Basic Learnings in Industrial Safety and Loss Management

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Assisted by Mette Rasmussen, M.Sc., E.I.T.

January 1998

"The first ***DUTY OF BUSINESS*** is to survive, and the guiding principle of business economics is not the maximization of profit - it is the avoidance of loss."

-Peter Drucker

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APEGGA
The Association of Professional Engineers, Geologists and Geophysicists of Alberta

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- PETER DRUCKER

A Brief History of Industrial Safety Practices

Until the early 20th century, industry's focus was heavily on the machines that made mass production possible, rather than on the people who operated them. Therefore, the design of the machines did not accommodate the worker, and workers seldom received in-depth training. The health and welfare of the workers, adults as well as children, were not the employer's concern. Long work days, which were intended to produce maximum profits for the company, increased the chances of accidents and resulting injuries or even deaths. However, the accident rate was not considered important, since workers were viewed as expendable commodities.

A 1906-07 survey of the Pittsburgh steel industry in Allegheny County, Pennsylvania found that 526 workers had died in industrial accidents in one year. When these results were widely publicized, people became aware of the state of industrial safety and pressed for change. The first worker compensation law was passed in Wisconsin in 1911. Canada followed soon after with the passing of the Ontario Workmen's Compensation Act of 1915.

Safety-conscious organizations began to evolve. For example, the National Safety Council was formed in New York in 1913, the American Society of Safety Engineers in 1911, and the Industrial Accident Prevention Association in Ontario in 1917. The US Bureau of Labor Statistics was formed to tabulate and publish facts on industrial accidents and the US National Bureau of Standards began to publish safety standards for materials and equipment.

These changes represented significant progress. However, safety still generally meant simply the absence of injury. Injury prevention measures usually involved changing the design of machines; for example, putting guards on machinery.

In the 1930s, employers began to adopt a broader preventive approach as recommended by H. W. Heinrich. In the more progressive industries, managers—who up until this time had been responsible only for quality, costs and production—were now also made responsible for safety. However, the fact that unsafe actions by workers are the immediate cause of a majority of accidents was still generally used as an opportunity to blame the workers when disasters occurred.

The industrial safety practices of the late 20th century, which emphasize accident prevention and control as opposed to freedom from injury, have been largely developed since the end of World War II. Over a period of several decades, managers in industry have come to understand that total loss control involves examining **all** loss exposures, including people, environment, assets and production, and that incidents occur mostly because of problems in management systems. Workers have a responsibility for safe practices, but they should not be solely blamed for accidents. Everyone who works in a plant or factory is responsible for what happens there.

The laws governing industrial safety have also evolved, and have had a significant influence on industrial management and policy. During the 1980s and early 1990s, Canada's environmental and workplace health and safety regulatory requirements increased significantly.

Benefits of the Integrated Approach to Industrial Safety and Loss Management

Most major industries in Alberta today have safety and loss management programs that are designed to promote "the reduction of risk to people, the environment, assets and production." This definition of safety and loss management programs is the one used in this handbook.

Risks to people include injuries on the job (or even death) and health problems that can be attributed to a person's work. Following are the major reasons why successful industries strive constantly to reduce the risk of employee illness and disability:

- to avoid short and long-term suffering of victims and their families
- to protect and retain experienced and well-trained employees, and reduce absenteeism
- to attract new employees who are well qualified and likely to stay with their employer
- to increase morale and job satisfaction

Risks to the environment include the impact of industry on air, water and land, not only during crisis situations and industrial accidents, but on a daily basis. In most cases, a company's definition of "environment" includes the work environment as well as the ecosystem beyond the workplace.

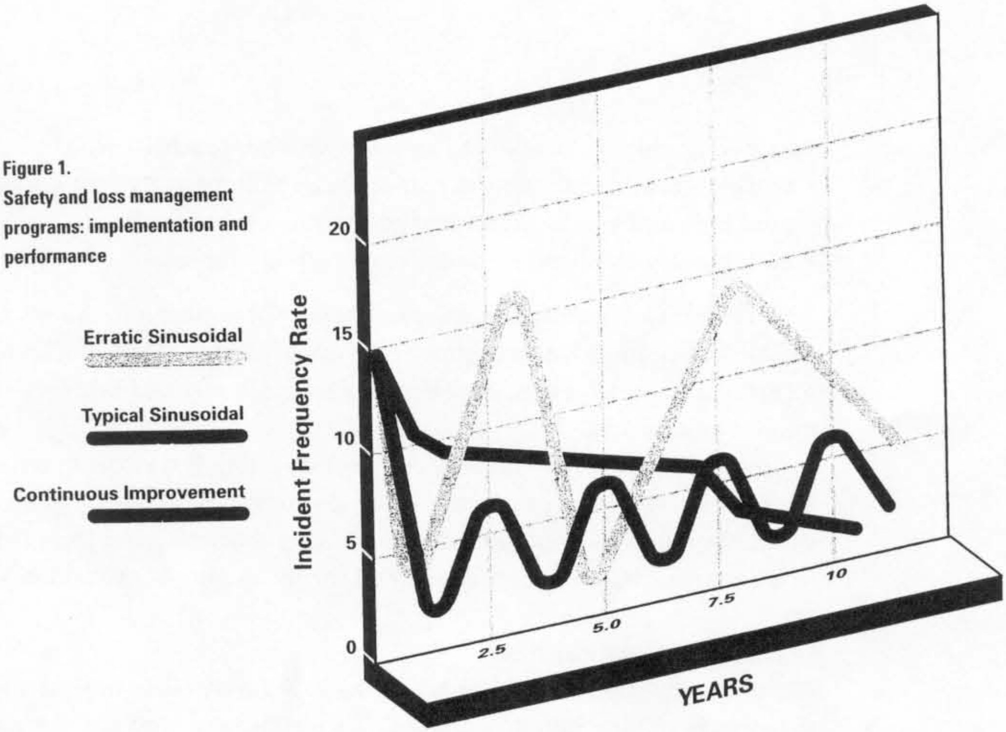
Risks to assets include:

- damage to equipment, facilities and transportation systems
- loss of feed stocks, product and other company materials

Risks to production include delays and interruptions in the work (either sporadic or chronic), and damage to the industry's image in the marketplace.

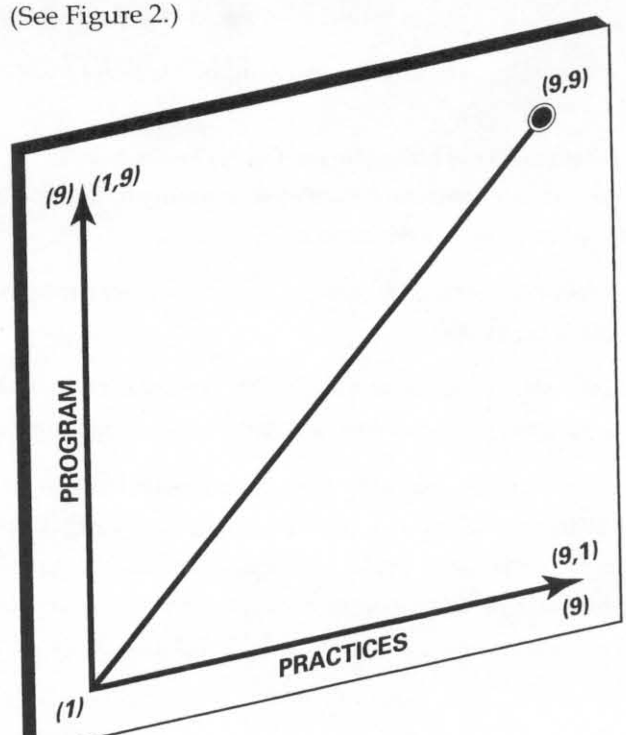
Reducing each of these risks involves continuous efforts to improve safety and loss management results. Typically, industries redouble safety and loss management activities immediately after a major incident or series of incidents, and then reduce the level of activity as time passes—until the next major event happens. Figure 1 illustrates this phenomenon.

Figure 1.
Safety and loss management programs: implementation and performance



Managers have a responsibility to provide leadership and keep the level of commitment to safety and loss management practices as high as possible at all times. This means going beyond the usual first steps—such as publishing procedures manuals, updating equipment and training staff—to actually change people's attitudes and beliefs. The real test is in seeing safe practices adhered to in the field—thoroughly, continuously and voluntarily—with or without the presence of a supervisor or professional staff member. (See Figure 2.)

Figure 2.
The contribution of programs and practices to safety and loss management performance



y-axis: procedures, manuals, equipment, training programs, etc.
x-axis: how effectively it gets done (voluntary compliance)

Many companies have adopted an integrated approach, in which:

- workers' health and safety is part of the overall management system (and the emphasis is on incident prevention and control)
- both management and staff take responsibility for safety

An integrated approach is an effective way of reducing incidents and losses. This approach also improves the quality of life in the workplace for all employees at all levels, increases production levels and improves the quality of products.

Some companies may initially consider devoting less effort to reducing the risks to assets and production costs in order to cut costs and increase the profit margin. However, most companies find that accepting high risk levels in these areas reduces productivity and / or the quality of the end product.

Company Safety Policies

It is not really possible to have zero risks in industry (as in almost any other situation involving human activities). Each company must set its own policy on standards and acceptable levels of risk. The policy should be based on current legal requirements and ethical codes, and on the company's capacity to absorb losses without major effects on the bottom line.

Ideally, a company's safety and loss management policy will have full support from management and extensive input from staff. If the policy is carefully designed, clearly stated and widely circulated, it will assist employees and contractors in carrying out their tasks effectively, and it will raise public awareness of the company's goals.

Following is a sample company policy:

Policy on Industrial Safety and Loss Management: Energy Products Ltd.

Industrial safety and loss management is an integrated and consistent approach to eliminating incidents and reducing risks to people, production, facilities and the environment.

Energy Products Ltd. is fully committed, on a continuous basis, to applying industrial safety and loss management programs throughout all operations in our business.

Energy Products Ltd. will therefore provide safe and healthy working conditions while demonstrating excellence in incident, fire and security protection and compliance with laws and regulations and procedures.

Energy Products Ltd. recognizes that excellent safety and loss management processes can be achieved only through the active participation of everyone at all levels, including contractors, and with full integration of these processes into everyday activities. Consequently, safety and loss management activities must include all members of our company, contractors and the public at large. All employees, contractors and the visiting public must comply with the company's rules, regulations and procedures.

Ms. Fe Thatcher
President and Chief Executive
January 1998

The following definitions are derived mainly from three sources: the Industrial Safety and Loss Management Program, Faculty of Engineering, University of Alberta; the Industrial Accident Prevention Association; and the Canadian Standards Association.

The three key definitions that are essential to the understanding of this handbook are presented first, and additional terms are then listed alphabetically.

Key Definitions

Integrated safety and loss management program:
A program designed to reduce the risk to people, environment, assets and production in an integrated manner in all industrial settings.

Incident/accident:
"Incident" is the preferred term in this handbook because "accident" implies a lack of control over the situation. Accidents are usually thought of as simply bad luck.

Incident: An undesired event that results (or could result) in injury to people, damage to the environment or loss of assets and/or production. (Note that the definition of *incident* includes both an actual loss and a near-miss.) An incident leading to a loss is most often the result of contact with a substance or source of energy (mechanical, electrical, thermal, etc.) above the threshold limit of the body or structure involved or the environment.

Accident: An undesired event that results in harm to people, damage to environment, damage to property or loss to process—or a combination of these.

Additional Definitions

Assessment:
A process that evaluates activities, facilities or systems against requirements or expectations.

Competent person:
In Alberta's *Occupational Health and Safety Act,* "competent", in relation to a worker, means "adequately qualified, suitably trained and with sufficient experience, to safely perform work ... without, or with only a minimal degree of, supervision".

Critical few:
A basic management principle stating that a small percentage of specific items account for the majority of all incidents and costs. (The 80/20 Rule, Vilfredo Pareto, 1843-1923.)

First aid injury:
Injury attended to through the use of standard first aid treatments, with no time lost on the job.

Hazard:

The potential of a machine, equipment, process, material or physical factor in the working environment to cause harm to people, environment, assets or production. For example, a chemical has the potential to cause adverse effects a various levels of exposure.

Hazard identification:

Recognizing that a hazard exists and defining its characteristics.

Housekeeping:

A way of controlling hazards along the path between the source and the worker. Good housekeeping means having no unnecessary items in the workplace and keeping all necessary items in their proper places. It includes proper cleaning, disposal of wastes, clean-up of spills and maintaining clear aisles, exits and work areas.

Human error:

Human error, which accounts for the majority of incidents, includes not only errors by workers but also errors such as engineering deficiencies and lack of adequate organizational controls, and poor management systems.

