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MANAGEMENT OF MAJOR HAZARD PLANT*

EDWARD J. CHALLIS

Imperial Chemical Industries Limited, Petrochemicals Division, P.O. Box 90, Wilton, Middlesborough, Cleveland TS6 8JE (Great Britain)

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Summary

The principles of good management which apply to all factories are particularly applicable to the management of major hazard plant. However, installations having major hazards are characterised by the high technical content of the management of their operations. Thus there is the added need to ensure very good technical and people management systems when dealing with these plants.

The management problem can be divided into three parts: (1) The provision of top quality technical management; (2) The special attention needed in the design and layout of the equipment; and (3) The special attention needed in the management of people, both the operating crew within the factory and members of the public and their Local Authority representatives who are outside the factory gates.

Arrangements for good technical management must include a system for ensuring both adequate qualifications and relevant experience in the key management at each installation. Attention to design and layout of equipment will bring in philosophies which encourage increased automatic protection against major incidents, the adoption of intrinsically safer processes with lowered inventories and reduced conditions of temperature and pressure, and enhanced arrangements for maintaining the integrity of containment.

The high potential hazard which exists in major hazard installations necessitates the use of a much more open approach at all levels in discussing risks and safety precautions with the total operating crew. Such discussions will provide a greater feeling of confidence in the individual operators and repair men. There is also a useful feedback for technical management which will improve their ability to write clear operating instructions and on some occasions to design better equipment for the control of emergencies. Finally, there is a need to carry this philosophy outside the factory fence and into the public domain. Simple explanations of the potential risks in a major hazard installation and the precautions taken to avert emergency situations, are an essential feature of modern communication between the factory management and the officials and elected representatives of Local Authorities. On occasions there has been value in taking this approach into the general public domain where major hazard installations are sited within residential areas.

In summary, the higher potential hazards which exist in major hazard plant call for deeper technological thinking in the management area and a greater degree of explicit explanation and explicit planning in the relationships between the factory management, the controlling Authorities and the factory operating crew.

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Introduction

The management of large factories has always required the use of good management systems, a proper hierarchy of trained managers and good supervision of the total working crew in the factory. The consideration of "Major Hazard Installations" brings in an additional and very important factor — technology.

It is therefore a key point in setting up management structures for major hazard installations that the over-riding role of technology is clearly understood. Appreciation of this principle means that qualified technologists will be needed in the first level of executive management as well as further up the management structure. The young men who will occupy these posts will have spent their formative years in technical and academic training and will therefore be deficient in the arts of management, yet the operating and repair crews in the major hazard factory will require human management in exactly the same way as their fellow workers in factories canning peas or making machine tools.

Another characteristic of the major hazard installation is that the dangers are less easily perceived by ordinary people who have not had a technical training. It is easy to appreciate the danger from a massive machine tool or a ladle of hot metal; it is less easy to see the same danger in a large pump transferring gasoline at high pressure and temperature or a pressure tank containing 10 tes of liquified chlorine. The characteristic of the high technology plant which forms a major hazard installation is its ability suddenly to produce an emergency situation because of a fault condition which can only be appreciated by those who have a technical understanding of what is going on within the pipes, pumps and equipment.

It can be seen therefore that the fundamental problem in setting up a safe management system for major hazard installations is how to bridge the gap between the technical understanding of hazards in the executive management and a similar understanding of those hazards in the process and repair crews who handle the plant. The matter is essentially one of human relations and human understanding. I make no apology for stressing this point because it is frequently overlooked in the erudite technical discussions which take place around technical problems of safety, security of containment and minimisation of damage when things go wrong.

Key points for good management

There are a number of points which are key to the good management of a major hazard installation. They cover the provision of adequate technical management, the provision of equipment which has special features in its design which will aid the management of the high hazard; and the provision of special attention to human relationships between the technical management and the non-technical population both within the factory and outside in the public domain.

