of Tambora but one which is one magnitude smaller on the volcanic explosive index scale (VEI) (T. Simkin et al.,1981), combined with one or more other ones which are somewhat smaller in turn and, therefore, more probable.

On the other hand it appears reasonable, at least according to the data presently available, to discount the impact of an Apollo body on earth. Craters of a diameter of about 10 km which are the consequence of the impact of a body approximately half a kilometer in diameter and associated with a liberation of energy equivalent to about 10^4 MT of TNT have been estimated to be associated with a global return period of about 10^5 years.

In other areas, the neglect of what one could call the obvious is more common. For instance, plants processing one of the more inflammable varieties of hydrocarbon compounds and located in earthquake zones are far more exposed as regards a catastrophic conflagration or explosion than such plants outside of earthquake zones. Still, very little is done to optimize such risks.

This holds good for flood protection in seismic zones as well. The Chinese moved some 4×10^8 m^3 of earth and built dikes along the rivers which took extremely heavy human toll in the past. Such dams may, however, be destroyed by earthquake at the time of a flood or shortly before it and it is surprising that this appears not to have been considered in the design in spite of the seismicity of some regions.

One of the most frightening neglects in terms of the catastrophic loss potential in terms of life and property is as well associated with earthquakes. It has been neglected in the past to compile earthquake damage statistics which would have allowed to quantify the influence of the various parameters contributing to losses. This forced us to collect data ourselves in order not to have to rely on "guesstimates".

To conclude this chapter it may be said that risk research and its application are still in a state of infancy. Large modern complex projects, however, would benefit very much from the refinement of such tools.

We will now discuss some specific risks and start with fire and explosion, which are not, as English usage has it, Act of God, but very much influenced by people and therefore man-made. The discussion will concentrate on chemical plants.

Fire and Explosion

The following lines try to give an outline of a systematic, albeit synoptic analysis of causes and consequences of fires and explosions in chemical plants and of conclusions which may assist in deciding on economical loss prevention measures.

Most losses can be traced back to one or more factors which caused the fire and/or explosion. Only about 10% of the events remain unsolved.

One way of classifying loss-causing parameters may be illustrated by the following algorithm.

$$X_F = f\,(m, i, d, t, h, tech, e).$$

Herein X_F is the total fire and explosion risk, which is a function of the material (m) handled, ignition sources (i), distribution of material (d), time (t) during which the fire or explosion may develop, human factors(h), and technical causes (tech) , as well as environmental agents(e). This subdivision is to a certain extent artificial because, the human factor, for instance, controlls practically all other factors. It is the human being which decides on the material to be processed and the quantities used, introduces most of the ignition sources, designs the distribution of combustible material in the plant whether in a directional sense or regarding masses, plans fire fighting which controls time available to the fire or explossion suppressants, determines which training should be given to the operators, which technical components will be incorporated in the plant and which standards shall be applied, and, finally, which standard of protection against, e.g. earthquake, storm, or flood will be selected.

In spite of this it is useful to categorize the loss causing factors, and, this may be mentioned here, the plant items involved at the outset of the incident, in order to throw light on the characteristics of the accidents. Only by such studies one may hope to come to grips with the problems. We mention in passing that the above algorithm only describes the most essential aspects. For a refined analysis a more detailed approach is needed which cannot be discussed in this report.

The material (m) is characterized by factors like calorific value, ease of ignition or explosion, quantity, etc. The more dangerous one or more properties described by the parameters of a given material are, the greater the care to be applied in its handling Unfortunately designers and operators of such installations get accustomed to the material processed, and even the layman is less impressed by one ton of cyclo-hexane - the type of material which was involved in theFlixborough explosion than by a ton of dynamite. Therefore the latter is stored behind barbed wire, the former and many other highly dangerous chemicals are often handled quite carelessly.

Thinking in analogies does help in connection with many problems of life, why not converting sometimes tacitly the material processed into tons or kiloponds of a well known explosive? Such a conversion will show that steam under pressure is as energetic as gun powder and that most hydrocarbons, particularly in gaseous form, are much more destructive than dynamite.

Sources of ignition (i) can be smoking (this risk is not removed entirely by forbidding to smoke in a plant or area of it!), welding, soldering, open fires or hot parts, sparks, e.g. from static electricity, lightning which may also be handled among environmental perils, reactions, and other causes.

One is normally cautious within the area which is considered dangerous, but does one really know which area should be defined as dangerous? The catastrophe at Feyzin, France, occured because gas heavier than air escaped and reached a road which had not been closed to traffic. There it was ignited by a passing car. Many hydrocarbons are or can become gasses heavier than air which will spread as an explosive gas-air mixture over a considerable distance if weather conditions are favourable, in particular if an inversion is prevailing.

Pipes and their accessories contribute considerably to accidents, as will be discussed later, one is therefore well advised not to be too optimistic regarding probability of leaks developing in such items, which release dangerous material.

A combination of hazardous process materials with enhanced chances of ignition results in cumulative exposure, which should be considered in any careful analysis. In plants using hydrocarbons, solid, liquid and gaseous hydrocarbons represented more than 50% of the materials first ignited, more than 20% involved other organic solvents. As source of ignition electricity including lightning was to be blamed in a full quarter of all incidents. The latter percentage could even be higher as unknown sources of ignition accounted for a full 28% in the nearly 500 cases evaluated here, and as regards the 25% of cases caused by electricity a further 15% have to be added to allow for static electricity. This means that at least 40% of all accidents studied here were caused by some form of electricity. Welding and cutting was to be blamed in ten percent of the incidents. Do safety engineers, for instance, realize that the production of sparks and therefore the ignition probabilitty, can be very much influenced by selecting proper electrodes?

The examples show that it would be particularly rewarding to scrutinize the plant regarding electrical sources of ignition. It is quite certain that a thorough familiarization of the maintenance team responsible for electrical equipment with such aspects would be a great help in reducing the number of such ignition chances. A 20% improvement would mean about 10% less accidents.

On the other hand gas burners caused only about 3% of the losses. An improvement of 20% in the safety of this item would augment the overall safety by less than 1%.