Incident investigation:

Systematically gathering and analyzing information about an incident in order to identify basic causes and recommend ways of preventing the incident from happening again.

Incident recall:

A system to encourage employees to report all incidents, including near-miss incidents, in a no fault/no blame atmosphere.

Injury frequency rate:

$$\text{Frequency rate} = \frac{\text{(Number of injuries x 200,000 hours)}}{\text{(Total exposure hours)}}$$

Notes:

Total exposure hours = Total number of persons x number of hours worked.
200,000 hours represents the total approximate time that 100 persons would work in one year.

Injury severity rate:

$$\text{Severity rate} = \frac{\text{(Number of lost work days x 200,000 hours)}}{\text{(Total exposure hours)}}$$

See notes above.

Loss control or loss prevention:

Measures taken to prevent and reduce loss through injury and illness, property damage, poor work quality, etc.

Loss control reporting:

A system for reporting all losses to people, environment, assets and production.

Lost time injury:

Absence from work for more than one work day.

Medical aid injury:

An injury that is attended to by a medical doctor but is minor enough to allow the injured person to return to the job on the day of injury.

Near-miss:

An incident that could have resulted in a loss, but did not.

Personal protective equipment:

Any device worn by a worker to protect against hazards; for example, dust masks, gloves, ear plugs, hard hats, safety goggles.

Practices:

Carrying out well defined and established procedures—an area that needs meticulous attention.

Preventive maintenance:

A system for preventing the failure of machinery and equipment by:

- knowing reliability of parts
- maintaining service records
- scheduling parts replacement
- maintaining inventories of the least reliable parts and parts scheduled for replacement

Procedures:

Step-by-step description of safe and efficient approaches to tasks, jobs or activities.

Process:

Any activity involving the production, manufacture, use, storage or movement of potentially hazardous materials.

Process change:

Any modification or change to a process.

Risk:

A function of the probability of an unwanted incident and the potential severity of its consequences.

Risk analysis:

The use of available information to estimate the risks of a hazard—to individuals or populations, property or the environment. Risk analyses generally contain the following steps: scope definition, hazard identification, probability analysis, consequence analysis and risk estimation.

Risk assessment:
The process of risk analysis and risk evaluation.

Risk control:
The process of making decisions about managing risk, and implementing, enforcing and re-evaluating the effectiveness of those decisions from time to time. (The results of risk assessment are used in this process.)

Risk evaluation:
The stage at which values and judgments enter the decision-making process, explicitly or implicitly. A range of alternatives for managing risks is identified by considering the importance of the estimated risks and the social, environmental and economic consequences.

Risk management:
The complete process of understanding risk, assessing risk and making decisions about implementing effective risk controls.

System (activities):
A set of *steps* or *activities* taken to ensure that stated objectives are achieved. A typical system includes these **key elements:**
- agreed-upon objectives and documented procedures
- statements about who is responsible and accountable for implementation and execution, and how resources will be allocated to make this possible
- a measurement process to determine if desired results are being achieved
- a feedback mechanism to provide a basis for further improvement

System (physical):
A bounded, physical entity that achieves a defined objective in its environment through interaction of its parts. This definition implies that:
- the system is identifiable
- the system is made up of interacting parts of sub-systems
- all the parts are identifiable
- the boundary of the system can be defined

Task:
A set of related steps that make up a discrete part of a job. Every job is made up of a collection of tasks. For example, answering a phone or entering data into a computer are tasks of an administrator's job.

Task analysis:
A technique used to identify, evaluate and control health and safety hazards linked to particular tasks. A task analysis systematically breaks tasks down into their basic components so that each step of the process can be evaluated thoroughly. Also known as **job hazard analysis.**

Under current legislation, today's industries cannot ignore the negative impact of their activities on people and the environment. For infractions to worker safety and environmental laws, industries can be fined as much as $1 million, and individuals can also be imprisoned.

The *Occupational Health and Safety Act* states the obligations of employers and workers with regard to safety and sets out penalties for failing to meet those obligations. (Copies may be purchased from the Queen's Printer.)

The *Environmental Protection and Enhancement Act,* along with the statutes of Environment Canada, set standards and limits regarding the emission of certain substances in certain amounts. (See *Environmental Practice: A Guideline,* published by APEGGA as a supplement to the Professional Code of Ethics.)

Although the following summaries for both of the above Acts are provided here for easy reference, all engineers, geologists and geophysicists should take care to read and study copies of the pertinent legislation, along with the accompanying regulations, and keep copies of the Acts and regulations readily available.

Occupational Health and Safety Act

Section 2: Obligations of Employers, Workers, etc.

Every employer must take reasonable and practical steps to ensure the health and safety of employees and any other persons present on the work site. The employer must also ensure that employees are "aware of their responsibilities and duties under this Act and the regulations."

Workers are obligated to take reasonable care to protect their own health and safety and that of other workers present. Furthermore, workers must help the employer to ensure their health and safety and that of other workers on the site, including workers employed by a different employer (contractors, etc.).

Suppliers must take reasonable and practical steps to ensure that:

- any tool, appliance or equipment supplied is in safe operating condition
- any tool, appliance, equipment, designated substance or hazardous material supplied complies with the Act or the regulations

Section 2.1: Prime Contractor

A prime contractor for a work site is the contractor, employer or other person who enters into an agreement with the owner of the work site to be the prime contractor. If there is no agreement, the owner of the work site is considered the prime contractor.

A prime contractor is required if two or more employers are working at the work site at the same time. It is the responsibility of the prime contractor to ensure, as far as it is reasonably practicable to do so, that the Act and regulations are followed and complied with in respect of the work site.

Section 27: Existence of Imminent Danger

Workers must not perform any work task or operate any tool, appliance or equipment if they have reasonable and probable grounds to believe it will create imminent danger to their own health and safety or that of another worker at the work site. Imminent danger means a danger that is not normal for the occupation, or a danger that would cause a person in that profession not to perform the work task.

Section 32: Offenses

If offenses against the *Occupational Health and Safety Act* are committed by responsible people and are proven, the fine for first offense can be up to $150,000 and a further $10,000 per day for the period the offense is continued. This first offense can also result in imprisonment not exceeding 6 months. The maximum fine is $300,000 and a further fine of $20,000 per day for the period the offense is continued and a prison term not exceeding 12 months.

Other important sections in the *Occupational Health and Safety Act* that require the active participation of engineers, geologists and geophysicists:

- Multiple obligations (section 2.2)
- Serious injuries and accidents (section 13)
- Regular inspection of work sites (section 20)
- Report on designated substances (section 24)
- Controlled product (section 24.1)
- Joint work site health and safety committees (section 25)
- Written health and safety policies (section 25.1)
- Code of practice (section 26)
- Where disciplinary action is prohibited (section 28)

OVERVIEW OF KEY ELEMENTS OF SAFETY AND LOSS MANAGEMENT PROGRAMS

Effective industrial safety and loss management programs include a number of key elements that, in combination, form the basis for:

- designing, constructing and operating the company's facilities
- controlling performance by the company, departments and individual employees

This handbook presents 11 program elements, which are drawn from the programs used by leading industrial companies and a program designed by the International Loss Control Institute (ILCI), now called Det Norske Veritas, Incorporated (DNV). Note: The ILCI/DNV program has approximately 20 elements.

Other successful programs that may be of interest include CAER (Community Awareness and Emergency Response), API (American Petroleum Industries), OSHA 1910 (Occupational Safety and Health Administration) and ISO 9000 (The International Organization of Standardization).*

The 11 elements described here are:

1. management leadership, commitment and accountability
2. the assessment, analysis and management of risks
3. design, construction and start-up
4. operations and maintenance
5. the competency and training of employees
6. the competency and integration of contractors
7. change management
8. reporting, investigating and analyzing incidents, and taking follow-up action
9. collecting information and documentation on operations and facilities
10. community awareness and emergency preparedness
11. the evaluation and continuous improvement of programs

Individual companies will need to adapt these elements in accordance with:

- input from employees, who must take ownership and be responsible for implementing the program
- the company's objectives
- the company's style of operation
- the size of the company
- the location of the company
- the type of business

Companies often start by implementing only a few key elements and then expanding as the program matures. Ideally, each element is well defined and has specific standards and objectives.

*More information about these programs is available at the Alberta Labour Library, Occupational Health and Safety section.

1. Management Leadership, Commitment and Accountability

Managers play a key role in planning, organizing, leading and maintaining a safety and loss management program, and in providing the necessary resources. The goal of managers should be to make the safety and loss management program a part of the business plan and culture of the company, and to integrate it with all other company activities. Managers should strive to make everyone in the organization accountable for achieving results and promoting continuous improvement.

Managers need to be aware that:

- people are their most important asset
- safety and loss management provides a significant opportunity for managing costs and improving operational reliability

Following are examples of the roles that managers can play in supporting and promoting the company's safety and loss management program.

Leadership by example. All managers consistently adhere to safety and loss management directives, procedures and rules.

Visibility. Managers visit work sites regularly, during normal operations—not just when things go wrong. They interact with workers; for example at toolbox talks, site inspections and / or monthly safety meetings. Managers actively listen to staff input and feedback, and if possible take steps to resolve issues that are raised.

Leadership through objective-setting and stewardship. Managers establish a visible process of objective-setting and stewardship that involves all members of the organization. There should be constant measurement to see whether objectives have been met, and appropriate action taken to address areas where weaknesses become evident.

Line responsibility. Managers constantly emphasize that safety and loss management is a line responsibility. Safety professionals are a resource, but they are not in charge of and fully responsible for safety. Every employee is encouraged to be a safety officer.

Management participation. All managers take part in safety and loss management activities, at least on some reasonable frequency. (They are involved as participants, as well as leaders.)

2. The Assessment, Analysis and Management of Risks

In this handbook, the term "risk" is defined as a function of the probability of an unwanted incident and the potential severity of its consequences. In other words, the focus of risk management is on losses that have not yet occurred.

Risk management involves eliminating hazards and reducing risks to people, the environment, assets and production. It includes understanding and accepting residual risks after solutions have been put in place—risks are analyzed, quantified and categorized, and then managers decide how and to what extent certain risks can be effectively reduced. This is a never-ending process.

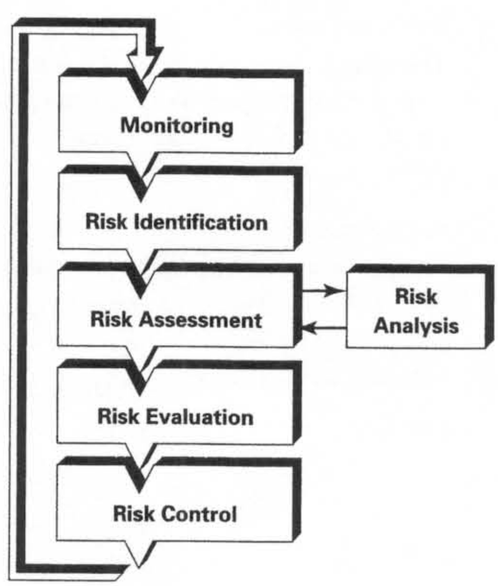
This is the definition of **risk management** used in this handbook: the complete process of understanding risk, assessing risk and making decisions about implementing effective risk controls.

Risk management involves these essential steps, which are constantly repeated:

- system monitoring
- risk identification
- risk assessment
- risk analysis
- risk evaluation
- risk control

These steps may be applied, for example, to physical facilities, procedures, work practices, human factors and organizational changes.

Figure 3.
Risk management flow chart



Definitions

In this handbook, the following definitions are used (see pages 9 to 12 for additional definitions).

System (activities):

A set of **steps or activities** taken to ensure that stated objectives are achieved. A typical system includes these key elements:

- agreed-upon objectives and documented procedures
- statements about who is responsible and accountable for implementation and execution, and how resources will be allocated to make this possible
- a measurement process to determine if desired results are being achieved
- a feedback mechanism to provide a basis for further improvement

System (physical):

A bounded, physical entity that achieves a defined objective in its environment through interaction of its parts. This definition implies that:

- the system is identifiable
- the system is made up of interacting parts of subsystems
- all the parts are identifiable
- the boundary of the system can be defined

Monitoring:

Any activity that is intended to detect deviations and potential risks, ranging from visual checks to hi-tech sensing systems. Monitoring should be the responsibility of staff at all levels, every day.

Risk identification:

The recognition of factors or conditions which could promote failure or loss. This step is often experience-driven but must also adapt to new inputs. Risk identification is really the trigger for the risk management process to begin.

Risk assessment:

The process of risk analysis and risk evaluation; that is, the quantification and ranking of risks in an objective, informal and user-oriented way. Risk assessment precedes a decision to mitigate or control a risk. Otherwise, all risks would be treated equally.

