures to control risks cannot be selected, nor can the control measures be implemented with due diligence. In short, without a proper understanding there will not be proper risk management; inadequately informed operating managers cannot manage operations safely, inadequately informed business managers may make unsafe demands on operating management. It follows that the understanding must be maintained at a high level otherwise there will be a drift down the 'slippery slope' with an increasing risk of incidents occurring. But beware the understanding degenerating into complacency. Maintaining the proper understanding requires appropriate refreshers and reminders for the management in position and appropriate induction for new managers (see the incident case history in example 1-1 for a 'cautionary tale').

The 'risk portfolio' outlined in Example 2-16 is a useful tool to help business management understand SHE risks and the risk management actions necessary.

Example 1-1**:**

Case history – consequences of lack of understanding of hazards.

Decomposition of an inorganic nitrate-based mixture released toxic fumes which caused the death of a plant maintenance worker. The plant had been producing a range of product mixtures containing the heat sensitive nitrate for twenty years. From research work done during development of the process, it was well known that certain mixtures were susceptible to self-sustaining decomposition at process temperatures. Operating procedures prohibited the production of such mixtures. Some product and process development R&D had continued when the plant went into production and training programmes initially required that, prior to taking responsibility for the plant, the operating manager spent time with the research staff in order to become thoroughly familiar with the product and process hazards.

During the five years or so before the incident, business and organisation changes had resulted in the R&D support being run down eventually to nil – one reason being that the technology was believed to be 'mature' such that further development was unlikely to be viable. That change diminished considerably the knowledge base and previous arrangements for hazard awareness training were no longer possible. Maintaining continued hazard awareness and the training of new operating managers became fully dependent on plant staff.

Investigation of the incident revealed that reject product material was being reprocessed. That was a routine procedure when necessary but was subject to the authorisation of the operating manager that the incorporation of the rejects would not cause a unstable mixture. Originally, the operating manager would take advice from the R&D staff in cases where the reject material was not positively known to be compatible with the nitrate. On the occasion of the incident the reject material originated from another plant and it was not understood by the current operating manager that it contained substances that would initiate decomposition.

A significant factor in this incident was the gradual degradation of the understanding by the management of the basis for safety of the plant and the consequences that could result from the

plant hazards. Inadequate alternative hazard training arrangements and insufficient 'checks and balances' were introduced to compensate for the diminished knowledge base that resulted from the business and organisation changes.

1.3 The risk management cycle

To be effective, risk management needs to be a systematic process. Typically it will follow a plan-do-check-feedback management loop with actions at both business executive and operating management levels, see figure 1-2.

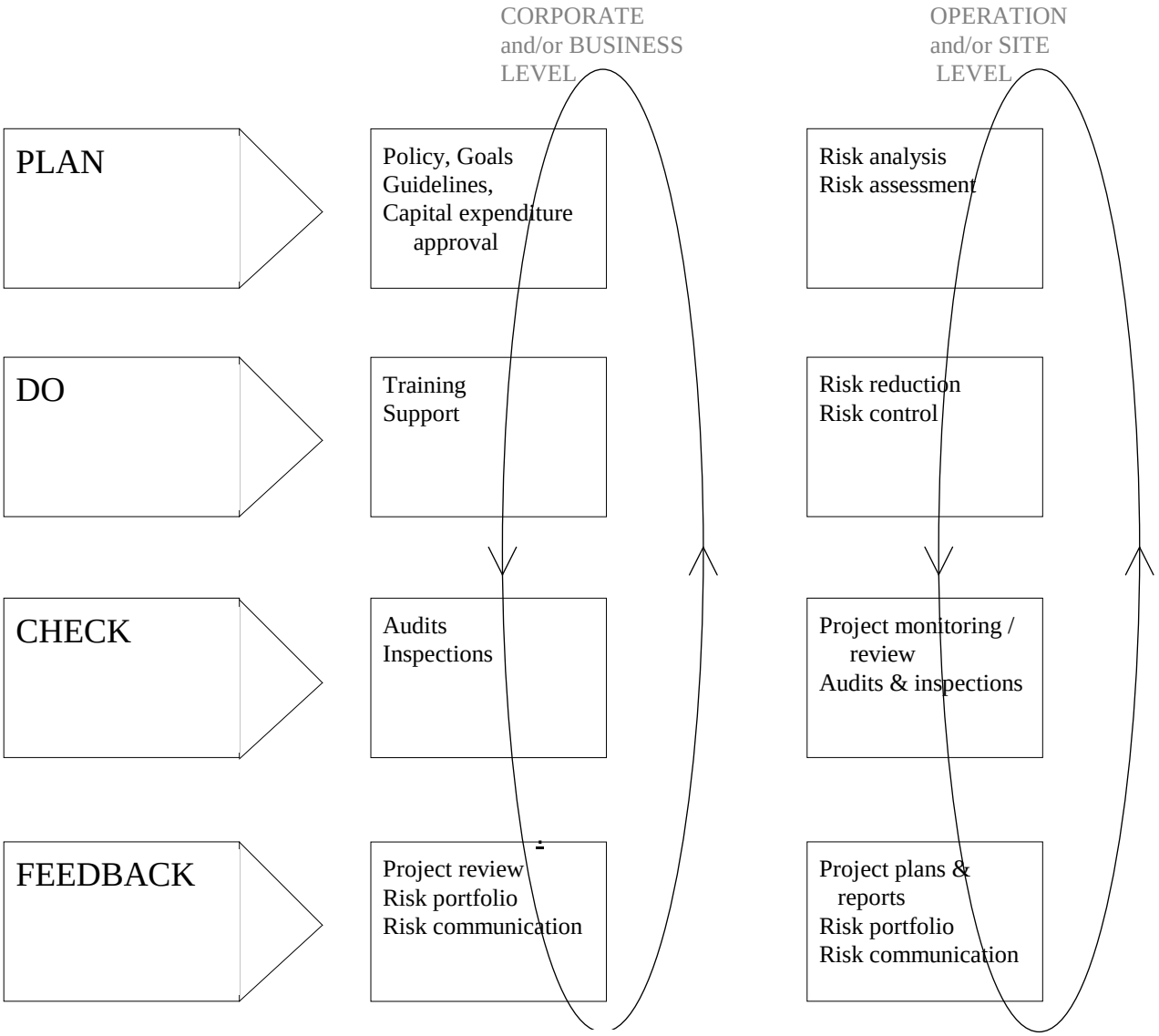


Figure 1-2 Typical risk management cycles

At the higher level (e.g. corporate or business sector executive management in a larger organisation) the actions should include:

- clearly define risk management policy and objectives
- set performance goals and improvement targets
- understand the risk profile for the business
- ensure appropriate risk management procedures are put in place and implemented
- provide the necessary trained resources
- monitor performance and revise targets for further improvement.

Building these aspects into a risk management system is discussed further in Chapter 2.

At the lower level (e.g. the operating management) the risk management process involves a number of generic stages. These stages need to be covered in an appropriate way and to an appropriate extent.

1.4 Typical risk management stages:

For risk analysis and assessment:

1. Identify

- the hazard(s) (i.e. what could cause harm)
- who or what could be exposed to the hazards

2. Understand and evaluate

- the possible consequences of the hazard(s)
- the possible hazardous events and their likelihood
- the possible exposures to the consequences of those events.

3. Assess

- the significance of the risk arising from the combination of the likelihood of the hazardous events and exposure to their consequences

For risk reduction and control:

4. Select

- the appropriate measures to control the risks to a sufficiently low level, including risk elimination where economically and technically feasible (where there are alternative measures, evaluate the options in order to select the best option).

5. Implement

- the control measures to ensure safe operation

6. Monitor and review

- the implementation of the control measures to ensure their integrity is maintained and to give assurance of ongoing safety.
- to learn from experience and to identify and explore opportunities for risk reduction improvements.

7. Communicate

- to all those with a part to play in the risk management process to ensure they know what they may have to do
- to those to whom the risks may give cause for concern and require assurance that the risks are being properly managed

(NB – there are other valid definitions of the generic stages of risk management which cover the same issues but differ in the words used and number of stages defined.)

In practice the application of risk management principles will not necessarily involve all the discreet stages as shown above. Also, in some cases, the sequence might vary with certain stages being carried out more or less simultaneously and with some iteration between stages to evolve the optimum solution. However in all cases hazard identification to an appropriate extent (ie **Stage 1**) is a vital starting point. Thereafter, different situations may call for different approaches for **Stages 2 to 4**. In some cases, for example, the selection of control measures (**Stage 4**) will start as soon as the hazards are identified. Whatever risk management approach is adopted, an appropriate implementation of **Stages 5 to 7** is always necessary.

1.5. Implementing the risk management stage

It can be said that there are two distinct approaches to risk management. One approach is what can be termed a 'rule-based' approach. This is typically applied where the hazards are mostly self-evident from past experience and the measures for effective control of the risks (the 'rules') are well defined. The 'rules' are typically laid down in national legislation, codes of practice, industry or company standards, all of which will have been developed through good operating practice based on the lessons learned from experience.

The alternative and complementary approach can be termed the 'risk-based' approach, in which hazards are identified by a mixture of creative thinking and structured critical examination and subjected to a technical analysis to help decide the most effective means for control of the risk.

The 'rule-based' approach might be said to be to be the more traditional, but it is not static. The 'risk-based' approach is more modern and analytical. It is increasingly used as techniques of hazard and risk analysis are continually developed. These developments also allow refinement of the 'rules' of a 'rule-based' approach and so the two approaches are complementary and, in practice, there is often a blend of the two.

1.5.1 Applying the 'rule-based' approach

Situations where the 'rule-based' approach can be appropriate are:
- small product and technology range
- technology mature and further developments unlikely
- hazards well known
- control measures (ie the 'rules') can be specified
- limited geographical scope of operations, e.g. in a single or few countries only

The rule-based approach is the simpler approach. The ***Stage 1*** requirement of risk management (see definition of Stages above) requires only a broad scale identification of a hazardous situation to confirm that it is one for which a relevant set of rules has been defined. The detailed identification of the specific hazards that can arise in the situation and the considerations necessary for ***Stages 2 and 3*** have already been made in the development of the pre-determined rules. ***Stage 4*** requires only that the appropriate rules are selected to ensure the prevention of hazardous events and the mitigation of potential consequences.

The 'rule-based' approach is good as long as the 'rules' fully cover the situations to which they are applied. But rarely are situations static and problems can arise from rigid application of the 'rules' if their applicability is not properly understood. For example, a potentially dangerous situation could arise where a change introduces a hazard for which the 'rules' do not provide proper protection. Conversely a change may decrease the hazard and the 'rules' could then lead to over protection with possibly unnecessary cost.

1.5.2 Applying the 'risk-based' approach

The risk-based approach requires appropriately detailed consideration of ***Stages 1 to 4*** on a case by case basis. Advantages of the risk-based approach are that it is flexible to cope with virtually any situation and that it allows more scope for judgement. Management is obliged to <u>think</u> through each case rather than to simply apply the pre-determined 'rules'.

Situations where the 'risk-based' approach may be more appropriate are:
- wide product and technology range
- frequent introduction of new products, materials and novel technologies

- control measures need to be developed on a case by case basis

In some companies the risk-based approach is well established and the trend in many others is to move from a rule-based to a risk-based approach. (See example 1-2).

Example 1-2: *Clariant*

Moving from rule-based to risk-based risk management.

Determining firewater retention capacity for a warehouse:

Old rules:

"The firewater retention capacity to be provided is:
3 m^3/te for flammable goods and
5 m^3/te for toxic and highly toxic goods"

New risk-based standard:

"The need to retain fire-fighting water is assessed based on the pollution potential of the stored goods and their combustion products, ie considering in particular, toxicity, eco-toxicity and adverse effects from intense colour or bad smell. Where fire-fighting water retention is necessary, the respective capacity is determined by the largest fire-fighting water requirement of those compartments that could be involved in a fire of goods which make water retention necessary. Sufficient additional capacity is available for rainwater."

The use of various structured techniques characterises the full systematic application of the risk-based approach. For example, checklist or guide-word driven critical examination is used for hazard identification (i.e. ***Stage 1***). There needs to be appropriate literature reviews and scientific research when necessary to understand processes and their hazards, i.e. the thermal aspects of chemical processes, explosion and electrostatic phenomena and others (see reference 1). It is also important to review incidents that have occurred on similar processes, both within the company and elsewhere, in order that lessons to be learned from those incidents are taken into account.

Stage 2 often requires some technical analysis to quantify, to an appropriate extent, the possible consequences of hazardous events and maybe their likelihood. 'Event tree analysis' is a useful tool to increase understanding of the consequences of hazardous events, particularly when several alternative outcomes are possible (e.g. loss of containment of a flammable chemical, see figure 1-3).

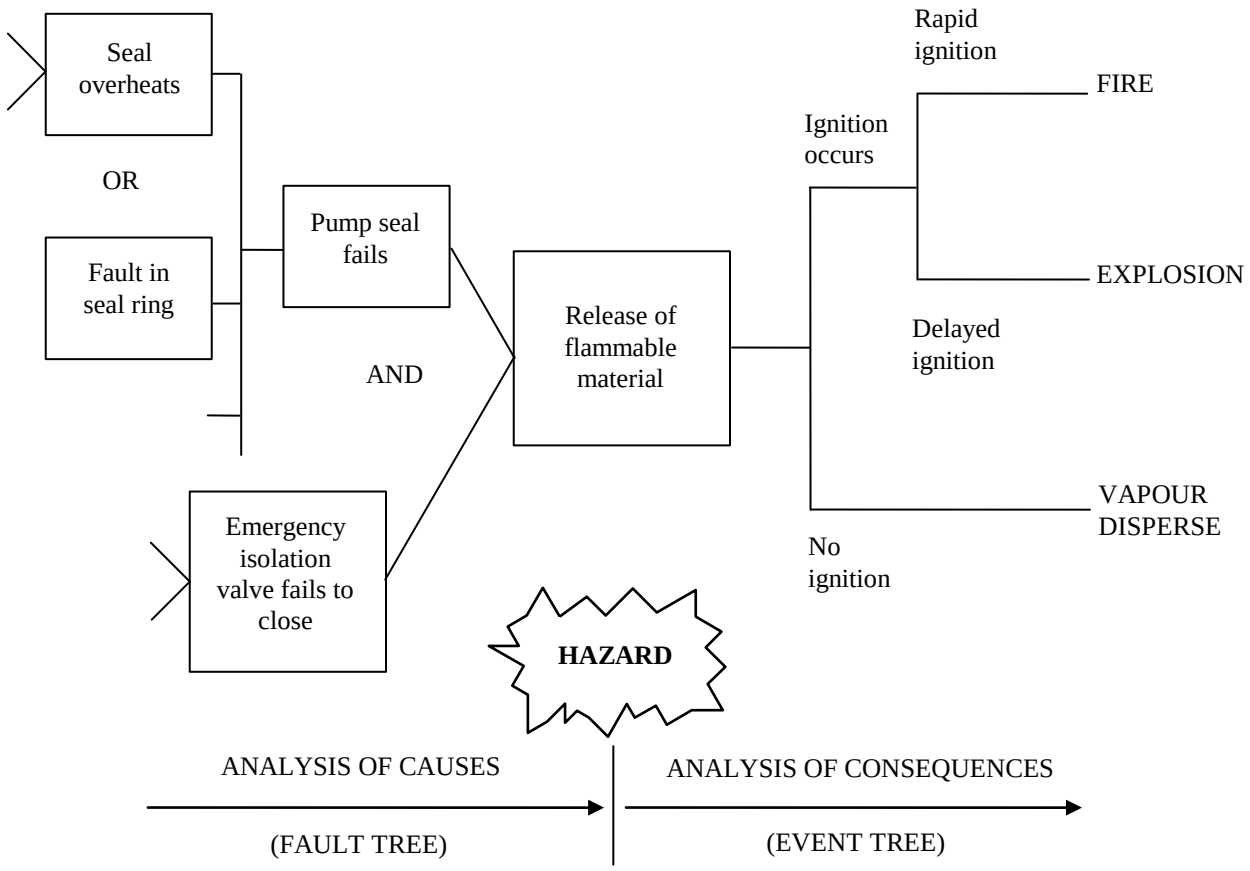


Figure 1-3: Tools to help hazard analysis

Mostly the considerations for evaluating event likelihood will be judgmental but 'fault tree analysis' is a useful aid to understanding the combination of events and conditions that can lead to a hazardous event – (see also figure 1-3). These and other techniques are well described elsewhere (see references 1,2 and 3 for example) and will not be discussed further in this report.

