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MAJOR ACCIDENT PREVENTION OR MITIGATION IN THE CHEMICAL INDUSTRY*

prepared by

Section for Integrated Industrial Projects
Department of Industrial Operations

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Contents

INTRODUCTION

The objectives of the present study are to provide guidelines for ...mination, insofar as possible, of large-scale accidents in the chemical ..dustry and to mitigate consequences of those accidents when they occur. The study will focus on good engineering design and operating disciplines as the means to eliminate catastrophies in the chemical process industry. Mitigation of effects of accidents, once the accident occurs, is best achieved through a well-understood and rehearsed emergency contingency plan.

The accident which occured in Flixborough, England, illustrates the above principles.1/ In 1974, a fire and explosion at a chemical plant in Flixborough killed 28 workers and injured 36 others. Property damage extended through a wide area and included more than 1800 houses and 160 factories and shops. The Flixborough plant had six reactors. The accident occured due to lack of good engineering design and lack of operating discipline. One reactor was disabled and a temporary pipe was rigged between reactors 4 and 6 but temporary rigging was tested only for leaks, not for the strength of the entire temporary assembly. Once the accident occured in a temporary pipe the lack of a well-rehearsed contingency plan contributed to the property loss and loss of life.

When it comes to major accident prevention there is no substitute for engineering design and operating discipline. Once an accident has occured, there is no substitute for a well-understood and fully-rehearsed industrial emergency contingency plan.

1/ Operating discipline: a key to safety, Douglas A. Rausch, Chemical Engineering Progress, pp. 13-15, Vol. 82, 1986.

II. PLANNING IN ORDER TO DEAL WITH CHEMICAL INDUSTRY EMERGENCIES

The general purpose of planning for chemical industry emergencies is to prepare to meet any foreseeable emergency. Contingency plans for emergencies can be developed at several levels of sophistication, depending on the degree of completeness required as well as on the purpose of the plan itself[2/]. The instructions for a machine operator in the case of fire in a chemical plant will differ significantly from those governing the co-ordination of different ministries or agencies in the case of a chemical plant disaster, even though both are parts of contingency plans.

All good contingency plans have three elements in common:

Analysis of the hazards
Identification of resources
Description of actions for the mobilization of personnel and equipment and duties in case of emergency.

These elements need not appear as specific sections of the plan, but should be phases developed during the preparation of the plan. Section A of this chapter will discuss the most common types of contingency plans, indicating which type of plan is most appropriate to a given planning purpose. Hazard analysis and resource identification will be dealt with in sections B and C.

A. Types of plans

Contingency plans can be classified according to their content and form, which are directly related to the purpose the plans should serve. For the chemical industry purposes of the game, contingency plans may be grouped in three categories.

1. Lists of resources and equipment, and telephone rosters
2. Action guides
3. Co-ordination plans.

However, a comprehensive plan can include features of two or even all three categories.

1. Lists of resources and equipment, and telephone rosters

Lists of possible resources and equipment are prepared for use in an emergency, together with locations and way the resources can be alerted (if people) or obtained (if material). The telephone usually offers the quickest and easiest way of mobilizing some of the resources, but alternative methods, such as radio transmitters or alarm systems, can also be used.

Possible hazards must have been considered at the time of plan preparation but these may not be mentioned explicitly. The plan does not describe subsequent actions to be taken. It is designed for response personnel such as a fire department or trained industrial personnel who know the action to be taken at the chemical plant.

2/ Industrial Emergency Contingency Planning, UNIDO/IS.598, 21 August 1985.

The resource and equipment lists maintained by the response personnel at the chemical factory usually describe the resources available within their own organizations. Lists of technical experts and equipment at other local companies may be useful. Even when an industry is covered by a national or city contingency plan, it should know the extent of the local capabilities and resources so that the information can be made available to the person or team in charge in cases of emergency.

This kind of plan is most suitable for individual chemical plants. It is simple and little preparatory work is required. Skilled personnel who know what to do with the plan are required.

2. Action guides

This kind of plan generally consists of a few pages or cards, preferably of a convenient size, carried by people who are most likely to encounter an emergency (such as a truck driver transporting hazardous chemicals or an emergency squad in a chemical plant). The plan may also be posted at key points throughout the industrial plant. Action guides are generally subsidiary to more comprehensive plans. They are designed to ensure that a few basic things always get done, such as extinguishing small fires at the very onset, containing spills of hazardous materials before they spread, or preventing access to dangerous areas. They should never be relied on as the sole response to an emergency. The action guides may be supplemented during the co-ordination phase of fighting the emergency. An action guide may be all that plant personnel need for handling a small emergency. However, a co-ordination plan covering that chemical plant will also be necessary to provide follow-up response to a large-scale emergency.

3. Co-ordination plans

A designated response agency, such as a fire department, the civil defence agency, or the control centre of a large industrial plant may have detailed specific field responsibilities defined in the co-ordination plan. A city or national plan will define the responsibilities and capabilities of various community response agencies and explain how to activate them.

The plan will contain information on whom to notify and how in the case of an accident, and it may indicate in outline form the initial actions to be taken by the response personnel. The co-ordination plan will also describe the response organization and procedure.

A hazard analysis section will be generally included in the co-ordination plan: it will also specify the vulnerable areas and include detailed maps of the region. The plan also should indicate the type and timing of exercises and training sessions. A response plan should be regularly updated.

A good co-ordination plan defines the responsibilities of various agencies, groups, or individuals under various emergency response conditions. Co-ordination plans tend to be rather comprehensive, and are mainly used at the national level or in very large cities. National disaster plans prepared by civil defence organizations are often primarily co-ordination plans and may include technological disasters as part of a matrix showing who does what during different kinds of disasters.

A co-ordination plan indicates the administrative procedures that should be followed in cases of emergency. It notes the chain of command within each of the agencies or groups involved in the emergency response operations and specifies a chain of command when they work together. Such a plan thereby co-ordinates the actions of those agencies or groups.

B. Hazard analysis

Basic to emergency planning is an understanding of the problems one might anticipate. Hazard analysis should be the first step in any planning; for example, it should also be included as a site-specific part of a co-ordination plan.

1. Identification of hazards

A hazard is any situation that has the potential to damage life, property and/or the environment. When preparing a hazard identification related to chemical industrial accidents, the following questions should be answered: What type of hazardous materials and/or industrial processes exist? Where is each of these located (or through what route does it pass)?

2. Identification of vulnerable areas

What can the above identified hazards affect, and how?

3. Assessment of risk

What is the likelihood that the hazard will occur and affect the vulnerable areas? The methodologies used in risk assessment may be qualitative or quantitative.

4. Hazard analysis for national or municipal contingency plans

(a) Identify possible sources of hazardous materials, (chemical manufacturers, users, storers and transporters).

(b) Contact the officials in charge of the chemical industry and interview them in person using a written questionnaire. The questionnaire should aim to establish:

Hazardous materials and trade names
Hazardous properties
Quantities
Product safety information and emergency guidelines
Types of storage/shipping containers
Transportation routes/frequency
Persons to contact for technical assistance
Company accident plans, and possibility of interfacing with community plans.

(c). Identify particularly vulnerable areas: people, property and environment. Fire and police departments are good sources of information when planning for large industrial accidents which could spread outside the plant. As examples of vulnerable areas outside the plant one may consider sensitive public health concerns:

Drinking water intakes
Vulnerable population centres
Hospital locations
Schools, playgrounds.

(d). Map the sources of hazardous materials, important transportation routes, and sensitive areas, using different colours for each. In so doing, use both street maps (to show where population is affected) and topographical maps (to identify flow and drainage patterns).

(e). Consult records (the industry, newspapers, police, and fire department records) for actual industrial or industry-related accidents and mark them on the map.

(f). Make a written description of what the map reveals, paying attention to any obvious pattern, such as areas of known or potential accidents, clusters of industrial production, and storage of hazardous materials.