Risk analysis:

The use of available information to estimate the risks of a hazard—to individuals or populations, property or the environment.

Risk analyses, which are used mostly when the potential losses are critical and need to be defined in absolute terms, generally contain the following steps: scope definition, hazard identification and risk estimation. Risk analysis is an objective and formally structured approach to doing a risk assessment. Input is received from several different sources. The analysis tends to be rigorous, methodical and much more time-consuming than risk assessment. Most likely a risk assessment will be done prior to the risk analysis, as a first step.

Risk evaluation:

The stage at which values and judgments enter the decision-making process, explicitly or implicitly. A range of alternatives for managing risks is identified by considering the importance of the estimated risks and the social, environmental and economic consequences.

Risk evaluation puts the risk into perspective and determines whether the risk is acceptable or needs to be acted upon. This step is influenced by the organization's policy on acceptable risk and the costs/benefit of risk reduction.

Risk control:

The process of making decisions about managing risk, and implementing, enforcing and re-evaluating the effectiveness of those decisions from time to time. (The results of risk assessment are used in this process.)

Risk controls (for example, safety practices, procedures and training) mitigate but never totally eliminate a risk.

Industries assess and analyze risks in order to decide how those risks can be eliminated or reduced. (Or, in some cases, they decide that the level of risk involved is acceptable and requires no further action.)

Often, a company will carry out risk assessments and analyses when they are considering a major change. For example, risk assessment and analysis might be done:

- for initial project selection
- for final approval of a project
- for basic and detailed engineering
- during construction
- for start-up
- during normal operations
- for plant additions and continuous improvement initiatives
- for plant shutdowns and maintenance
- for plant demolition and site clearance

For more information about the assessment, analysis and management of risks, see pages 37 to 45 of this handbook, and the Canadian Standards Association publication, *Risk Analysis Requirements and Guidelines.*

3. Design, Construction and Start-Up

Historically, safety and loss management standards, procedures and practices were not integrated into design, construction and start-up activities. However, introducing safety and loss management programs from the outset, including monitoring and stewardship activities that promote continuous improvement, are highly recommended. During design, construction and start-up, there should be safety and loss management criteria and objectives for: design standards and practices, project management, risk assessment, quality control, and pre- and post-start-up reviews and activities.

4. Operations and Maintenance

The safe and reliable operation and maintenance of a facility depends on these factors :

- effective procedures and thoroughly established practices
- qualified staff who consistently execute these procedures and practices
- structured inspections and maintenance systems
- reliable safety systems and control devices
- timely and accurate updating regarding changes (in operations and maintenance, standards, practices, procedures, designs, etc.)
- checks and authorizations through a work permit system
- special procedures for managing high-risk operations

There should also be special procedures and systems to ensure compliance with environmental objectives and regulations; for example, tracking hazardous emissions and wastes, and the efficient and effective abandonment of facilities.

5. The Competency and Training of Employees

Industrial safety depends heavily on the people who are involved. Therefore, managers must establish, adequately fund and use carefully designed systems for the selection, placement, ongoing assessment and effective training of employees.

6. The Competency and Integration of Contractors

Companies today are heavily dependent on the services of contractors of all types (for example, experts in computer software and management systems, construction services, etc.). In some cases, the number of contractors on a site can be as much as three times the number of employees. Since contractors have become an integral part of the operations of most companies, their actions and input can have a major impact on safety and loss management activities.

Managers must therefore ensure that contractors' activities are consistent and compatible with the company's standards, policies, procedures, practices and business objectives. This means establishing systems for evaluating and selecting contractors, and for helping them to improve (encouraging self-monitoring, providing feedback on deficiencies in performance and quality of work, etc.).

Over the last 20 years, deficiencies in company / contractor relationships have been the major cause of a number of serious industrial disasters. For example, this was the primary source of the Phillips 66 polyethylene plant explosion on October 23, 1989, which killed 23 workers and injured 282 others. Property damage totaled $800 million and the loss in production was $850 million. This incident resulted in the largest single insurance claim in the world up to that time.

For more information about the competency and integration of contractors, see pages 57 to 58 of this handbook.

7. Change Management

Change is a given in any industrial operation today. Industry practices must reflect current laws and regulations, and make the best possible use of current technology. Managers must also strive constantly to produce a better product more efficiently in order to remain competitive in a global economy. The result is frequent changes in procedures, standards, facilities and personnel.

Most industries handle major changes well, particularly if there is a project manager assigned to the task. However, there are also numerous small changes occurring almost daily, and often they do not get the same kind of attention. This can be an Achilles heel.

Whenever a change is made, large or small, permanent or temporary, managers and staff should ask these four questions:

- What could go wrong?
- How could it affect me or others?
- How likely is it to happen?
- What can I do about it?

Procedures for managing change should include:

- identifying and assessing the changes
- determining who has the authority to approve changes
- acquiring the necessary permits
- communicating the potential consequences of a change and the required compensating measures
- analyzing safety and environmental implications
- documentation, including reasons for changes
- time limitations
- training

8. Reporting, Investigating and Analyzing Incidents, and Taking Follow-Up Action

Whenever there is an incident, including a near-miss, there is an opportunity to learn and use the information that is gained to take corrective action and prevent a similar incident in the future.

Typically, investigating an incident involves these steps:

- responding to the emergency promptly and positively
- collecting pertinent information about the incident
- analyzing all causes
- developing recommendations and taking appropriate remedial action
- following through to determine the effectiveness of actions

In most cases, an incident is best investigated by staff who know the people and the area; for example, the supervisor or team leader. However, major incidents will also require special investigations teams with members who have specific and relevant expertise.

Near-miss reporting is important because, although there are no damages, understanding the basic causes can help to avoid future incidents that do incur damage. Near-miss reporting helps to raise awareness and provide a refresher course when people are beginning to forget what they have learned in safety training programs.

9. Collecting Information and Documentation on Operations and Facilities

In order to assess and manage risk, the owners and operators of industries must have available all necessary information about operations and facilities. For example, properties of the materials handled, potential hazards and regulatory requirements. To effectively collect and maintain the necessary information and documentation, managers should:

- State clearly who is responsible for collecting and updating information and ensure that all staff understand their roles in this area.
- Identify drawings and other pertinent documentation, such as records covering operation, maintenance, inspections and facility changes, and keeping these documents accessible and current at all times.
- Identify and document the properties and potential hazards of materials involved in operations, and ensure that the staff who need this information have received it.
- Identify and document applicable regulations, permits, codes, workplace standards and practices, and ensure that the staff who need this information have received it.

10. Community Awareness and Emergency Preparedness

People want and need assurance that industries in their communities are adhering to safety and environmental standards. Concerns among community members may include:

- public health and personal safety, short-term and long-term
- the potential for damage to personal property (fire, explosions, vapour clouds, etc.)
- the potential for damage to the environment, short-term and long-term
- fear of unknown risks resulting from having an operation or project in the neighbourhood
- the potential for other losses, such as declining property values, traffic congestion and esthetic issues

In turn, industries have to rely on the surrounding community for various types of support and assistance, particularly in case of an emergency, when the local fire, police and medical services will be invaluable.

These are some of the major components of a community awareness and emergency preparedness plan:

- clearly defined responsibilities that are openly communicated to all involved
- emergency response plans that are documented, accessible and clearly communicated
- the equipment, facilities and trained personnel that are required for emergency response (clearly identified and readily available)
- simulations and drills scheduled at appropriate intervals to provide a state of readiness and ensure continuous improvement

For more information about community awareness and emergency preparedness, see pages 47 to 49 of this handbook.

11. The Evaluation and Continuous Improvement of Programs

In an effective safety and loss management program, frequent monitoring and evaluation provides information that managers and staff can use to continuously improve the program. Unfortunately, this element is quite often overlooked or inadequately implemented.

These are some important aspects of effective evaluation programs:

- Operations or projects are assessed at appropriate intervals (depending on complexity and risk factors) to ensure that all elements of the safety and loss management program are meeting their objectives.
- Multi-disciplinary teams with the necessary expertise are used to conduct the assessments.
- Recommendations by the assessment teams are documented, evaluated and implemented as appropriate.
- The assessment process itself is reviewed periodically to ensure its continuous improvement.

Causes of Incidents

"Incident" is the preferred term in this handbook because "accident" implies a lack of control over the situation. Accidents are usually thought of as simply bad luck.

Incident: An undesired event that does or could result in injury to people, damage to the environment or loss of assets and / or production. (Note that the definition of "incident" includes both an actual loss and a near-miss.) An incident leading to a loss is most often the result of contact with a substance or source of energy (mechanical, electrical, thermal, etc.) above the threshold limit of the body or structure involved or the environment.

Accident: An undesired event that results in harm to people, damage to environment, damage to property or loss to process—or a combination of these.

Table 1 shows examples of injuries to the body, where energy exceeded the threshold limit. Similar examples can readily be found for exceeding the threshold limits of buildings, structures, facilities, equipment, environment, etc. (One source of such examples is the case studies that are included in this handbook.)

Table 1.
Injuries caused by delivery of energy in excess of local or whole-body injury thresholds

TYPE OF ENERGY DELIVERED	PRIMARY INJURY PRODUCED	EXAMPLES AND COMMENTS
Mechanical	Displacement, tearing, breaking and crushing, predominantly at tissue and organ levels of body organization.	Injuries resulting from the impact of moving objects such as bullets, hypodermic needles, knives and falling objects and from the impact of the moving body with relatively stationary structures, as in falls and plane and auto crashes. The specific result depends on the location and manner in which the resultant forces are exerted. The majority of injury is in this group.
Thermal	Inflammation, coagulation, charring and incineration at all levels of body organization.	First-, second-, and third-degree burns. The specific result depends on the location and manner in which the energy is dissipated.
Electrical	Interference with neuromuscular function and coagulation, charring and incineration at all levels of body organization.	Electrocution, burns, interference with neural function as in electroshock therapy. The specific result depends on the location and manner in which the energy is dissipated.
Ionizing radiation	Disruption of cellular and sub-cellular components and function.	Reactor incidents, therapeutic and diagnostic irradiation, misuse of isotopes, effects of fallout. The specific result depends on the location and manner in which the energy is dissipated.
Chemical	Generally specific for each substance or group.	Includes injuries due to animal and plant toxins, chemical burns, as from KOH, Br_2, F_2, and H_2SO_4 and the less gross and highly varied injuries produced by most elements and compounds when given in sufficient dose.

Source: Bird and Germain, *Practical Loss Control Leadership*, 1992.

Today's safety and loss management programs are based on a belief that almost all incidents can be prevented, or at least the degree of severity reduced, with the exception of natural disasters. Incidents have causes; they do not just happen. Therefore, a key factor in any effective industrial safety and loss management program is understanding the causes of incidents such as those described above—both immediate causes and underlying, basic causes.

This is a relatively new approach to industrial safety. Up until the 1960s, industrial owners and operators spent little time analyzing the causes of incidents. They thought they already knew the major cause: it was carelessness on the part of the workers. Consequently, safety programs focused on disciplinary action and / or incentive programs, and staff often responded by attempting to cover up or conceal problems in order to avoid discipline or collect rewards.

It is certainly true that **human error*** is a major cause of incidents. For example, human error was a primary factor in the Flixborough, Exxon Valdez, Piper Alpha and Phillips 66 disasters. Marsh and McLennan's review of large property damage losses indicates that human error was the main cause of 20% of the 170 major incidents occurring over the period 1962 to 1991. For each of these cases (property damage attributed to human error), the average loss was approximately $51.8 million. In contrast, only 4% of the major incidents studied were caused by design errors (although their average loss value was $57.6 million each).

But, it has to be recognized that human error often stems from managers' decisions and policies as well as from a variety of other factors beyond the worker's specific actions and usually beyond the worker's control. What causes workers to be careless? Few actually want to sustain an injury or risk their lives. Carelessness is therefore likely to be the result of, for example, insufficient training or a feeling that safety is "somebody else's problem."