Stage 3, assessing risk, is largely a matter of judgement taking account of any relevant guidelines and criteria. This element is discussed further in Chapter 3.

The understanding generated by working through ***Stages 1 to 3*** enables the risks to be prioritised, risk elimination possibilities to be explored and appropriate control measures for remaining risks to be identified at ***Stage 4.*** In practice, ***Stage 4*** will often proceed in parallel with ***Stages 1 to 3***. Often there may be alternative risk control options that need to be evaluated in terms of efficacy, cost, practicability etc. In selecting control measures a typical approach is to work through the following considerations, in order to select the prime means of controlling the risk:

1st consideration – Increase 'inherent SHE' (see also paragraph below):

- Are there opportunities to eliminate or reduce the hazards and/or their potential consequences?
- Are the remaining hazards at a level that should be avoided?

2nd consideration – Physical means of control:

- Are the hazards of sufficient magnitude to require physical/engineering means of controlling risk?
- Are the hazards of sufficient magnitude to require multiple layers of physical/engineering control?

3rd consideration – Administrative means of control:

- What special administrative procedures are required to ensure the integrity of any necessary physical means of control?
- Can the risks be adequately controlled by the direct application of suitable formal administrative procedures?

4th consideration – General operating procedures and training:

- What operating procedures are necessary to minimise the demands on any specific risk control measures?
- Can the risks be adequately controlled by suitably defined operating procedures and appropriate training?
- What personal protective measures (e.g. equipment and clothing) is required for personnel?

(NB: The above questions are typical of those to be asked but not comprehensive)

"Inherent SHE" is an approach in which opportunities are sought to eliminate hazards at source wherever possible. Where this cannot be achieved a hierarchy of measures are considered such as reductions in the quantity of hazardous materials, storage under conditions such that the consequences of an incident are less severe . The approach is most effective when applied at the earliest stages in a project although there are also cases where it has proved valuable on existing plants. A 'Note on Good Practice' in Inherent SHE has been produced by EPSC (ref 4).

The risk management strategy adopted has to be cost effective: if it is not the activity may be safe but it is unlikely to be viable. Whilst reducing risk by adopting solutions that give better 'inherent SHE' should always be a first consideration, economic factors have to govern whether or not such solutions can be adopted in practice. The assessment procedures applied and the prime measures selected to control the risk should be commensurate with the risk i.e. as simple and economic as possible in relation to the level of the risk. The less the likelihood of the hazardous situation to be prevented and the less severe the consequences that could result, the more simple can

be the prime means of protection and vice versa. Figure 1-4 illustrates a typical generic framework for matching the prime safeguards to the risk.

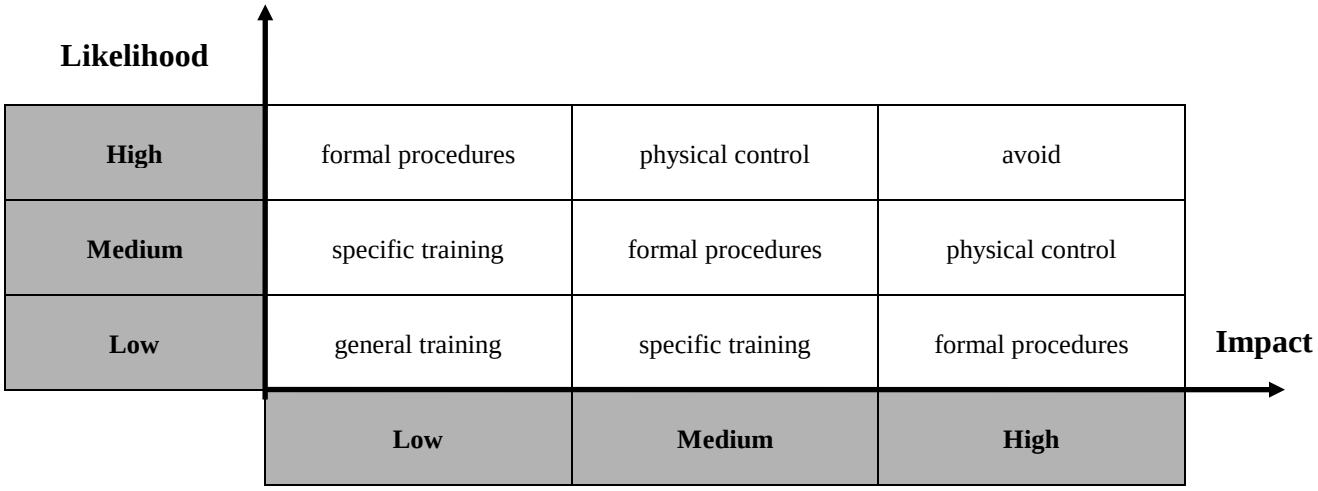


Figure 1-4: Matching the prime safeguard to the risk

1.5.3 Common aspects

Stages 5, 6 and 7 are essentially common to both the 'rule-based' and 'risk-based' approaches to risk management and can be implemented in a similar way.

Stage 5 – implementing the control measures – requires procedures to ensure that the selected measures are properly specified, designed, made, put in place, operated and maintained.

Then ***Stage 6***, requires there to be routine and systematic monitoring and review of performance. The objectives are not only to ensure that the risk continues to be controlled at least to an acceptable level but that opportunities for risk reduction are identified, examined and implemented where reasonably practicable.

Opportunities for risk reduction will be generated by the investigation of those incidents that do occur, including the 'near misses', i.e. the abnormal or unexpected events that do not result in actual harmful consequences. It is important, when following up incidents, to remember loss control theory in which the immediate or direct causes of an incident are themselves the result of some underlying basic or root cause (see for example section 5.4 of reference 5). While it is important to identify and correct the immediate causes of an incident, the investigation should study and endeavour to determine the underlying 'root causes'. Correction of 'root causes' gives more effective long-term incident prevention.

Finally, ***Stage 7*** requires there to be appropriate communication whenever needed during the risk management process. There will be a need for 'internal' communication

to others in the organisation who need to know how and why the particular risks are being controlled and what actions they may be required to take. Examples 2-14, 2-16, 3-2, 3-3, 3-4 and 3-5 include ways of displaying risks which are useful for internal communications.

There will also be a need for 'external' communication, for example, to the public, pressure groups, the emergency services and the regulators, all of whom may need information and assurance that the risks are being properly managed. Conducting that risk communication is a difficult area and is beyond the scope of this report.

Example1-3 is the general guidance for risk management given in one company.

Example 1-3: *BP* ***HSE Risk management***

Every Business Unit and Team in BP agrees performance targets which include HSE performance. There are many potential scenarios which could result in failure to reach those targets. Systematic risk management ensures that these scenarios are properly understood and given appropriate attention.

The risk management process involves the following activities

- **identifying** hazards or threats
- **assessing** the risk to delivery of targets associated with those hazards or threats
- **evaluating** risk elimination/reduction measures
- **implementing** the risk elimination/reduction measures

Operations Integrity Assurance System (OAIS) Element 2 sets out the expectations for risk management. A wide variety of techniques and processes are available appropriate to the circumstances and level of risk involved, but there are essentially ***three categories of risk***:

Business Risk is a term to describe all risks facing a business. Typical risks will be political, financial, competitive, technological and HSE related. Management of business risk is owned directly by the Business Unit management team and typically involves:

- identification of high level risks – including HSE risks which may further be categorised into workplace risks and process/technical risks as outlined below.
- use of a risk matrix to capture severity and manageability of perceived risk
- management action plans to provide demonstrable assurance of key risk management.

Workplace Risk is the risk to workers due to health and safety hazards in their normal working activities. Typical consequences may be injury, death or damage to health. Some workplace accidents may include property damage and business interruption. Reputation damage is likely in some circumstances. These risks are often managed by individuals or front-line teams and involve:

- structured hazard potential assessment
- formal task risk assessment for routine and non-routine jobs
- control by standing procedures or permits to work
- informal assessments by individuals in the course of a task
- self-regulation checks and audits to ensure that systems and procedures are working effectively

Process and Technical Risk is a term used to describe risk due to failure of the performance of process equipment. There are two types of failure that should be considered:

- failure of the equipment to deliver business performance (e.g. quality/quantity of output, reliability, energy efficiency etc.) Typical adverse consequences include failure to meet emissions requirements, noise standards or the impact of off-specification product.
- major hazard risk due to accidental release of process fluids. Typical consequences include toxic clouds, fire, explosion and pollution.

Such risks are typically assessed by technical specialists/teams and involve:

- formal identification, assessment and management of risks involved in a particular project, operation or activity
- hazard identification processes such as HAZOP
- quantified assessment processes such as QRA

Key concepts of risk management

Risk assessment is the process of estimating the likelihood of an accident occurring, the magnitude of the consequential loss and making a judgement about the significance of the risk.

risk = frequency x consequence

Risk may be expressed either:

- ***qualitatively*** e.g. high/medium/low or
- ***quantitatively*** e.g. dollars or expected mortality/year

Risk management decisions must consider both frequency and consequence e.g. a $1000 loss every year may be considered to be equivalent to a $1 million loss once per 1000 years. The ***expected annualised loss*** should theoretically determine the level of attention which any risk should justify and the resources devoted to reduce it. There may, however, be good ethical or business reasons for being more risk averse in some circumstances.

Strategies for risk management

Strategies must be cost effective; if they are not then the organisation ***may*** be safe but will certainly not be competitive.

- ***start with simple risk assessment processes***…..detailed methods are expensive and should only be used where simpler studies indicate cause for concern
- ***work across all three categories of risk***…. Identify and rank major business risks but remember that basic task assessment in the workplace will not only prevent injury but may well contribute to the management of major risks
- ***concentrate on the effective use of resources*** in areas where these give greatest return

Risk communication is a difficult area. Social perceptions of tolerable risk are strongly influenced by subjective factors such as whether people feel they are well informed and fairly treated. Effective risk communication rests nonetheless, largely on effective risk management; people do not want to hear about theory but rather what is actually being done to manage the risks which concern them.

BP self-insures unless required to insure by law. Advice on insurance policy relating to HSE risks should be sought from BP Insurance (INS).

(Full text of guidance dated August 1997)

2. ‘Establishing a system of risk management/assessment’

2.1 Management system structure

Experience of process safety management in general was shared by the Management Systems Sub-committee and published in a previous EPSC book (reference 6). Reference 7 is also useful further reading. The basic framework for a systematic approach is a ‘plan – do – check feedback’ continuous improvement management loop. Figure 2-1 is typical (taken from reference 6).

This type of management system structure can be applied to any aspect of management of an activity, including the overall management of safety, health and environment protection of which risk management is a major constituent part.

A company’s risk management system will reflect the type of organisation, location and the nature and range of hazards to be managed. Some companies have a culture in which management practices are specified in detail and precise conformance with them is expected. Others specify requirements in more general terms and allow scope for more flexible application as long as the risk is acceptably controlled. A company with a narrow and stable product range might favour the former approach with, for example, details of the system defined corporately and made mandatory for all the company’s operations. On the other hand, a company with a wide and frequently changing product range might favour the more flexible approach. This is the more common approach. Typically, corporate mandatory requirements are set in broad terms and each operation is required to establish local detailed procedures to implement the corporate requirements.

In some cases a company’s risk management system may be set up and implemented as a distinct system implemented in parallel with the systems covering other aspects of the operation. In other cases, a company’s risk management system may be a part of the company’s overall management system with the risk management requirements integrated with other operating requirements. Where systems for different management aspects are separate, there should be inter-linking so that all aspects that impinge on a situation are properly considered, e.g. major issues raised in SHE audits or risk assessments must be taken into account in long term investment plans.

The appropriate arrangements for a company will depend on the organisational culture of the company. Example 2-1 gives a summary of one company’s specific system for the overall management of safety, health and environmental risk.