The distribution factor (d) is in the interpretation used here rather complex, as it involves horizontal or vertical distances, quantity of dangerous material as spread throughout the plant, particle size if solid material is handled, areas endangered, considering a probabilistic approach to wind directions, and other related factors. Unfortunately the technological trend is towards increase in exposure, as distances are kept as short as possible and quantities of dangerous material handled are raised continuously. There is a general trend to install additional components in a plant which originally provided reasonable spacing. Inadequate spacing is aggravated if traffic difficulties exist in the plant in the case of an emergency, if the water supply is inadequate, or if supporting structures have not received sufficient fire-resistive protection. We will therefore have to look here at the combination of such factors.

In the HPI-industry losses determined by inadequate spacing account for about 35% of all accidents, next to equipment failure the most important item. Even if a plant is at hand which has not been spaced properly or where later expansions have impaired the original situation, one does not have to abandon all hope. With some thought and few modifications, traffic condition can be improved. Water supply may be modified easily even in a crammed plant, and one may even weigh the cost of installing larger diameter pipes against the expense of a chemical additive to water used for fire fighting which makes water "more fluid" and permits pumping of an increased volume through the original pipes Finally fire protection to supporting structures can nearly always be applied spending very little extra money.

The extent of a fire in particular, of explosions to a less spectacular degree, is very much a function of time (t) . We have here two main factors, the speed of combustion and of propagation of a fire, and the time required to bring efficient fire fighting into operation. Not much may normally be done in connection with speed of combustion or with explosions, once they occur. (As mentioned earlier, some explosions can, however, be controlled by suppressive devices.) The propagation of fires is, however, a different case. Quite frequently a fire may spread quite easily because not much thought has been invested in finding out where one could introduce impediments like easily accessible valves for shutting down the fuel supply to the fire, coffering fills in trenches, walls, etc., or which objects should be removed because they constitute fire bridges. Fire fighting is a problem concerning equipment, distances and training, to name some essentials. Equipment may be improved or pooled if several plants are located in the same industrial area. If one should bank on public fire squads one is well advised to study the time required for such groups to reach the site during rush hours. Such a study will frequently reveal grave shortcomings. Regular drills including and based on emergency programmes should be considered a must. They should consider all sections of the plant and all types of accidents. Drills which have not been announced should be frequently practised.

Also in this respect thinking in analogies may help. Anyone who has played a musical instrument knows very well how proficiency drops if practising is discontinued for some time. Any surgeon who has to consult a handbook if an emergency develops during an operation is a menace, and this applies to a fire fighting team which is not exelently trained. Referring to the example of the surgeon one may add a somewhat cruel but nevertheless correct analogy. It pays to compare the value of the life assurance or workmans' compensation normally in force with the value of a large plant, also considering that this plant provides the livelihood for a multitude with the average care exercised in these cases.

Such losses can be reduced very much if all people involved are properly instructed and trained and this not only because the probability of accidents is reduced, but because fire fighting is commenced faster and is more efficient. If we assume a linear spreading of a fire, halving of the time would halve the loss, if we consider that an exponential spreading is more likely, at least as long as sufficient fuel is available, a saving in time will save money in an exponential way.

Human failure (h) is a grave problem which becomes more costly with the increase in size of the plants and to a certain extent more probable if the people involved are overtaxed by the ever increasing complexity of modern projects. As a direct loss causing agent human failure accounts for about 15% of all accidents. The rate of failure is not constant during the week or during the shifts. It is three times higher on a Monday than on Wednesday, and on the last day of the working week nearly as high as on Monday. About 50% of the accidents occur during the first and the last working hour, the remaining half during the rest of the working day. From this a lesson may be learned. One should void such dangerous periods for critical operations, and if this may not be feasible, introduce additional qualified supervision. If one operator has a probability of failure of 1 permille and if an independent supervisor performs equally, the combined probability of failure changes from one in one thousand operations to one in one million operations. This shows that additional safety may be bought for very little money.

A further headache is that technical personnel, whether workmen, foremen, engineers,or the technical management, is not trained at institutions, schools or universities with the probability of failure foremost in mind. This is very regrettable because people trained in this incomplete way generally design, built, erect and operate chemical plants wearing pink spectacles. They are trained to believe in and to see success and not to realize that the technical world is full of diseases. Properly organized training programmes which are repeated and suitably adjusted at regular intervals could do much to make plant operation more reliable.

There is a vast field of technical failures, i. e. failure of equipment for technical reasons, in chemical plants. This may be surprising but one would do well to remember that, for instance one percent of a large sample of flat bars have a tensile strength which is nearly 20% below the desired value, seven samples among hundred are ten percent below the standard, and among one thousand samples there is about one which is a full 25% below standard. In chemical plants austenitic steels are much used. Does the average operational engineer realize that the load which causes failure after,e.g. 100,000 hours at 600 centigrades ranges from 12 to 24 kiloponds per sguare millimetre? Pipework in a medium-size refinery is generally longer than 1,000 kilometers. It is not surprising that accidents caused by pipes and accessories account for nearly one quarter of all losses. One does not need a "Bermuda-Triangle" to sink a ship, a chemical plant or a nuclear utility, the normal failure distribution of material, or defective material may do.

If we look at the direct loss causing factors we find that equipment failure is responsible for nearly 70% of the accidents. This is an alarming figure and we shall therefore look at some details.

Design and manufacturing deficiency account for10%, selection of unsuitable material for more than 30%, faulty installation, and insufficient maintenance contribute about 12% to the losses.

In connection with the item involved it was mentioned already that pipes and accessories claim nearly 25% of the number of accidents. Pumps and compressors contribute 12%, an equal figure arrises from leakage of unknown origin, destillation and separator columns cause 11% and milling, pelletizing and bagging units an identical percentage. Tanks for holding and storage contribute 6% of all losses in spite of the fact that they are not complex items.

Last but not least, one will have to take note of the fact that the increase in unit size results in a higher accident frequency. Considering number of accidents per 100 pieces of eguipment one can say that the number of accidents goes up by 60% if one compares 10 and 50 MW steam turbo sets, it doubles if we hold 2,000 against 1,000 KW electric motors, and it increases by 400% if we compare 2,000 with 500 KVA transformers. If preventive maintenance is properly organized one can hope to reduce the failure probability by at least 10%. This would improve the overall plant safety as regards fire and explosion by about 7%. The Flixborough, UK, disaster was precipitated by a makeshift pipe connection to by-pass a reactor which had developed a crack. This pipe was inadequately designed and not properly tested before the plant was started again. It failed and a tatal loss to the plant was the consequence with much additional damage to a township in the vicinity.