For example, who is ultimately responsible in the following situation?
Six infants had died in the maternity ward of the Binghamton, New York, General Hospital because they had been fed formulas prepared with salt instead of sugar. The error was traced to a practical nurse who had inadvertently filled a sugar container with salt from one of two identical, shiny, 20-gallon containers standing side by side, under a low shelf, in dim light, in the hospital's main kitchen. A small paper tag pasted to the lid of one of the containers bore the word "Sugar" in plain handwriting. The tag on the other lid was torn, but one could make out the letters "S..lt" on the fragments that remained. As one hospital board member put it, "Maybe that girl did mistake salt for sugar, but if so we set her up for it just as surely as if we'd set a trap..." (ISLMP)

*Much of the information about human error provided here is taken from D. E. Embrey's *Managing Human Error in the Chemical Process.*

Immediate causes are circumstances that immediately precede an incident or develop during it. Immediate causes, which generally include substandard practices and / or substandard conditions, are usually easy to identify. For example:

SUBSTANDARD PRACTICES	SUBSTANDARD CONDITIONS
Operating equipment without authority	Inadequate or improper protective equipment
Failing to follow established procedures	Defective tools, equipment or materials
Making safety devices inoperable	Fire and explosion hazards (hidden)
Failing to use personal safety equipment	Poor housekeeping; disorderly workplace
Servicing equipment that is in operation	Hazardous environmental conditions
Working while under the influence of alcohol/drugs	Inadequate training, expertise, etc.

Basic causes, which are the reasons for the existence of the immediate causes (substandard practices and conditions), are more difficult to identify. Often, they are not evident until after an incident has been thoroughly researched and investigated. These are examples of typical "basic" causes:

PERSONAL FACTORS	JOB FACTORS
Inadequate physical/physiological capability	Inadequate leadership/supervision
Inadequate mental/psychological capability	Inadequate engineering
Physical or physiological stress	Inadequate purchasing
Mental or psychological stress	Inadequate maintenance
Lack of knowledge	Inadequate tools and equipment
Lack of skill	Inadequate work standards

These three questions will help to identify basic causes:

- Why did the substandard **practice** occur?
- Why did the substandard **condition** exist?
- What **failure** in supervision / management permitted the practice or condition to exist?

Often, the first answer to a "why" question will only scratch the surface of the issue. The questions must continue until the root cause becomes clear. For example:

- Why did the worker engage in a substandard practice? Because of lack of training.
- Why was there inadequate training? Because the budget for training was cut.
- Why was the budget cut? Management did not consider it a priority.

In this example, management's response might then be to give a higher priority to training programs. Clearly, it is important to determine the basic causes so that programs can be established to mitigate or prevent future incidents.

There are many causes of incidents, and often there is more than one contributing factor. A system can fail because of the kinds of people involved, the amount of training they have had or the way the system is designed (including, for example, outdated procedures or an unsuitable working environment). Or all of these factors may have contributed to the failure.

Overall, the most common basic causes are inadequate programs and program standards, or inadequate compliance with program standards. In other words, managers have a major responsibility for preventing and mitigating incidents. It is their responsibility to integrate the principles of safety and loss management into all four of their essential functions: planning, organizing, leadership and control (stewardship).

One of the most important steps a manager can take is to involve workers as active problem solvers; for example, giving them ownership of processes and inviting their input regarding technical methods. As well, those who design, construct and operate industrial facilities must recognize that employees do not perform at 100% of their efficiency at all times (they are only human). Therefore, there is a need for fail-safe devices, redundancies in controls, special procedures and practices, improved training methods, teamwork and so on.

Investigating Incidents

There are a number of reasons for investigating incidents:

- to identify the substandard practices and procedures that caused the incident
- to identify the management system that failed to prevent it from happening
- to recommend remedial action to prevent it from happening again

Prescription without diagnosis is malpractice, whether it be in medicine or management."

- KARL ALBRECHT

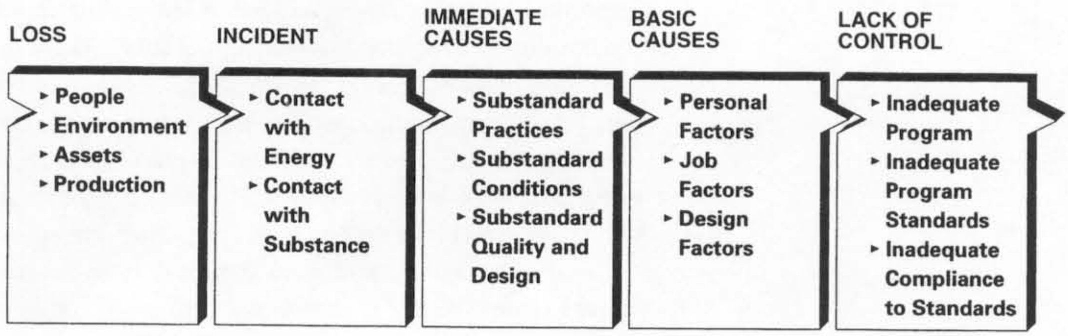
By reporting minor incidents, staff can help to identify problems in the operation before they become major incidents. Managers cannot investigate an incident if they do not know about it. Reporting also helps to develop a database that can be used for trend analysis.

Note: Under Alberta's *Occupational Health and Safety Act*, incidents involving bodily harm resulting in a worker's being admitted to hospital for more than two days must be reported to Alberta Labour.

As illustrated in Figure 4, systematic incident investigation includes:

- a description of the top event (losses and incidents)
- determination of contributing events (immediate causes)
- analysis of contributing events to determine the basic causes and lack of control

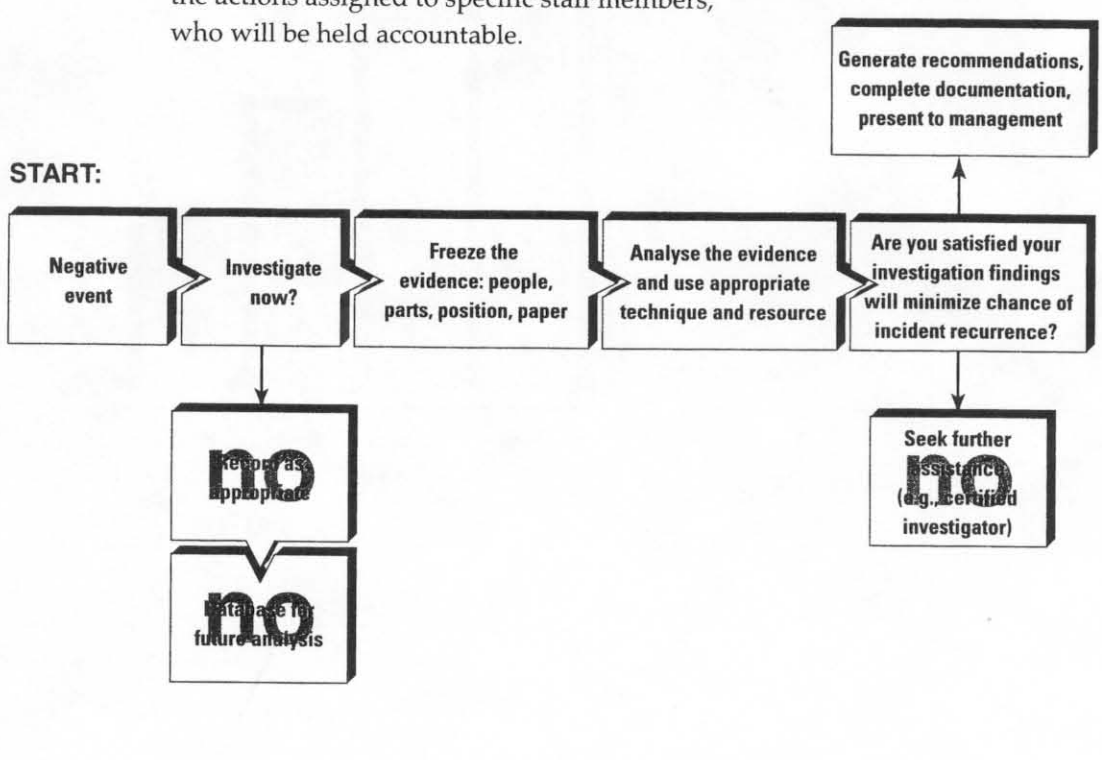
Figure 4.
Model for investigating incidents



Note: The above model is based on a model developed by F.E. Bird Jr. and G.L. Germain, *Practical Loss Control Leadership,* 1992.

An incident investigation report must include appropriate recommendations for action, not just facts and conclusions about how the incident happened. The recommendations should lead to an action plan with responsibilities for the actions assigned to specific staff members, who will be held accountable.

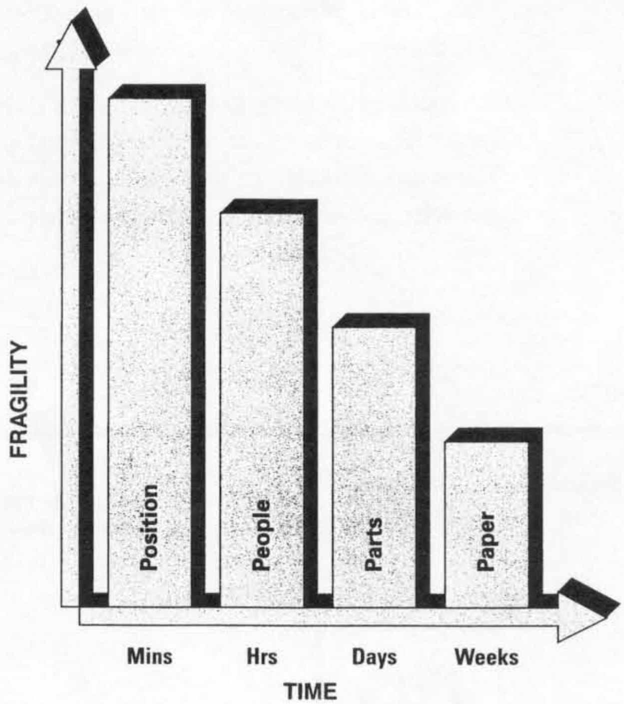
Figure 5.
Incident investigation flow path



Fragility of evidence. Although the sooner the better rule applies to investigations, a judgment often has to be made about which investigations need to be done immediately and which ones can wait. If there is a waiting period, it is important to freeze the evidence; that is, keep it in a form that will meet the investigators' needs (see Figure 5).

The major confusion that can occur following an incident may cause important evidence to be damaged or left to deteriorate. Figure 6 shows the fragility of evidence as a function of time. To get the full benefit of a high quality investigation, the site of the incident or event must be secured (i.e., frozen) within minutes. The position of people should be recorded, and material and debris should not be removed. People who witnessed the event should be interviewed within hours, before there is time for witnesses to discuss their observations with each other. Paper and computer logs that document the process and work done before and during the event are easier to preserve and therefore may not require attention for as long as several weeks.

Figure 6.
Preserving the evidence



Interviewing techniques. Employees who have witnessed an incident should be interviewed individually, in a neutral and private place—not in the "boss's office."

To conduct an effective interview:

- Strive to make the interview objective and impersonal.
- Use open-ended questions to gather information, and closed (Yes or No) questions to confirm what has already been reported.
- Focus on listening and recording, without commenting or attempting to direct or influence the interview.
- Encourage the witness to provide additional input at a later date, when he or she remembers other details or thinks of other points to make (even the smallest detail can be of great importance).

THE FLIXBOROUGH DISASTER: A CASE STUDY

The Flixborough disaster was a major turning point for risk studies in the chemical and refining industries, worldwide. This event significantly raised the awareness of government, industry and the public regarding the hazards of large chemical plants.

Flixborough Works of Nypro (UK) Limited was a first-class chemical plant located on the outskirts of Flixborough, a small, rural village approximately 160 miles north of London, England. Although the plant had an excellent design, an explosion completely devastated the plant and the surrounding area on June 1, 1974. Houses four miles away from the plant had structural damage and windows blown out. The subsequent fire was in the same order of magnitude as the largest fire during the London Blitz in World War II.

Fire trucks responded from the nearest town, Scunthorpe, which is five minutes away, and within half an hour 30 fire trucks had arrived. It took more than two days to bring the fire under control, and eight days after the explosion workers were still cooling down certain areas. During the first two days of the fire-fighting operation, there was panic about radioactive release, but the radioactive source, part of a small device used by metallurgical engineers, was found to be intact.

The plant, which was owned and controlled by two very large public corporations—Dutch State Mines and the National Coal Board of Britain—was never rebuilt at this site.

There were huge **losses** to people, environment, assets and production.

- 28 people were killed, mostly operators of the plant, and 100 were injured. It took quite a number of days to recover all the bodies because of site devastation.
- There was extensive black smoke from the fire for a number of days. The official reports do not mention any environmental damage, but if an event of this kind occurred in the 1990s, with our increased awareness of environmental issues, there would be a public outcry, major media coverage and a government inquiry.
- 2,400 homes, shops and factories were damaged in some way. The off-site damages extended as far as eight miles away from the plant.
- The whole plant was totally destroyed. The replacement cost would have been approximately $180 million in 1995 dollars. (The plant was not rebuilt.)
- A large inventory of chemicals was lost: 66,000 gallons of naphtha, 11,000 gallons of toluene, 26,000 gallons of benzene and 2,000 tons of anhydrous ammonia. An estimated 433,000 gallons of flammable liquids were involved in the fire.
- Production and export losses were estimated to be approximately $120 million.
- There were many lawsuits as a result of this incident, and some took several years to be settled.
- The incident tarnished the reputation of Nypro, and of the whole chemical industry in the western world. The communities in the area around Flixborough lost all confidence in Nypro and their management team.