(g). Try to estimate the probability of industrial accidents at the chemical plant: the most difficult part of the whole analysis. The probability of an accident can be estimated in qualitative categories such as low, medium, or high risk.

Examples of high risk factors are:

Past accidents
Major chemical industry production facilities
Chemical storage, production facilities or pipelines located in flood plains, near earthquake zones or in other areas subject to recurring natural disasters.

(h) Decide what would happen in the event of a disastrous industrial accident. Two things have to be considered: all the direct complications of a really large accident, and secondary effects (such as traffic jams).

Time, resources, and priorities dictate the extent to which a hazard analysis is conducted. A thorough industrial survey might develop and analyze a long set of "what if" scenarios to assess the vulnerability of the plant and surroundings.

A good hazard analysis should help decide:

The type(s) of contingency plan(s) required
The degree of detail needed in the plan
The types of response to emphasize in the plan
The location of response and clean-up resources
The type of help needed if resources available do not suffice.
When this help may be contacted and/or located.

Hazard analysis for plant contingency plans

No single ideal hazard identification system exists. For example, a firm involved in batch manufacture of a large number of organic chemicals should be much more interested in screening chemicals and reactions than a firm operating an ethylene plant.

The safety audit is a useful tool. It consists in a critical, detailed examination of all facets of a particular industrial activity with the objective of minimizing danger. It is usually carried out by a team of professionals who produce a formal report and action plan, including emergency procedures.

Table 1 shows the contents for a hazard analysis procedure.

Table 1.

Hazard analysis checklist

a. Plant site (more easily carried out if an environmental impact analysis was carried out before the final plant site was selected)

Example:
Could toxic fumes from fire, explosion, or other accidents at the plant affect the surrounding community?

b. Plant layout

Example:
Are administrative buildings and warehouses on the periphery of the plant? Are storage tanks away from the periphery, not too closely spaced, and diked or buried?

c. Structures

Example:
Do all buildings conform to the national building code for industrial structures? (If none exists, perhaps the country should adopt one.)

d. Materials

Example:
Have the quantities of materials in all stages of production handling and storage and all physical states been considered in relation to the hazards of fire, explosion, toxicity and corrosion?

e. Chemical process evaluation

Example:
Have the primary hazards of each process been identified and examined in detail?

f. Unit operations, transport and storage

Examples:
1. Have the potential hazards of all materials involved been evaluated?
2. Are precautionary measures taken to guard against accidental release of flammable or toxic liquids, gases or combustible dusts?

g. Operator practices and training

Example:
Are operators trained in the utilization of protective equipment such as emergency clothing and breathing apparatus?

h. Equipment

Example:
Is the safety equipment adequate for the hazards?

C. Identification of resources

After the hazard analysis, the next step is to identify the resources (equipment, people, and agencies) that could be made available to combat possible accidents. The resources should be identified for at least the two simplest contingency plans - resource lists and telephone rosters, and action guides.

Response planning: identifying resources and functions of emergency response or support groups

Chemical industry contingency plans should always be examined in order to ascertain the appropriate resources required to face industrial emergencies. When planning at the government level for accidents spreading beyond the plant boundary, all organizations capable of providing immediate active and material support in the event of an accident should be identified (table 2).

The accident response capabilities of the various response agencies or groups can be determined by asking questions about the following topics:

The person in charge
Personnel assigned: training and skills
Equipment available
Existing emergency response plans and activities
Defined responsibilities and duties
Existing mutual aid or interagency agreements

Table 2.

Possible Industrial contingency response or information sources

National agencies

Ministry of Industry
Ministry of Interior
Minitry of Transportation
Ministry of Labour
Ministry of Energy
Ministry of Public Works
Environmental Protection Agency (if present)
Armed Forces
Coastguard (if present)

Municipal agencies

Mayor/City Council/City Administrator
Civil Defence (if present)
Fire Department
Public Works Department
Roads
Water Supply
Sanitation

Industry

Chemical and Petrochemical Plants
Refineries
Other large industrial facilities
Spill Clean-up Contractors (if present)
Trade Associations and Professional Societies

Voluntary organizations

Red Cross or Red Crescent
Local Citizens Associations
Service Groups

United Nations organizations

United Nations Development Programme
United Nations Disaster Relief Organization
United Nations Environment Programme (especially the International Registry of Potentially Toxic Chemicals)
World Health Organization (including the International Programme on Chemical Safety)
United Nations Industrial Development Organization

III. PREVENTION OF RUNAWAY CHEMICAL REACTORS

Recent incidents in the chemical industry leave no doubt that uncontrolled runaway chemical reactions can result in hazardous situations and loss of life.

Safe operations can be improved by the systematic evaluation of processes and plants to identify sources of risk, especially major risk, and by using the results of such evaluations specify realistic safety measures and require their implementation and maintenance. This procedure must integrate the evaluation of chemical reaction hazards with process development that may not yet have yielded a full scale industrial processed plant design and finally, plant operation and maintenance. So the essential feature of the hazard evaluation is to link it and to maintain that link to full-scale processes.[3/]

Incidents in the chemical industry occur especially from runaway exothermic reactions. Although the factors leading to this kind of situation vary from incident to incident the kinetics of the runaway reaction can be said to depend very much on the chemistry of the particular process; therefore it is important to look for and identify general trends that reflect the essential features of hazardous chemical reactions which may run away. When in the aftermath of a serious runaway chemical reaction the facts have been obtained, rarely is unknown chemistry involved. For example, in the case of an exothermic runaway reaction it is frequently a side reaction which has done the damage. This reaction may not play a significant role in the normal process but due to accelerated temperatures or concentration conditions outside the values present in the normal process, a side reaction may assume enormous proportions.

The test procedure after a reaction hazard has occurred must be capabl of detecting and quantifying these side reactions, examining what could develop under all expected process conditions. What can be learned from this examination is that processed descriptions should specify normal variations in process conditions that can be expected in full-scale manufacture so that chemical reaction hazards might be anticipated. Not only the chemical engineer who may have developed the process but the plant manager must recognize that both process specification and hazard evaluation are important and present him with operating boundaries within which to operate. He must know when operating conditions move outside limits so that he will know when he has a potentially hazardous situation on his hands. Every process under development for full scale consideration must be tested. This testing can include bench-scale work with reaction materials, it can also include computer simulation. The testing procedure must be sufficiently simple for a large number of process variations to be assessed. The testing procedure must begin with the full knowledge that certain chemicals and reaction types such as nitrations and dazotisations are generally recognized as more dangerous than other types.

3/ "Hazard evaluation and process design", by Dr. N. Gibson, from Control and prevention of runaway chemical reaction hazards, IBC Technical Services Ltd., London, 1987.

Once process comparison with other commercialized reactions of a similar type have been made and the pilot scale quantification completed, the pilot scale studies of the process and computer simulations will have identified sources of risk. The quantification of this risk is the next objective. This quantification must provide data that enables safety measures to be specified. The entire process of quantification must be compatible with the engineering production and commercial criteria which are established for the process at hand.

Finally, not only must the plant manager learn from incidents at other plants and the development work at this plant on a new reaction, the plant manager must know that he is the one at the bottom of the corporate managerial ladder that must recognize the bases of safety and how these must be implemented and maintained.

Assessment of possible chemical reaction hazards in the plant has four stages. These are:

(a) Definition of the process, its operating conditions, and the design of the plant in which the process will operate.

(b) Evaluation of the nature of the chemical reaction or reactions hazards.

(c) Selection and specification of safety measures, including reaction conditions.

(d) Implementation and maintenance of these safety measures. Even if the procedure is well organized, the infrastructure of the company and the way the information passes to the chief in command will depend on how successfully the assessment process is implemented. So although early identification of potential hazards ensures efficient process development and design, the implementation of a successful chemical hazard assessment should continue to operate during the research and development work while the transfer and scale-up to pilot plants level is taking place. The procedure should be in force before full-scale manufacture is established.