A few words may be mentioned in connection with environmental factors. They are in particular lightning, storm, inundation and earthquake. Also in this connection one has to see the probability of an event as compared to the cost involved in improvements, i.e. performing a cost-benefit analysis.

Lightning protection is normally so cheap if compared to the disaster which may result from a lightning, that it should be optimized in nearly all installations. Inundation may become an increasing problem in the future bacause large plants are normally built in areas which are naturally flat and require little earthwork before installing the project. Such plains are of an alluvial nature and therefore subject to a certain risk of inundation. This risk may be quite grave near to rivers or the sea if the area is exposed to tidal bores, or if a place is at hand where ponding may occur.

If we assume a return period of 50 years for such an accident and if we consider that a very large loss may be the consequence, a cost-benefit diagram will tell us soon which dike should protect the site, or which foundations should be raised and by how much.

Earthquake can be a pronounced peril in certain areas where the earthquake probability is high and where the subsoil is soft, a factor which increases damage quite considerably. Loss probability minimization may not be very expensive; a study is certainly recommended. The most vulnerable items involved are electrical equipment a failure of which may foil orderly shut-down of the plant, top-heavy items and pipes in the plant which may be exposed to excessive loads if equipment connected to them oscillates at different frequencies. Remedial measures are generally not expensive and may also be introduced in an operating plant or during routine maintenance.

In conclusion it is noted that one should not overlook that the direct loss caused by a fire and explosion is only one part of the problem. The accident will normally always cause an interruption in production and this loss, which may include loss of markets as well, can be larger than the material damage. An increased operational safety means that the propability of such losses diminishes as well.

Human Failure

Some aspects of human failure have been mentioned already in the earlier chapters. Now a general approach to the problem will be discussed briefly.

The main parameters controlling human failure can be represented by the following algorithm:

$$H_{G\&R} = f\ (T,\ Exp,\ Ra,\ M,\ Rp)\ .$$

The risk of human failure for general and residual reasons is therefore the function (f) of the training a person has received (T), the experience (Exp), the risk awareness (Ra). the motivation this person has to prevent accidents (M), and the personal risk of the person if an accident should occur (Rp).

Even if we discuss these parameteras sequentially it must be realized that a clear distinction is not always possible and that the effects of these aspects often overlap.

The training should be considered including childhood. It is not only the professional training or the one on the spot, or during special courses, but the education by the parents and friends. Very obviously this training has an influence on risk awareness but in general not as much as some may think.

Theoretical training is one thing, experience with accidents, preferrably with a large number of them must, however, be considered even more important, in particular if several favourable assets coincide, viz. an excellent training, a tendency of the respective person to analyze events critically, a proper measure of risk awareness and, last but not least, plenty of experience with accidents. In an earlier chapter the number of observations required to develop damage or event probability distributions was discussed. What was stated there holds here as well.

Risk awareness appears to be predominantly a psychological property of the person concerned, which can be altered least by teaching, and not even much by experience. A simple but convincing example are motoring accidents. Such accidents do not afflict people randomly but people who are gifted with acute risk awareness suffer less accidents than other motorists who appear to be incapable of learning. The simple lesson herefrom is to remove persons from important , risk-controlling positions which do not agree with their mentality.

Modern society has come to realize that motivation is a very important parameter and to some extent the key to success. Proper motivation will consider the most efficient approach to motivate the people concerned. The broad spectrum of human inclinations must be considered in this respect, and the different degree to which people may be motivated.

Anyone who is directly or indirectly exposed to the consequences of accidents, i. e. who runs a personal risk, will to some extent adjust his actions to this exposure. One should, however, not believe that increasing the personal risk is the most efficient way to motivate people. Someone who, for instance, lacks a proper measure of risk awareness will be imune to some extent to a certain personal risk.

Damage to Industrial Equipment

We have learned from more than thirty years of research that damage to industrial equipments and/or the monetary loss resulting herefrom can be categorized for the purpose of a first-hand assessment of the accident potential and for considering remedial steps. The following three illustrations serve to demonstrate some cases and permit at the same time an assessment of remedial steps.

It must, however, be stressed that the immediate loss or damage is only part of the problem. Reducing accident probability, i. e. shifting the damage probability distribution to a lower level will at the same time have a very beneficial influence on the risk of indirect damage or losses.

RECOMMENDATIONS

According to the algorithms contained in this paper or according to more sophisticated models a catalogue of exposure should be elaborated. It should show priorities and remedial steps together based on cost-benefit analysis. This catalogue should not only consider direct damage but consequential losses.

This catalogue should receive its final touches with the help of an expert. Experience has shown that even well-trained persons who lack the required experience will otherwise initiate steps which are economically not warranted.

The following suggestions address some of the parameters discussed

1. Plant lay-out should be analysed assuming different disaster scenarios.

2. Preventive maintenance should be introduced, in particular for exposed items.

3. Proper attention must be given to the high incidence of accidents during testing and for some time after commissioning of a plant.

4. Ageing of critical elements and wear and tear should be controlled, if required by non-destructive testing.

5. Fire drills considering all scenarios must be performed regularly, and if possible without prior announcement.

6. Adequate safety factors must be considered in planning, design, construction, and operation.

7. Much emphasis should be given to passive (intrinsic) safety.

8. Persons with a decisive influence on risk should be screened as regards their risk awareness.

9. Critical operation and/or repair should not be done during periods and hours incorporating an increased probability of human error or failure.

Fig. 1. Relative importance (simplified) of various causes of accidents depending on the type of the machinery. For risk analysis and optimization far more detailed information is applied. Even this simple illustration shows that one has to look far more for manufacturing and design defects in pumps than in steam turbo generators. The graph does not consider the performance of large modern transformers which are far more beset by design and manufacturing problems than those shown here.

Fig. 2. Schematic illustration of the relative importance of breakdowns of the parts most frequently involved per type of machinery. This picture, however, only considers numerical aspects. The cost or interruptiveness of failures is not necessarily correlated directly with the failure of these parts. Exposure is after all the product of frequency of breakdowns and of the severity of the consequences. This demands an analysis under at least two headings.

Fig. 3. Importance of breakdowns of individual components of boiler feed pumps. It shows that risks may be improved very economically if ample damage statistics are available. It is seen that three parts contribute nearly 75% of all accidents. If the performance of these three parts can be optimized by 10 to 20% this will improve the reliability far more than any successful effort to alter the accident frequency of all remaining items (9 = other items).