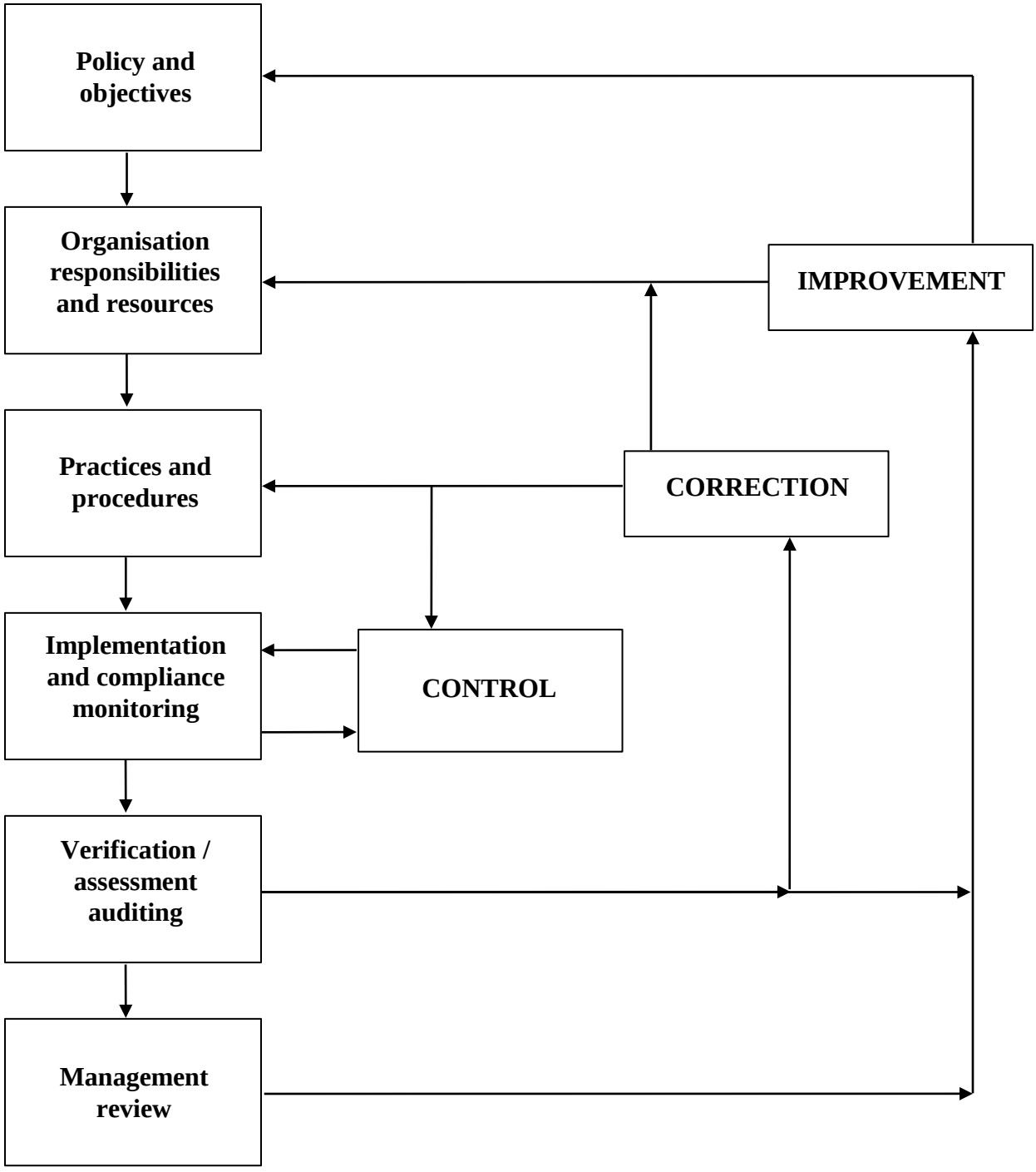
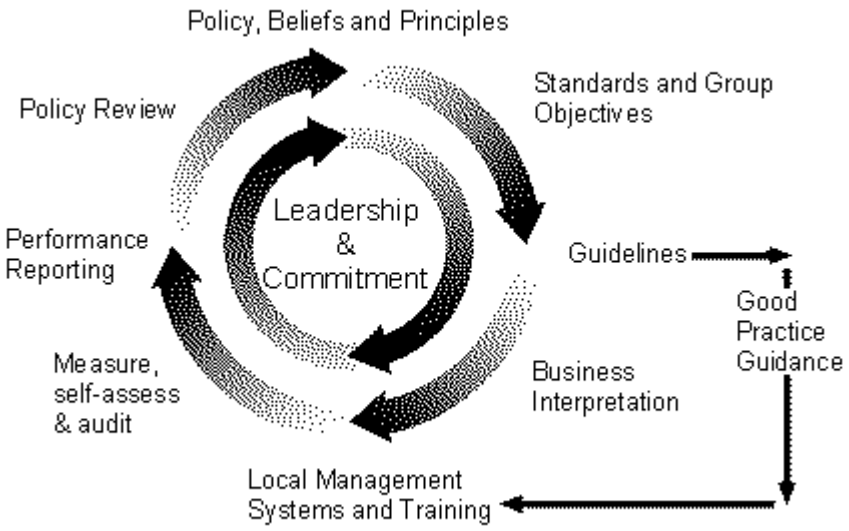


Figure 2-1: Typical management system structure

Example 2-1: *ICI*
Summary of the system for Safety, Security, Health and Environment (SSHE) management in ICI

SSHE Management Cycle



Line management is responsible for SSHE performance and the implementation of local regulatory requirements and ICI Group's SSHE Policy and Standards. Implementation is by means of:

(a) equipment - through high engineering and maintenance standards, so that equipment is 'fit for purpose'.
(b) procedures - through locally prepared, documented procedures and/or other systems
(c) people - through training, involvement and other programmes to help people contribute to SSHE improvement.

ICI Group SSHE Policy provides the essential framework requirements that set out clearly where the Group stands on SSHE management.

ICI Group SSHE Standards are the essential minimum requirements to secure the implementation of SSHE Policy. The 21 SSHE Standards, and their respective guidelines, have been defined in terms of the SSHE aspects that need managing in the ICI Group. They have been grouped together under six headings, broadly recognisable from most national Responsible Care programmes. These headings are, Managing Improvement, Employee and Contractor Health & Safety and Security, Product Stewardship (including Distribution), Community Awareness and Emergency Response, Process and Equipment SSHE, Environmental Protection & Pollution Prevention (a typical SSHE Standard is given in example 2.6).

Group SHE Objectives are published every five years. The current objectives, *Challenge 2000*, are due to be met by the end of year 2000.

ICI Group SSHE Guidelines set out the global management principles which should be incorporated into local procedures, instructions or other systems. These principles include good management practice and practical controls that should be applied to help implement the ICI Group SSHE Standards. They do not address detailed regional or local legal requirements.

Legislation in some countries or codes of practice used in some business sectors may set additional or more stringent requirements that should be followed.

Business Interpretation - The SSHE hazards and risks, performance and organisation of ICI's international, regional and functional businesses vary in nature. Therefore businesses may wish to develop, amend or directly adopt the SSHE guidelines. In some cases business may decide the guideline is not applicable to their business;

Good Practice Guidance - A great deal of good practice and experience is available in addition to the SSHE guidelines, to help managers implement the guidelines and to help authors write local procedures.

Local SSHE Management Systems are the means that local management use to implement the requirements of the ICI Group SSHE Policy and Standards and local legislation. They consist of:

(a) procedures and other systems: setting out the detailed documented arrangements for compliance with the ICI Group SSHE Standards and local laws

(b) training: ensuring people's understanding of what is expected of them;

(c) auditing: checking that both understanding and application is in place (see operational auditing below).

Although the SSHE Standards are mandatory across the entire ICI Group, the application, formality and degree of implementation within a particular activity will be appropriate to the operational risk profile, the local and national regulatory requirement and any voluntary management programmes adopted.

Measurement, Self-assessment and Audits are how line managers assure themselves that their systems are achieving the desired results. Measurement of SSHE performance and self-assessment of the effectiveness of implementation of the ICI Group SSHE Standards are carried out locally. In addition, independent audits provide an assessment of the effectiveness of implementation of the ICI Group SSHE Standards and to identify necessary improvements and share good practice. There are three levels of audit used in ICI. These are:

(a) Operational Auditing. Confirmation of compliance against local instructions and relevant local legislation and the understanding of those involved of the requirements. It includes behavioural auditing and is carried out by local personnel.

(b) Specialist Auditing. Periodic in-depth checks on the adequacy of instructions or systems covering one particular aspect of SSHE.

(c) Management Audits. These provide an overall assessment of the effectiveness of the local systems for managing the SSHE risks and issues relevant to the audit unit. Management audits are carried out by management from outside the audit unit and/or from outside the business.

Performance Reporting takes two forms, performance against objectives of the SSHE improvement plan and compliance against SSHE requirements. Each location will report performance against objectives to their business. Businesses then report overall performance to the ICI Board. The extent of local compliance with SSHE requirements, as assessed by self-assessments and audits, is collated by business and country through the 'letter of assurance' process and reported annually to the ICI Board.

POLICY REVIEW - SSHE Policy, Standards and business performances are kept under review by the Executive Council who also approve ICI strategy and overall resource.

A company planning to set up a risk management system for the first time will initially need to carry out a ranking of identified hazards and their potential impacts to enable an appropriate management system to be established (e.g. as is called for by ISO 14001). In general the greater the hazards of an activity the more formal and defined should be the risk management system. Some of the assessment tools mentioned in Chapter 3 can be used for such a ranking exercise.

The prime objective of the risk management system is ongoing satisfactory control of the risks. But the system should be dynamic not static, with an in-built requirement to identify and implement improvements whenever possible; both improvements aimed at eliminating or reducing risks and also improvements to the system itself.

2.2 Elements of the risk management system

2.2.1 Element 1: Policy and objectives

This first element has to be a clear statement of intent which sets out the basic objectives the company is committed to achieve with its risk management system. Normally this will be a concise statement, typically one page, but despite its brevity, it is a vital starting point. It should be signed by the chief executive of the company who must be personally committed to making it possible for the fundamental requirements of the policy to be put into practice. Mostly the policy statement will cover all aspects of safety, health and environment protection. Examples 2-2, 2-3 and 2-4 are from producing companies, example 2-5 gives the HSE objectives of a contracting company.

Example 2-2: *BP*

BP's commitment to health, safety and environmental performance

Everybody who works for BP, anywhere, is responsible for getting HSE right. Good HSE performance is critical to the success of our business.

Our goals are simply stated – no accidents, no harm to people, and no damage to the environment.

We will continue to drive down the environmental and health impact of our operations by reducing waste, emissions and discharges, and using energy efficiently. We produce quality products which can be used safely by our customers

Wherever we have control or influence we will:

- consult, listen and respond openly to our customers, neighbours, and public interest groups
- work with others- our partners, suppliers, competitors and regulators- to raise the standards of our industry
- openly report our performance, good and bad
- recognise those who contribute to improved HSE performance

Our business plans include measurable HSE targets. We are all committed to meeting them.

HSE Policy signed by BP Group Chief Executive, January 1996

Example 2-3: *Clariant International Ltd*

The Corporate Principles for Environment, Safety and Health

1. One of Clariant's most important objectives is the safety of its worldwide activities and the protection of people and the environment.
2. For this purpose, we set protection goals which are valid throughout the Clariant Group.
3. Suitable measures are taken to reach these protection goals and to avoid or reduce risks.
4. Local laws and provisions are binding for all companies in the Clariant Group. Where they are deemed to be inadequate, Clariant standards shall apply.
5. Comprehensive risk identification and assessment is a pre-requisite for Clariant's activities.
6. Attainment of these goals is supported by ESH (Environment, Safety, Health) management, which is an integral component of all functions and activities.
7. ESH measures are carefully evaluated in order to achieve the best possible cost/benefit ratio.
8. All employees assume responsibility for ESH in line with their function, level of authority, specialised knowledge and training. Open dialogue promotes a positive attitude towards ESH.
9. The units of the Clariant Group take contingency measures to control and limit the consequences of an incident.
10. Clariant is committed to continuous improvement of the ESH performance by developing new and better products, processes and services, with the most efficient use of resources and minimisation of environmental impact. Regular inspections and audits support this process.
11. Employees, authorities, customers, shareholders and the public are informed regularly of Clariant's ESH performance.

Signed by Clariant International Ltd Chief Executives, December 1997

Example 2-4: *Novartis*

Health, Safety and Environment Policy

Health, Safety and Environmental Protection (HSE) are part of our commitment to conduct our activities in harmony with society and nature and without compromising the health and safety of our stakeholders. We expect all our employees to implement the Novartis HSE Policy.

We integrate Health, Safety and Environmental Protection into our business strategies to add value to the enterprise, to manage risk and to enhance the reputation of Novartis.

- The health and safety of our employees, neighbors, customers and consumers, and the protection of the environment are company priorities consistently pursued throughout the group.
- We take HSE into account in all business decisions and activities. Business sectors establish proper structures and allocate sufficient resources in order to live up to this policy.
- Each employee shall comply with the HSE guidelines and the laws applicable to her or his area of operational responsibility.

We want to be a leader in Health, Safety and Environmental Protection by managing these disciplines actively, consistently, and efficiently.

- We strive for continual improvement in our HSE performance. We measure progress and verify compliance with our own HSE guidelines and regulatory requirements through audits and management reviews.
- We foster awareness and a sense of responsibility for HSE among our employees; to this end we provide appropriate information and training and develop their HSE skills.
- We optimize the use of natural resources and minimize the environmental impact of our activities and of our products over their life cycle. We assess HSE implications to ensure that the benefits of new products, processes and technologies outweigh remaining risks.

We care about the expectations and concerns of our stakeholders.

- We provide our employees with safe workplaces. We promote programs to maintain or improve the health of our employees.
- We inform our customers and the consumers about the characteristics of our products and give advice on their proper use and safe disposal.
- We cooperate with our suppliers and contractors and offer assistance to enable them to achieve an HSE performance matching our own.
- We recognize the interest of our shareholders, neighbours, the authorities, and the public at large in our HSE performance. We openly communicate and provide the information necessary to understand the risks and effects of our operations on health, safety, and the environment.

Novartis is committed to the Business Charter for Sustainable Development of the International Chamber of Commerce and to the Responsible Care Program of the Chemical Industry.

HSE Policy dated January 1997

Example 2-5: *Snamprogetti Group*

HSE Management Objectives:

- To minimise the possibility of accidents and damage during all phases of the project and to guarantee a safe working environment for people, in compliance with the stated Health, Safety and Environmental Specifications and National and International Regulations;
- To ensure compliance with the acceptability criteria stated for the project;
- To identify all potential hazards associated with the project, and to develop prevention, control and mitigation measures to eliminate or minimise harm to people, damage to plant or equipment, or adverse environmental damage;
- Minimise the risk associated with the plant based on ALARP justification;
- To review the impact of interface HSE activities on the project, communicate to Company to resolve them in accordance with the Scope of Work;
- To encourage the adoption of a positive, proactive, committed safety culture throughout all the phases of the project.

Some companies supplement the broad objectives of their policy statements with further more specific, but still succinct, statements to amplify the policy requirements. Such further statements are given a variety of names, e.g., 'Group SSHE Standards' (ICI), 'Operating Integrity Management Procedures' (Exxon), 'HSE Expectations' (BP),'Corporate Standards' (DuPont), 'ESH Strategies' (Clariant). Through these statements the basic objectives of sub-sets of the policy requirements can be elaborated, with regard to process risk management for example (see example 2-6).

Example 2-6: *ICI*

Group Safety, Security, Health and Environment (SSHE) Standard 17

Plant and process design, development and hazard review.

SSHE implications shall be taken into account in the development of new processes. There shall be systems for the management of projects and the design of all new facilities, plants equipment and processes. Relevant studies shall be carried out to identify hazards and security threats and to assess risks to people, assets and the environment. Identified hazards shall be eliminated or the consequent risks reduced so far as is reasonably practicable. Design and construction shall be in accordance with relevant Group Guidelines, local codes and regulations. The best available industry recognised SSHE practice shall be used in the construction of new plants.

For existing plants there shall be periodic reviews of hazards to identify opportunities for their elimination or the reduction of associated risks, and to check the adequacy of risk control measures.

The basis for control of risk for new and existing facilities shall be documented.

Where technology is transferred, the recipient shall be provided with all necessary information available to the Group.

2.2.2 Element 2: Organisation, Responsibilities and Resources

There must be adequate arrangements made to implement the system, in effect to ensure that the good words of the policy and other supporting statement can be translated into the necessary actions to make things happen. The arrangements need to cover organisational requirements, including the resources necessary to implement the system. The roles and responsibilities of key persons must be made clear.

The overall responsibility for managing the risks of an activity rests with the business executive management who 'own' the activity. The responsibility for implementing requirements of the risk management system at working level rests with the operating management directly in control of the activity. In some instances operating managers themselves may carry out the necessary risk assessments but often they will need the help of specialists. For the assessment of more significant risks a team approach is often used (see example 2-7 for the typical responsibilities of a risk management team).

Example 2-7: *Rohm and Haas*

Defining responsibilities

The role of the risk management team is to:

- Ensure that good practices are followed.
- Ensure that legal requirements are met.
- Verify that the quality of the MAPP* study was adequate.
- Evaluate the risk and determine that it is acceptable and meets company guidelines.
- Pursue opportunities for significant risk reductions
- Verify that a system is in place to manage the residual risk once all the agreed risk reduction measures have been taken.

*MAPP stands for Major Accident Prevention Program, the name given by Rohm and Haas to their process risk management system, see Example 2-12.

In some instances, a company may have central in-house resources which play a key role in implementation of the system across all its operations. In other cases, the in-house resources are devolved and mainly within specific operations and implementation of the system is done primarily by local resources. Many companies supplement their in-house resource with 'outside' expertise. However, in all cases, the line management of an operation must retain the prime direct responsibility for managing the risks of that operation. Line management should also facilitate employee participation in the development of risk management programmes.