I would like to deal with these three areas separately under the three headings The Management, The Equipment, and The People. It will be noted that I have included the management of relationships in the public domain. This is a peculiarity of major hazard installations which is not found in other factories of comparable size. It is far more than a conventional "Public Relations" operation and has been made necessary because of increasing public awareness that major hazard installations are capable of producing sudden emergency incidents which can bring harm to the public outside the factory fence. Typical examples of this are of course explosions such as that at Flixborough, and toxic emissions which can cause alarm and some medical upset in the public area beyond the factory fence. It is necessary also to combat unreal and unwholesome fears engendered by over-dramatic presentations in the media. This is all part of good management because a modern factory can be run efficiently with minimum interference from external authorities only if the public and their elected spokesmen have a feeling of confidence in the factory management.

The management

Works management structure is a most important aspect of any organisation and the key positions must be held by men who have a good technical qualification and a satisfactory amount of experience in managing both the equipment and the men under their control. For satisfactory management of a major hazard plant there must be a clear executive line from the Works Manager down to the senior supervisor (Fig.1). This is particularly essential in major hazard plants because of the rapidity with which a hazard can develop and the gravity of the consequences to both people and equipment should a major incident become escalated. Experience has shown that a strong executive atmosphere must exist in a works team if the potential major hazards in a plant are to be contained and minor incidents prevented from escalating to full potential.

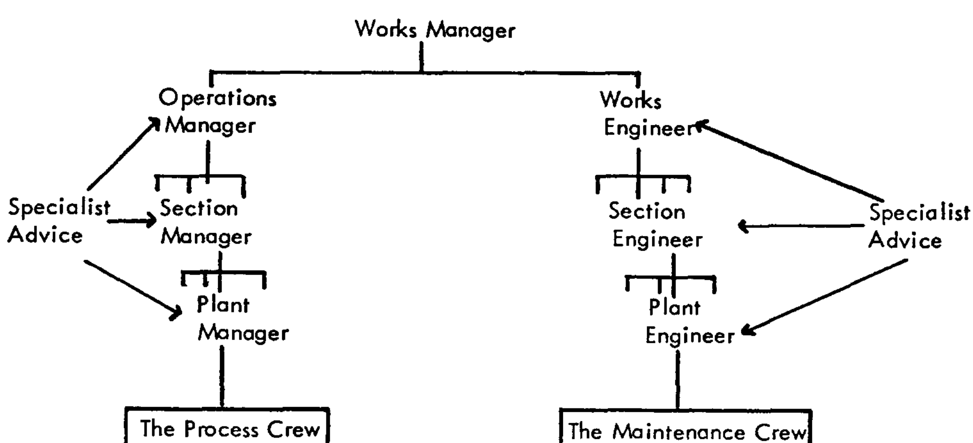

Fig. 1.

For the same reasons it is also necessary that the technical manager is seen clearly to be executively in control of the day to day operation of the plant. It is not satisfactory in my opinion for managers in charge of high hazard plants to regard the job as "managing from the office". There is a temptation for technical graduates to adopt this stance partly because of their inexperience in managing and partly because of the natural desire to apply their technical skills in calculation and design. Many large plants will have sufficient technical problems to require the use of graduates full time on solving the problems and designing new equipment to implement the solution. However, such men must play an advisory role and the Plant Manager and Plant Engineer must regard the technical management of the day to day problems on the plant as his full-time occupation.

It is clearly necessary for young technical graduates to obtain relevant experience before they can be accepted as fully satisfactory for the management of major hazard plant. This brings up the problem of how that relevant experience is to be obtained. There are several solutions — the use of a position as Assistant Plant Manager is one and the employment of young graduates on specific tasks concerned with the operation of the plant is another. Whichever way is adopted it is essential that the young graduate becomes physically familiar with the plant and the process crew who operate it. This means that he must spend a significant part of every working day actually in the plant and talking to the men. Only in this way will he get the experience of the small and sometimes silly things that go wrong in plant operation and repair and lead to conditions which may provoke an incident. To put it shortly there is no substitute for on-the-plant experience for the graduate manager, be he in charge of the process operation or the repair organisation.

It is clearly useful to have a more senior executive in the works structure with experience and qualifications which at least match those of the first line managers. Such a man will be able to "step down" and take over the first line manager's job to cover for sickness or any other absence. He can also of course cover for new graduates who are obtaining experience as first line managers. If he does this, then he must make sure that he pays more than normal attention to the daily operation of the plant.