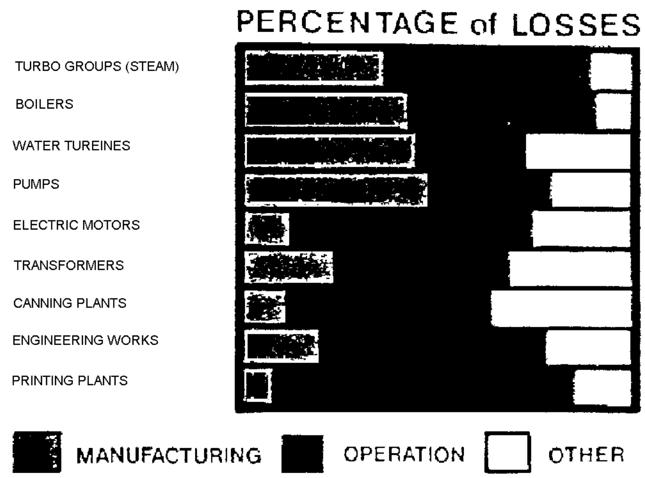

Fig. 1

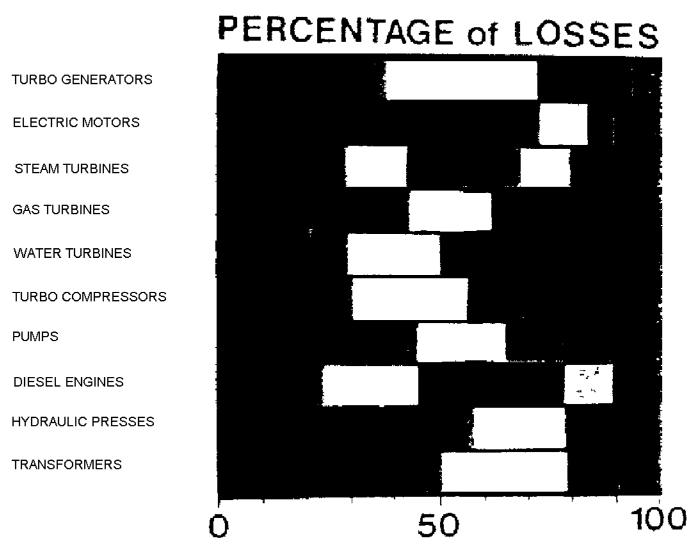

Fig. 2

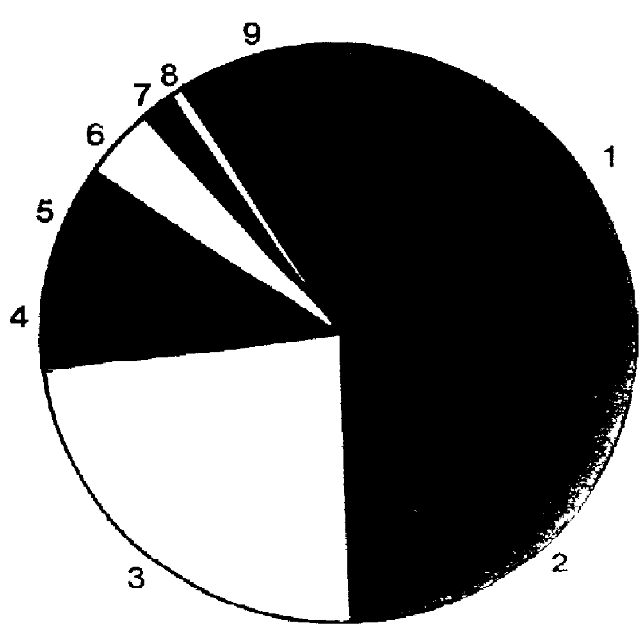

Fig. 3

III. A. 7. CIVIL DEFENCE ASPECTS

1. INTRODUCTION

1.1. Civil Defence Objectives

The longterm objective is to enable the Republic to take steps towards the mitigation of the adverse impact of earthquakes, and other natural and man-made disasters on the socio-economic structure of the country.

The immediate obetive is to:

(a) review existing techniques and facilities for disaster preparedness and management.

(b) improve efficiency in the search, rescue and location of people trapped under debris.

(c) improve the efficiency and preparedness of the life-support, health and aftercare services for the injured and the homeless.

(d) review existing technical facilities and equipment needed for effective disaster response.

(e) formulate technical criteria for the design and development of modern search and rescue equipment.

(f) establish systems of training and education for all levels of the civil defence structure from senior management to communities and individual members of communities.

Methodology

For Civil Defence generally we had three meetings and discussions with senior Soviet Civil Defence officials at State level in Moscow.

In Armenia, we had four meetings with senior Civil Defence officials of the Republic at the Civil Defence Headquarters in Erevan.

In both instances full and frank discussions were held and we were given a detailed insight into civil defence strategy and tactics for disaster situations. Due to pressure of time we were unable to have direct talks with security, fire or health services, except for the Soviet Red Cross. We were disappointed that industry showed a marked reluctance to provide visiting facilities, and this area was, in our view, one of the most significant.

In considering education and training we had a chance to visit the Moscow Regional Civil Defence School. We were not ahle to visit a similar establishment in Armenia, or any practical training grounds (called in the Soviet Union 'training fields').

2. OVERVIEW AND GENERAL ISSUES.

2. 1. General Organization.

Losses in human lives and property from all types of disaster have been rapidly escalating in spite of measures undertaken by governmental and other agencies to promote disaster preparedness planning and organisation in order to mitigate the adverse consequences of disaster.

The earthquakes at Spitak and Dushanbe demonstrated the extreme vulnerability of human settlements to this type of disaster and the losses caused by these earthqakes are often made more destructive due to secondary effects triggered off by them (e.g. landslides, mudflows, avalanches, fires and damage to industrial installations).

The USSR Scientific Research and Development Institutes are well known for the high standards they have achieved in the field of earthquake risk assessment, land use zoning and mapping. However there is much room for improvement in disaster management for cities and regions threatened by earthquakes, especially when their impact is aggravated by secondary effects, and in all other disaster risk areas, both natural and manmade.