The risk management arrangements should include provisions for referring decisions to the appropriate level of authority. Some companies have appointed 'risk managers' to whom higher level risks need to be referred. A function of the 'risk manager' is also to monitor the implementation of the risk management system (see

example 2-8). Typically a company will have a senior executive level SHE Policy committee which deals with high level SHE issues across all aspects of SHE which may include the authorisation of actions in the case of high hazard/risk situations. In some company's there may be arrangements to convene on an 'as required' basis an 'Ethics Committee' or 'Major Risks Committee' to whom particularly significant new risk situations have to be referred for approval or rejection. Such a committee would typically include, or seek the advice of, experts external to the company.

Example 2-8: *Exxon Chemical Company*

Implementation of an integrated worldwide risk management system – summary.

The arrangements for implementation of the system are:

At Operating Unit level:
- a Risk Manager is appointed to oversee local implementation of the risk management system and to ensure that special consideration is given to situations of defined Higher Potential Hazard (HPH)

At Regional Level:
- a Senior Risk Management contact is appointed to review the 'health' of the system as implemented in the units within the region and to get involved in decisions regarding HPHs

At World-wide Level:
- a SHE Policy Committee is established which requires assurance from the regions regarding the satisfactory implementation of the system and considers actions regarding HPH situations.

The duties of the Risk manager are:
- Know the SHE hazard of operations in his area
- Understand the potential consequences of the hazards
- Understand the controls of the hazards
- Be responsible for the implementation of an effective risk management system ie
    - Assurance of competent personnel
    - Assurance that a risk management plan exists and is effectively implemented
    - Approve the controls for the identified risks
    - Achieve timely closure on identified risk findings
    - Communicate Higher Potential Hazards to the Senior risk Management contact.
    - Ensure risks are managed to ALARP

The duties of the senior Risk management contact are:
- Designate and supervise the Risk Managers
- Review the 'health' of the risk management systems of units, focussing on higher level hazards
- Ensure risk management plan address all risks of units
- Approve the follow-up plan for handling HPHs and timely closure of follow-up actions

Appropriate experience and training is, of course, necessary for proper implementation of the system. Training schedules should be drawn up which specify the training requirements for key posts with procedures setting down the means for ensuring that the necessary induction, specialist skills and refresher training is given. Provision should be made to ensure that training needs are systematically identified and that qualified people are assigned to SHE related tasks and activities.

Example 2-9 is how one company has specified the fundamental requirements that its management must implement to establish adequate training provisions.

Example 2-10 indicates how one company develops its SHE training programme.

Example 2-9:

<u>Expectations for HSE-Management – Element 2</u>
<u>Training</u>

Ex 2.1: Training needs are systematically identified and periodically updated for all jobs. Training ensures that all members of the organisation have the understanding and skills to carry out their duties with proper regard for the safety and health of themselves and others, as well as for the protection of the environment.

Ex 2.2: A written program is used to describe the training for HSE that has been developed for each level of the organisation. This program includes:

- Orientation and induction of new and transferred employees as well as leaders
- HSE training for leaders at all levels
- Formal review, refresher and update training
- Knowledge and skill training
- Operating processes/operating procedures overview
- Training for trainers
- Licensing requirements fore higher risk equipment or procedures
- Maintenance of training records

Ex 2.3: The training program is robustly communicated throughout the organisation

Example 2-10: *Ciba Geigy*

Extract from guidance on EHS training.

Each organisation unit (site, production building, infrastructure area, etc.) develops a yearly training programme for all employees and keeps records of all training activities per individual and per training session or seminar. Line management is responsible for identifying the training requirements and providing the resources. The Group and Regional EHS organisations have the responsibility to offer a standard course training course programme for professional job assignments as outlined in the tabulation below.

Job Assignment	Basic Principles in EHS	Incident Investigation and Reporting	Explosion Technology/ Electrostatic	Thermal Process Safety	Toxicity/ Industrial Hygiene	Environmental Issues	General Course Process Safety	Refresher Training
All New Employees	X							
Operations and R&D Management	X	X	X	X	X	X	X	X
Production Engineers/ Chemist	X	X	X	X	X	X	X	X
R&D Engineers/ Chemists	X		X	X	X	X	X	X
Environmental Personnel	X	X			X	X	X	X
Health Personnel	X				X			X
Safety-Personnel	X	X	X	X	X		X	X
Project Engineers	X		X	X	X	X	X	X

2.2.3 Element 3: Practices and procedures

The practices and procedures to apply in order to implement the stages of risk management (as defined in Chapter 1) need to be established. These are not necessarily the detailed methods to be used but a definition of what has to be done, when and by whom. Sometimes separate procedures may be defined for each distinct stage of risk management. In other cases the procedures are drawn up to cover specific situations to be managed. One particular situation to cover is the development of a new process and plant. Another is the assurance of an existing activity for which reviews are required when a change is planned and also for the periodical reviews to give assurance that risk management continues to be satisfactory.

Example 2-11 outlines a multi-stage sequence of safety reviews used for the process risk management on a project for a new process and plant. This multi-stage approach is typical of that used by several companies (see also Section 5.1 of reference 6 for a similar example). Example 2-12 outlines a site/facility targeted risk management approach with an emphasis on consequence reduction and Example 2-14 outlines an audit-driven approach to risk management.

Example 2-11: ICI Eutech

Hazard Studies for project risk management

Formal documented procedures are used to ensure that the hazards associated with any project are adequately considered. The procedure involves six studies applied to a project at key stages (see table below).

The hazard Studies are to cover all relevant SHE issues. Identified hazards should be eliminated, or minimised wherever this is reasonably practicable. Where any significant hazards to people or the environment remain, then an assessment of the risks from those hazards should be made. Assessments are to be carried out by competent people trained as specified.

The hazard studies should ensure that the design is consistent with relevant legislation and Company guidelines with regard to risk. If the risks of a proposed activity cannot be reduced to a tolerable level this shall be brought to the attention of the Executive management responsible for the project.

A project SHE dossier should be assembled including a record of all hazard studies together with other relevant SHE related data.

Where there are no significant hazards inherent in the project, the hazard study procedure may be curtailed at the end of study 1, provided that the appropriate persons agree and that the basis for the curtailment is recorded.

The hazard studies are carried out by a team of appropriate design and operations staff with a study leader who has received specified training.

Hazard Study	Stage	Main Purpose
1	Development	Identify basic hazards and ensure that the understanding is sufficient to enable SHE issues to be properly assessed.
2	Project definition	Examine developing design to identify potential hazard events. Identify opportunities to minimise consequences and ensure provision of protective measures to give adequate control of risks.
3	Design	Critical examination(eg HAZOP) to review the developed design and/or procedures to check that that provision is made to prevent or control any deviations that could have hazardous consequences.
4	Pre-commissioning	Checks that: - process plant is built to the intended design, -actions from preceding studied have been implemented - operating instructions and emergency procedures are satisfactory for safe operation.
5	Pre-commissioning	Enables those responsible for SHE on site to satisfy themselves that the implemented project meets relevant legislative and company SHE requirements
6	Early operation	Confirms that studies 1-5 completed and documented in line with procedural requirements. Reviews early operation to ensure it is consistent with design intent with regard to SHE issues. Identifies and records any changes or difficulties for future reference

Example 2-12: *Rohm and Haas*

Major Accident Prevention Program

This approach places the emphasis on reducing the consequences of accidents, thereby encouraging inherently safer technologies. It is a completely standardised approach making it possible to be used in a consistent way by plant personnel not necessarily having a strong technical background. Standardised action levels and acceptable risk criteria guide the management process. The MAPP process consists of:

- Hazards identification
- Damage classification
- Risk analysis
- Risk management

Hazard identification:

The chemicals, their quantity, state, temperatures and pressures are identified and assessed using the Chemicals Hazard Index and the Fire and Explosion Index (The CHI and FEI are the consequence ranking tools developed by Dow). The indices together with local priorities are used to produce ranked lists of toxic and flammable chemicals, adjusted according to proximity of population, equipment age and complexity. Standard assessments of frequently used chemicals are maintained by the corporate safety department and can be used to simplify the process

Damage classification:

Credible release events are identified by a critical examination of plant schematics. A standardised list of release types is used in combination with containment deviation guide-words to generate release scenarios. The consequences of the scenarios are evaluated using computer tools. The output is the damage potential as a function of the distance from the event. Three 'Action Levels' are defined according to the extent of consequence effect:

1 Threshold of objectionable odour/ significant reversible health effect
2 Threshold of irreversible effects
3 Threshold of life threatening effects

For each credible hazard scenario the hazard zones corresponding to the Action Levels are determined in order to identify:
- chemicals that have the most severe off-site consequences
- the type of event that could lead to major accidents
- the maximum possible impact of an event

Risk analysis:

An evaluation team is formed to conduct an examination of the design, operation, logistics and management systems that affect the overall risk profile of the facility. The team develops recommendations to the damage potential considering these basic strategies:
- modification of equipment to reduce possible release rates
- modification of the state of the material released
- provision of a barrier between the release and the atmosphere
- relocation or modification of the release point

When the team has completed its damage limitation recommendations, a defined minimum risk analysis is performed depending on the seriousness of the event in order to determine ways of reducing the likely frequency of the hazardous events taking note of Corporate guidelines and criteria. The minimum risk analysis to be performed is specified according to the off-site action level (see table below). When complete, the findings and recommendations of the evaluation team are presented to the risk management team.

Risk management:

Strategies to manage the residual risk are developed by a risk management team whose role is to:
- verify that company's operations follow good practice and comply with the law
- evaluate and pursue further opportunities for any significant risk reduction which is economically feasible
- verify that the quality of the MAPP study was adequate
- re-examine the overall risk to see if the residual risks meet company guidelines
- assist the facility manager in developing a process hazards management plan.

The risk management team may decide to quantify the residual risk through the use of QRA or other hazard analysis technique.

Specified minimum risk analysis requirements

All levels	**Good practices/emergency response review** - Ensure that laws, corporate standards and accepted good practices are followed. -Evaluate training, procedures, maintenance, emergency response and safety reviews.
Action level 1	**Damage reduction** - Develop and test strategies to reduce damage should a loss of containment event occur. **Consideration of on-site impact** - Review the areas of explosive, fire and toxic impact to verify that employees are not exposed to unreasonable levels of risk
Action level 2	As above plus: **Frequency reduction** - Sufficient to identify opportunities to reduce the likelihood of representative events and evaluate the applicability of several risk mitigation strategies. **Safety analysis** - Test process and recommendations against a benchmark guideline
Action level 3	As above plus: **Corporate level Risk Management Team** - A partnership between the site, business unit (manufacturing manager) and Corporate safety is formed to evaluate the actual level of risk for residual Action level 3 events. The Risk Management Team will decide if further risk studies (HAZOP, QRA, fault tree analysis) are necessary.

2.2.4 Elements 4 and 5: Monitoring and verification

As for all management systems, the implementation of the risk management system must be monitored and verified. For this purpose, it is necessary that the practices and procedures are defined and written in terms that are auditable, that is, it needs to be clear who is required to do what and when.

Experience of monitoring and auditing practice has been shared by the Sub-committee and published in reference 5. Further exchange of experience is planned.

Monitoring is essentially a local function and is conducted primarily by staff of the activity who periodically check that operations are being conducted in accordance with the required practices and procedures. It seeks to answer the question: 'Do we do what we say we do?'

Verification usually requires auditors from outside the activity (though not necessarily from outside the company) who have the specialist knowledge and experience to test the practices and procedures against appropriate good practice in order to answer the question for the local management: 'Is what we say we do good enough?'

Example 2-13 outlines the internal assessments carried out within a company to evaluate the implementation of its risk management system.

Some companies use the audit element as the prime driver for risk management – see Example 2-14.

In some cases a company may chose to have its management system verified by 'external' experts. This will be required if it has been decided to implement in accordance with a national or International standard, ISO 14001 for example.

Example 2-13:

Evaluation of HSE-Management systems

Evaluation of company HSE-management systems is done via internal assessments to assure that all HSE activities, including risk evaluation and assessment, are effectively performed at its operations world-wide.

The assessments are performed for 16 HSE-related activities (i.e. product stewardship, process safety, documentation, emergency planning, etc) using a risk orientated management systems model that contains the following steps:

1. Management commitment (the 'Policy')
2. Co-ordination (Who's in charge?)
3. Identification of needs (What's really important? – includes consideration of critical impacts, tasks, hazards, legal and other requirements, evaluation and prioritisation of risks, etc which are needed to define and establish ongoing programs to manage and control those risks.)
4. Ongoing programs (Implementation activities – e.g. what's being done to manage risks?)
5. Employee participation (for program development and execution)
6. Training (Do the right people know how to do the job correctly?)
7. Communication (Are the right people getting the right information?)
8. Monitoring and measurement (What information should be checked to see if we are meeting our objectives and targets for continuous improvement?)
9. Review and improvement (Are we achieving expected results?)

Example 2-14: *BASF*
Audit driven risk management

Each year a Corporate S&E audit is carried out at each site. This evaluates both S&E performance and the site hazards and presents the results as a risk profile or portfolio for the site. The presentation of results in this way to senior management has been found beneficial because it relates readily to financial risk management of which they have particular experience and interest. The objective of the risk portfolio is to show the site risks and the requirements for action with regard to management of the risks. The steps in developing the risk portfolio are:

- systematic evaluation of the hazards and S&E performance
- systematic assessment of the risk by correlating hazards with S&E performance
- visualising diagrammatically the hazards and S&E performance to derive the actions to be taken.

Criteria have been defined for the evaluation of both S&E performance and the hazards.

S&E performance criteria: These are defined for each of the following categories:

1. Organisation
2. Training
3. Safety
4. Environmental protection

Each of these categories is further broken down into key parts to facilitate the evaluation. For example, to evaluate Safety the following is considered:

- Operational procedures, manufacturing instruction
- Hazard identification, hazardous substances and preventive health care
- Review of facilities
- Plant inspections
- Permits
- Personal protective equipment (PPE)
- Investigating accidents and incidents
- Plant safety

For each of these constituent parts five levels of performance attainment are defined to enable the performance to be scored on a scale 1(excellent) to 5(very poor).

Hazards criteria: These are defined for each of the following categories:

1. Substances
   - fire, explosion
   - health impacts, environmental damage
2. Reactions
   - exothermic reactions
   - process parameters
3. Associated field
   - residential areas
   - industrial plants
   - employee exposure

For each category, five levels of significance are defined on the basis of which the hazards can be scored on a scale 1(very low) to 5 (very high), corresponding to the 5 levels on the matrix.