Level 1 - Definition of the process.

In the case of full scale manufacture, process descriptions often include specific values for such parameters as temperature, reaction conditions, time and types of solvents. The hazard assessment can only cover a process operating within these fixed values. The hazard assessment is not able to consider variations that are unforeseen in the process conditions, even such as small changes in temperature, concentration and holding times of materials (either the ingredients or intermediates or products).

Hazard assessment at this level will rarely produce a satisfactory level of safety.

Level 2 - Process definitions including variations.

A hazard assessment at a higher level will give a more acceptable level of safety. The next higher level is called level 2 and includes normal variation in operating parameters. This level recognizes that in actual plant operations, process conditions will vary. The range of values in which parameters should be permitted to change without corrective action is defined as the normally operated process.

One example is the acceptable variation of the temperature of a batch reaction. In some cases this may be as much as plus or minus ten degrees centigrade. However, the analyst must be careful not to include reaction levels that may be dangerous. For example, the hold time at elevated temperature for analysis of product purity in a plant is normally one hour. If such a holding time is extended to twelve hours on week-ends this may cause a situation in which side reactions which are suppressed or dormant during the brief period of one hour at the elevated temperature can accelerate drastically to a dangerous level during the 12 hours holding time on the week-ends.

To conclude, a hazard assessment based on the level 2 process definition is designed to adequately protect the normally operating process.

Level 3 - Out-of-the-ordinary situation.

A still higher process definition is termed level 3. This covers certain out-of-the-ordinary situations, although not common, which are known to occur in chemical plant processing. Examples of these are failure of an agitator in process vessels or loss of cooling. These are generic variables which are not specific to individual processes. The effect of them in the hazard assessment will define the condition for a level 3 assessment. Unless a plant is designed to eliminate the above variables or deal with their consequences, then the effect on the reactor stability and the consequences of a runaway action has to be included in the hazard definition.

Level 4 - All conceivable abnormal situations.

Level 4 is the hazard assessment which includes all conceivable abnormal situations. A large number of abnormal conditions can be postulated that would result in exothermic activities. Examples are contamination of the reactor by a reactive chemical used in another process, unacceptable variations in raw material quality, or the possibility of a fire elsewhere in the plant spreading and overheating the reactor.

Level 3 is considered the minimum standard that would lead to an acceptable level of safety in a majority of processes in the chemical industry. Level four additionally seeks out the probability and consequences of any abnormal situation that conceivably could occur in the plant.

Although the emphasis in this study is prevention of accidents in the chemical industry, the reader may also be concerned with the problem of dealing with an uncontrolled reaction. Once an uncontrolled reaction has developed in the plant, the most appropriate safety measures depend on the kinetics of the runaway reaction. Data such as temperature, pressure and rates of solution are required. There are techniques and commercially available equipment that can provide the data. As one example, accelerating reaction rate in an uncontrolled reactor may increase exponentially. However, the cease in agitation may improve the situation by allowing the components of the reaction mass to separate into specific layers. The personnel, should be cognisant that restarting the agitator might suddenly produce another runaway reaction which would be substantially greater than that from just jacket cooling the reaction vessel. Any protective device, such as a reactor vent, must be designed keeping in mind the worst possible case of failure that may occur in this reactor.

In summary, safe operation in the chemical process industry is based on:

(a) Process control that prevents conditions being achieved under which uncontrolled reactions (usually exothermic) will be initiated;
(b) In an ideal plant, process control to minimize the probability of a runaway reaction would be combined with protective measures in the case of such a runaway.

Options for protection are, in addition to process control:

(a) Containment;
(b) The possibility for rapid, or crash cooling of the vessel;
(c) Inhibition of the reaction in the vessel;
(d) Venting of the reactor automatically under conditions outside the normal process operation.

Other remarks which can be made about safety measures will depend on the detailed information available on the process. This information can include toxicity of products, magnitude and rate of known reactions outside the normal operating parameters and the practicability of implementing and maintaining safety measures which were discussed in level 4. The modern chemical process industry most commonly uses process control and reactor venting as safety measures.

Techniques exist in the chemical process industry for the evaluation of chemical reaction hazards and the implementation of practical safety measures. However, the selected safety measures must be cleared with the engineering design personnel, manufacturing personnel, and the chemical engineering and chemistry personnel who have interaction with manufacturing. The safety measures must be compatible with equipment design construction, operation and maintenance routines. If financial considerations preclude installation of safety measures on an old reactor, it should be scrapped. The personnel responsible for accident prevention must be sure that the important features of implemented safety measures must be understood and appreciated by the operators.

The procedures for the maintenance of the plant must be expanded as necessary in order to include a regular check of the safety equipment. The engineering design personnel must inform the safety personnel of any change in process conditions or plant construction which might affect the safety of various manufacturing processes within the plant. This requirement may introduce new conditions not considered in the initial hazard assessment. The safety personnel must therefore have a procedure available whereby effects of change can be carefully evaluated. Safety engineers must not give in to expediency in order to minimize the interruption of production.

IV. RISK ANALYSES OF UNIT OPERATIONS IN A CHEMICAL PLANT EXAMPLE OF A DISTILLATION TOWER[4/]

In order to illustrate the risk analyses of major unit operations which take place in the chemical industry, the risk analysis of a batch distillation tower is described. The analysis includes the stages of design, construction, and operations.

This risk analysis was carried out during the design, construction, and trial operation of an actual batch distillation tower used for separation of methanol from organic product.

The objectives of this analysis are threefold:

(a) To provide a safe design basis for a batch distillation tower of about 5000 litres capacity to be used for separation of methanol from organic products.

(b) To illustrate the use of risk analysis techniques at a practical level and demonstrate their application throughout the design and construction of a unit going into a major chemical plant.

(c) To investigate the effectiveness of alternative risk analysis methods in an actual industrial unit and gather sufficient information to allow a cost benefit analysis and optimization of analysis of risk.

This risk analysis was carried out to a greater level of detail than would be required in normal industrial routine. The procedures in the analysis were rigidly defined and the experiment of carrying out the risk anlysis was well controlled.

The objective of carrying out a risk analysis during a unit design is to produce a plant which is as safe as is practicably possible. In some instances this may involve balancing the cost of safety equipment against the probability of failure, but in Denmark such questions are usually decided as a result of legislation and standard requirements which already seek a good safety level for the plant.

In the case of the distillation tower, a very important measure of success is whether the risk analysis has been complete. This can be defined either as:

(a) The proportion of potential risk sources found by the analysis, or
(b) The proportion of actual risk, measured by expected loss, found by the analysis.

The question of the actual running of the unit has not been ignored since operator error modes have been studied in the analysis. A complete list of potential error modes was established, since the number of possible operator interactions with the unit and the plant is limited.

4/ <u>Risk analyses of a distillation unit</u>, J.R. Taylor, O. Hansen, C. Jensen, O.F. Jacobsen, N. Justesen, S. Kjargaerd, RISO-M-2319, RISO National Laboratory, DK4000 Roskilde, Denmark, March 1982.

Completeness of the risk analysis can also be checked by comparing the results during the design phase with the actual experience in operating the unit in the plant. This approach has also been taken in the Danish study.

Finally, the portion of identified potential risk sources which subsequently prove to be actual risk sources is a very educational facet of the risk analysis. This was possible in the distillation unit studied here because the analysis went from design through operations phases. The problem is that a large number of possible risk sources may be fairly easy to identify if the only statement made is "this source of risk may be a threat". Considerable more work may be required to confirm that "this source of risk is a threat". Therefore the risk analysis should not only be complete but should be discriminating.

A final aspect when comparing risk analysis techniques is cost. In this study the Danish engineers measured cost in terms of engineer hours required to carry out the risk analysis.