Civil Defence in the Soviet Union, and in the Republics, has traditionally been regarded as essentially a service dedicated to the protection and survival of the population in war. Consequently it has been, and still is, attached to the Ministry of Defence. This attachment is emphasised by the Minister of Defence holding the portfolio of Chief of Civil Defence.

Thus the mandate formulated for Civil Defence is, inter alia:

* To protect the population from weapons of mass destruction.

* Carry out rescue in the epi-centre of the area of destruction.

* Provide information to the population.

* Training the population, including industry, in the aims and objectives of civil defence.

Recently, after the Chernomyl catastrophe, the mandate of the Civil Defence has been enlarged, and it now also includes the mitigation of natural and industrial disasters.

2. 2. Industrial aspects

Industrial catastrophe requires a skein of incidents to unwind and create a specific situation at a specific time and under specific conditions. Many of those incidents could be occasioned by minor matters. All of them could coincide by sheer chance, then the unthinkable becomes the possible.

It appears to us that, in Armenia, there are many ageing industrial plants which have survived the onset of time. But as with carthorses and railway locomotives and human beings, when assessing the condition of a plant or factory or any industrial installation the span of years cannot be taken in isolation. Other factors must be taken into account. The base quality; the use or employment; the degree of care and attention during the working life of a plant all are significant factors. Sometimes a deceptively impressive exterior conceals subtle working decay. In addition other factors can combine to create conditions under which the possibility of being overwhelmed by disaster hangs literally by a hair trigger. An otherwise tolerable human error; some trifling commonplace mechanical failure; even some sequence of routine acts, all of them safe when performed in isolation, but one chance catalyst occurs then the possible becomes the inevitable.

3. SPECIFIC THREATS AND ISSUES

3. 1. Industrial Disasters

When considering the general factors relating to industrial hazards the key words on which to focus are: fire; explosion; toxic effects; biological effects; radiological effects.

On the territory of the Republic there are a number of potentially hazardous industries, in which any of these hazards may occur, either singly or in combination. Toxic effects may accompany fire, explosion may be accompanied by radiological effects.

The Armenian Nuclear Power Plant, which was closed in April 1989, still contains potentially dangerous radioactive material. We understand also that potentially hazardous nuclear waste is disposed of on-site.

In addition there are 29 chemical plants which may also be considered dangerous, and a numher of plants which may be regarded as hazardous from a fire or explosion point of view. Particularly hazardous are such major production plants associated with chlorine and ammonia which are located in Erevan. Due to the close proximity of urban development, at risk from these installations in the city are about 52,000 people, of which, it is estimated that 34,000 people could be seriously affected or killed in event of a major disaster in one of these plants.

3. 2. Transport Disasters.

Bearing in mind that many major hazard incidents involving hazardous substances have occurred in the transport mode, we noted that the Republic has about 500 kilometres of railway, two major airports at Erevan and Leninakan, and a fairly extensive road network linking all major cities and towns. We understand that there are normally about 15/22 trains per day running through the Republic each comprising 50 wagons.

Although we were not able to ascertain exactly the loads of these trains it is reasonable to assume that an increasing number of hazardous materials are being carried by both road and rail transport. Some materials are volatile, some are toxic, some are flammable. A hazard exists in every case, especially at interchange and marshalling yards.

With regard to the Airports there are a large number of flights in and out of the Republic of both passenger and freight traffic. Although aircraft do not carry hazardous materials, per se, they nevertheless form a potential threat to the towns and cities over which the flightpaths are directed, and more directly to the two major city terminal airports and their environs, especially during the take-off and landing modes.

B. DETAILED STOCKTAKING: INDUSTRIAL DISASTERS.

1. Procedures and Methodologies.

1. 1. Industrial Disasters

Chiefs of industries should carry out assessments of their activities to ensure that all that is reasonably practicable has been done to avoid or reduce danger.

It is therefore incumbent upon management to initially determine:

* where within the plant there is potential for a major emergency.

* given that potential, the possible consequences in terms of risk to people and spread of damage both within and without the plant

* the adequacy of existing resources and arrangements to handle the most serious foreseeable emergency.

* what further provision or action is required.

All this should be determined by carrying out a SAFETY AUDIT, particularly in those areas of the plant where large amounts of hazardous materials are processed or stored, but not overlooking other sources of hazard, e.g. equipment, machinery or operator capability.

A safety audit is not necessarily a quantitative risk assessment, but aims to disclose the weaknesses and strengths and the main areas of vulnerability to risk. It should subject each area of the industries' activity to a systematic examination with the object of minimising loss. Every component of the total system is included namely:

* management policy.

* attitudes

* training and education.

* features of the process and the design and layout of the and construction of the plant.

* operating procedures.

* emergency plans.

* personal protection standards.

* accident records.

* emergency equipment and appliances etc.

A formal report and action plan should then be prepared AND MONITORED by an independent outside body preferably from the local government authority.

When assessing the potential for loss or damage, account should be taken of such factors as:

* population densities in the areas likely to be affected.

* the location of any incident in relation to built-up areas and other sources of hazard.

* prevailing winds.

* the probahility of contaminating crops, water supplies, drains etc.

* the presence of radioactive materials.

* the possible effects of the collapse of high rise structures

Design techniques to minimise, detect and control releases should be built and utilised wherever possible.

Emergency Operating Centres should be in general designed to maximise the safety of control personnel, allow control of the plant to be maintained and provide ability to monitor and shut down other parts of the process and safeguard plant records.

In order to adequately ensure that effective emergency plans exist within an industry it is necessary to have the local Regional authorities monitor such plans to make certain that such plans encompass the effects of incidents both 'on-site' and 'off-site'. The Republic's Civil Defence Service, with its regionally based officers are in the best position to assist in the preparation and coordination of such contingency plans, giving the optimum use of expert staff and resources compatible with the principles of the '"all hazards approach" to civil defence planning and organisation. Such coordination will ensure that all emergency plans are regularly tested, validated and exercised within the plant, and with other industries and authorities.

C. DISASTER PREPAREDNESS.

1. Overview of the Situation.

Civil Defence in the Soviet Union is a national service firmly based on the Ministry of Defence with the Minister of Defence as its ex-officio Chief of Civil Defence. Policy is formulated by the State through the Council of Ministers and passed down to the Republics for implementation through the Republic council of Ministers and the territory Civil Defence Organisation. Within the broad policy guidelines set out by the central government, each Republic appears to have a measure of autonomy to develop its own Civil Defence strategy.