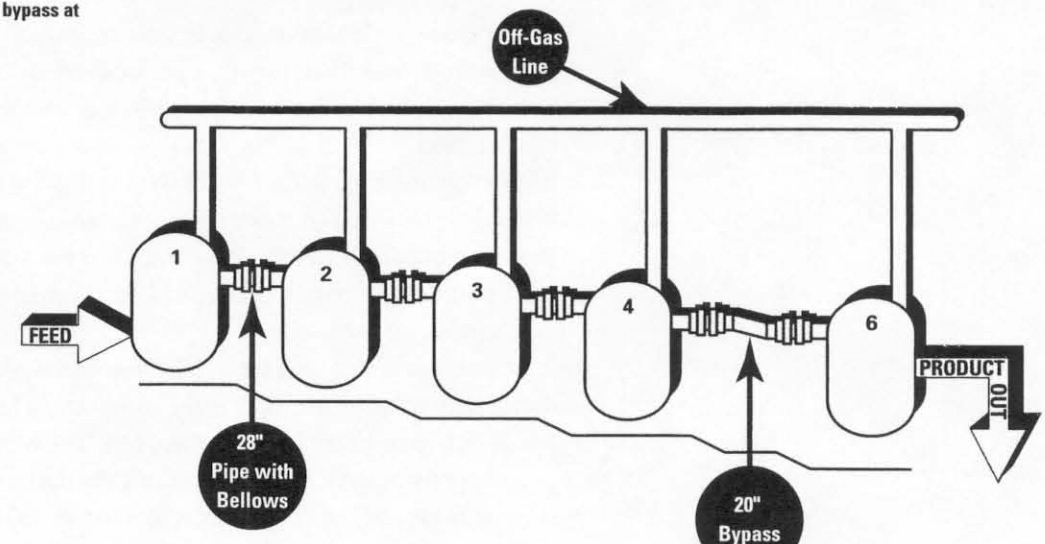
Immediate causes. The latest safety measures were incorporated into the design and construction of Phase 2 of the plant, where a process of oxidizing cyclohexane to cyclohexanone took place. The process involved keeping the cyclohexane at a pressure of 8.8 kg / cm^2 (approx. 9 bar) and at a temperature of 155° C, using a batch of six reactors in a series.

At the time of the explosion, the plant contained approximately 300,000 gallons of cyclohexane (which has a low flash point of -20° C).

The reactors' construction used a gravity feed of cyclohexane from one reactor to the next. The reactors were connected with very short, 28-inch-diameter stainless steel pipes and stainless steel bellows (expansion joints). After two years of reliable production, a crack developed in reactor 5 and it was taken out of service. The crack was caused by workers pouring water over the reactor because of a significant vapour leak from a small connection.

To resume production, a 20" diameter stainless steel bypass was designed, constructed and coupled from reactor 4 to reactor 6 (see Figure 7). Because of differences in the heights of the reactors, the bypass was built as a "dog leg." The bypass was also much longer than the regular connections between the other reactors. The plant went back to production and operated successfully for approximately two months before the disaster struck.

Figure 7.
Layout of reactors and temporary bypass at Flixborough



The bypass was poorly designed. The pipe between the bellows extending from reactors 4 and 6 was too long and it had poor support. The bypass was capable of rotating, and it would do so when the pressure slightly exceeded the normal level. The bellows were not designed to take this kind of strain, and the rotation of the bypass caused the bellows to fail. The bypass fell to the ground.

Most of the liquid in the reactors vaporized through the resulting openings in reactors 4 and 6. A huge vapour cloud of cyclohexane floated over the plant site and found a source of ignition (possibly a furnace). It exploded with a force equivalent to 40 tons of TNT.

These appear to be the major **basic causes**:

1. Eager to get the plant back into production, managers did not seek out experts who could do the job properly.

   The bypass was a "quick and dirty" design carried out by a young, less experienced process engineer. There was no mechanical or civil engineer on site who had the the appropriate experience for handling this job. Senior management must have realized they had a deficiency in expertise, since they had previously advertised for additional engineers from different disciplines for this site. Also, since the two owner companies were very large, they could easily have had any number of engineers with the right experience quickly travel to the site and carry out a proper design. Other alternatives would have been to bring in consultants or contact the original contractor.
2. The engineer who designed the bypass either did not consult the bellows manufacturer's literature (which stated that only straight connections were safe) or decided not to follow the manufacturer's advice.
3. If the staff who built the new bypass noticed that the design did not meet the standards, they did not bring this concern to the attention of management.
4. Since the owners of the plant specialized in coal mining and distribution, not manufacturing chemicals, they may not have recognized that the lack of a design engineer at the Nypro plant was a serious problem.
5. Management was not paying attention to previous incidents that led up to the disaster. The crack in reactor 5 was caused by deviations from standard practices. Cooling water was used to condense the cyclohexane vapour leak. The nitrate concentration in the water caused a crack in the reactor. This poor practice should have alerted management to weaknesses in their organization and the technical skills of staff.

The Flixborough disaster provides numerous lessons for those who are planning to pro-actively reduce the risks in their industries and operations. For example, this case study shows clearly that:

- Professional staff must recognize the limits of their knowledge and expertise, and ask for help and consultation when necessary.
- A team of people from different disciplines should handle projects involving design changes. For example, the Flixborough situation would have benefitted from input from chemical (process) engineers, mechanical engineers, metallurgists, chemists, maintenance staff and a consultant from the company who built the plant, etc.
- Whenever possible, the inventory of hazardous materials should be kept at minimal levels. Hazardous materials should be stored safely.
- Risk assessment should be carried out on any significant design change, before initial operation.

For more information about the Flixborough disaster, see *The Flixborough Disaster: Report of the Court of Inquiry,* 1975.

Risk reduction solutions can be in the form of:

- procedures
- training
- organizational improvement
- communications
- control systems
- design systems
- substitution in the process
- personal protective equipment
- simulations
- other

However, before managers can decide which proposed solutions are suitable, they must:

- complete a risk assessment/analysis, using a variety of techniques that apply to the specific situation
- do a cost/benefit analysis
- check whether these solutions have been successfully applied before in similar situations

Risk assessment, analysis and management is most appropriately carried out by teams with appropriate expertise. The team leader should be primarily a facilitator who keeps the team focused, emphasizes objectivity and encourages the participation of all team members.

Buy-in from the employees who are directly involved is also essential.

As illustrated in Figure 8, these are some of the most commonly used risk assessment and analysis techniques, in order of their level of complexity (casual to structured):

- Risk observation in the field
- Checklists
- Simplified logic tree analysis
- Simple (semi-quantitative) risk assessment
- Hazard indices (Dow Index)
- Failure mode and effects analysis (FMEA)
- Hazard and operability study (HAZOP)
- Fault tree analysis

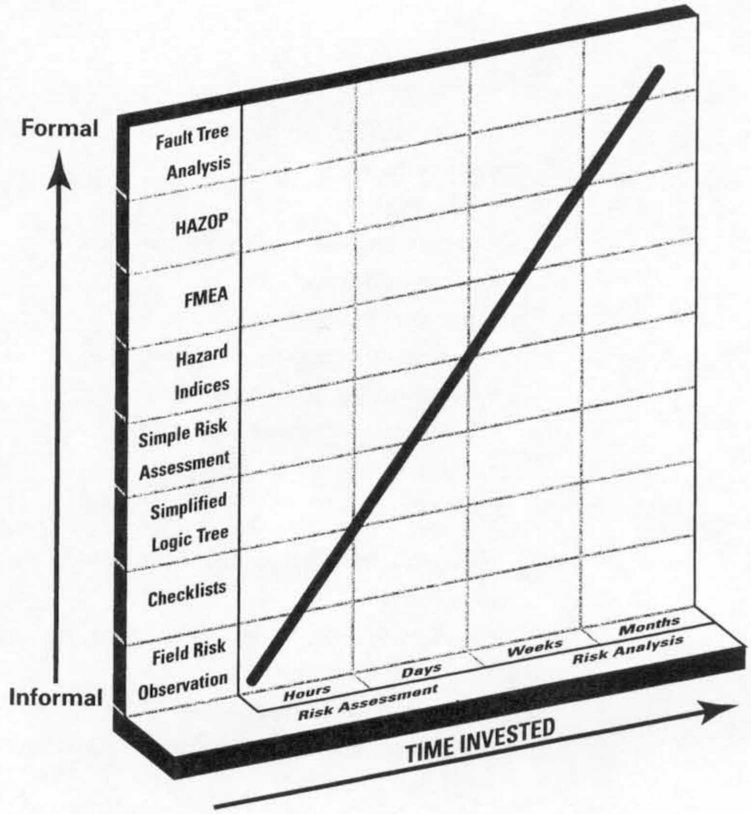


Figure 8.
Time required for various types of risk assessment/ risk analysis techniques

Risk observation in the field. One simple and effective technique is to train and encourage employees to constantly observe changes that could result in higher risks or negative consequences. For example, they might notice an abnormal sound in the equipment or an unusual odour. Or they may have some concerns about the effects of a change in procedures or a reorganization of the facilities.

Employees can help control risk by constantly asking themselves these questions as they carry out their normal tasks:

- Why am I doing this?
- What could go wrong?
- If something went wrong, could it affect me and/or others?
- How likely is it that something will go wrong?
- What can I do to prevent that?

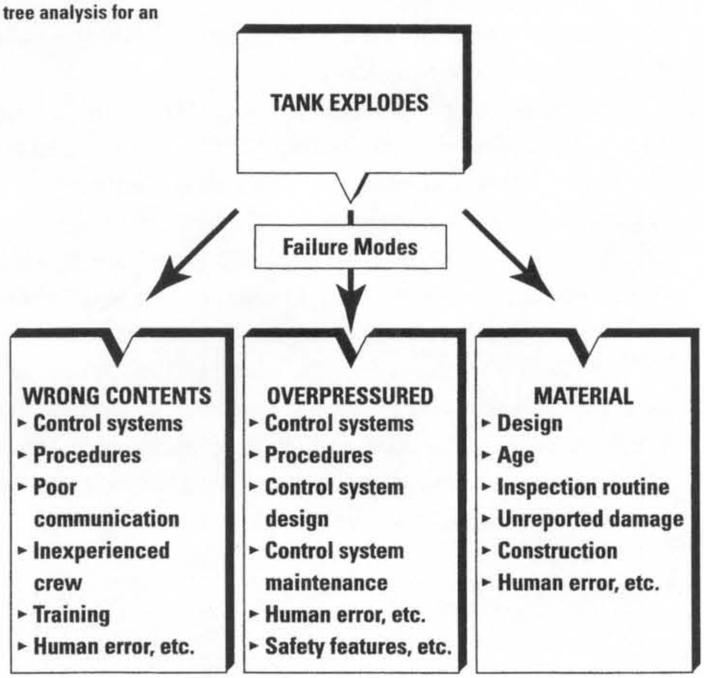
Frequent safety sessions will help people to remember that risk assessment is a key part of their job. Employees also need to know how they should go about reporting their observations, and they should be able to expect a prompt response to any reports they submit.

Checklists can be helpful in pinpointing deviations from established codes and standards of good practice. For example, a commercial air pilot and crew check the critical functions on an aircraft before take-off, and if there are major deviations found, the aircraft is grounded until the problem is solved.

Although checklists can be extremely useful, they are only a starting point. They should never be used as the only tool for assessing and analyzing risks. Managers and staff must always be aware of other pertinent matters that are not included on the checklist. Checklists vary greatly in quality and level of analysis, and are never really complete. Also, they cannot meet the needs of every situation.

Simplified logic tree analysis. Unlike the other techniques described in this section, the simplified logic tree begins with the effects (that is a potentially hazardous situation) and works back to the possible causes. For example, if the undesired event is an exploding tank, possible causes include having the wrong substances in the tank, using too much pressure and failing to keep the tank in good condition. In turn, the causes of these mistakes could be poor communication, human error, poor design, unreported damage and so on. (See Figure 9.)

Figure 9.
Simplified logic tree analysis for an explosion



The simplified logic tree provides a graphic representation of the interrelationships among basic causes. A team of managers, engineers, geologists, geophysicists, business people, operators and mechanics (including people with hands-on experience) can develop this type of tree and then trace the branches and sub-branches to select the risks that are most likely to exist in their situation. They can then plan how best to prevent an undesired incident.