In order to be as sure as reasonably possible that major accidents will not occur in the operation of the batch distillation tower, all of the component parts of the unit are analyzed for risk. The distillation unit itself consists of the following major parts:

(a) A distillation kettle. This is heated by steam and stirred (to improve heat transfer).
(b) A storage vessel which has the function of supplying a continuous stream of feed to be distilled into the distillation kettle.
(c) A short-packed column allowing separation of the vapour during distillation.
(d) A condenser with a proportioned reflux back to the column.
(e) An additional cooler ensuring temperature control of condensed liquids.
(f) Four distillate receivers. These are for methanol, impure methanol, impure urethane, and pure urethane.
(g) A vaccum pumping system which will allow the operator to conduct the distillation under vacuum. The vacuum system includes a condensor cooled by salt water as a vapour trap.

The batch distillation tower is controlled by a small computer which can implement both sequential and continuous control. The computerized programme has a fixed sequence of control stages and only limited sequence variations such as allowing the operator to control the timing of the sequences. The operator can start the next step in a procedure and he can also stop a procedure. Extensive safety instructions are included in a programme to prevent the start of procedures under unsafe conditions.

The distillation unit is filled by pumping the product mix containing methanol to the distillation kettle from a transportation tank. When the kettle is sufficiently full, then the storage vessel is filled so that it can automatically continue the feed during the distillation process. Then the distillation kettle is heated and distillation begins. The heating is controlled to maintain an appropriate rate of separation and the correct pressure drop across the distillation column.

The distillation process produces relatively pure methanol which is transferred in the first distillate receiver. Automatically the methanol mixture flows into the storing vessel in the proximity whenever the level in the kettle falls below the desired amount. The pure methanol distillation ceases when a particular distillation temperature has been reached. That having been reached, then vacuum distillation is begun. First off is the impure methanol, then impure product, and finally pure product. The switching between the different fractions occurs on the basis of temperature, and the second fractions are collected in separate receivers. Upon completion of the distillation, various receiving vessels can be emptied into transportation vessels. The residue from the distillation has the form of a thick, readily freezing liquid. It is emptied to 55-gallon drums and transported away from the plant to be incinerated. Then the entire distillation unit is rinsed and cleaned out with water.

The risk analysis includes the intake coupling for the feed of the distillate and extends through to the couplings to transport containers and the ground tank. The vacuum pump is included in the analysis but the transportation tanks are not. Incidents which might occur during repair or maintenance were not analyzed. Nor was an attempt made to check the construction strength of vessels receiving different distillates, and other mechanical features during the risk analysis. These were not ignored, however: such checks are a normal part of the plant design procedure and checking is already well standardized.

Eighteen separate equipment design modifications were fitted to the distillation tower in order to make certain of safe operation. Certain of these were added as a result of the risk analysis but many were standard good engineering construction practice. In the case of operation of the distillation tower a set of procedures list seventeen steps which must be followed for safe practice. One example of a safety feature which was added because of the risk analysis is the overflow pipe on the distillation feed storage tank. A safety feature which is good engineering construction practice is the addition of a pressure rupture disk on the distillation kettle. Certain of these steps are automatic because of the use of the programmed computer for control of the distillation tower. For example, the distillation kettle is prevented from being emptied unless there is a receiving drum with less than 100 kilogrammes of solvent or product within. It may also not be emptied if the temperature is too high.

The major risk associated with the operation of the distillation tower is a sudden release of methanol or methanol product mixtures. This release may be of hot material such as methanol at its boiling point. Methanol vapour is poisonous but the much more likely threat is auto-ignition which could cause an explosion and a fire. Then the plant personnel should be cognisnt that fighting methanol fires with a foam extinguisher is not possible because the foam is destroyed by the liquid methanol. On the otherhand, using a water extinguisher is effective because dilution of the methanol with water rapidly produces a dilution of the mixture so that the methanol no longer is flammable.

Still another possible problem is the spill of product because it includes dimethyl carbonate which is poisonous. Another major potential risk in the distillation tower is overpressurizing which could lead to a vessel rupture explosion. Although measures have been taken to prevent splash of residue of methanol on the operator, there remains the possibility that this could happen if he is in the neighbourhood of the distillation tower when a release occurs. However, the main acceptance criterion adopted for the risk analysis is that no single failure of equipment and no single operating error should result in release of overpressurized liquids, or similar extreme events where the failure probabilities were judged to be inordinately high.

The risk analysis described in this section was carried out as part of the design process of the chemical plant. In practice this meant that hazard analyses and safety analyses were begun at a flow-sheet stage. During the piping and instrumentation diagram stage of the design there was even a qualitative analysis of possible procedural errors at the initial stage of formulation of the plant processes. Finally, prior to the conditioning of the new plant, checks were carried out according to an outline list called "safety officer checks".

The risk analysis was carried out by a team. The team leader was the plant design engineer in charge of the project. Others were the plant safety officer, and two risk analysts who had engineering training in their backgrounds. A direct feed-back of results was possible at each stage of the analysis; the benefit was therefore an early recognition and correction of design problems, and, in some cases, recognition of safety problems which would otherwise have been overlooked.

The team met frequently and prepared action sheets as rough minutes of safety analyses of particular unit operations within a plant. Each subproject was mentioned, possible problems were noted, and then means of solving those problems were suggested. In some cases flow diagrams were prepared in rough to aid the team in seeing possible safety problems and the risks associated with them.

The plant was analyzed for risk according to the following calendar:

January 7, initial planning meeting;
February 22, first plant design analysis;
April 27, first hazard analysis;
May 27, completion of the hazard analysis;
May 29, comparison of desk hazard analysis with a walk-through of the plant.
November 15, initial commissioning of the plant. Walk-through by the safety officer.

In total the hazard analysis required ten working days. The safety check after the plant had been built took four working days. Additionally around ten working days were spent outside the safety analysis meetings in evaluating specific problems.

During the meetings of the safety analysis team small problems which arose during the analysis were discussed for a few minutes. If the problem proved too difficult or insufficient information was available, a particular person was appointed to solve the problem and this responsibility was noted in the minutes of the meeting. That person then brought to the next meeting a so-called action sheet or flow diagram which outlined the problem in sufficient detail and how it could be remedied.

In total, the information on which the risk analysis was based consisted of:

(a) The plant flow sheet including piping and instrumentation diagrams through all stages of design, including desired revisions;

(b) The plant production and operating instructions which describe the operator's responsibilities, including safety (such as standard responsibilities for handling methanol, for handling leaks and abnormalities in performance);

(c) Plant control programming tables;

(d) Plant layout drawings;

(e) Description of the automatic control devices for the plant.

Initial risk analyses

(a) Literature survey. At the beginning of the project a survey of scientific literature was carried out to determine the properties of the various chemicals used in the plant and the potential reactions.

(b) In addition experimental tests were performed on the reaction producing the urethane. One result of this was the realization that under failure conditions, the pressure could be higher than initially thought (the failure condition would consist of the failure of the temperature control device and the bursting of the pressure disk or blockage of the blow-down line). As a result, an additional pressure gauge was added as a part of the plant instrumentation.

Hazard analysis during operation

This method involves the following stages:

(a) A flow-sheet on piping and an instrumentation diagram of the plant is required.

(b) A so-called volume on the diagram is numbered. A volume may be a tank or it may be a pressure vessel; it may be a pump, a section of pipe which can be closed off, or a drain pit. A general definition would be any volume which can be closed off from other volumes and in which mass and/or energy can accumulate.

(c) For each specific volume the risk analysis describes the possible disturbances that could be produced, for example a list may be titled: "Breach of vessel boundary due to.....(and then the variables would be listed such as temperature, pressure, level, concentration, degree of mixing, pH reduction or oxidation reaction.)

(d) For each possible disturbance, causes and consequences are described and written down.

(e) For any new problems discovered either the risk group prepares a solution into its working list or the problem is given to a person in the group to present a solution of the problem at a later date.