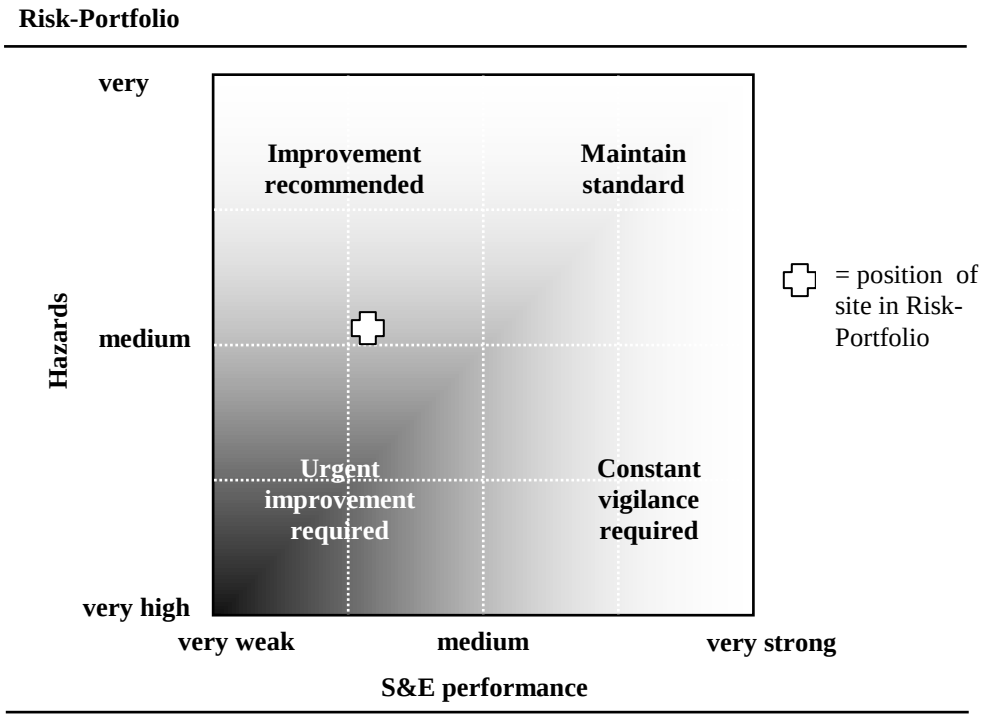
Evaluation	1	2	3	4	5	
Characteristics of substances	**Amounts of substances in tons**					
Combustible	< 100	< 1 000	< 50 000	< 100 000	> 100 000	**1**
Flammable (21°C– 55°C)	< 10	< 100	< 5 000	< 50 000	> 50 000	**2**
Flammable (< 21°C)	< 10	< 100	< 5 000	< 50 000	> 50 000	**3**
Highly flammable (flashpoint) < 0°C and boiling point < 35°C), fire promoting		< 0,2	< 10	< 50	> 50	**4**
Explosive		< 0,2	< 10	< 50	> 50	**5**

The hazard is based on the quantity involved and the inherent hazard of the material. These are added and averaged. For example, 50 ton of flammable (<21^{o}C) would score:

- 2 points for quantity (horizontal axis in table above)
- 3 points for inherent hazard (vertical axis in table above)
- average points is therefore 2.5

High hazard (black zone in risk portfolio), points score	> 3
Medium hazard (grey zone in risk portfolio), points score	2 < x < 3
Low hazard (white zone in risk portfolio), points score	< 2

The overall scores for S&E performance and hazards are evaluated from the various individual scores in the audit and analysis. The hazards evaluations are then correlated with the corresponding S&E performance evaluations to construct the S&E profile/portfolio on the chart shown over. From this, possible improvement actions are identified.



2.2.5 Element 6: Management review

An objective of monitoring the implementation of the system is to identify possible improvements to policies, practices, organisation and resources. The management review element of the system is to consider recommendations from the monitoring together with SHE performance and ensure that any appropriate corrective or improvement actions are taken (see Example 2-15).

Example 2-15: *Novartis*

Strategic sector HSE review process

For each business strategic sector an HES review is carried out annually. The function of this is to:
- review the overall sector HSE situation (ie HSE management, HSE risks, HSE Issues)
- determine and control the sector HSE targets.
- reach agreement on Corporate audits.

The participants are:
- the sector head with selected members of the Sector Executive committee including the HSE officer.
- Heads of Group Technology and Corporate HSE with selected members of Corporate HSE.

The agenda for the review is:
1. Review of last year's targets.
2. HSE – Situation and evaluation of audits
3. Major risks and the risk portfolio*
4. Health performance

5. Safety performance
6. Environment performance – emissions, key pollutants
7. Resources and energy
8. Bio safety
9. Issues and issue portfolio
10. Targets for next year

The outputs from Sector reviews are fed into the Corporate HSE review.
(* See Example 2-16 for an outline of the risk portfolio)

Risk profiles (see Example 2-16) are used by some companies as part of the management review process. These are summaries of many hazard identification and risk assessment studies relating to an area of activity and display the most important items of each study. The resulting summary gives an overview of the risks of the area of activity which might be a site, an affiliate company, a business unit, a division or the entire company. The summaries are useful for the internal risk communication to the line management responsible for the activity.

Example 2-16: *Novartis/Clariant*

HSE Risk portfolio process

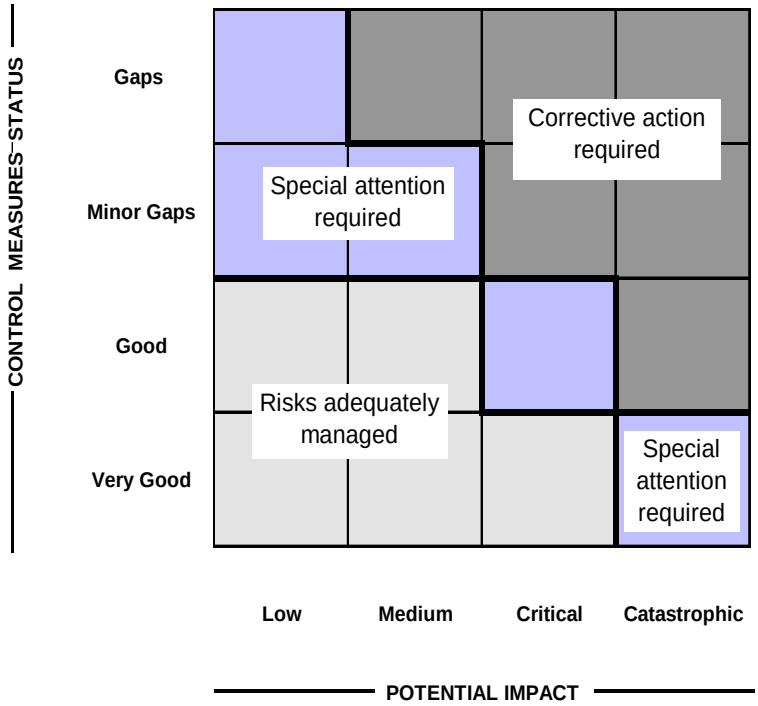
A common approach is used throughout the company to generate a risk portfolio which gives an overview on risk exposure of:
- people
- the environment
- financial performance
- reputation

The overview is of major risks at site, business sector, country and group level, consolidated from the bottom-up. The objectives are:
- to promote management awareness, involvement and support
- to provide a basis for strategic planning, setting goals, determining priorities and action plans
- to record improvement.

The portfolio is developed from risk analyses of individual projects, activities or facilities together with the findings of HSE audits with regard to the present status of the control measures. The potential impacts of identified significant hazard scenarios are assessed and plotted on the risk portfolio matrix against the corresponding status of relevant control measures.

From the matrix, scenarios of concern can be readily identified and relevant improvement action initiated. The portfolio is also a useful aid for risk communication within the organisation and to the higher management levels.

The matrix:



Definition of potential impact:

Potential impact	To people	To environment	To reputation	To financial performance
Catastrophic	- Threat to life of of one person outside site. - Threat to life to >10 people on site	- Irreversible damage to the environment	- Loss of group image in more than one continent	- More than 3 billion sFr. (= 1% of turnover 1997)
Critical	- Severe injury to people outside of site. - External evacuation. - Threat to life to 1-10 persons on site.	- Damage to the environment that is reversible within several years.	- Loss of group image in an important country (market).	- Between 3 billion and 300 million sFr.
Medium	- External alarm - One fatality or severe injury on site with partial disability.	- Damage to the environment that is reversible in less than one year.	- Loss of group image in minor markets.	- Between 30 million and 300 million sFr.
Low	- Injury	- Reportable pollution.	- Local media coverage only.	- Less than 30 million sFr.

Definition of present status of control measures;

Gaps	Deviations from legal or industrial standards.
Minor gaps	Concept for risk control exists but leaves deficiencies for secondary items.
Good	Good concept for risk control covering all aspects.
Very good	Excellent protection concept realised with special emphasis on control of major hazards.

3. 'Assessing the significance of risk'

Risk assessment is the vital foundation for risk management and comprises the first three stages of risk management as defined in Chapter 1, section 1.4. Of those stages hazard identification together with the understanding and evaluation of the possible hazardous events and their consequences are essentially analytical processes (sometimes referred to as hazard and risk analysis). The hazard and risk analysis becomes risk assessment when the value judgements necessary to consider the significance of the risks are added (i.e. Stage 3). This chapter elaborates this assessment stage and gives practical examples of the methods and guidelines that are used by some companies to structure the judgement process. Reference 3 is useful further reading.

3.1 Type and extent of risk assessment

The risk assessment can vary considerably in its extent and formality and first a number of general points need to be made.

- In many cases, a specific risk assessment may not, in fact be required. For situations already well understood, it can mostly be taken that the application of relevant recognised codes and standards will provide a sufficient level of risk control. In effect, the codes and standards have themselves been developed on the basis of previous risk assessments

- In the majority of cases where specific assessments are necessary, the assessments typically are predominately or wholly judgmental. The acceptability or otherwise of the risk is judged (and relevant control measures selected) primarily on the basis of experience

- However, new or unfamiliar hazards and their associated risks mostly need some degree of analysis to ensure adequate understanding. Even then, a qualitative evaluation of the hazards and exposure will sometimes give a sufficient evaluation of the risk

- For more significant hazards and risks some quantification of either or both hazard and exposure and hence the risk will generally be necessary for greater understanding

Whatever approach to risk assessment is adopted, a fundamental tenet is: ***'risk assessment is a means to an end, not an end in itself'***. The point being that the purpose of an assessment is to enable, for example, process options to be compared and control measures to be selected. On the other hand, if safeguards can be confidently specified on the basis of experienced judgement and established practice

then a detailed risk assessment would serve little purpose and should not be necessary. Risk assessments should not be done simply as an intellectual exercise.

3.2 Risk screening

In many situations there will be a range of risks to be considered and the level of the risks might vary considerably. An important aspect of risk management of such situations is to prioritise or rank the risks in order of significance so that the more serious risks can be given priority attention. The screening process essentially amounts to a coarse scale hazard and risk assessment from which those risks requiring more detailed and careful assessment can be identified.

Hazard Indices, such as the Dow Fire and Explosion Index and the Chemical Exposure Index (see reference 2 and 3), are used by some companies for risk screening. Where such indices are applicable, an index value can be set which, if exceeded, indicates that a detailed risk assessment should be carried out.

A commonly used, and more versatile, approach can be based on a risk matrix and is discussed later in this chapter; example 3-3 outlines a typical approach.

3.3 Quantitative hazard and risk assessment

A quantified assessment will usually need to include estimates of the consequences of hazardous events in order to understand the extent of harm that could result. Sometimes the quantification may also include estimates of the probability of the hazardous events occurring. Where event probabilities are quantified, it may be possible to combine them with the evaluations of consequence, in order to make a numerical estimate of the likelihood (i.e. the risk) of a particular level of harm arising. The result is a so-called quantitative risk assessment (i.e. QRA). It has to be emphasised that the quantification of probabilities, which is required in order to calculate numerical values of risk, should only be carried out when there is confidence that there are sufficient experience and data available to make meaningful estimates. Even then, calculated risk values are mostly subject to considerable uncertainty and their interpretation and use requires care.

Quantitative probabilistic risk assessment has its advocates and is used in some companies and, more particularly, by some regulatory authorities, notably UK and the Netherlands, primarily to assist with land-use planning issues.

Some of the advantages of the technique are:

- It can be the basis for consistent decisions, particularly when different types of hazards have to be considered. For example, it can enable a comparison, in the

same risk terms, of different types of hazard, e.g. a fire and explosion hazard with a toxic gas hazard
- It can be used to analyse the various contributors to an overall risk as a basis for determining the major contributors. This can be a useful for targeting improvement activities to best effect
- It can be a useful way of demonstrating that certain events are so unlikely to occur that no specific actions may need be taken to protect against them

Some of the drawbacks of the technique are:

- It can be a complex analysis, frequently computer-aided, and, as a result, the analysis can lack 'transparency'
- There is a danger of over-confidence in the estimates of probability
- There may not be sufficient specific data available for a particular case
- Assumptions generally have to be made and sometimes the limitations of these can be overlooked

Because of such drawbacks, QRA is not a universally accepted approach. In an alternative approach, quantification is limited to more deterministic methods in which the consequences and effects of certain defined hazard scenarios are evaluated. The scenarios are selected on a judgmental basis as ones which are considered to have some definite chance of occurring. In particular they may be what is judged to be 'worst case' or 'worst credible event' scenarios.

Some advantages of such a 'deterministic' approach are:

- It is not dependent on possibly questionable probability data
- Using a defined set of scenarios can be a basis for a consistent approach to the assessment of similar types of hazard in similar situations
- The analysis is less complex and hence more 'transparent' than QRA

Some drawbacks of the deterministic approach are:

- It cannot compare different types of hazard on a consistent, 'equivalent risk', basis.
- Where the technique is applied with a rigid, prescribed, set of scenarios there can be the possibility of over-estimating the 'risk' of some situations and under-estimating the 'risk' of others.
- There can be wide variations in what is considered the worst credible event.

For more discussion of the relative merits of QRA and the deterministic approach see the EPSC report on Safety decisions, and safer designs: quantitative risk and deterministic methods. *(To be released by EPSC shortly)*

3.4 Guidelines and criteria for risk assessment

Although assessing the results of hazard and risk analysis is heavily dependent on experienced judgement, it is helpful to have some guidelines and criteria to assist decisions. Following are some examples of the various guidelines and criteria used in some companies.

3.4.1 Accepted standard practice

Where appropriate recognised engineering codes and standards are available, their application can mostly be taken to control risk to a sufficiently low level. This premise is written into the statements of performance in Examples 2-6 and 3-6. The premise can only hold good, of course, as long as the codes and standards are wholly relevant to the particular situation.

Codes and standards mostly improve with time as experience accumulates. This, in turn, gives a measure of risk reduction where updated codes or standards are introduced. However, the extent to which existing situations are 'retro-fitted' to meet the requirements of an updated code or standard can be a judgement according to the significance of the update. Clearly, if the change is one with important implications with regard to safety, the changed requirements should be implemented. Sometimes it may be impractical to implement a changed requirement and, in such cases, it would be necessary to identify some alternative action which may need to be taken to achieve a corresponding improvement. For example, an up-dated vessel design code might call for an increased corrosion allowance; existing vessels might not meet that requirement but could be subject to a more stringent inspection regime to compensate.

3.4.2 Precedence

It may be possible to judge that a proposed new situation is satisfactory by comparison with an existing situation the risk of which is already deemed tolerable. The existing situation may itself have been judged satisfactory as a result of specific risk assessment or by virtue of its having become established good practice. Comparative hazard and risk analysis could be used to demonstrate that the risk of a proposed situation is not significantly different from the 'acceptable' existing situation. Example 3-1 is a guideline based on this principle.

The dictum of 'continuous improvement' requires that this approach is not used to justify a risk that could be reduced by further measures which could be economically applied. Also, care needs to be exercised to check that there are no adverse cumulative effects from added increments of risk.