Simple (semi-quantitative) risk assessment is a simple but effective tool for evaluating the majority of risks that occur in industry. In this approach, members of a multi-disciplinary team, who among them have a full understanding of the system under review, agree on:

- a statement of objectives
- a clear definition of the system(s) to be analyzed
- the design and operational details of the system
- a list of principal categories of concern
- a list of all known assumptions and constraints
- the time constraints that govern the risk assessment
- the staff required (and available) to support the risk assessment at various stages

The basis for the team's decisions is the risk equation (RISK = a function of probability x consequences).

This technique can be effective only if the team has support from management and a commitment that key recommendations evolving from the study will be implemented. If a risk is identified, management must take action to reduce that risk to an acceptable level. (If there are areas where the team does not feel qualified to suggest appropriate controls or make recommendations, they should consult with other experts.)

The assessment is done using a risk assessment worksheet, as illustrated in Table 2. The team reviews the plant, facility or operation under normal conditions, before any particular incident has occurred, and addresses potential scenarios—their impact, their probability, the level of risk involved, the recommended controls and the estimated residual risks after recommended controls have been implemented.

Residual risk is a level of risk that:

- the company or project team considers acceptable in a reliable and safe operation (with reference to the company's objectives and standards)
- the society at large considers acceptable (with reference to the pertinent laws and regulations)

Table 2.
Semi-quantitative risk assessment

System: Propane filling depot
Scope: Normal operaton

Legend: I = Impact, P = Probability (L = Low, M = Medium, H = High)

ITEM	CONCERN	IMPACT RATIONALE	I	PROBABILITY RATIONALE	P	RISK	CONTROLS	RISIDUAL RISK
Propane Tank	Leak	Loss of inventory or small fire	L M	Highly unlikely since tank is code built and tested	L	M	Leak test system before commissioning	L
	Catastrophic failure	Explosion and fire causing injuries and property destruction	H	Tank is protected from over-pressure by relief valve Fire or external impact could damage tank	L	M	Provide security barrier around tank. Post-evacuation notices in event of fire.	L
Piping	Flow restriction	Inconvenience to user May present fire hazard	L	Debris or corrosion products in line Possible ice plug	M	M	Regular maintenance. Provide heat tracing on line to prevent freeze-up. Develop filling procedures.	L
	Leak	Loss of inventory Small fire	H	Piping subjected to abuse may develop leaks at connections	M	H	Regular leak testing. Erect "no smoking" signs and remote isolation valve.	M
	Rupture	System depressured Large flash fire possible, involving the tank	H	Highly unlikely if quality piping system installed External object could strike piping	L	M	Install bracing and shield around piping. Design regulator to quick shut-off if downstream pressure drops rapidly.	L
Metering	Calibration error	Customer overcharged Poor public relations	M	Not likely, given the frequency of refilling the storage tank	L	L	Keep accurate records and calibrate system on a regular basis.	L
	Valve may freeze open	Cannot shut off sytem causing spill	H	Unlikely if sytem is designed properely	L	M	Trace circuit. Install emergency shut-off.	L
Customer	Spill propane on ground or on hot surface	Fire or explosion	H	Possible but not likely	L	M	Post-operating instructions and hazards warnings. Install quick shut-off.	L

Source: Syncrude Canada Ltd.

Table 3 illustrates the criteria that companies typically use to determine what is a high, medium or low risk. These criteria can be changed to suit the system involved, and there can be more than three levels of ratings (e.g., levels one through five instead of high, medium and low).

Table 3.
Generic risk criteria

Legend: P1 = People, E = Environment, A = Assets and P2= Production.

RATINGS	IMPACT	PROBABILITY
H	**High** P1 Disability injury, loss of body part or fatality E Reportable violation, toxic release A High repair cost (typically> $100 k) P2 Loss of function of facility for extended period, with business consequences, major quality deviation	**High** ▸ Repetitive event ▸ At least once a year ▸ Several times in the life cycle of a project ▸ Has happened frequently in similar circumstances ▸ Greater than 50% chance of occurring
M	**Medium** P1 Medical injury E Non-reportable spill, non-toxic release A Moderate repair cost (typically> $10 k) P2 Short-duration loss of function, serious quality deviation, medium business impact	**Medium** ▸ Infrequent event ▸ May happen only occasionally (less than once a year) ▸ Has been observed in similar circumstances ▸ 10 to 50% chance of occurring
L	**Low** P1 First aid injury E Minor leak, non-toxic fugitive emission A Low repair cost (typically< $10 k) P2 Brief deviation or minor quality deviation	**Low** ▸ Unlikely event ▸ Never happened to date ▸ May happen less than once in 10 years ▸ Has never been observed but is still felt to be a possibility ▸ Less than 10% chance of occurring

Hazard indices such as the Dow index are especially useful for ranking the relative loss potential of plants and processing facilities that handle flammable, combustible or reactive materials. They are not as useful for facilities such as generating plants, office buildings, and water treatment and distribution systems.

In Dow Chemical's "Fire and Explosion Index" (F. and E.I.), which is one of the most popular index procedures, the F. and E.I. is calculated and the Maximum Probable Property Damage (MPPD) estimated. The base MPPD is the dollar value of all the equipment in the exposure area and the actual MPPD is the base modified by a credit factor for safety features designed into the process.

An experienced, professional team is required to perform the calculations, which include:

- process unit material factor (MF)
- general process hazards factor (Magnitude F1)
- special process hazards factor (Relative Probability F2)
- the Fire and Explosion Index (generally, MF x F1 x F2)

Note: See Dow's "Fire and Explosion Index" hazard classification guide for derivation of factors.

Failure mode and effects analysis (FMEA). Since a hazard can have several origins, there is a need for detailed analysis of potential causes. Reliability engineers use FMEA to trace the effects of the failure of individual components on the overall failure of equipment. (Many manufacturers also use FMEA to test products before putting them on the market.)

FMEA may be especially useful in testing equipment that is critical to the health and safety of the employees, as it can direct attention to critical components, and support the establishment of an effective preventive maintenance program.

The **hazard and operability study (HAZOP)** is a systematic and thorough technique that can be used to identify all possible deviations and understand the serious consequences that these deviations can have on other parts of a process and/or facilities. In an ideal situation, a HAZOP would be conducted during the design stage so preventive measures can be implemented from the outset and without excessive cost or effort.

A HAZOP should be conducted by a knowledgeable team of five or six people with different backgrounds (engineers, geologist, geophysicists, maintenance and operation personnel, etc.). They begin by brainstorming to identify potential hazards. The focus at this point is on identifying the problems, not solving them.

The team then applies a set of guide words to potential deviations from the design intentions in order to generate possible consequences and causes. For example, the guide words include: NO or NOT (NO flow in pipe), MORE or LESS (transfer of MORE liquid), REVERSE (What if the liquid flows backward?) and OTHER THAN (The valve shut down instead of opening up).

The guide word approach can be adapted in the following ways:

- to meet various objectives: for example, maximizing results with a limited amount of work by team members or using a risk matrix (see Table 3) to incorporate risk estimates
- to suit various levels of assessment: for example, working first at a systems level, then to screen for high risk systems, and then moving to the components
- using information from checklists, either to replace some guide words or help in selecting relevant guide words
- using the knowledge base of the participants (instead of guide words) to identify deviations

Fault tree analysis, which is one of the most widely used risk analysis techniques, is a graphic representation of the interrelationships among basic causes of an undesired system incident. A fault tree can be used for qualitative analysis (to answer the question, "How can this undesired system incident occur?"). And it can be used for quantitative analysis; that is, to answer the questions:

- What are the chances of this undesired system incident occurring?
- Which causal factors are significant?
- How can the risks be reduced?
- What are the risk benefits from specified risk reduction measures?

Fault tree analysis is a very flexible technique that can be used at varying levels of detail and complexity. Fault trees are particularly useful in assessing risks in industrial operations whose success depends on the appropriate interaction of design criteria, process variables, equipment, control systems, management systems, operators and maintenance activities.

Events are the basic building blocks of the fault tree, and causal relationships among events are defined in terms of "logic gates." Two simple fault trees, illustrating the use of the AND and OR logic gates, are shown in Figure 10. The fault tree leading to a *Fire* includes the AND logic gate: *Oxygen,* AND *Ignition Heat,* AND *Fuel* all have to be present at the same time for *Fire* to occur. The fault tree leading to *Ignition Heat* includes the OR logic gate: either an *Open Flame* OR a *Static Spark* are sufficient for *Ignition Heat* to occur.

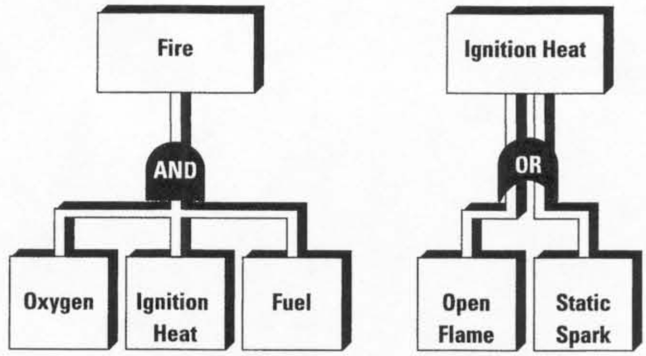


Figure 10.
Fault tree diagrams with AND and OR gates

There are many variations of these basic logic gates, but most fault trees are based on the AND and OR gate approach.

To use a fault tree, first evaluate the probability of occurrence for each of the basic events located at the bottom of the tree. Then use the fault tree logic to calculate the probability of the undesired system incident identified at the top of the fault tree.

For more information on risk assessment and analysis, see T. Kletz, *HAZOP and HAZAN;* R.E. Knowlton, *A Manual of Hazard and Operability Studies; and Dow's Fire and Explosion Index Guide* (American Institute of Chemical Engineers).

The major purposes of an industry's **community awareness program** are:
- to address public concerns about the presence of industry in their neighbourhoods
- to engage community members' input and support for the industry's risk management programs

In establishing a relationship with the public, industries will need to consider factors such as these:
- the current status of the industry's work on risk assessment
- the nature (and health) of the industry's current relationships with the community
- the amount and type of communications expertise that is available in the company
- the amount of communication on safety and emergency preparedness that has been done with employees (who are the industry's first audience)
- the current status of the company's communication plans

Managers must develop and continually update their communication plans. One of the key components of a communication plan will be designating and training speakers who can effectively talk to the public about the company's business and its objectives (before, during and after significant changes have occurred, and particularly in connection with emergencies). The plan should also include an orientation program for new employees that includes information about the company's communication plan. All employees are ambassadors in their informal contacts with the public outside of the workplace.

Covello and Allen (US Environmental Protection Agency) have developed seven cardinal rules of risk communication:
1. Accept and involve the public as a legitimate partner.
2. Plan carefully and evaluate your efforts.
3. Listen to the public's specific concerns.
4. Be honest, frank and open.
5. Coordinate and collaborate with other credible sources.
6. Meet the needs of the media.
7. Speak clearly and with compassion.

Some additional tips regarding effective communication with the public:

- Use only designated and trained staff to handle formal communications (talking to the media, speaking at public meetings, etc.).
- Build on previous communications activities that have increased the company's credibility and positive relationships with the community.
- Focus on risk reduction actions the company has already taken: work that has been done to prevent incidents and key response capabilities in the event of an incident.
- Use both oral and written communications, and treat any written communication as a potentially "public" document.
- Be prepared to react to the media coverage that may be the result of communications activities.

An **emergency response plan** should also be developed, with input from managers, staff and the community. The finalized emergency response plan must be fully documented, easily accessible and clearly communicated.

Equipment, facilities and trained personnel needed for an emergency response must be identified and readily available (either full-time members of the company's fire and rescue teams or fully trained regular employees who respond to emergencies, or a mixture of both). On or off-site medical personnel must also be involved and ready to respond. Simulations and drills must be scheduled at appropriate intervals to provide a state of readiness and ensure continuous improvement.

If there are other industrial complexes close by, it is desirable to involve them too, and to develop mutual aid agreements such as those that are in effect on Refinery Row in Edmonton and among the Fort Saskatchewan chemical and industrial plants.