(f) The degree of analysis may reach the level of invidual pipes if there is reason to believe that some problem could occur at such a sub-level (too much mass flow, too much heat flow, too high a concentration, too high a pressure, for example).

(g) The procedure explained in (f) was repeated by the risk group for each vessel and, if necessary, individual piping.

In the case of the batch distillation tower, the team prepared a second set of tables after the initial screening had been completed. The tables contained the most likely causes of disturbance in the distillation tower and the most common cures for these disturbances.

A few general remarks: This second version of the risk analysis should, in principle, provide a complete analysis of all disturbances in the unit. If it does not, then this may be because:

(a) Not all operating states have been considered;
(b) The listing of causes is too complex and might be better suited to an alternative analytical method such as a fault tree;
(c) The listing of consequences is too complex and the more likely consequences are not distinguished from unlikely consequences.

Some general observations on the risk analysis process as carried out by the risk group analyzing the batch distillation tower:

The risk analysis was carried out within a group that frequently engaged in brain-storming. Discussions in the group tended to become long and detailed. The secretary had to exercise a good deal of discipline in order to make sure that the time used by the group was not excesive. The secretary found that recording of causes and consequences could be difficult because of the rapid rate of discussion. As a result the initial minutes tended to be too terse. The secretary later insisted on preparing a fair copy which could be typed out later in order to produce results that could be used as plant documentation.

Another important function of either the chairman or the secretary of the group was to eliminate repetition. For example, there was a tendency for a disturbance originally stated as a consequence to reappear as a cause. The team found that time could be saved by cross-referencing from table to table as these were prepared in draft during the discussions.

A novice might consider that analysis of a batch distillation tower was hardly necessary since so many have been built with different purposes in chemical process industries all over the world. However, each situation is a little bit different and in this case, the risk analysis team found twelve modifications to the plant. Many of the modifications would have been uneconomical if these had been delayed until the plant was built. An example was the interchange of a sight glass and splash trap in a condensor outlet. The purpose of the change was to reduce the risk of possible sight glass breakage due to liquid or vapour hammer. The actual degree of risk was considered to be small but the cost of the change in design process was less than the cost of five minutes effort of the team using eraser and pencil. The team found that what took most time in the risk analysis was not the analysis itself but the resolution of the problems which were identified, including selection of the proper modification to implement.

Actual error analysis of the batch distillation tower

The method chosen for the analysis of the distillation tower was action error analysis. This methodology involves:

(a) Listing each step in the operating procedure;

(b) Describing the response in the plant for each step in the operating procedure;

(c) For each situation describing a range of possible error modes and plant responses to these errors, the error modes considered to constitute a complete list were as follows:

Action too early
Action too late
Action ommitted
Too much action
Too little action
Too lengthy action
Too brief action
Actio. n the wrong direction
Actio n the wrong object within the tower
Wrong action in general.

The team, therefore, used the following sequential analysis procedures:

(a) The immediate consequence of the action on the directly affected component;

(b) Effects of changes in the first component on those components directly related to it. This took account of alternative consequences which could occur because of different component states.

(c) Applying step (b) to the tracing of effects along pipes and cables taking account of alternative component states at each stage. The team noted the importance of remembering the full range of effects which a disturbance can cause. For example, pressure effects can travel upstream, against the normal flow of a liquid. Fires, vibration, and escaping jets of liquid can transfer effects via routes which are not shown on flow-sheets or piping diagrams.

To reduce the effort expended in carrying out the action error procedure, the team used pre-printed action error analysis sheets. One sheet was used for each action in the normal operating procedure and the extension sheets were used for those actions or errors deemed to have especially complex consequences or substantial likelihoods of occurrance.

V. NATIONAL CONTINGENCY PLANNING FOR CHEMICAL INDUSTRY EMERGENCIES[5/]

Industrial accidents are an unavoidable by-product of industrialization. For explosives or other chemicals manufacturing companies the possibility exists that an accident will develop into a large-scale disaster. On 24 September 1977, lightning ignited an eight-million-gallon tank of diesel fuel at the Union Oil Company Refinery in Romeovile, Illinois, U.S.A. Subsequently two additional tanks containing a total of seven million gallons of gasoline were ignited. The situation was brought under control after two days of fire fighting and the use of 20,000 gallons of foam concentrate as extinguishing agent. Eighteen fire departments were involved in the operation.

National contingency planning is the only effective way to combat large-scale industrial accidents. National resources are mobilized and a co-ordination effort mounted at a level higher than any private company can manage. The direct intervention of the government authority is required. Therefore national contingency planning is a governmental responsibility. Many public institutions, from ministries to fire departments, may be involved in development, and implementation of the plan.

A well-conceived national contingency plan will:

- Limit the consequences of an industrial accident in terms of human lives and economic losses
- Enable the country to organize and utilize properly national emergency forces and resources in case of industrial disaster
- Co-ordinate the emergency response actions between the plant and the response forces
- Make available to single industries emergency resources that they would not be able to obtain otherwise
- If properly publicized, the plan will instil confidence within the industry and the public
- Delineate the authority of the government in industrial emergency response and industrial safety.

A. Preliminary planning steps

National contingency plans are mainly co-ordination plans. Therefore the focus will be on the distribution of general responsibilities and tasks in case of a major accident. A hazard analysis will be the first step in the planning process, followed by the specification of emergency responsibilities of the different ministries and agencies.

One ministry or agency should be given the initiative to commence the planning process. This might be the national fire fighting force. Then the representatives of the other important ministries or agencies should be brought, for example, together in a series of meetings to develop the plan. The first meeting might make clear the need for such a plan and how everybody could be called upon to meet expected needs. Participants would then be requested to indicate in writing where their agencies could best help.

5/ Industrial Emergency Contingency Planning, op.cit.

After the written submissions had been organized and analyzed, command organization would be discussed at the second meeting. The agencies would also identify all other groups, or organizations that could provide assistance to their command staff assignment. A list should be compiled and edited of the resources available from each agency, how the resources are obtained (day and night), how they can be used, and the approximate amount of time required to reach a disaster in different districts.