Industrial Civil Defence is however directly governed from the centre through the Chiefs of Plant, who are heads of Civil Defence for the enterprises.

In the Armenian S.S.R. Civil Defence covers the whole territory of the Republic with its Headquarters and Operational Base in Erevan. The Chief of Civil Defence is the Chairman of the Council of Ministers of the Republic, assisted by the Chief Civil Defence Officer, who is a fulltime professional. His role is that of Staff Officer and Operational commander to the chief of Civil Defence.

Each of the 37 Regions in the Republic is similarly organised, with the Chairman of the Regional Council as Chief of Civil Defence, assisted by a wholetime professional Civil Defence Officer.

All communities have a volunteer Civil Defence Officer with responsibility to the Council of the community.

The City of Erevan is a Region in its own right, but in this case the Military Commander is the Chief of Civil Defence for the City/Region. In Ministries, committees, institutes and industries Chiefs of Civil Defence are the Heads of the respective organisations. For all activities on civil defence there is a related department headed by a fulltime worker in Civil Defence. There are also permanent emergency commissions headed by first deputies of the respective plants and industrial complexes, Chiefs of ministries, commissions etc. are also included. The administration of the commissions falls to the Headquarters of Civil Defence.

Following the Chernobyl disaster an order extending Civil Defence functions was promulgated by the Central Committee and council of Ministers of the USSR, laying additional tasks on Civil defence to protect the population from natural and industrial disasters.

Following this order recommendations sent from the State Civil Defence Headquarters were received hy the Republic Civil Defence Headquarters, and a plan was prepared prior to 7th. December 1988.

This plan was in two parts. Part 1 dealt with the risk assessment for all Regions of the Republic, and Part 2 sets out the organisation, implementation and execution of the plan, together with an information and communication section.

The plans are sectoral, and we saw those relating to Dam burst emergency, which with mudflows and landslides had been given priority. These plans for warning, monitoring and evacuation appear well founded, and have been tested in an emergency in May 1988 when the Spandariyan dam had a tunnel failure resulting in a major flooding emergency. 16,150 people were evacuated in 2 hours with no casualties.

Earthquake plans were not completed by the time of the Spitak earthquake, as a result the operational structure was ill-prepared for the catastrophe which befell the Republic.

2. KEY ISSUES ARISING FROM THE EARTHQUAKE.

2. 1. Coordination.

One of the major drawbacks to the effective control and organization of the operations was the lack of overall coordination of services and organizations. This key factor has its roots in the general lack of coordination of planning in the pre-disaster phase, and stems from the rigid compartmentalization inherent in the system.

From the evidence we received, and as shown in the overview to this section of the report, there are numerous Ministries, Institutions, Organizations and departments all with a specific contribution to make to the overall disaster plan, but it is clear that with a lack of a firm central coordinating authority with which to bring all these disparate bodies together, and to centralize all the civil defence planning into one coherent whole, the management of the disaster of 7 December 1988 was bound to have numerous problems, lying in the fact that although all these groups have generally the same objectives - namely to lessen suffering and to guarantee recovery - their membership. organization and strategies differ widely and in many cases were not complementary.

It appears to us that this problem of coordination can only be overcome if Civil Defence is given a clear mandate to undertake all major emergency planning and disaster preparedness measures.

The disaster management plans are clearly to theoretical and do not define the terms of reference for any of the organizations or services concerned in disaster relief, with a consequent breakdown in the chain of command.

2. 2. Communications.

A vital element in effective disaster preparedness is good communications. In all respects there was, at least in the early stages of the operations, a complete communications bottleneck. This was due to the total destruction of the telecommunications facilities along the line of the shock, and by the destruction of equipment and facilities housing the line communications. There was an army communications system used by the command to coordinate the use of available resources.

External communications within the republic, to central government, and to international sources were severely limited for some time.

The limited communications facilities which were eventually installed were severely restricted by virtue of the sheer volume of traffic generated.

Information of the population was also almost non-existent. This problem exacerbated the difficulties of the relief forces, particularly as numerous reports with exaggerated or alarmist tendencies circulated not only among the people in the disaster area and the Republic, but also externally to the international community.

This problem resulted in the influx of people into the disaster area, primarily Leninakan and Spitak. This took considerable efforts to control and actually impeded recovery efforts.

The news media was an extremely disruptive influence, when it could have been of value to the operations if properly handled. They frequently hindered response actions in their efforts to obtain camera coverage or to interview rescue workers, senior officials or other response workers. Local radio, Radio Erevan, was not used as a communication link, and was apparently not written into any emergency plan.

2. 3. Structure and Organization.

One of the key organisational problems was the destruction of centres of command, and the death of senior officials of Civil Defence in the epicentral area. This issue made almost ungovernable effective deployment of civil defence resources in the disaster areas, and led to small ad-hoc units of control being established, with a consequent compartmentalization of services and organizations.

Organization for civil defence did not take into consideration the extent of the catastrophe, and there were no plans for an alternate or Emergency Operating Centre, to take the place of those put out of action.

Neither was there an attempt to establish Forward Emergency Operation Centres, mobile units of management, to organise deployment, movement, and utilisation of relief services and resources, giving rise to the inevitable inequitable distribution of scarce resources and manpower, and almost certainly the under-utilisation of surviving personnel, and the provision of adequate, precise intelligence to senior levels.

Imprecise reconnaissance, and even lack of reconnaissance resulted, in the earlier stages, of an underestimation of the scale of the catastrophe, especially in the rural settlements. Although the Republic had a disaster plan it was impractical, because of lack of experience with such an unprecedented emergency. Above all, lack of prior exercise, study, coordination and above all training, precluded optimum emergency response.

2\. 4. Relation to the Military.

It would be expected that because of the close relationship of Civil Defence with the Ministry of Defence that the military response would have been rapid and effective, but this was not so.

Whilst acknowledging that disaster relief is not the primary mission of national military forces proper, overruling demands of humanity will sometimes compel their immediate involvement to alleviate extreme human suffering and distress. However, when such assistance is required during disasters, it should be restricted to the minimum required to accomplish the mission, should be committed for the minimum length of time possible and should interfere with normal military activities as little as possible.