Example 3-1: *ex ICI (see NB below)*

Comparative frequency of specific hazards

"For similar circumstances with respect to the exposure of persons to the hazards, the frequency of a new specific hazard may be deemed acceptable if it is similar to the frequency of an existing comparable specific hazard that has been deemed to satisfy the statement on tolerability of risk *(see Example 3-6)*.

This approach may be considered when the consequences of, and exposure to, a hazard cannot be estimated with sufficient accuracy to permit a reliable estimate of risk. It is only valid when the situations are comparable with regard to the nature and the likely effects of the hazard."

NB This is an extract from guidance developed in 1985 for use in major hazard businesses which are now no longer part of the ICI Group.

3.4.3 Risk matrices

Some form of consequence/frequency matrix is the most commonly used risk management decision aid. Most typically they take the form of a 4 x 4 or a 5 x 5 matrix but other arrangements are also used. One axis of the matrix has a consequence scale and the other a hazardous event frequency scale. Mostly both scales are defined in qualitative or semi-quantitative terms. They feature 'word picture' descriptions of hazard outcomes for a range of consequences set against descriptive indicators of frequency (risk). Consequence descriptions can cover the full range of vulnerabilities, that is, health and safety of personnel, environmental impact, business interruption and material damage, impact on the public and company reputation.

Several examples of essentially similar risk matrices are given below to illustrate how different companies have developed the approach to suit their needs. The matrix approach can be used both for risk screening and for more detailed assessments for process and plant design.

Example 3-2 is a typical consequence/frequency risk matrix.
Example 3-3 is a matrix specifically for risk screening purposes.
Example 3-4 is a matrix primarily for design purposes.
Example 3-5 is a matrix approach used for risk screening, action planning and design purposes.

The risk matrix is usually banded into regions determined by the significance of risk and the actions that may need to be taken (e.g. as in Example 3-3). Most usually, a three tier framework is used to help judge the tolerability/acceptability of a risk. Figure 3-1, taken from reference 8, shows a typical framework which has:

- An ‘intolerable’ region where the risk cannot be justified whatever the benefit might be. If the risks of an activity fall into this region immediate action should be taken to reduce them or the activity discontinued, irrespective of the costs involved.

- A middle region where the risk is deemed tolerable but subject to the requirement to take such action as is feasible to reduce the risk to a level which is as low as is reasonably practicable (ALARP).

- A region of low risk where the risk can be deemed very low indeed or “broadly acceptable”. No further consideration of the risk may be necessary.

In considering whether a risk is ALARP, the cost of any risk reduction measures may be weighed against the risk reduction benefit that might be achieved. The higher a risk the more an operator could be expected to pay to reduce the risk. Where the risk is less significant, the less, proportionately, can an operator be expected to spend to reduce the risk further. An operator is not expected to implement risk reduction measures whose cost would be in gross disproportion to the benefit to be gained (see also section 3.5.1).

The matrix approach is useful for the broader risk screening assessments of a site, facility or business region which may be needed both to provide an overview of the risks and to identify and prioritise concerns needing management attention. See Example 3-3 (a ‘risk screening process’) for an example of a matrix used for that purpose. Note that the matrix scales, particularly the incident likelihood scale, are defined to reflect the wider scope of the situation being assessed. For example, the impact of an event may be of less significance at country or regional level than at site level.

It can be helpful to define matrix scales with a measure of quantification giving corresponding numerical indicators within or against the ‘word picture’ definitions. In some instances the scales are fully quantified. Example 3-4 includes an example of a quantitative frequency scale.

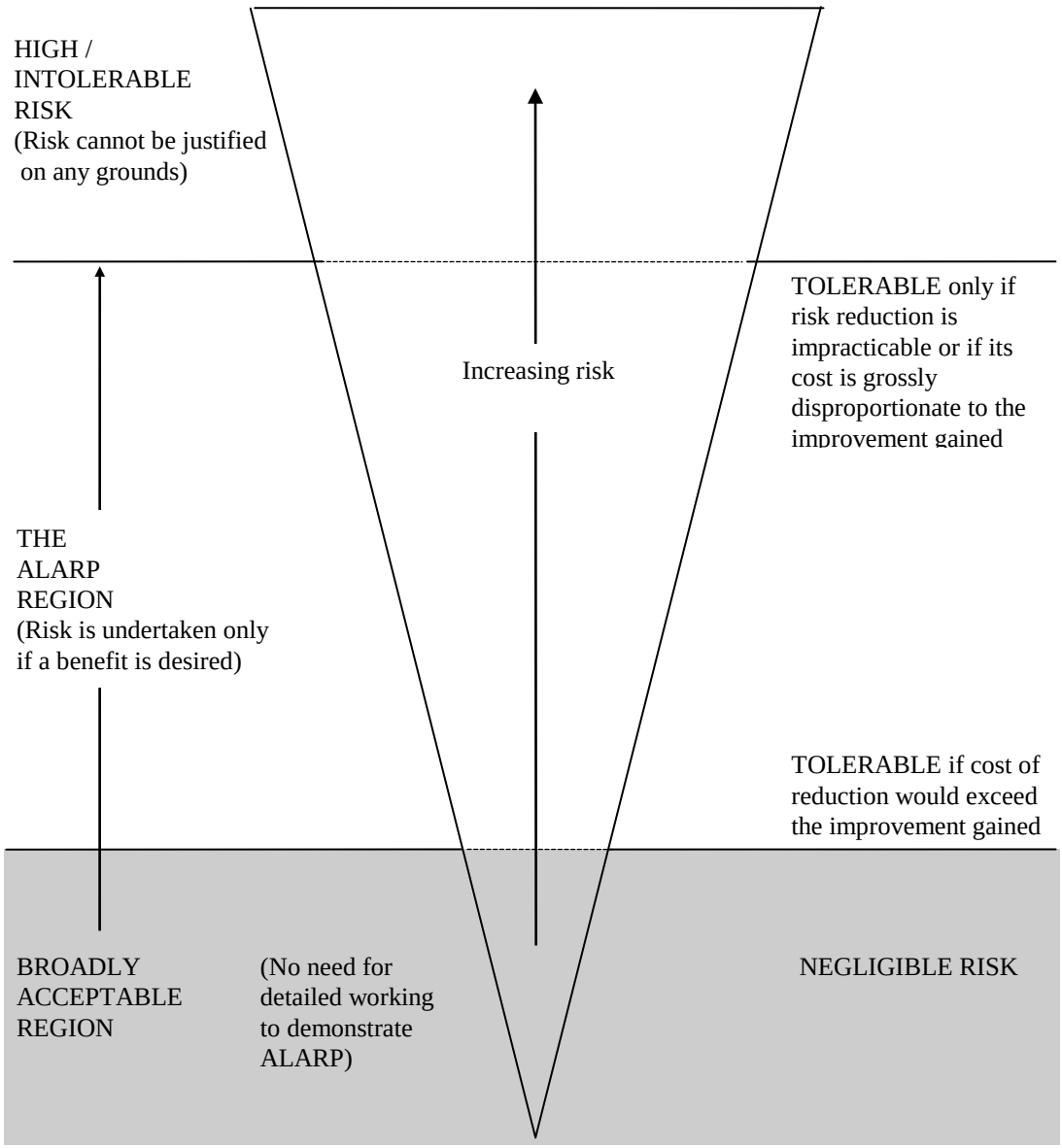


Figure 3-1: Typical three-tier framework for significance of risk
(taken from reference 8)

The principle objective of risk assessment is to allow appropriate control measures to be put in place. The measures should be commensurate with the level of the hazard and potential risks; the greater the hazard and potential risks, the more 'barriers' should be provided. Although this requires judgement on a case by case basis it can be helpful to define some 'ground rules' with regard to the number of barriers for different situations. Example 3-4 is an example of a matrix for project design purposes and also includes an example of such guidelines.

Note that for project design purposes the matrix scales, particularly the incident likelihood scale, are defined somewhat differently from those for risk screening because of the narrower scope of the assessment (contrast the matrices in Examples 3-3 and 3-4).

Example 3-5, Zurich Hazard Analysis (ZHA), is a standardised risk assessment approach utilising a 6 x 4 matrix. ZHA is used by several companies for the assessment of new projects and for the management of changes that have significant SHE implications. The 'standard' matrix scales are deliberately defined in coarse terms only. The user establishes more detailed severity and likelihood definitions and also 'acceptability' criteria as appropriate to the situation to be assessed.

Example 3-2 *Exxon*

Risk matrix

The matrix is defined with four levels of consequence and five categories of probability. It is used to record anticipated, hypothetical scenarios that describe how a hazard could result in harm or damage. Data to position a particular hazard on the matrix in relation to its consequence and probability is generated by judgement, experience and the use of engineering assessment tools. As approved by the Company legal department, the matrix uses only words to describe both consequence and likelihood.
Although detailed hazard analysis may be used to place scenarios on the matrix, the presentation is simple and useful for risk communication.

Considerations for determining probability category [(1)]

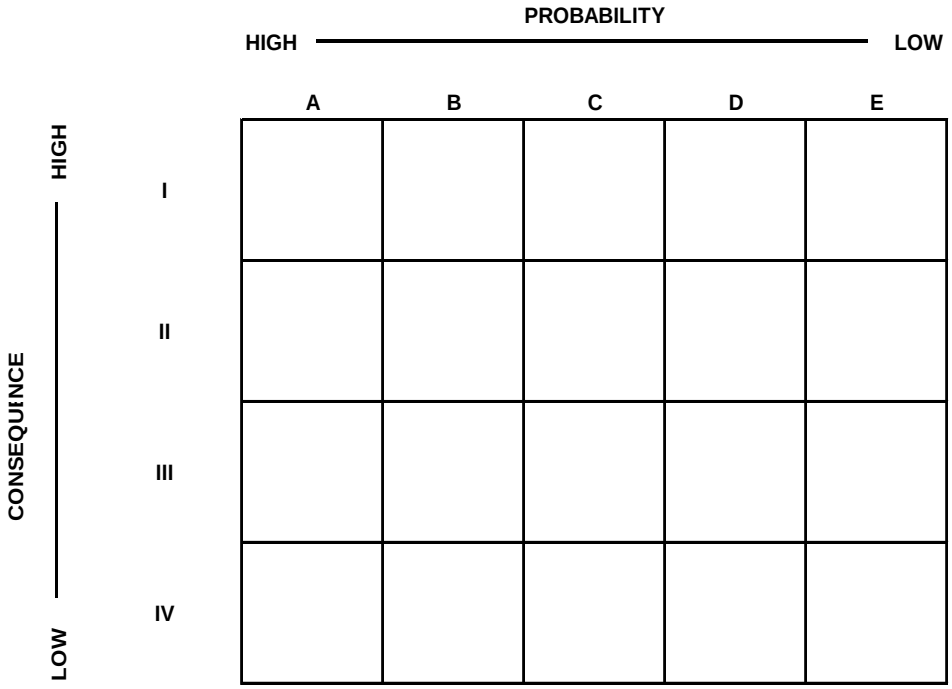
Probability category	*Definitions*
A	Possibility of repeated incidents
B	Possibility of isolated incidents
C	Possibility of occurring sometime
D	Not likely to occur
E	Practically impossible

Considerations for determining consequence category [1]

Consequence category	*Health and safety*	*Public disruption*	*Environmental impact*	*Financial impact*
I	Fatalities / serious impact on public	Large community	Major / extended duration / full scale response	Corporate
II	Serious injury to personnel / limited impact on public	Small community	Serious / significant resource commitment	Region / affiliate
III	Medical treatment for personnel / no impact on public	Minor	Moderate / limited response of short duration	Division / site
IV	Minor impact on personnel	Minimal to none	Minor / little or no response needed	Other

(1) To the extent possible, estimates of probability and consequence should be derived from experience during the life cycle of similar operations in Exxon and its affiliates. Industry experience should be considered when limited Exxon experience is available.

The matrix:



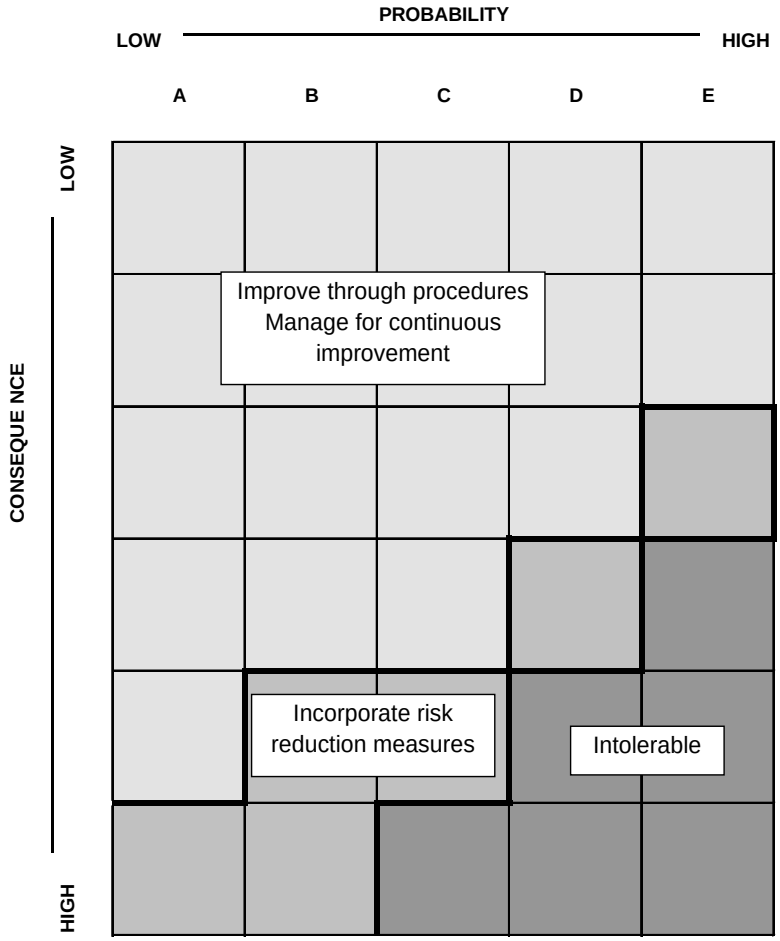
Example: 3-3 *Shell*

Risk screening process

Steps in the process are:

- Indicate the risk tolerability criteria on the matrix
- Plot the identified and assessed hazard scenarios on the matrix
- Identify key scenarios for management attention

Matrix



Incident consequences scale:

Rating	People	Assets	Environment	Image
0	No injury	No damage	No impact	No impact
1	Slight injury	Slight damage	Slight impact	Slight impact
2	Minor injury	Minor damage	Minor impact	Limited impact
3	Major injury	Local damage	Localised impact	Considerable impact
4	Single fatality	Major damage	Major impact	Major national impact
5	Multiple fatalities	Extensive damage	Massive impact	Major international impact

Incident probability scale:

A	B	C	D	E
Never heard of in process industries	Heard of incident in chemical industry	Incident has occurred in Shell Chemical	Happens several times per year in SC	Happens several times per year at location.

Example 3-4: *Shell*

A risk matrix for the initial assessment of a Unit and to determine level of protection.

Incident scenarios identified as feasible for the Unit being assessed (e.g. an off-shore rig) are evaluated and plotted on the matrix below. Scenario event frequencies are calculated as Unit frequencies using data from company experience as far as possible, e.g. 5 accidents of a certain type in the North Sea in one year with 20 rigs operating gives a frequency of 5/20 (0.25) per year.