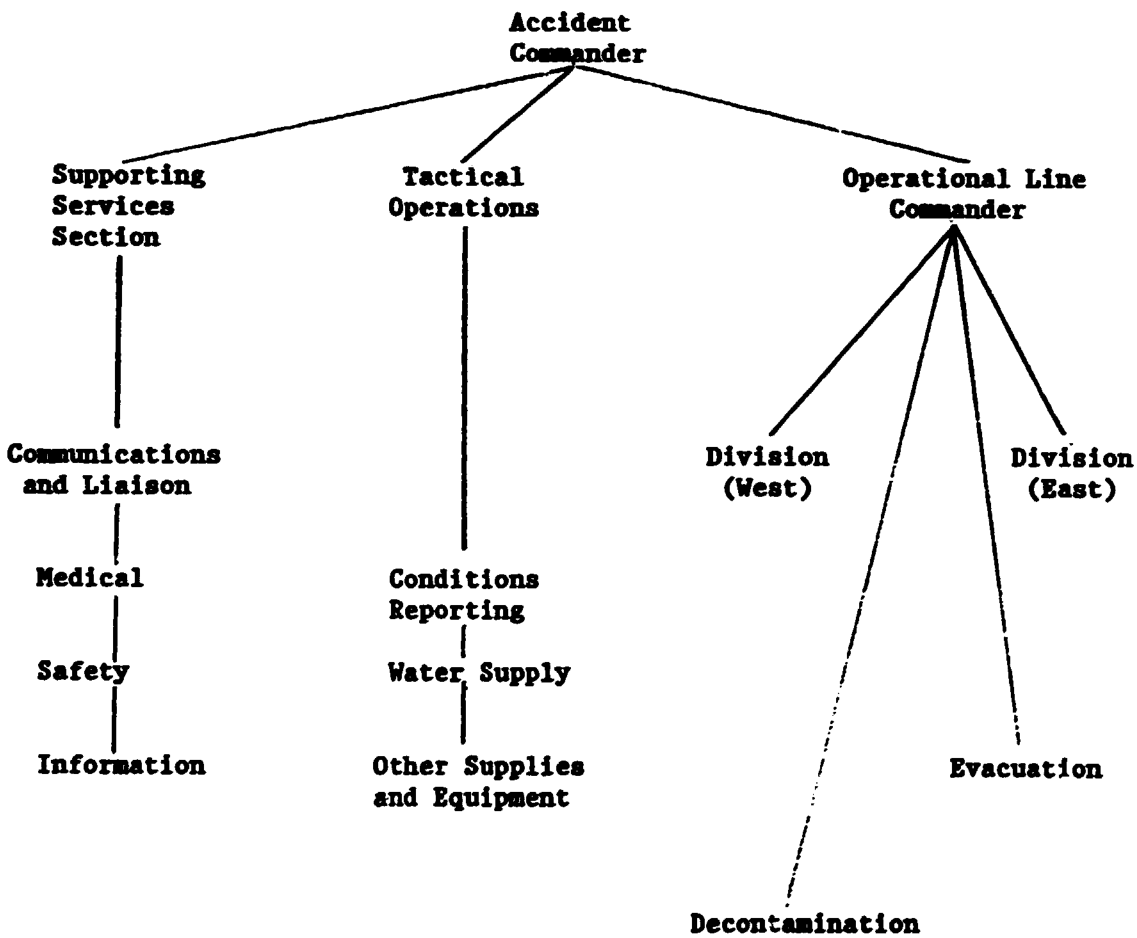
The written preparation of the full contingency plan would be initiated at the next meeting. The national contingency plan should include a section for each agency function, such as evacuation or safety, and outline the specific duties. For example, the police role could include municipal, provincial and national personnel. The role of each would be designated as well as the responsibilities of specific units, such as traffic and communications.

B. Command and service structures

Two of the main objectives of a national contingency plan are to define the command structure and to organize the different response agencies into that structure so that the numerous necessary operations could be carried out during large scale accidents. A suggested organization chart of the command structure is shown in figure 1.

Figure 1.

Organization chart - Command structure for the national contingency plan



(a) Accident commander

The accident commander is responsible for managing all emergency operations at the scene. He should direct the operations from a command post appropriate to the magnitude and nature of the incident. From this post he could, if necessary, obtain additional expert service and co-ordinate the actions of the operational forces using an emergency communications system.

The commander must co-ordinate fire fighting tactics with other actions such as process or pipeline shutdowns, and seek advice from chemical plant or carrier personnel with knowledge or specialized training in dealing with dangerous products involved. He must be prepared to apply tactics necessary to confine and control the emergency.

The accident commander has two primary means of appraising the emergency. The first is by visual observation of the emergency scene. Secondly, if the command post is not adjacent to the scene, someone else may make a visual check of the scene and report to the commander. An indirect method consists in checking the preplanning in the national emergency contingency plan.

If the accident commander leaves the command post, authority should be delegated to another officer and the commander should remain in constant radio contact with him.

(b) Overall command structure

The accident commander should delegate authority and responsibility as necessary to line and staff members. The commander is then free to develop the overall strategy and make the tactical decisions.

The line officers are responsible for achieving the objectives of the accident commander's strategy such as fighting a fire or evacuating an area. They are headed by the operational line commander. A divisional officer may be responsible for each front of the emergency.

The staff officers provide technical assistance and support. The tactical operations section develops alternative strategies and tactical approaches for the commander's review. The logistics section co-ordinates and acquires needed supplies, equipment, and personnel. Supporting services provide communications, medical services, and others.

(c) Line operations

The operation line commander is the on-site tactical commander and has immediate responsbility for removing injured or exposed persons and limiting the spread of the fire or hazardous material. He reports to the accident commander. His subsequent responsibilities include decisions about:

The type of operation: control, attack, or withdraw
Resources needed by each group to carry out these operations
Escape routes to safe areas and appropriate retreat signals
Handling unexpected hazardous situations
How long personnel are to stay in action before rotation or being relieved

The operations at large accidents can be divided into geographical areas of appropriate size with division commanders.

The responsibility of a division command officer should be to supervise the crew and co-ordinate its actions with other crews. The crew must function as a team; the officer should be concerned at all times with the safety and protection of the crew from exposure to toxic fume inhalation, explosion, or other hazards. The crew may also have other functions, such as evacuation or decontamination.

(d) Supporting services section

The supporting services section may include a communications officer, medical officer, safety officer and information officer. This section directs radio communications (including those to other agencies), treats the injured, maintains overall safety, and handles the media.

Communications and liaison officer. The communications officer must establish communications with all units responding and on the scene, outside agencies and technical information sources. He should record arriving agencies and keep track of their assignments. They should inform him of any resource shortages. He handles all transmissions into the command post and dispatched from it. The accident commander may of course require direct communication with the operation line commander.

The communications and liaison officer should have a detailed list of telephone numbers of local doctors and outside agencies which may have to be called. The communications officer should also know where to obtain additional equipment such as power megaphones, portable radios, power antennae, mobile telephones, or an emergency switchboard.

The communications and liaison officer also co-ordinates the actions of the outside agencies who can offer assistance to the emergency operations. Some of the agencies with whom the liaison will be maintained include law enforcement; rescue or emergency medical services; local government officials; utility company personnel, especially water, sewer, telephone, and electrical; health officials, hospitals, and ambulance services; the city lawyer for legal advice, if necessary; local, environmental agencies; local contractors for heavy equipment; service groups for facilities if evacuation of large numbers is necessary; manufacturers' representatives or trade association officials who respond to provide technical assistance.

Medical officer. The medical officer is responsible for providing first aid to those rescued and making sure that they are promptly transported for treatment. He may have to establish an aid station to take care of victims or injuries; for major accidents, it may be necessary to set up an entire field hospital. If necessary he will request the supply officer to obtain medical supplies, resuscitators, oxygen, and ambulances. He should have complete knowledge of local hospitals and notify them so that one is not overcrowded while another awaits victims.

The medical officer may have to co-ordinate with a coroner on identification procedures, removing bodies, and establishing a temporary morgue. In situations of lesser magnitude the duties of the safety officer and the medical officer may be combined.

Safety officer. The safety officer is responsible for the safety of everyone: emergency response personnel at the scene, the public living in the area and spectators, if any. He ascertains whether there is a potential risk from hazardous materials. Other duties are: informing the accident commander of safety problems; assisting in strategic and tactical planning; and reviewing all sector status reports to identify danger. The safety officer must have the authority to stop unsafe operations immediately if deemed necessary. He should make sure that special protective clothing is worn when necessary. He may also have to establish crowd control lines or decontamination procedures, along with monitoring the condition of everyone working on the scene.

The safety officer co-operates with law enforcement officials in order to block off the area, re-route traffic, and restrict access to the accident scene and the command post.

Information officer. The information officer is reponsible for providing accurate information to the news media. He should decide where the press can go. He may hold news conferences if the emergency continues. He may establish telephone lines for the media.

(e) Tactical operations

Tactical operations consist of the conditions officer and water supply officer. They are responsible for assisting the accident commander by developing alternative strategies and tactical operations. The planning is done in co-ordination with the logistics and operation line sections. The tactical operations section must also consider and present alternatives on how the operation line should be divided into divisions; what equipment and personnel should be held in reserve; the location of the staging area (where the reserve equipment is kept); possible accident spread, safety, and special problems such as shift of the command post, if necessary.

Conditions officer. The conditions officer keeps a record of what is happening on the scene and prepares progress reports of the situation for the accident commander. The reports should include the area involved, possibility and direction of spread, progress of the operation line forces, and any special factors, such as re-routing of traffic, arrival of special extinguishing agents, or evacuations procedures. The conditions officer should maintain an overall tactical control chart, which would detail the location of companies at the scene and their assignment. This chart would also show the sectioning of the accident fronts, the positioning of apparatus, and attack positions.