Aid must be given to the greatest extent possible through, and IN SUPPORT OF, civil agencies and civilian organizations. The military forces help by carrying out assigned tasks as directed by the competent authority or as necessary in emergency. They should NOT attempt to replace civil athority.

It does not appear that the military forces have been given a precise role in supporting the civil authorities in disaster, and certainly no clear guidance had been issued in advance, resulting in the confusion created at the time of the disaster, as to the authority and nature of the relationship between the civil and military authorities. It is probable that this confusion arose out of the lack of command structure referred to above, but it is more likely that the lack of individual and combined training, coupled with the ever present problem of lack of joint planning and coordination which caused the difficulties.

2\. 5. Training.

A major issue arising out of the 1988 earthquake underlines very obviously the three elements of training required for effective disaster preparedness, namely:

2\. 5. 1. Technical and skills training, especially in relation to search and rescue, immediate medical aid and mass casualty care.

2\. 5 2. Disaster management training.

2 5. 3. Education for the general public.

If these three criteria had been met, then the number of people extricated alive from the debris could have been much greater. There is a possibility, and it cannot be put any higher than that, but the possibility is that many of the victims died because of lack of knowledge of elementary casualty handling and rescue techniques. Certainly engineering techniques and rescue equipment did not match up to the tasks in hand. Rescue teams were working on the same problems, seemingly ignorant of the most effective search and rescue techniques.

Local help, of which there was plenty, was not utilised and organised due to management ignorance of methods and organisation. There was a grave lack of small tools for immediate rescue, which could have effectively been carried out by untrained local personnel, under the guidance of trained senior staff. The former were not used because there were none of the latter to undertake this role.

2. 6. Planning Scenarios.

There are a number of definitions of a disaster, and disasters take many forms, with durations which can last from a few seconds to many years. Most definitions can however be summarised as an occurrence of such a magnitude as to create a situation in which the normal pattern of life in a community is suddenly disrupted, and the people are plunged into helplessness and suffering, and, as a result, may urgently need protection, life support and life sustaining requirements.

In this report disasters are divided into two categories according to their causes:

- Disaster caused by natural phenomena.

- Disasters caused by technological or man-made events.

Subclassification can be made according to the origins of the disaster:

2. 6. 1. Natural Disasters.

1. Meteorological disasters - storms, (cyclones, hurricanes, tornadoes, typhoons, hailstones and snowstorms), intense periods of cold spells, heatwaves and droughts (possibly causing famine).

2. Topological disasters - avalanches, landslides, floods.

3. Telluric and tectonic disasters - earthquakes, tsunamis, floods.

4. Biological disasters - insect swarms (locusts), epidemics of communicable diseases, agricultural epidemics (crop diseases. animal infections).

2. 6. 2. Man-made or Technological Disasters.

1. Transportation accidents (land, sea and air, and including space vehicles.)

2. Structural failures of buildings, dams etc.

3. Mine and quarry disasters.

4. Nuclear radiation accidents and failures of nuclear plant, power stations, nuclear powered machinery in ships. Accidental release of weapon systems.

5. Chemical and other industrial accidents causing wide spread pollution of the atmosphere.

6. Breakdown of public sanitation systems.

7. Civil disturbances.

8. Refugees - movements of large numbers of people usually across frontiers.

9. Warfare - conventional, chemical or nuclear, and acts of terrorism

An analysis of the foregoing broad scenarios give an understanding of the hazards likely within the Republic. From this analysis some areas can be presented in the form of hazard maps; there can be developed indications of where the planning priorities lie, the nature of the steps which need to be taken to reduce that risk, and the resources required to meet the threat.

RECOMMENDATIONS

1. Emergency Management and Disaster Preparedness.

1. 1. The frequency of disaster situations in the Armenia SSR, and the magnitude of the losses and disruption attributable to the Spitak earthquake, show clearly that these unscheduled events create a recurrent problem for the Republic which is to be seriously considered.

Whilst it is certain that other parts of the world suffer much worse, this does not reduce the need for Armenia to face the problems as they affect the country and to seek ways of developing an effective strategy for coping with them in the future.

The tendency of most people, in many countries, up to now has been to regard disasters as unavoidable afflictions which must be suffered because nothing can be done about them. Fortunately there is a minority that is not completely fatalistic and some AD HOC precautions are usually taken, such as the creation of a warning system. In a few countries like Armenia, where forethought has progressed further, emergency plans exist for dealing with the immediate crises of rescue and relief. But these separate measures do not add up to a carefully thought out coherent and comprehensive strategy. Armenia should seek to build on what has been achieved by evolving such a strategy and the purpose of this section of the report is to suggest the form which the strategy might take.

■ Recommendation 1 - Armenia should mitigate as far as possible the damage, disruption and suffering caused by major disasters by adopting a strategy of loss minimization which must form part of the general strategy of disaster preparedness and be included in future national plans.

1. 2. In order to develop this strategy it is essential that it is supported by the State at national level by an effective and coherent policy, with a clearly defined responsibility placed on a single national agency, which has the full statutory responsibility for disaster preparedness, mitigation and recovery.

■ Recommendation 2 - That Civil Defence measures are strengthened and supported by effective national legislation so that sufficient legal powers exist for the efficient operation of the disaster plans and the provision of adequate finance.

1. 3. One constant criticism arising from the disaster has been the lack of coordination between all the services and agencies concerned. This lack of coordination led to duplication of effort, an inability to establish a comprehensive command and control structure, and an unnecessary compartmentalization of all organizations concerned with relief. The result was to produce a structure not unlike that of many of the buildings of the area. The fragmentation of effort was to the detriment of the surviving population.

■ Recommendation 3 - That the State Commission for Emergeny Situations should be established as the centralizing body at highest level to ensure preparation, development, continuity and the use of the emergency plans and procedures, and with the power of sanctions to enable enforcement of desired action when needed.

1. 4. Although an Order on Civil Defence functions by the Central Committee and Council of Ministers gave the Civil Defence Service additional tasks to protect the population from all types of disaster, it is obviuos that Civil Defence was unable to achieve the objectives. This was because the Civil Defence Officers both nationally and locally do not enjoy the status and authority which should be vested in them. We are certain that this problem results from the stultifying effect of the traditional attachment of Civil Defence to the Ministry of Defence. The changing role of Civil

Defence was reflected in the failure of management to utilise civil defence, to recognise the need for strong and firm leadership which should have been provided.