I have dealt at length with the abilities needed at the first line of executive technical management because I believe these are of vital importance in the safe management of major hazard installations. However, the management structure needs to be supported by good management systems. The more commonly used systems such as permits to work, authorisation for entry into vessels and record systems for storage and handling of product are commonly understood.

A permit to work is required before work commences on a major hazard plant. I believe some attention should be given to providing checklists of hazards which may be present to remind the supervisor that precautions may be required. It is particularly necessary that such checklists are provided in major hazard installations to jog the memory of those who day by day sign authorisations which result in the plant equipment being isolated, rendered harmless and given to repair men for work to be done.

A newer management system which has been found valuable on major hazard installations is the introduction of a control system for modifications to the plant in the form of an authorisation sheet. Such a sheet needs to have check lists printed on it, which will jog the memory of the designer and authoriser. A typical list is shown in Fig.2. It has been found beneficial to extend the use of this authorisation down to quite minor modifications. Experience has shown that it is not only major modifications like the disastrous one at Flixborough which can cause trouble. A violent upset to a process can be caused by a modification involving only a few feet of 1½″ bore pipe if that pipe happens to by-pass some security system or give access to reverse flow into some other part of the equipment. In all major hazard installations realisation of a hazard is effected by loss of containment. If hazardous materials cannot escape from the plant then a hazardous situation will not develop. It is therefore vital that pressurised systems are regularly inspected and repaired where necessary. A feature of good management for major hazard installations is the operation of a comprehensive system of records in which each vessel and major pipe system in the plant has a unique engineering description on file. To this description is added at regular intervals the written reports of inspection, both internal and external, and any other written reports which detail actions taken as the result of inspection. This Pressure Vessel Inspection System should have rules about the frequency of inspection, the qualifications of the inspector and the qualifications and level of authority of those executive managers who are permitted to authorise repair work and to shorten or lengthen the frequency of inspection. The rules of the system often fill a book. The heart of the system is the pressure vessel record which should be based on the Works and is a living dossier of the inspections and repairs made to the equipment.

The equipment

The design of major hazard plant requires more than good professional engineering. An essential feature of a good installation is the experience at operating level which has been put into the design team. A good management system should be able to show that the major hazard plant which it is running has been designed with the benefit of operating experience. Formal systems such as Hazard and Operability Studies (HAZOP) are a useful way of crystallising and injecting this operating experience. However, it is very valuable to have members of the design team who have themselves had operating experience on similar plants and are therefore capable of visualising the consequences of minor or major failures in the equipment.

The equipment in major hazard installations should reflect the following philosophies in the design and layout: High integrity of containment; Automatic limitation of an incident; Automatic protection of equipment; "Second Chance" safety; Accessible layout; Limitation of inventory.

Safety Assessment

Plant	Title	Reg no

Underline those factors which have been changed by the proposal.

Process conditions

temperature
pressure
flow
level
composition
toxicity
flash point
reaction conditions

Operating methods

start up
routine operation
shutdown
preparation for maintenance
abnormal operation
emergency operation
layout and positioning of
  controls & instruments

Engineering methods

trip and alarm testing
maintenance procedures
inspection
portable equipment

Safety equipment

fire fighting and
  detection systems
means of escape
safety equipment for
  personnel

Environmental conditions

liquid effluent
solid effluent
gaseous effluent
noise

Engineering hardware and design

line diagram
wiring diagram
plant layout
design pressure
design temperature
materials of construction
loads on, or strength of:
  foundations
  structures
  vessels
  pipework/supports/bellows
temporary or permanent:
  pipework/supports/bellows
  valves
  slip-plates
  restriction plates
  filters
instrumentation and control
  systems
trips and alarms
static electricity

lightning protection
radioactivity
rate of corrosion
rate of erosion
isolation for maintenance
  mechanical-electrical
fire protection of cables
handrails
ladders
platforms
walkways
tripping hazard
access for
  operation
  maintenance
  vehicles
  plant
  fire fighting
underground/overhead:
  services
  equipment