The matrix:

Consequence per event (see scale below)

Probability (see scale below)	**LOW**				**HIGH**
LOW	100 to 10,000	1000 to 100,000	10,000 to 1,000,000	100,000 to 10 MM	10 MM and up
	10 to 1000	100 to 10,000	1000 to 100,000	10,000 to 1,000,000	100,000 to 10 MM
	1 to 100	10 to 1000	100 to 10,000	1000 to 100,000	10,000 to 1,000,000
	0.1 to 0.2 10	1 to 100	10 to 1000	100 to 10,000	1000 to 100,000
HIGH	Up to 1	0.1 to 0.2 10	1 to 100	10 to 1000	100 to 10,000

(The figures in matrix cells above are the product of the probability range and financial consequence range. Hence, for each cell they give a measure of the annualised business loss that could result from an event whose estimated probability and consequence parameters place it in that cell.)

The matrix is banded into risk levels according to the following risk legend:

Risk legend	Low risk	Moderate risk	High risk

Definitions of consequences per event:

Business	Up to $10,000	$10,000 to $100,000	$100,000 to $1 MM	$1 MM to $10 MM	$10 MM and up
Reputation	Negligible	Minor	Community impact	State impact	National/ International impact
Environment	Negligible	Minor	Localised	Major	Extensive
Personnel	First aid(s)	Minor injury or illness	Multiple injuries or illness	Serious injury or illness	Fatality (ies)

Definitions of annual probability of event:

Has occurred in Unit	Times in 10 years	0.1 to 1.0 per year
Has occurred at Location	Times in 100 years	0.01 to 0.1 per year
Has occurred in Company	Times in 1000 years	0.001 to 0.01 per year
Has occurred in Industry	Times in 1000 years	0.0001 to 0.001 per year
Has never occurred	Times in 100,000 years	Up to 0.0001 per year

From the risk legend and the position of the scenario in the matrix, minimum control measures required are as follows, according to the rating of risk level:

Prevention measures:

Low risk: At least one procedural barrier
Moderate risk: At least two barriers
High risk: At least three barriers

Recovery measures:

Low risk: At least one measure to abate
Moderate risk: At least two measures (detection, abatement)
High risk: At least three measures (detection, abatement, emergency)

Measures to limit escalation:

Low risk: At least one work instruction
Moderate risk: At least one control (procedure or hardware)
High risk: At least two controls (procedure or hardware)

Example 3-5: *Clariant*

Zurich Hazard Analysis

First a 'Hazard Catalogue' is developed. This is a listing of identified hazard scenarios with an evaluation of their severity and likelihood. From that the numbered scenarios are plotted onto the matrix to generate the 'Risk Profile'.

The team has to define the classes/categories on both axes of the profile matrix for each study individually. There are no fixed rules. Based on the definitions chosen, the team also defines the 'protection level' i.e. the line separating the acceptable and non-acceptable risks.

From the matrix any 'unacceptable' scenarios are readily identified, i.e. those above the 'protection level'. The profile is also useful presentation of the risks of the project, or other situation, for risk communication purposes. An 'Action Plan' is developed which will move any 'unacceptable' scenarios into the 'acceptable' region of the matrix by reducing the severity or likelihood of the scenario.

Broad descriptions of matrix scales, to be developed for each study:

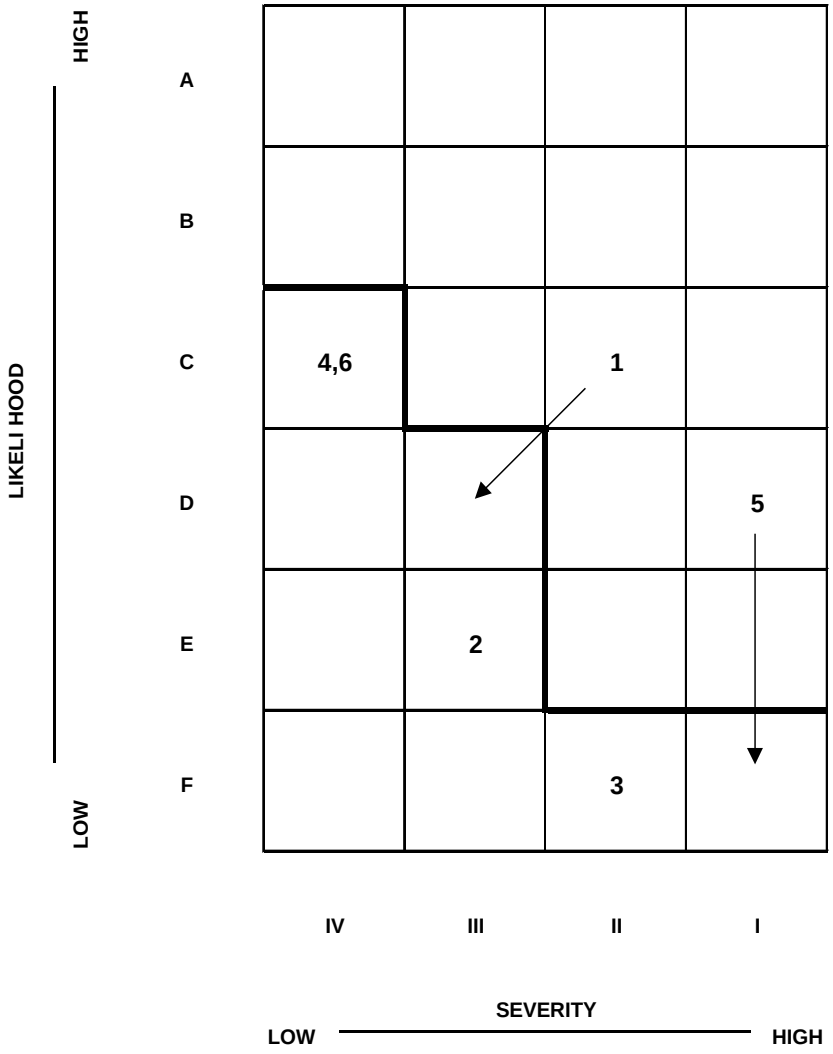
Severity of effect:

I: catastrophic
II: critical
III: marginal
IV: negligible

Likelihood of occurrence

A: frequent
B: moderate
C: occasional
D: remote
E: unlikely
F: impossible

The matrix



3.4.4 Risk criteria

Where quantitative or semi-quantitative evaluations of risk are made, some form of corresponding semi-quantitative or quantitative criteria are required against which to assess the results. Companies that use this approach set criteria taking account of the accumulating expert and regulatory knowledge base. The background and detail is well discussed elsewhere (see references 8, 9 and 10 for example).

Criteria may be required for two types of situation:

1. To assess the significance of the risk to individual persons, either workers on-site or members of the public off-site. These are referred to usually as criteria for 'individual risk'.
2. To assess the significance of the risk of an incident with the potential to cause multiple fatalities. These are referred to as criteria for 'group' or 'societal' risk.

Criteria for individual risk are usually expressed as the annual chance of a single person suffering a defined level of harm (e.g. death). Although there is no universal agreement on the levels of risk that can be judged 'acceptable' or 'tolerable', there is a reasonable consensus on the band of individual risk within which judgements have to be made. Some companies have set individual risk criteria noting that consensus. In some instances there are criteria set by the regulatory authority that have to be noted.

Most quantitative risk assessments carried out in companies are for the evaluation of individual risk. But, even when QRA is used, it is generally limited to situations involving major hazards and then only applied to a small proportion of hazard scenarios. Most situations are assessed without QRA.

Criteria for group or societal risk are usually expressed in terms of the annual frequency with which a defined number of persons could suffer a defined level of harm. This is a contentious area. Evaluations of group risk are subject to much greater uncertainties than individual risk and there is no consensus on levels of acceptability/tolerability. Mostly specific quantification of group or societal risk is only attempted when there is a regulatory requirement and any criteria/guidelines set by the regulatory authority are used.

Criteria may be set as a 'limit value' of risk which should not be exceeded. The risk management aim is to reduce the risk as far below the limit value as is reasonably practicable. Examples 3-6 and 3-7 include criteria set on that basis. Example 3-8 is an example of the alternative approach which sets upper and lower risk criteria to define the limits of a three zone framework as is illustrated in Figure 3-1.

Numerical values of risk are not easily comprehended by most people. The 'word picture' approach used to define the scales of risk matrices can also be used to define risk criteria in more easily understood terms. Example 3-6 is an example of this approach in which the criteria are first stated in essentially qualitative terms which are capable of interpretation in quantitative terms.

Risk criteria set as a risk of death can be emotive. Example 3-9 gives an alternative approach in which the criteria are described as indices rather than risk values. One index is defined in terms of the mean time between incidents capable of causing the specified level of harm. In effect, that index is the reciprocal of a risk value.

Example: 3-6 *ex ICI (see NB below)*

Summary of guidance and criteria for tolerability of risk

The principle guidance was given as a qualitative performance standard the main points of which were:

- when planning, designing and modifying plants and operations handling chemicals, hazard studies will be commenced before detailed design to identify associated hazards (Note 1). Where reasonably practicable such hazards will be eliminated
- The risks (Note 2) from the hazards remaining will be reduced to a tolerable level by the appropriate design of equipment and operations which will be based on the relevant most up-to-date Codes of practice available supplemented by safe practices developed from operational experience
- If the risks associated with the proposed activity cannot be reduced to a tolerable level the proposed activity will not be operated
- Where any significant hazards remain which can give rise to risks of fatal injury to employees and/or to members of the public, then an assessment of those risks should be made
- In judging the tolerability of risks associated with all new plant/processes, and modifications to existing plants/processes, the following guidelines shall be observed, with due regard to the uncertainties in the assessment procedure:

    (a) For the **employee at greatest risk** from the activity concerned, the annual risk of fatal injury from a chemicals-related accident should, wherever reasonably practicable, be no greater than the average risk of a fatal accident occurring to a fit adult of working age at home in the UK

    (b) For the **member of the public exposed to the greatest risk**, the risk of fatal injury as a result of a chemicals-related accident arising from company activities should not be significant when compared with other risks to which he or she is exposed in everyday life in the UK

    (c) If the potential consequences in terms of injury to people as a result of a chemicals-related accident can be very high, the probability that the accident might occur should be correspondingly low

Notes: In the context of the above:

1. Hazard is the potential for acute injurious effects resulting from accidents involving chemicals in which the harm results primarily from the properties of the chemicals involved
2. Risk is the likelihood of a specified level of harm arising in a specified period

Guidance was developed giving numerical criteria to facilitate the interpretation of the qualitative performance standard in quantitative terms. The numerical criteria were set as upper limit values of risk to be taken as indicative, not absolute. The upper limits were not be exceeded unless adequate justification could be demonstrated. In practice, the stated aim was to achieve risk levels as far below the upper limit as was reasonably practicable. The guidance included the diagram below which indicated the limit values in the band of risk within which judgements on tolerability had to be made. It is important to note that the limit values were used to assess major peak risks to the person(s) at greatest risk, they did not indicate the overall average risk expected to be achieved.

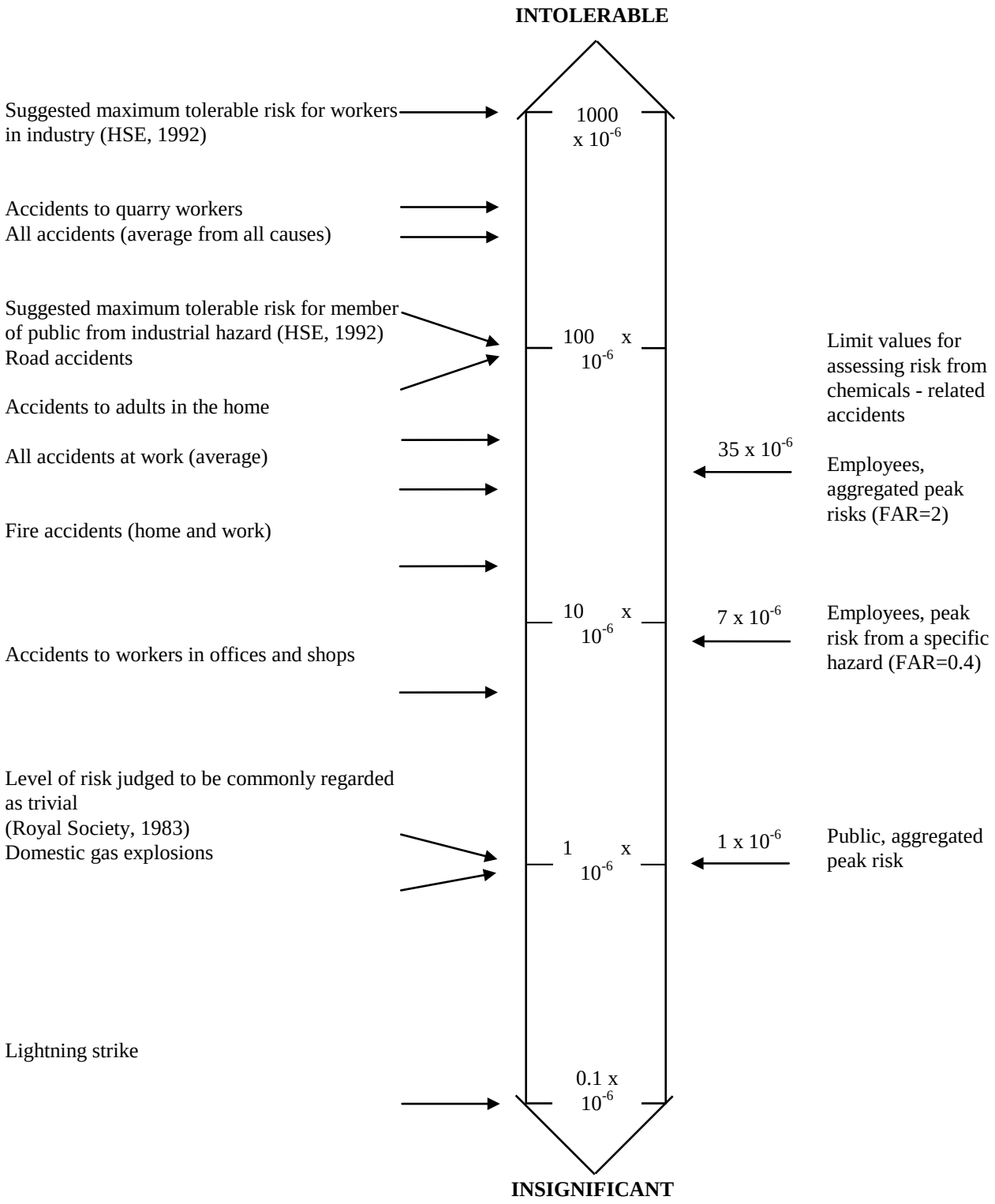


Figure example 3.6 : The band of risk and risk limits in terms of risk of death per person per year
NB This is an extract from guidance developed in 1985 for use in major hazard businesses which are now no longer part of the ICI Group.