■ Recommendation 4 - The role, responsibilities, organization and tasks of Civil Defence should be clearly defined, and the service established as the recognized national organisation for all phases of national disaster preparedness.

1. 5. The immediate loss of headquarters and chiefs of services made the ineffective command and control of the operations inevitable. This resulted in inappropriate levels of organizations endeavouring to restore some semblance of order. Unfortunately ineffective reconnaissance in the early stages resulted also in imprecise intelligence on the scale of the catastrophe, especially in the rural settlements, inappropriate organisation of the relief services, lack of clear and precise information to the relief services, and poor programming of the utilisation of the relief services, both national and international.

■ Recommendation 5 - A comprehensive command and control structure should be established to ensure that:
(a) headquarters/command posts are suited to the task.
(b) there is effective delegation of responsibility and authority.
(c) there is effective liaison and coordination.

■ Recommendation 6 - A system of Emergency Operation Centres from State to Republics regions and communities should be installed with adequate interconnecting communications links, and a system at standby centres to allow for the degradation or destruction of any one centre.

1. 6. There is no doubt that the absence of reliable communications links, and the limitations of the communications service in the Republic contributed a great deal to the confusion in the operations and the deployment of the services. The communications facilities and the planning for communications facilities did not take into consideration the scale and extent of such a catastrophe. There was an absence of adequate mobile means of communication, and little or no thought had been given in advance to alternative systems. In addition there was little or no adequate communication with the affected populations in the area. Local radio played little or no effective part in the operations, when in fact it should have been the linchpin of the whole public information network. There was no information facility established in or near the centre of operations, and the interest in the international media was grossly underestimated. There were without doubt serious problems with sources of information, and how information was conveyed. Inevitably some official news sources were coufused about the facts which could have been cleared very easily and turned to advantage by the use of a trained information officer attached to the disaster management services.

■ Recommendation 7 - That adequate communication facilities be provided to allow free flow of information up, down and accross the chain of command, and that such facilities be made as strong and as diverse as possible, taking advantage of specially engineered speech private wires connected to terminals to provide simultaneous speech and telegraph transmissions over the same circuit, and all such facilities be duplicated and hardened against the effect of damage.

■ Recommendation 8 - More effective provision be made to allow for facilities for the news media and a free flow of information to the public, and provision is made to reinforce the existing communication facilities in emergency.

1. 7. It is evident that the concept of fixed emergency operations centres was flawed, as the destruction of such centres in the devastated areas showed. Lack of reconnaisance and intelligence hampered early deployment of rescue services, all of which could have been, to some extent ameliorated by the use of mobile operations units with effective command facilities.

■ Recommendation 9 - That mobility of operations is developed to ensure:
(a) efective operations around a wide periphery of damage and destruction.
(b) the insertion of mobile forward emergency operations centres.
(c) unimpeded movement of stores, equipment and relief personnel.

1. 8. The disaster showed that there was lack of training at all levels, from management down to the people in communities. Disaster plans had not been tested and validated, and officials at all levels had little knowledge of the role and capabilities of other services. The training needs are shown to be:
(a) Threat and vulnerability analysis.
(b) Information systems and management.
(c) Crisis communications and management.
(d) Logistics.

■ Recommendation 10 - a complete review of all training throughout the State and the Republics be instituted to develop a higher proficiency in all areas of disaster management and technical training. (see Annex B - project proposal)

1. 9. The lack of effective specialist rescue and life support equipment led to unnecessarily lengthy rescue operations. More lives may have been saved by quicker and more energetic relief operations in the initial stages. Deployment of heavy equipment must be as fast as possible to avoid exacerbating the situation. An efficacious system regarding the use of small rescue tools in the hands of trained and semi-skilled local personnel, directing the work of the thousands of untrained survivors, is essential.

■ Recommendation 11 - A complete review and revision of all existing equipment and resources for rescue, first aid, life support services and rehabilitation should be instituted, with priority given to strengthening the provision of materials and tools for rescue, and that consideration be given to providing portable tool small rescue kits for issue to communities, rescue services and civil defence specialist leaders. (An example is shown in Annex C.)

1. 10. The national and international humanitarian response to the disaster was overwhelming, and as a result additional problems were generated. Shortages in the coordination of the main forces, a lack of clear formulation of tasks to services and overseas aid groups led to duplication and dispersion of effort.

■ Recommendation 12 - That effective control arrangements and communications be established for requesting, reception and deployment of national and international aid and assistance.

1. 11. All disaster plans must be exercised, tested and validated at regular intervals and at all levels. This can only be achieved through management exercises at Regional, National and State level under the supervision of senior officials.

■ Recommendation 13 - A major disaster management exercise be held in the Republic, and initially under the direction of UNDRO, utilizing the game theory technique, and involving all organisations, departments and services to test the validity of all disaster preparedness plans at all levels.

1. 12. The industrial capability to aid the community was not adequately utilised. The main resources of organised manpower, technical skills and material things that can be immediately available after a disaster are those that lie within industry, and in view of the time required to set up alternative arrangements on the necessary scale it is clear that the role of industry cannot be confined to the protection of the lives and morale of its own employees and industrial property. Although this remains essential, the aim must be extended to include effective deployment, under the direction of the Civil Defence Authority, of surviving industrial resources, both in the operational and life saving phases, and, in the much longer, subsequent rehabilitation and restoration period.

■ Recommendation 14 - That provision should be made as a matter of some urgency to bring industry into civil defence planning at State, Regional and community levels, and that all the resources of industry should be made available to the civil defence authorities in an emergency situation.

1. 13. It is clear that there is little or no control over the possibility of collateral industrial accidents and the effect on the commuity following a major disaster. Industrial emergency planning should take into account all the possible hazards both within and without the complex which may have an effect

on the stability of the plant and its functioning. Adequate protection of installations is urgently needed.

■ Recommendation 15 - That legislation should be produced to establish on the hazards and safety of industrial plants, and that civil defence authorities should have oversight of all industrial emergency plans both within and without the plant.

■ Recommendation 16 (Added by the Editor) - All headquarters of Civil Defence and all other centres the functioning which is essential during and after a catastrophe, like police, fire stations, hospitals, communication, utilities, should be inspected expertly to ascertain their status and chance to survive a catastrophic event. If the performance of such facilities could be impaired, ways and means should be studied to strengthen them and/or to introduce redundancy.