Within the categories listed below, does the proposal	Yes or no	What problem has been created which affects plant or personnel safety and what action is recommended to minimise it	Signed & date
Relief and blowdown			
1 Introduce or alter any potential cause of over/under pressuring (or raising or lowering the temperature in) the system or part of it?			
2 Introduce a risk of creating a vacuum in the system or part of it?			
3 In any way affect equipment already			

Area classification

4 Introduce or alter the location of potential leaks of flammable material?

5 Alter the chemical composition or the physical properties of the process material?

6 Introduce new or alter existing electrical equipment?

Safety equipment

7 Require the provision of additional safety equipment?

8 Affect existing safety equipment?

Operation and design

9 Introduce new or alter existing hardware?

10 Require consideration of the relevant Codes of Practice and Specifications?

11 Affect the process or equipment upstream or downstream of the change?

12 Affect safe access for personnel and equipment, safe places of work and safe layout?

13 Require revision of equipment inspection frequencies?

14 Affect any existing trip or alarm system or require additional trip or alarm protection?

15 Affect the reaction stability or controllability of the process?

16 Affect existing operating or maintenance procedures or require new procedures?

17 Alter the composition of, or means of disposal of effluent?

18 Alter noise level?

Safety Assessor .... date ....

Checked by... Plant Manager Checked by .... Engineer

It cannot be too highly stressed that integrity of containment is a key parameter for the safe management of major hazards. Clearly the design organisation plays a major part in ensuring the integrity of equipment, but the operating management has a larger part to play than is normally realised. Pressure vessel design to recognised codes will give a very high standard of containment, but this will be maintained only if a regular inspection and rectification work is carried out. I have referred to a management system of pressure vessel inspection already.

Experience shows that pipework and moving machinery are much more likely to be sources of a major hazard incident than pressure vessels. An analysis of failures in a typical large works over a number of years has shown that 50% of incidents were caused by "failures in pipework due to design or operation". In fact many of these failures arise from inattention to detail either at the construction stage or during operation. The management of a major hazard installation must carry the responsibility for checking newly constructed plant before it is put into service.

A checklist (Fig.3) is therefore provided to act as an aide memoire for tech-

PIPELINES AND PIPEWORK

When carrying out plant reservations checks, the following list of possible faults should be looked for.

		Tick When Checked
1.	Screwed plugs in pipes, only permissible on air, water, nitrogen under 100 psi, 1½" NB and below	
2.	Faulty welding	
3.	Missing joints	
4.	Odd sized bolts	
5.	Black bolts in cold joints	
6.	Faulty pipeline supports	
7.	Pipe not resting on supports	
8.	Are expansion slippers safe? e.g., will they push off structure when line is hot?	
9.	Check spring hanger settings	
10.	Faulty spring hangers	
11.	Low point drains fitted where necessary, and high point vents	
12.	Lagging — missing, damaged, loose etc.	
13.	Vent and drain blanks fitted where necessary	
14.	"Weep holes" in Relief Valve exhaust lines, only on Non H/C or atmos RVs	
15.	Have all slip plates been removed and spec plates turned?	
16.	Spring Hangers — Have restraining pins been removed?	
17.	Make sure pipework is up to the P & I diagram specification	
18.	Necking off Hazard — is there any equipment, or small bore pipe projection that can be accidentally broken off?	
19.	Are small branches, i.e. drains, sufficiently clear of pipe supports?	
20.	Do drain lines run to underground drains? They should not flow over paved areas	
21.	Flanges lagged up	

Fig. 3. Reservation check list.

nical and supervisory management who are taking over newly constructed plants. Pipelines run everywhere in a plant and it is easy for pipe hangers and support to become jammed and subsequently cause the pipe to bend or break. An operating management system must include regular inspection of these comparatively trivial details if a pipe system is to remain leak-free.

Rotating machinery such as pumps can give rise to very dramatic incidents if bearings fail and the resulting mechanical disruption breaks up the mechanical seal or gland where the rotating shaft goes into the pump. A quite hazardous fire is an example of a typical incident arising from such a disruption. Again regular inspection and preventive maintenance schedules are an essential feature in the management system if the risk of major hazard is to be reduced.