Example: 3-7 Rohm and Haas

Risk guidelines for new facilities

Community individual risk	The maximum individual risk of a fatality to a potential resident at the plant boundaries	$< 10^{-5}$ per year (risks below 10-7 regarded as negligible)
Community societal risk	The maximum societal risk to residents (10 or more fatalities)	$< 10^{-5}$ per year
Industrial individual risk	The maximum individual risk of a fatality to an employee of a neighbouring firm	$< 10^{-5}$ per year
Industrial societal risk	The maximum societal risk to employees of a neighbouring firm (10 or more fatalities)	$< 10^{-5}$ per year
Employee personal risk	The maximum individual risk of a fatality to an on-site Rohm and Haas employee	$< 2.5 \times 10^{-5}$ per year

Example: 3-8 *BP*

Recommended three-tier framework of risk criteria

(Three-tier framework similar to that illustrated in figure 3-1)

	Description	Total individual risk to workers (per year)	Total individual risk to members of the public (per year)
Zone A	Levels st which risk reduction must be considered	$> 10^{-3}$	$> 10^{-4}$
Zone B	Levels at which mitigation, or at least additional risk assessment is required	10^{-3} to 10^{-5}	10^{-4} to 10^{-6}
Zone C	Levels at which further reduction of risk need not be considered	$< 10^{-5}$	$< 10^{-6}$

Example: 3-9 *DuPont*

Risk criteria applied when QRA is used.

Quantitative risk assessment may be used in the case of hazards of extreme concern and when large capital expenditure is required.

The following guidelines are applied:

On-site risk

Internal criteria for:

- Individual Hazards Index (IHI)
- Process hazards Index (PHI) for on-site personnel group risk

Off-site risk

Follow international criteria for:

- Individual risk
- Group risk

IHI is defined as fatal injuries per 100MM hours exposure to an activity. This is equivalent to the parameter (FAFR) introduced by ICI in 1974 and is a useful measure of peak risks to individuals while they are performing hazardous tasks of short duration.

PHI is defined as the interval between occurrences of an undesired top event (determined by fault tree analysis) multiplied by the probable number of fatalities if the top event were to occur.

IHI and PHI enable process risks to be put into perspective by relating the index values of a process, derived by risk computations, to statistics of the same parameters for a variety of occupational, voluntary, involuntary and disease risks. The criteria DuPont applies for IHI and PHI are used to determine priorities rather than to make decisions on acceptability. There is an over-riding requirement always to search for feasible ways to reduce process risks further.

3.5 Making decisions

Management is about making decisions and decision making aids are built into many of the risk assessment processes that have been outlined – see, in particular, examples 2-11, 2-13, 2-15, 3-3, 3-4.

3.5.1 Cost/benefit considerations

Quantitative risk assessment enables the improvements that could be achieved by particular risk reduction measures to be set against the cost of implementing the improvements as an aid to selecting the most viable options.

One simple methodology, used in some companies, is to compare the estimated annualised cost of a hazardous event with the estimated annual cost of implementing measures to reduce the risk of damage. The former is approximately given by the estimated potential cost of the damage caused multiplied by the estimated frequency of the incident. The magnitude of the ratio of the two costs may help resolve some cases. When assessing the cost of incidents it should be noted that several studies have shown that the 'hidden costs' of incidents are several times the 'visible' costs.

It is wise to use such cost-benefit techniques within a framework which recognises that it would be unjust and inequitable to expose people to very high levels of risk. This approach has been adopted by the HSE in the UK where three levels of risk and appropriate actions have been defined (reference 8) as already outlined in section 3.4.3 and figure 3.1 of this report. Risks which are below the intolerable level, but above the broadly acceptable level need to be reduced 'As Low As Reasonable Practicable' (ALARP). Cost benefit can be used to decide which improvements need to be implemented. In general risks are only accepted if the costs involved in their elimination would be **disproportionate** to the costs of the accident or incident involved.

Interpreting this principle is largely a matter of judgement using previous decisions as a guide. Sometimes the practice from risk management in other sectors can be helpful - see example 3.10.

Example 3.10

Application of ALARP in the UK

A reference figure sometimes used for cost/benefit calculations is the 'equivalent cost of a fatality prevented' of £0.95m which is used in assessing road improvement schemes. Any improvement where the cost of avoiding a fatality is less than this figure should be implemented. Even where the cost is several times the above figure the disproportion rule would mean that the improvements should be made. No upper limit has been defined but it would be unusual to require improvements where the costs are very much greater than, say more than 10X, the above figure.

In using cost benefit analysis consideration also needs to be given to the difference between risks to employees and risks to members of the public. Employees have some element of choice in accepting a risk and can be seen to gain financially through their wages. By contrast members of the public have limited choice in accepting a risk and will usually receive no direct financial gain. These differences need to be reflected in the cost /benefit analysis.

3.5.2 Uncertainty and other factors

When using quantitative risk assessment, it needs to be recognised that estimates of risk, however cleverly quantified, can only be approximate. Where quantitative risk criteria are set, whether by a company or a regulatory authority, they cannot really be regarded as absolute because of the, possibly considerable, uncertainty there will mostly be in the risk estimates which have to be assessed against the criteria. Decision making has to be a pragmatic judgement. It needs to take account of the uncertainties in any risk predictions. It needs to take note of achieved performance and the application of established design standards and methods as well as any social and economic factors that should be considered. Hence some deviation from numerical criteria may be justifiable. It is beyond the scope of this report to discuss the complex issues there may be in decision making; reference 11 is some useful further reading.

4. 'The Challenge of Assured Risk Management'

Good risk management requires there to be a good system in place and good compliance with the system. The challenge is to have full assurance that that is the case at all times. The audit and review elements of the system are vital aids to having assurance. However, it is also necessary to be aware of, and avoid, the pitfalls and negative influences that can degrade risk management. We need to heed the lessons from incidents where risk management has failed. Two disasters which provide graphic examples are reviewed below.

The Challenger disaster:

The first is the disaster that befell the NASA space shuttle called, somewhat ironically 'Challenger'. In January 1986, shortly after lift-off, a critical double O-ring joint seal between segments of the booster rocket failed, causing hot gases to impinge on the main fuel tank. The tank exploded, destroying the shuttle and killing the seven astronauts on board.

Extensive research to understand the reasons for the disaster identified some organisational/cultural issues which influenced decisions leading up to the accident (reference 12). They are relevant to most risk management situations. In brief some of the influences were (see footnote[1]):

- A tendency in a technical regime to develop a culture which is ready to accept (through rational argument) incremental increases in the 'riskiness' of a situation (e.g. the acceptance of more and more 'demands' on a control 'barrier').
- Production centred, 'risk-taking' business culture which can erode SHE priorities and have adverse effects on SHE decisions. Competition and scarce resources can create pressures for cost reduction for meeting production schedules. Beware the 80-20 syndrome – it is vital to recognise when '80%' is not enough, especially when assessing risk.
- 'Organisational secrecy' between, for example, operating management, technical support and business management, as result of incomplete information exchange (not necessarily deliberate).

[1] Acknowledgement: The discussion of the Challenger disaster is based on a presentation by G K Haseltine of Du Pont, who studied the investigation reported in reference 11

A summary of some of the key aspects of the Challenger disaster

The technical causes of the disaster involved the O-ring seal between segments of the booster rocket. This had a primary O-ring backed up by a secondary O-ring for redundancy. Early in the programme (in fact, nine years before the disaster) it had been noticed that, under thrust conditions, the joint segments separated slightly, exposing the O-rings to some hot gases. The double O-ring prevented leakage but the design was recognised as not optimal although it was considered satisfactory after some reinforcement of the joint. Complete redesign was ruled out on the grounds of the cost and delay that would have been incurred. The reinforced joint mostly performed satisfactorily through several launches. However, on some occasions, examination of recovered boosters revealed that the primary O-ring had suffered partial erosion and, in one case, sufficient erosion to allow gases to blow past the ring. The secondary O-ring had remained sound in those instances and, after assessment, it was concluded that the overall integrity of the seal, with the redundant second ring, remained satisfactory. But then both O-rings failed on the January 1986 launch.

The NASA space programme in the 80's had a commercial goal of 24 self-financing, payload carrying, flights per year by 1990. That goal had been set in response to tax-payer criticism that the programme was too costly. There was significant pressure to reduce costs and increase the frequency of flights.

Three organisations at widely separated locations had to communicate with each other on the night of the ill-fated launch. These were the design contractor, mission control and the launch site. The day before the launch was very cold and engineers at the launch site remembered some problems with the O-ring seals during a previous launch in cold weather. That prompted an enquiry to the design contractor with the question "is it safe to launch in cold weather?". The design contractor did not have hard data on the resilience of the O-rings at low temperatures – an investigation of O-ring performance had been planned some time previously but was cancelled because of its likely cost. Based on their judgement, two design engineers had sufficient concerns to recommend that the launch be postponed. That recommendation was communicated to mission control but not directly to the launch site.

Mission control challenged the recommendation, knowing that it was essentially judgmental and not based on hard data. Although anxious not to postpone the launch unless really necessary, they did start to prepare for postponement. The design contractor's people reviewed the situation. The two engineers, who made the first judgement, remained of the opinion that the launch would be unsafe and were initially supported by their technical director. Others were less certain and, influenced by a vice-president with more commercial thoughts, the technical director changed his mind and a consensus conclusion that the launch could go ahead after all was reported back to mission control. Mission control informed the launch site that the launch should go ahead. The subsequent investigation revealed that it was not communicated to the launch site that the decision to proceed had been based on a consensus conclusion regarding the dependability of the O-ring seal. With hindsight, it could be supposed that the engineers at the launch site would have queried the decision from mission control (despite mission control being the higher authority) had they been aware that it was based on a recommendation that was not unanimous.

No rules were broken, there was no intent to do harm, but seven persons died.

Consider whether your company's risk management system would cope with a similar situation by asking questions such as these:

- Does safety have adequate priority?
- Are there sufficient 'checks and balances' to ensure that critical decisions are soundly and transparently based?
- Is there 'organisational redundancy' to ensure that key risk assessments are looked at from another perspective, by other pairs of eyes, perhaps from outside the company?
- Are deviations from the normal thoroughly assessed with regard to the ability of the technology and operating systems to cope?
- Are the limitations of critical protective systems fully understood?
- Is risk management information openly shared between any separate parts of the organisation that take crucial decisions so that the basis for decisions has the full support of all those involved?
- Is there any evidence of over-confidence?
- Is there commitment to a goal of 'zero incidents'?

The Piper Alpha Disaster:

The second disaster with important lessons for risk management involved the North Sea oil production platform Piper Alpha, which was totally destroyed on 6 July 1988 by an explosion and fire which caused the deaths of 167 people on the platform. A significant factor was that Piper was not only a production platform but also received, from neighbouring platforms, oil and gas to be boosted in pressure for transferring onshore.

In considering that disaster it is helpful to bear in mind the following six useful principles for the safe management of a major hazard installation:

1. Hazards should be recognised and the worst foreseeable consequences understood by the operations and business management responsible.

2. Equipment and facilities should be provided which are "fit for the purpose" of reducing the risk from the hazards as far as is reasonably practicable.

3. Systems of work should be put in place to operate the equipment and facilities within the design intent and to maintain its integrity.

4. Appropriate staff should be provided and given sufficient information, instruction, supervision and training to operate the equipment, systems and procedures.

5. Foreseeable emergencies should be identified and appropriate warning, response and recovery arrangements put in place and practised.

6. Monitoring and auditing should be carried out to measure SHE performance. Consultation and review arrangements should be established to progress SHE issues, set targets and promote improvement.

These requirements can be thought of as links in a safety chain. Any weakness in any of the links will compromise safety. From the enquiry into the Piper Alpha disaster (see reference 13), it was evident that, in the risk management of operations on Piper, there were significant weaknesses in every link.

Summary of the Piper Alpha disaster

On the night of the disaster, a pump for pressurising propane rich condensate tripped and could not be restarted. The spare pump had been prepared for maintenance but the relevant Permit to Work documentation appeared to indicate that, apart from electrical isolation, no work had been done. The pump was therefore electrically reconnected and started up. However, a safety relief valve had in fact been removed from the delivery side of the pump and condensate leaked from the valve seat flange which had not been securely blanked off. A second permit to Work had been issued for removal of the relief valve but it was not with the permit covering the overall pump maintenance job nor were the two permits cross referenced. The enquiry revealed that such faults in the permit to Work system were not uncommon.

The leaking condensate caused an explosion in the pump enclosure which ruptured fire walls. The enclosure had not been designed to resist an explosion. An extensive fire resulted which was made worse by oil which continued to be pumped to Piper from other platforms. That continued pumping was as a result of poor and untested inter-platform emergency arrangements. It substantially prolonged the fire. There was some fixed fire protection in the form of water spray headers but the water pump, designed to start automatically in the event of fire, had been isolated because divers had been working under the platform. As a precaution for diver safety, it had become standard practice to isolate the pump whenever divers were in the water, whether or not they were working near the pump suction. As underwater work went on for much of the time the overall safety of the platform had often been compromised through ill thought out safety arrangements. In fact, even had the water spray pump started, the sprays would likely have been ineffective as it was known that the distributor pipes were partially blocked. That had been a long-standing problem, identified by fire protection audits, for which no satisfactory remedial action had been taken.

The oil fire impinged on the large diameter gas riser pipes through which gas was transferred to Piper from neighbouring platforms. Those pipes ruptured and the ensuing fireball engulfed the whole platform. The extreme consequences of rupture of the gas risers had been recognised in a hazard study commissioned to review the need for a fireboat serving platforms in the area. However, no particular risk management action to take account of that major hazard scenario was taken.

There were some casualties directly as a result of the fire and explosions but most of the personnel on the platform made their way to the emergency assembly point in the accommodation module. The module was designed with some fire resistance but was not proof against the thick black smoke from the oil fire. Rescue by helicopter was impossible and it became evident during the enquiry that no-one took command in the emergency and no order to abandon the platform was given. Some men, on their own initiative, jumped into the sea and survived to be picked up by the boats standing by. However the majority stayed in the accommodation module and died as a result of the smoke.

In the space of three hours the platform was totally destroyed and 166 men died, one more died later in hospital.

A particularly significant factor in the Piper Alpha disaster was the lack of an effective risk management assurance process. There was plenty of auditing of certain operations on the platform but it seemed to be of poor quality and resulted in little improvement action.

Consider whether the process for risk management assurance in your company is adequate by asking some questions such as these:

- Is the scope of the assurance process sufficient to review performance in all the aspects that it should, for example, does it cover all the six principles listed above?
- Does the assurance process cover the part played by corporate and business management in risk management as well as the part played by operations management?
- Are all aspects of the assurance process conducted by competent persons with sufficient authority?
- Does the assurance process have a verification element involving an input from persons independent of the business and operations management?

The disasters reviewed emphasise that risk management must take account of 'human factors' alongside the technical issues. The organisational culture needs to be right with all people having a proper attitude to safety and behaving accordingly. The assurance process needs to have elements that cover those aspects. It can be helpful to define the features of the organisational culture that is desired and the behaviours required of managers and workers. At the working level, monitoring by behaviour observation techniques can often be readily done to identify and correct unsafe practices. At the broader level, the behaviour of managers may be amenable to assessment against defined requirements. It is beyond the scope of this report to consider these issues further but Chapter 5 of reference 5 gives some practical examples. Experience of managing 'human factors' is also being shared between EPSC members through the PRISM project.

Finally, it is worth keeping in mind what Brian Appleton, one of the technical assessors on the Piper Alpha enquiry, called the 'bottom line of safety'; he ended his presentations on the lessons to be learned form the disaster with these words:

"Safety is not an intellectual exercise. It is the total of all our efforts on safety that determines whether those that we work with live or die."

References

Listed below are the information sources referred to in the report. This is a small sample of the large amount of literature that can be consulted for more information on various aspects of the subject of risk management.

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