An emergency response plan should include:

- detailed directions for combating any emergency that may occur in the company's facilities or projects
- evacuation plans for the public in the immediate surroundings in the event of a disaster (including designated leaders who will have a fully operational communication system at their disposal)
- governmental (statutory) requirements and communication responsibilities
- detailed emergency procedures, which are also distributed to all concerned and displayed in convenient and strategic locations
- a detailed list of available equipment and resources, and of trained responders
- definitions/descriptions of roles and responsibilities
- plans for refresher training of supervisors, firefighters, rescue teams, medical personnel and workers
- systems that are available for broadcasting alarms or calls for assistance, either in the plant or in nearby affiliated organizations (and the routes that should be used to reach them)

- a list of personnel who will be directly in charge of:
  - combating an emergency
  - securing and protecting workers and equipment
  - safeguarding equipment and other remaining assets after a disaster
  - investigating and reporting serious injuries to the proper authorities
  - handling transportation needs
  - contacting and responding to city, provincial and federal officials; insurance companies; news media, etc.

For more information on community awareness and emergency preparedness, see *Emergency Planning for Industry* (Canadian Standards Association).

Many Canadian corporations have adopted a due diligence approach to their business practices in order to minimize their risks of fines and imprisonment of key personnel. In 1978, the Supreme Court of Canada created the defense of due diligence in a decision involving the City of Sault Ste. Marie. Before this decision was made, health, safety and environment statutes had been regarded as absolute liability statutes; that is, if a health, safety or environmental incident occurred, you (whether you were a corporation or an individual) were guilty no matter what you had done to prevent it from occurring.

Many courts across Canada have said due diligence, or "all reasonable care", involves considering the steps a reasonable person could have taken in the circumstances:

1. Was there an effective loss management system (to prevent ill health, pollution and workplace injuries) in place prior to the offense?
2. Was the system operating effectively?
3. Was the system being maintained?
4. Did the accused person reasonably but mistakenly believe in a set of information which, if true, would render the actions or lack of actions innocent?

Canadian courts apply a number of criteria when determining the standards of care required to demonstrate due diligence. These include:

- industry standards common to the work being done
- special standards that might dictate a higher level of care, such as:
  - -the degree of knowledge or skill expected of the person
  - -the location of the operation (e.g., a highly sensitive environment)
  - -the severity of potential harm
  - -the extent to which the underlying causes of the offense were beyond the control of the accused
  - -the alternatives; that is, what **was** done against what **could have been** done

The following summaries are based on information provided by The Engineering Council, UK.

Piper Alpha: Fire on a North Sea oil platform

June 7, 1988; 167 dead

Contributory causes:

- There was a breakdown in communications and Permit to Work system at the shift changeover.
- The initial explosion put the main power supplies and the control room out of action.
- Regulations did not require remote but potentially hazardous events to be assessed systematically.
- The safety policies and procedures were in place but the practice was deficient, e.g., frequency of emergency training.

Actions take afterwards:

- Regulatory authority was transferred from the Department of Energy to Health, Safety and Environment.
- Industries were required to set goals for risk education.
- Industries are required to demonstrate that the safety management system is effective, comprehensive, quality assured and auditable.
- Design requirements were established, e.g., provision of emergency shutdown valves and temporary safer refuges.

For more information, see *The public inquiry into the Piper Alpha disaster* by Lord Cullen (London: HMSO, 1990), ISBN 010113102X.

Challenger Space Shuttle Disaster
(Mission 51-L exploded soon after take-off)

January 28, 1986; 7 dead.

Contributory causes:

- A seal with a faulty design was unacceptably sensitive to a number of in-service factors.
- To accommodate a major customer, the sub-contracting company reversed its position and recommended the launch. The company did not listen to the advice of the engineers it employed.
- The NASA management structure permitted internal flight safety problems to bypass key Shuttle managers.
- The Safety, Reliability and Quality Assurance workforce was reduced, partly due to budget and time pressures.

Actions taken afterwards:

- A design re-evaluation included tests over the full range of in-service conditions.
- Formal, objective criteria were adopted for accepting or rejecting identified risks.
- The Safety, Reliability and Quality Assurance department was strengthened, and it adopted a system for documenting deviations and resolving them. (The system included trend analysis.)

For more information, see *Presidential commission on the space shuttle "Challenger" incident*, W.P. Rogers (US, GPO, 1986).

Hyatt Regency Walkways Collapse, Kansas City

July 17, 1981; 114 dead

Contributory causes:

- The design of the two walkways' suspension connections did not comply with the building code.
- The decision to change the design was made by telephone, and was not documented.
- The structural engineer's design drawings did not clearly assign design responsibility to the steel fabricator.
- The structural engineer did not take enough care in reviewing the drawings that the steel fabricator sent back.

Actions take afterwards:

- The responsibilities of project team members were formalized.
- Structural engineers were reminded that they assume overall responsibility for their designs.

For more information, see *Investigation of the Kansas City Hyatt Regency Walkways Collapse,* US Department of Commerce, National Bureau of Standards, NBS Building Science Series 143, Library of Congress Catalog Card Number: 81-600538.

The Sinking of the Titanic

April 14, 1912; more than 1500 dead

Contributory causes:

- The usual practice for liners in the vicinity of ice in clear waters was "to keep the course, maintain the speed and trust to a sharp look-out to enable them to avoid the danger."
- The ship's radio officer was catching up on a backlog of communications; some outgoing messages from passengers took precedence over ice warnings.
- There were 2,208 people on board and lifeboats to accommodate only 1,178; additionally, when the ship was evacuated many lifeboats were not totally filled.

Actions taken afterwards:

- Ships provided a lifeboat, or a lifeboat and pontoon raft, for each person on board.
- New rules required watertight bulkheads.
- All vessels carrying more than 50 people were equipped with a wireless and an emergency source of power.
- Rockets were used only as distress signals.
- An international conference (SOLAS, Safety of Life at Sea) was instituted and still continues today.

The best companies recognize that, under the *Occupational Health and Safety Act*, the prime contractor is fully responsible for the subcontractor's actions with regard to the health and safety of workers. These companies also understand that current trends such as downsizing are increasing employers' dependence on contractors. Therefore, successful companies will:

- treat contractors as they would their own employees
- investigate all incidents relating to people (employees **and** contractors, environment, assets, and production), and record, analyze, review and strive to continuously reduce incident frequency rates for work done by their contractors as well as their employees
- incorporate in their safety and loss management programs methods for addressing potential problems with company / contractor relationships

Companies should have a written policy that incorporates the above principles. For example, a company's policy could include the following provisions:

- The company will strive to engage contractors who are competent.
- The managers of contracting firms are responsible for directing and coordinating their own work.
- Contractors will comply with company and provincial / federal regulations, standards and policies.
- Contracting firms will provide personal protective equipment and ensure that it is used.
- Contractors will report incidents, including injuries and property damage.
- Contractors will do site inspections that include critiques and corrective action.
- The company will evaluate the health, safety and environmental performance of contractors (individuals, groups or trades, and the contracting firm as a whole).

Companies should also require their contractors to provide information about their safety program and safety performance, such as:

- a written safety policy endorsed by the contractor's top management
- copies of the contractor's safety manuals
- a description of the contractor's program for training staff about safety policy and procedures
- a description of the contractor's safety orientation program for employees
- the contractor's safety record for each of the last three years (the frequency per 200,000 hours worked for: numbers of fatalities, lost time cases, total lost days, medical aids and modified work cases)
- the contractor's WCB experience rating factor and industry average rating factor
- a description of the contractor's incident investigation procedures (including copies of forms) and the types of incidents that are investigated
- a description of how often safety meetings are conducted, who presents at and attends the meetings, how the topics are selected, etc.
- a description of how the contractor's safety programs apply to subcontractors and how successful implementation and compliance with the programs will be assured

The company must also ensure that contractors actually follow through on their safety and loss management program and that it is not just sitting on a shelf. Managers must ensure that contractors:

- receive the training and orientation they need to work on a site
- are fully involved in the safety and loss management program and understand their obligations in that regard

The managers of contracting firms should take steps to provide their workers with information and create avenues for receiving input from them. They might achieve these goals by:

- arranging meetings for contracted personnel to discuss and review upcoming critical activities and assess performance on completed activities
- holding daily team planning meetings for work groups (or as often as required)
- providing toolbox talks on specific topics as needed (for example, when new contractors arrive on site)
- critiquing their own performance levels

For more information on contracting, see these two documents published by the Construction Owners Association of Alberta: *The Owner's Role in Construction Safety—It Really Pays* (1991) and *An Owner's Guide for a Contractor's Health and Safety Management Program* (1996). Write to the Construction Owners Association of Alberta at Suite 1410, Oxford Tower, 10235 - 101 Street, Edmonton AB T5J 3G1. Phone (780) 420-1145. Fax (780) 425-4623.

Small companies of 50 employees or less make up 95% of Alberta businesses, and they employ more than one-third of Alberta's workforce. Small companies also sustain 44% of all Alberta workplace injuries. Workers' Compensation Board records indicate that many of the health and safety problems in small companies are related to noise, dust, chemical exposure, construction injuries and back injuries.

Research into safety practices in small businesses in Alberta*

Research suggests that many owners of small companies in this province believe they do not have safety problems. These are some of the findings of a 1988 study of small businesses in the Calgary area:

- More than half of small business owners surveyed perceived health and safety to be of limited significance. The owners had little to say when asked what they were doing to promote health and safety.
- The owners were much more concerned with personal protection against hazards than trying to reduce the hazards.
- Over 50% of the owners felt that health and safety is essentially the employee's responsibility. Owners often expected employees to know how to work safely without training or supervision. They provide the protective equipment, and the worker is expected to carry on from there and know how to work safely.
- Small companies tended to see health and safety hazards at work (and related incidents) as a normal part of doing business. They saw incidents as a matter of being lucky or unlucky.
- A large number of the small companies surveyed were rarely inspected by officers of Occupational Health and Safety. There were inspections by the fire marshal and these were taken seriously.
- Resources, both financial and technical, were reasons put forward by the owners for not being able to improve safety and loss management performance.

  Note: This is an invalid argument. Resources **are** available at minimal cost.

* Some of the information in this section is based on a 1988 study at The University of Calgary's Department of Community Health (Joan M. Eakin and Karen M. Semchuk, "Occupational Health and Safety and Small Businesses"). The study examined health and safety practices and attitudes in 50 small businesses in the Calgary area.

These are some of the characteristics of small businesses that have implications for safety and loss management programs:

- Many owners feel they do not have the moral authority to intervene in certain areas of their employees' health and safety. The owner and employees are often buddies or even relatives. (One half of the businesses studied had employees who were members of the owner's family.)
- Small businesses are more sensitive to fluctuations in the overall economy and must therefore lay off and take on employees as activity decreases or increases.
- Some parts of the work are performed by permanent subcontractors, who work alongside regular employees (Owners tend not to feel as responsible to subcontractors as to their employees.)
- Many small companies, especially in the service and construction sector, have their workers scattered over numerous sites, and the result is reduced control over safety practices.
- Employees tend to handle all kinds of tasks even though they may be specialized in one particular field. As a result, employees often do not fully understand the safety aspects of each of their different tasks.

Effective strategies for small companies

Although small companies do not have the resources to employ full-time health and safety experts such as physicians, nurses, industrial hygienists and risk assessment experts, managers and owners are still responsible for developing and operating a safety program. These are some of the safety strategies that are feasible and effective for small companies:

- Develop procedures and practices to eliminate or control potentially hazardous situations.
- Investigate (and learn from) all safety and loss management incidents, particularly near-misses.
- Establish and sustain a simplified safety and loss management program that suits the needs and budget of the company. Alberta Labour's *Occupational Health and Safety Manual for Small Business* suggests that a program for small companies could include these elements:
  - inspections
  - employee protection
  - housekeeping
  - fire protection
  - health and safety hazard analysis

- Understand and ensure compliance with provincial and federal laws on health and safety, and establish procedures and training in this area.
- Join the local industry association to network with companies that can provide guidance and expertise. Examples are the Construction Safety Association of Alberta, Alberta Road Builders and Heavy Construction, and the Chemical Producers Safety Association. (Addresses and contact names for these associations are available from the Occupational Health and Safety Division of Alberta Labour.)
- Locate sources of free or inexpensive services, such as:
  - government agencies (Alberta Labour, Alberta Environmental Protection, Workers' Compensation Board)
  - industry associations
  - employer groups
  - safety associations (Canadian Society of Safety Engineering, Industrial Accident Prevention Association, Canadian Centre for Occupational Health and Safety)
  - part-time consultants

Although there are already a variety of sources of support for small companies that wish to improve their safety and loss management performance, there appears to be a need for additional measures in this area. Some suggestions:

- The Occupational Health and Safety Division of Alberta Labour should continue to provide advice, guidance, coaching and information; and make available training programs and seminars for owners/managers at a reasonable cost.
- Industry associations should take additional steps to convince owners and managers that safety is good business.
- Larger companies who hire small companies as contractors should promote health and safety as a benefit to both their businesses.
- The Workers' Compensation Board rate incentives should be redesigned to encourage small businesses to conduct their work in a safer manner.
- Roundtable conferences involving management, labour, government and educators might help to encourage cooperation and produce ideas and recommendations for improving the safety performance of small companies.