Records of all decisions should be clear, establishing who made it, and why. Records will assist in planning for the next accident and point out areas for improvement. Records will also serve as a justification for monies spent during the accident.

Water supply officer. The vast majority of industrial accidents include fires. In such cases, a staff officer should be assigned the task of making available to the response teams the most common fire extinguishing agent: water. The water supply officer determines the location, accessibility, and quantities of water available form all usable sources, evaluates the accident water requirements and initiates operations to overcome water supply deficiencies. He should have maps indicating storage capacities, main sizes, hydrant locations, and flow available in the area. The water supply officer will need to know apparatus capacities, locations and numbers of lines in operation.

Supply officer. The supply officer maintains the staging area where the rescue equipment is kept. He will acquire, store, and record all resources. The supply officer sends tools, equipment and apparatus to the line divisions at the scene of the accident on orders to the accident commander. He must then inform the liaison officer of the assignments.

The supply officer must keep an inventory of equipment and make sure that supplies are maintained, including breathing apparatus; generators and lights for nighttime operations; special protective clothing; ample supplies of extinguishing agents; equipment for damming and diking such as dump trucks, front loaders, and bulldozers; extra supplies of hose; cranes and tow trucks; floating booms, absorbing materials for oil or chemical spills; decontamination or neutralizing materials for corrosives (lime and soda ash, for example); a supply of gasoline, diesel fuel and oil. Even if these are not within the stores maintained by the supply officer, he has an inventory list indicating where the equipment or material is available.

C. Actions under the National Contingency Plan

National contingency plans are comprehensive plans geared towards the organization of the emergency resources rather than the detailed description of specific actions to be taken. Some of the general indications on how to handle a major emergency are given below.

The sequence of events which culminates in the implementation of the national contingency plans is, in an idealized setting, the following:

a) The first alarm is communicated to police or fire fighters which arrive at the scene of the accident and begin the response operations.

b) The fire chief decides that resources are not sufficient to bring the accident under control. He asks for reinforcement from other fire departments in the same area.

c) The joint units still cannot control the accident. The ranking fire chief alerts the authority in charge of activating the national contingency plan.

d) An emergency is declared and the implementation of the plan begins.

The authority in charge of activating the plan will be, in general, a high ranking government official most likely in the Ministry of Interior. He may be the national fire chief.

1. **Establishment of the command post**

The command post is the operating centre from which control of the accident is maintained. All incoming information and feedback from the accident will be directed to this post.

In order to co-ordinate the actions of the response teams at the accident location, a field command post could also be established and placed under the authority of the operation line commander. All division or sector commanders should give periodic progress reports to the field command post. The reports should include the current accident situation and control possibilities, any rescue or evacuation procedures, safety concerns, the condition of the area affected by the accident, any further resource requirements, and any special hazardous developments. The reports are then channelled to the accident commander.

2. **Development and implementation of response strategy**

On the basis of all the information obtained, the accident commander will develop the accident response strategy. Generally speaking he has three options: control the accident, attack it, or withdraw. The response actions may be a combination of these three with co-ordinated activities carried out by the response teams.

Many problems arise in the decision making process during an accident. Most of them are attributable to lack of correct information and communication problems. Examples are unknown products, accident locations that cannot be seen or easily reached, committing response units prematurely, difficulties in co-ordintating response teams from many companies, multi-department or multi-agencies operations, and hesitation in decision making.

3. **Evacuation**

Evacuation is considered to be the removal of all private citizens, including non-working emergency response personnel and the press from the immediate area of danger.

Evacuation may be necessary downwind from gases and vapours, downgrade from liquids or high vapour density gases, or in a circular area for products that explode. A simple rule of thumb is to initiate evacuation for at least one mile.

Evacuation, especially when dealing with large numbers of people, immediately raises numerous difficulties and problems. Some of these are:

How to alert the people effectively?
How to handle persons who will not want to move unless they can see the imminent danger?
How will large groups be moved? (for example, Chicago once had to evacuate 16,000 persons from a silicon tetrachloride cloud)
How will persons in the area be moved if they cannot drive because of poor visibility?
How will the public be moved, if a vapour cloud is present? The routing recommended may need consideration before evacuation is initiated.
How will the final check be made to see that everyone has left the danger area, especially at night?
From where will sufficient trained personnel be obtained in a minimum of time to perform an adequate evacuation?

The personnel to do evacuation work may be a critical factor. In many situations the fire service will be concentrating on the control of the emergency and be able to carry out evacuation only in the immediate proximity.

4. Restoration of services

A number of vital services could be impaired by the accident. Examples are contamination of the ground water table supplying wells or the water source for a community's water filtration plant. Auxiliary water supplies would have to be provided for the population. Another example would be the restoration of electrical power. The fire department may have to supply emergency lights and power for its own operations while awaiting the intervention of the power company.

D. Legislation and standards

The existence and enforcement of proper legislation on chemical plant safety and accident prevention is a necessary prerequisite to minimize the catastrophes which require activation of the national contingency plan.

Questionnaires and chemical plant inspections by technically trained government representatives could be utilized for this purpose in order to learn:

1. Information relating to the installations

Type of industrial activities
A general description of the technical processes
The geographical location of the installations, predominant meteorological conditions and possible dangers arising from the location of the site
The maximum number of persons working on the site of the establishment; number of those persons exposed to hazards
A description of the establishment which is important from the safety point of view; the sources of hazard and the conditions under which a major accident could occur; a description of the preventive measures planned
The arrangements made to ensure the safe operation of the plant and to deal with any malfunctions that might arise.

2. Information on the substances present at the installations

Data on substance identification (chemical and trade names, empirical formula, composition and degree of purity)
Substances stored or used in connexion with the industrial activities
The stage of the activity in which the substances are involved or may be involved
The approximate quantities
The chemical and/or physical behaviour under normal conditions during the process
The forms in which the substances may occur or into which they may be transformed in the case of abnormal conditions
Final products, by-products and residues
Other dangerous substances at the plant
Detection methods available at the installation
Means available at the installation for rendering the substance harmless

3. Contingency information relating to major accident situations:

Emergency measures prepared by the manufacturer in the event of accidental dispersion of dangerous substances
Emergency plans, including safety equipment, alarm systems and resources available for use inside the plant, for dealing with a major accident
The names of the person and deputies authorized to set the emergency plans in motion and to alert the competent government authorities

Eventually, such information could be stored in a computirezed data bank.

The government could also require that serious industrial accidents be promptly reported. Steps could then be taken to alleviate the long-term consequences and prevent the recurrence of each accident. Examples of serious accidents are:

Any accident which causes death or results in disablement resulting in absence for more than a week from a person's regular job
Fires or explosions due to vapour, gas or dust which result in damages to the workroom or equipment and which cause more than one day's down time to the plant
Release of toxic substances in the plant which escape into the environment in concentrations which exceed acceptable limits

Information of an accident should be supplied by the chemical plant to the government. The report format might be:

Type of accident (explosion, fire, toxic release)
Description of the circumstances of the accidents
Dangerous substances involved
Nature and extent of damage to persons' properties and environment. both within and outside the plant
Causes of the accident
Data available for assessing the effects by the government

The manufacturers could be required by law to prove to the government that they have identified existing major accident hazards, adopted the appropriate safety measures, and provided the workers on the site with information, training and equipment in order to ensure their safety. The preparation of plant contingency plans could be considered as part of these protective measures.

Legislation on transport of hazardous industrial materials deserves special attention. A government mmay require that dangerous goods arriving at its frontiers be properly packed, labelled and carried according to national regulations. The government may prepare:

The list of substances prohibited for transport by road or by any other means
Special measures to be adopted when transporting certain classes of material
Special requirements for the construction of the carrier vehicles, train cars, or barges
Labelling, placarding and packaging systems for hazardous materials transport

The regulations adopted by the member states of the European Economic Community represent a good example of international legislative agreement on this subject.