Another key philosophy lies in the provision of automatic limitation of an incident by the use of quick closing valves and other automatic isolation devices which can be energised remotely. This philosophy is particularly important in the large major hazard installations associated with petrochemicals and oil refining. The size of these plants is such that the process crew is virtually powerless in an emergency to close valves and shut-off flows by hand. Automatic closure using powered valves must be a key feature of the design and operating management philosophies. Some years ago I coined the catch phrase "automatic plant needs automatic protection" and I still believe this encapsulates exactly the philosophy which management must employ. It is interesting that a remote isolation valve was actually used to contain an incident on a pump handling liquified ethylene at a 100 bars, which resulted in a release of ethylene gas for less than 30 seconds. Without this quick shut valve a major incident could have developed.

Automatic protection of this type must be easy to bring into action from the control room and it must be laid out in such a way that the control room men can easily understand which buttons to press when an emergency arises. Fire fighting installations surround equipment which processes high hazard liquid heat or flame spread. An incident will trigger the injection of fire-fighting steam and a remote button enables the process crew to activate the system at their will.

A good deal has been talked recently about "second chance safety". The simplest example of this is the well known bunding technique used in the oil industry for containment of storage tank contents if the tanks should split. However, in the petrochemical industry where liquid ethylene, ammonia and chlorine are stored in large quantities the simple bund alone is not enough. It is necessary to avoid presenting a large surface area of spilt liquids because such a lake of liquid will give a high vapour rate leading to large clouds of vapour either toxic or highly inflammable. On a liquified ethylene tank the external bund of concrete is virtually a second tank outside the special metal alloy inner tank which contains the liquified gas.

Consideration of access to major hazard units requires more than a "common sense" approach to plant layout. Such installations must be laid out with equipment in well defined blocks separated by clear wide roadways. These provide both access for dealing with the incident whether it is toxic release or fire and also give a fire break separation which helps to protect adjacent equipment from the spread of fire. Some detailed thought must be given to total access, particularly for fire fighting around rotating machinery. It is often the case that process pumps are set up in neat rows which results in an impenetrable jungle of process pipework around the whole pump area. The effect of such a layout on dealing with a major hazard incident can be quite dramatic.

Finally a management must pay attention to reducing the inventory of hazardous materials which exists in the plant. Whilst this is mainly a design problem it must also be an aim of operating management. There is often a choice which can be made between running with high inventories in tanks and surge vessels and running with the same vessels less than half full. It is good practice to reduce inventories, particularly at times when the risk of an incident is larger than normal, that is during the start up or shutdown of major hazard installations. It is to be hoped that the efforts now being placed by designers on the task of reducing plant inventories will bear fruit in the next generation of plants to be built in the 1980's. It must be remembered however, that reduced inventory often calls for a higher speed of response in the equipment which is processing the hazardous material. Such high speed changes cannot always be handled and damped out by better control. It must never be forgotten that rapid change in flow, pressure and temperature increases the chance of upsets in rotating machinery, process pipework and fired heaters. As always in the area of design one must be careful to avoid reducing one hazard only to increase another.

The people

The high hazard potential which exists in all major hazard installation calls for a much greater understanding of the risks of danger, the safety precautions, and the use of safety software, than is necessary in factories of a more general engineering nature. The high technology content of major hazard operations necessitates a special effort for the training of both supervisors and the operational crew. It is not sufficient that the men should know what to do in a given situation on the plants — it is essential that they understand why they are being given specific actions to take.

A typical control room in a major hazard plant focuses attention on two points. Firstly there are very few people involved in the operation of controlling a very large plant. Secondly there is a very large amount of data available to these men and a very great degree of automatic control, but in spite of this the plant is still being run "by hand". This is so even with plants having the most advanced on-line computer control. Shift supervisors and shift process men have to make adjustments to the operating parameters of the plant, by altering control settings on a conventional panel or by putting new data to on-line computer. When plant upsets develop those same men will have to take action which hopefully suppresses the perturbations. If these actions fail then other actions will have to be taken to deal with the more serious out-of-normal condition before a major incident develops.