Summary of Events

The Lodgepole exploration site was 20 km west of the hamlet of Lodgepole and 130 km southwest of Edmonton. The owner company had hired a drilling contractor to perform the reservoir development. A boom in the oil and gas industry in the province of Alberta in 1982 led to rapid growth and development, and in turn, a strain on the drilling contractors.

The drilling exploration for gas at this site was to be performed in a series of stages. The actual drilling operation commenced August 10, 1982, and the well was drilled to a depth of approximately 3000 meters. The installation of intermediate casing followed, prior to drilling into the expected productive formation. On October 15, 1982, the drilling crew initiated coring into the zone to produce samples for geological purposes. The first two cores were obtained with no apparent difficulties.

When the crew was obtaining the third core on October 16, 1982, fluids and sour gas from the formation entered the wellbore, producing kicks. Kicks occur when the pressure of the reservoir exceeds the static pressure of the drilling mud. For 16 hours after detection of the kicks, the crew fought, to no avail, to regain control of the well. On October 17, 1982, at 14:30, the well blew out of control. This situation lasted for 67 days, with a major release of gas and condensate. For 41 days of this period, all the effluent was on fire (major). Control was finally regained on December 23, 1982.

Losses

People

- two well cappers from a subcontractor died due to exposure to H_2S; a further 14 persons hospitalized
- 28 people evacuated; four families temporarily relocated
- estimated monetary loss due to law suits against the owner company and others: approximately $6 million

The most severe hazard to people was exposure to hydrogen sulfide gas (H_2S). Low concentrations cause headache, eye irritation, sore throat, nasal irritation, nose bleeds in children, pain upon deep inhalation and some shortness of breath. High concentrations cause immediate unconsciousness, permanent brain damage, or death if rescue is not immediate. The smell of H_2S was detected as far away as Edmonton. Edmontonians and others who were close to the well site could perceive the rotten smell for 67 days. Many were very upset and somewhat scared of the consequences. The upstream oil industry lost a lot of credibility.

Environment

Losses to the environment have been divided into three categories: air, land, and water.

Air: The blowout emitted substances that were harmful to humans, animals, vegetation and the aquatic habitat. There was a significant degradation of air quality over a large area during the blowout. Long-term effects were incurred by small animals and birds. There was alteration of the habitat for various wildlife species.

Land: The owner company clear cut some 290 hectares to facilitate reforestation and reduce fire risks. Approximately 39 hectares of soil required stimulation of natural biodegradation for full rehabilitation over a number of years.

Water: Ground water contamination was localized near the well and was not considered an immediate problem due to the isolation of the well. Aquatic life was not seriously affected, but the long-term effects are unknown. Contamination of Zeta Creek and the Pembina River also occurred and monitoring was required over several years to observe long-term effects.

Estimated damages to the environment were valued at $4 million.

Assets

The estimated monetary loss of assets (including the drilling rig, well head equipment and service equipment) was $8.5 million.

Production

On the production side, there were estimated losses of $30 million. These losses were due to decreased natural gas production. The event had negative effects on the operation of the entire company due to a strain on personnel. There were also losses in the form of additional wages to the company that finally got control of the well.

Total monetary losses

For the whole event, losses came close to $50 million. Estimates were arrived at through consultation with various industry sources (all amounts appearing in 1984 dollar value).

Immediate Causes

- **Failure of casing pressure monitoring equipment.** This prevented the drilling crew from recognizing the occurrence of the initial kick.
- **Failure of the degasser.** A degasser removes unwanted H_2S gas from mud. Its failure caused the drill pipe to be exposed to H_2S. The pipe became brittle, and eventually failed.
- **Insufficient mud.** Improper mud density and the lack of sufficient supplies of the proper mud on hand at the site greatly affected the efforts to regain control of the well. Mud of the correct density would have allowed less H_2S gas to get through and contact the casing pipe.
- **Drill pipe separation.** Hydrogen embrittlement caused the pipe to separate. This failure caused the drill pipe to be blown out of the hole, which in turn caused the initial blowout.
- **Traveling block hook latch.** Failure of this safety device prevented crews from regaining control via "Top Kill" methods.

All these immediate causes prevented the drilling crew from understanding the severity of the situation and from applying the proper kick control method, which could have prevented the blowout.

Basic Causes

The drilling plan and program was not sufficient. The owner company should have been prepared to encounter sour gas as an expected case scenario; that is, hydrogen sulfide (H_2S) resistant pipe should have been used along with other precautions. It would appear that they either did not have an effective safety and loss management program or did not ensure that their subcontractors practiced it. The prime contractor always has the main responsibility.

The drilling crew was generally well trained and experienced. However, certain omissions and errors occurred in the drilling practice, such as relaxing of standards for cores no. 2 and 3. Less time was taken to perform cores no. 2 and 3. Training must be backed up with solid practices. Also there may have been too much push for production over all other priorities.

The owner company's drilling foreman and the primary contractor's supervisor had been awake and working for over 24 hours when the well blew out. When the situation was critical but not out of control, they failed to request help from experts in Drayton Valley and Calgary, who could have provided a fresh look and better judgment. All personnel in these types of projects, in particular APEGGA professionals, must recognize the importance of requesting help before it is too late.

There seemed to be an improper system in place for learning from past mistakes. A well had blown out on one of the owner company's sites near Lodgepole five years earlier. Learnings from the earlier incident were apparently not applied to prevent the Lodgepole blowout from occurring. This reflected poorly on the incident recognition, investigation and analysis system.

The procedures employed did not take into account the failure of equipment. Furthermore, the drilling personnel were not trained in maintaining the equipment.

Emergency response was not as effective as it should have been.

Recommendations

The following recommendations are taken from the Lodgepole blowout report of the Energy Resources Conservation Board (ERCB), now called the Alberta Energy and Utilities Board (AEUB).

The Cause Of The Blowout

The following types of equipment should be examined for design, capacity and operational problems to ensure that they are adequate for worst case conditions:

- degasser
- casing pressure instruments
- traveling block hook latch
- Kelly hose (oil hose)
- blowout preventers (BOP)
- equipment for anchoring drill pipe

- The industry and AEUB (ERCB) should take any action necessary to ensure that drilling operations are carried out in a safe and reliable manner, particularly in the critical zone of sour wells. Special procedures should be developed, documented and used for operations in the critical zone. These would include detailed instructions respecting tripping in, tripping out, coring, testing and other operations where particular care is required.
- Standard kick control procedures should be reviewed to determine whether they allow for situations where equipment failures or other unexpected events occur during control of operations.
- The adequacy of the current training programs for drilling personnel should be reviewed and, in particular, consideration should be given to ensuring that they are effective in ensuring a crew's familiarity with kick recognition and control.
- Mud system design and operation should be reviewed respecting density, system capacity, back-up supply, scavengers, and the impact of H_2S on mud and the ability to pre-treat and recondition it.

Well-Control Activities

- Alberta Labour (Occupational Health and Safety) should give consideration to the development of an adequate, possibly compulsory, training program for workers who might encounter H_2S or other toxic gases in substantial amounts.
- The AEUB (ERCB) should consider how the experience and expertise needed to control a blowout would always be available when required.

Key Lessons for APEGGA Professionals

- In any operation, it is extremely important to ensure that all employees (company and contractors) are following correct practices and have a well designed safety and loss management program in place.
- While on the site, APEGGA professionals must continuously look for deviations and risks and bring them to the attention of the appropriate personnel.
- If they do not get a positive response to remedying the situation, they must take appropriate "whistle blowing" actions.
- It is very important to understand that the prime contractors have full responsibility for all the contractors and subcontractors under their direction. APEGGA professionals who will work as / for prime contractors must realize this responsibility and act accordingly. In fact, if they are on a site where the contractor is not complying with good practices, they may have to alert the proper authorities (i.e., the prime contractor or Occupational Health and Safety) to shut down the work.

Significant note: The owner company, and the primary and subcontracting companies involved in this case are all top-class organizations. They certainly learned from the experiences of this incident. These companies continue to work in a safe and reliable manner, providing a sound contribution to the Alberta economy.

Over the last 20 years a number of significant negative incidents have occurred in Canadian industry. We have chosen this one as an illustration because it is very suitable for our Alberta professional audience. In using this case we have no intention of singling out the companies involved.

Ethical codes adopted by professional groups such as APEGGA support and enhance the legislation applying to industrial risks. For example, this is the first rule of conduct in APEGGA's Code of Ethics: "Professional engineers, geologists, and geophysicists shall have proper regard in all their work for the safety and welfare of all persons and for the physical environment affected by their work."

In adhering to their code of ethics, members of APEGGA must ensure that all staff under their direction—employees and contractors—are following correct practices and have a well designed safety and loss management program. While on a site, APEGGA professionals must continuously look for deviations and risks and bring them to the attention to the appropriate persons. If the response is not positive, whistle blowing actions may be required. By law, prime contractors have full responsibility for all the contractors and subcontractors under their direction.

Despite a generally positive attitude towards safety and loss management issues in this province, safety-related issues are still costing industries in Alberta approximately $1.8 billion per year. Workers' Compensation Board costs alone amount to about $400 million per year, with an average of 55,000 serious injuries and 90 industrial deaths annually.

In addition, there are costs that cannot be quantified, such as damage to the environment and the suffering of injured workers and their families. And, when industry fails to maintain appropriate safety and loss management practices, there can also be a significant financial impact on contractors, investors and the public at large.

REFERENCES

Alberta Labour, Occupational Health and Safety Branch. *Occupational Health and Safety Manual for Small Business,* 1990.

American Institute of Chemical Engineers. *AIChE Technical Manual: Dow's Fire and Explosion Index: Hazard Classification Guide,* 1994.

Association of Professional Engineers, Geologists and Geophysicists of Alberta (APEGGA). *Environmental Practice, A Guideline.*

Bird, Jr., F. E. and G.L. Germain. *Practical Loss Control Leadership.* Loss Control Management, Det Norske Veritas, 1992.

Canadian Standards Association. *CAN/CSA-Q634-91. Risk Analysis Requirements and Guidelines. Quality Management. A National Standard of Canada.*

Canadian Standards Association. *Emergency Planning for Industry.*

CCPS - American Institute of Chemical Engineers: *Guidelines for Hazards Evaluation Procedures.* 2nd edition, April 1995.

Construction Owners Association of Alberta. *The Owner's Role in Construction Safety - It Really Pays,* 1991.

Construction Owners Association of Alberta. *An Owner's Guide for a Contractor's Health and Safety Management Program,* 1996.

Covello, V. and F. Allen. *Seven Cardinal Rules of Risk Communication.* US Environmental Protection Agency, Office of Policy Analysis, Washington, DC, 1988.

Eakin, J. M. and K.M. Semchuk. *Occupational Health and Safety in Small Businesses.* Department of Community Health, The University of Calgary, 1988.

Embrey, D. E. *Managing Human Error in the Chemical Process Industry.* Human Reliability Associates, Dalton, Lancashire, UK.

Energy Resources Conservation Board (ERCB). *Lodgepole Blowout Report,* 1984. Note: The ERCB is now called the Alberta Energy and Utility Board (AEUB).

Engineering Council, The (UK). *Guidelines on Risk Issues.* L.R. Printing Services Limited, 1992.

Flixborough Disaster, The: Report of the Court Inquiry. Department of Employment, London, England (H.M. Stationary Office), 1975. ISBN 0113610750.

Imperial Oil. *Operation Integrity Program: A Management Framework.* Esso Petroleum Canada, Calgary.

Kletz, T. *HAZOP and HAZAN.* 3rd edition. ISBN 1-56032-276-4.

Kletz, T. *What Went Wrong?* Gulf Publishing Company, 1994.

Knowlton, R. E. *A Manual of Hazard and Operability Studies.* Chemetics International Company, Vancouver, B.C.

Marsh and McLennan. *Large Property Damage Losses in the Hydrocarbon-Chemical Industries: A Thirty-Year Review.* M&M Protection Consultants, 1995.

Syncrude Canada. *Risk Management at Syncrude.* Corporate Loss Management, 1993.

University of Alberta, Faculty of Engineering. *ENGG 404 Industrial Safety and Loss Management.* Industrial Safety and Loss Management Program.

University of Alberta, Faculty of Engineering. *ENGG 406 Industrial Safety and Risk Management.* Industrial Safety and Loss Management Program.

U.S. Department of Labor, Occupational Safety and Health Administration. *The Phillips 66 Company Houston Chemical Complex Explosion and Fire,* 1990.

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