E. Municipal contingency planning

A national contingency plan should only be utilized in case of a major disaster. For smaller-scale accidents municipal resources might be enough to bring the accident under control. Contingency plans could also be drawn up at this levels. The procedures for preparing, organizing and implementing the plan are similar to those for a national plan. Therefore this appendix can also be utilized for this purpose.

F. Hospital contingency planning

The number of casualties caused by a major emergency could be so elevated in some cases, that the local hospitals may be overburdened. Therefore, each hospital management should also develop a contingency plan so that all the available resources may be mobilized and properly used in such events.

A hospital contingency plan should include a telephone roster of all the medical personnel listed according the proximity of their residence to the hospital. The University Hospital in Ghent, Belgium, has a 13-page emergency admittance plan updated annually. In recent years the plan has been activated five times due to emergency admittance of fifteen or more persons following an accident. One accident involved 17 injured persons resulting from the transport accident of a truck carrying inflammable industrial gas. In another accident 33 persons were admitted after inhaling chlorine gas released in an accident at an industrial plant.

G. Summary of the main objectives of a national contingency plan

In summary, the objectives of a national contingency plan should be:

Establish the authority responsible to declare a major emergency
Co-ordinate and unify the actions of different governmental agencies in case of a major industrial accident
Identify the resources that could be mobilized if necessary
Establish how responsibilities of agencies shift as more resources intervene to combat the accident
Establish how municipal and chemical plant contingency plans are going to fit into the national plan
Identify and organize the different services in charge of implementing the plan (e.g. the supporting services, logistics, tactical operations)
Define the procedures to update the plan and carry out training exercises
Identify the funds available to cover the expenses of the emergency operations.

VI. RECOMMENDATIONS

Governments are recommended to undertake the following activities in order to assist the chemical industry to establish and implement industrial contingency plans:

A. <u>At the chemical plants</u> (in co-operation with the government and/or the Association of Chemical Manufacturers)

1. Make a census of the existing industrial establishments in order to collect all the available information by means of which possible accidents could be identified, including flammable and other hazardous materials present at these installations.

2. Classify the larger chemical industries according to the relative hazards they pose to man and environment.

3. Set up regulations governing proper design, operation and maintenance for particular classes of hazardous chemical industries.

4. Establish standards and codes of practices for handling, storing or transporting hazardous materials within the plant (European codes might serve as a starting point).

5. Establish procedures for licensing and inspecting industrial installations and designate a governmental agency for enforcement.

6. Require manufacturers to show that they have identified the major hazards existing at their plants and adopted appropriate safety measures, including the preparation of contingency plans.

7. Require manufacturers of especially hazardous installations to prepare contingency plans for major emergencies. These plans should be flexible enough to be integrated with municipal, provincial or national response plans.

8. Require that even industrial establishments located in areas covered by governmental contingency plans develop their own plans, so as not to rely solely on public resources in case of an emergency.

9. Require the manufacturers to notify authorities of all serious industrial accidents.

10. Assign established agencies the task of preparing national, provincial and/or municipal contingency plans.

11. Provide fire departments and other action response groups with the equipment, manpower and training needed to combat major industrial accidents.

12. The Governments of the countries with well developed chemical industries should carry out a more detailed study in order to evaluate more accurately the extent and sources of industrial risk.

13. Both Government and plant owner must work together to ensure the safety of population in the neighbourhood of the hazardous plant which may be considered to be at risk.

14. National legislation has a wider task: it must cover such things as:

Arrangements for requesting and receiving emergency assistance from external sources;
Arrangements for facilitating the delivery of such assistance;
Protection from civil liability for assisting parties;
In another area, it must give effect to the provisions of international conventions, their recommended practices and required standrds in relation to all matters connected with hazardous substances.

15. This last point underlines the need for harmonization of plans and legislation between neighbouring countries and, at a different level, between plant owners and operators and the municipal, departmental and national authorities.

16. Local Governments should take measures to avoid the establishment of human settlements in proximity to industrial establishments. This could be implemented by preparing zoning regulations specifying areas reserved to industrial development and/or by creating industrial parks. Enforcement of such regulations should be as strict as possible to avoid creating hazards to the population.

17. Local fire departments should be brought to the highest level of intervention capability, since fire appears to be the most common widespread industrial hazard. Training of fire fighters would therefore be an essential feature in this scheme.

B. Transport of chemicals

1. Governments should undertake a preliminary analysis to identify the chemicals most frequently transported by road, rail, sea, or air.

2. By exchanging the information resulting from 1, areas for co-operation between neighbouring countries can be identified.

3. The chemical industries operating in the region should be encouraged to form an association for the development of a co-operative and mutually reinforcing system for responding to all chemical emergencies, and especially for those taking place at a distance from an industrial facility.

4. The general UN system of regulations for transport of dangerous goods is the basis for the specific regulations in transport of goods by sea, air, road, rail, and inland waters, should be adopted by all developing countries with some specific local adaptation. In introducing transport regulations it is recommended that special attention should be given to warning and information systems: drivers, police, firemen should know the meanings of the different labels. A special element could be added to the drivers' licensing course.

5. Simple public education schemes should be instituted so that hazardous loads will be readily recognized by the public themselves.

6. There should be some recommended itineraries, and possible the establishment of restricted hours for their use, and regulations reguiring safety vehicles to accompany hazardous loads. Special warning lights should be added to vehicles transporting hazardous loads.

7. The necessity to indicate (e.g. with special road signals) vulnerable-sensitive areas, such as a drinking water catchment area.

8. The need for having vehicles in good technical condition, therefore periodic technical inspection is recommended.

9. The speed limit should be indicated on the vehicle.

10. First aid and other emergency intervention means should be on board the vehicles.

11. The setting up of an intervention scheme. Here, close co-operation is needed between authorities, intervention teams and the industry involved.

C. Preparations at the initiative of industrial plants

1. Hazard analyses and contingency plans at the industrial plant level should be developed on the basis of guidelines established for similar industries in industrialized countries.

D. Co-operation among developing countries

Regional co-operation in the field of control of pollution and risk of accidents due to industrial installations could be envisaged in four areas:

1. Exchange of information on:
   Competent national structures
   Legislation
   National plans and other means of intervention.

2. Creation of a regional warning system:
   To report accidents
   Potential consequences on neighbouring countries/zones
   Prevention and control measures to be taken and mobilized.

3. Mutual assistance in terms of:
   Providing specialized personnel and experts
   Supply of means of monitoring and control
   Providing sites for the disposal of toxic substances
   Facilitating the movement of staff and material.

4. Establishment of regional norms for industrial pollution control including impact studies in order to ensure safety in industrial plants.

E. General recommendations for chemical installations

1. Governments should:

(a) See to it that the industrial installations within their territory have contingency plans and safety departments in charge of implementing these plans.

(b) Adopt incentives likely to help plants running big risks to make all the necessary arrangements in order to draw up plans for the protection of men, property and environment. These incentives could include, for example, the reduction of customs duties on safety and anti-pollution equipment. On the other hand, Governments could also encourage industries manufacturing such equipment to establish plants in their territory.

(c) Group industries so as to draw up mutual assistance plans in case of serious accidents in industrial zones.

(d) Associate national institutions concerned with environmental protection in the process of establishing new industrial zones and factories including decentralization policies.

2. The Governments of the developing countries are advised to set up or strengthen national structures which are administratively or technically in charge of regulating the control and the inspection of industrial units to ensure the security of men and environmental protection. This may thus help to reduce risks of industrial accidents.

3. Such structures constitute an indispensable basis for the implementation of a coherent policy in the field of environmental protection especially by drawing up a procedure for examining files of industrial plants and their classification according to the declared activities and potential risks.