Although many major hazard plants operate continuously for several hundred days between turn-arounds, there is nevertheless a daily need for small repair and renewal work which involves close cooperation between the process and the maintenance crews. Process people are responsible for isolating and making safe items of equipment, and the maintenance people are responsible for returning that equipment in a safe and operable condition. It is vital therefore that the process crew have a good grasp of the process fundamentals as well as a knowledge of the equipment, and equally that the maintenance personnel have some knowledge of what is happening on the process site.

It almost goes without saying that clear operating instructions must be available at all times. This requires attention from senior management because it is easy for a young technical manager to be over-enthusiastic in writing his instructions, and to mix a great deal of descriptive matter with the clear executive action which forms the basis of the operating instruction. Clear executive instructions are not easy to write but they are a key factor in good operation.

Whilst it is necessary for operating instructions to be clear, it is absolutely essential that emergency instructions are short, well understood and easily available for reference if required. Since Flixborough we have found that it has been a useful discipline for technical management to overhaul their emergency instructions and to pull them together into a single loose-leaf folder or an easily carried instruction card so that the emergency instructions become imprinted on the minds of all who work daily in the plant. I would like to stress once again that the techniques of the advertising world are often useful in getting home the message.

Modern plants are so large and contain so much potential power that men find themselves dwarfed by the equipment. It is essential that everyone on the plant should understand what he has to do if an emergency develops. In many cases his job will be to leave the immediate process area and if this is the case he should understand that clearly. The practice of giving everyone on the plant a small card which indicates where he is to go in an emergency and how to get there has tended to increase a sense of confidence in the workforce rather than create a feeling of alarm.

The strong theme running through this section is the need for technical management to explain clearly the risks of the potential dangers of major hazard installations as a prelude to explaining equally clearly the safety precautions and the emergency precautions which will enable the operating crew to retain control of the installation when things go wrong. We have found that an open approach on the subject promotes a better understanding of the day to day need for control and at the same time builds up a mutual trust between the operating crew and their technical management.

The same philosophy has been found to be valuable in dealing with the public domain. Immediately after Flixborough there was a natural and intense public concern about the safety of many major hazard installations. We have found that this concern can only be alloyed if the officials of local authorities and elected representatives of the community clearly understand the plant hazards and the safety philosophies. This is a delicate area of communication in which there are many opportunities for misunderstandings.

Relations between the technical management of an installation and the technically competent officials of the civil authorities are fairly easy to establish. Fire chiefs, local and central factory inspectorates, ambulance, police and emergency situations and good relationships established by the use of practice drills and simulated emergencies will stand up to the test of the occasional real incident.

Relationships with non-technical people such as councillors and other community leaders are more difficult to establish because of their lack of understanding of the technologies. We have found that our own workpeople often provide a valuable bridge between the technical management and the non-technical public outside the factory fence. Every reasonable opportunity should be taken to get some public involvement in the work of the factory either by engagement in community projects or by the use of "open days" where the process and maintenance crews act as guides to take local families round the plants and explain the key features. I personally feel that the use of such Works gatherings are a particularly valuable way of making a bridge with the community. The nature of the major hazard installation makes it difficult to organise these events and at the same time ensure the safety of the public. However, by limiting the numbers of people and strictly controlling the location of visiting parties it is possible to give members of the public a general feel for the installation.

There are many ways by which non-technical people both in the operating crew and in the public domain can be helped to understand the highly technical nature of the major hazard operation. Within the factory great use can be made of formal education procedures and of the new style safety committees now being reorganised under the most recent Health and Safety Regulations.

However, I would conclude by stressing that informal contact between technical management and the operating crew is still the best way of developing the trust which they must have in the technical experts who are needed to run safely the major hazard installations. Experience has shown that the best plant design, the strictest safety precautions, and the most elaborate safety software will all have a high probability of failure unless the technical manager is closely identified with the plant he runs and the operating team that he leads. It is this aspect of human management which will perhaps turn out to be the most important feature of safe operation in the 1980's.