ANALYSING THE PAST, PLANNING THE FUTURE, FOR THE HAZARD OF MANAGEMENT

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One may readily accept that the hazards of work situations are related to the management, and the management systems, which supervise and control those work situations. This author has anecdotal data which shows that "everyone knows" there is a relationship between those two factors, work hazards and management, so although the knowledge exists, in practice, in industry, many ways are found to avoid making the connection. The author's research into the chemical industry identified the connection, an identity which has been strengthened by many accident investigations performed through the last ten years and by a serious incident in Australia, all during the last few years. This presents the author's research to show the connection between hazards and management, uses accident investigations to confirm that connection, and uses a brief description of the incident further to demonstrate the connection.

INTRODUCTION

Management, on one hand, has been recognised by many writers as an art. On another hand, there are many who have written about management as a science. The proportioning of the two schools of thought may lean either way, and as with many such conclusions with divided schools of thought the truth is quite likely to exist somewhere between the two, showing management is a mixture of art and science.

The hazards of work situations differ in a somewhat similar and perhaps equal manner. There are hazards which may lead to accidents occurring relatively frequently and may harm only one person or a few, ranging from minor injuries to fatalities, and there are accidents which occur very seldom but may cause loss of many lives and considerable property damage.

Where does management fit into that spectrum? A reasonable answer suggests that management should act to prevent accidents from occurring by minimizing hazards, and one may be sure most management bodies act in that manner. But we have had, in Australia, some cases which have shown management has acted in ways which have increased hazards, and in some of those cases serious accidents have occurred.

The conclusion which this author draws from research on the relationship between hazards and management practices in the chemical industry, from accident cases investigated, and from a major chemical disaster, is the management of a company can itself be a hazard. And, of course, no-one in the organisation can control management behaviour, the iron curtains between management and employees, and between management and the world around it means no-one outside knows and can control management behaviour, and a management heading in that hazard direction doesn't control itself.

THE RESEARCH (FROM THE PAST)

This section is a summary of the author's doctoral project and its results[1]. The foundation of that can be seen in the author's employment history, which was in a variety of chemical firms, some using batch processes and some continuous processes. Reflection on what had been seen in these companies led to a personal conviction that there were differences between the management systems. At that stage, however, there was no idea of what constituted the "systems", the differences, or the firms' hazards.

From that the project began with the thought that there must be a relationship between the way a management behaves and what and how the company produces its goods. Towards the end of the work, as measures of variables progressed, it became obvious that what was being measured about management was not behaviour but practices, a fine distinction, perhaps, but brought about because the investigation looked at procedures, protocols, actions, what the management system actually did, rather than any possible motivating factors behind the action.

A tentative hypothesis was formed and as work progressed was extended into two parts:

> Identification of relevant chemical industry elements will enable companies to be ranked on a hazard-scale for each of those elements and for an overall hazard-rating. The individual hazard-ratings will present a 'hazard-profile' for each company.
>
> Identification of the elements will lead to producing an ideal model of the industry and its management. Comparison of the overall ranking and the profile of each company with the ideal model will indicate the probability of a major disaster.

A major feature of the approach taken in the research was the recognition that the physical items which form a production unit, the materials which flow through it, the processes which convert input to output, the people who work in the factory, and the management who control whatever happens, are not independent of each other. They are "elements" of a complete *system.* The "traditional" view of a chemical production unit can be described in the following which itemises the elements in a chemical production unit and how they fit with occupations in the industry:

> the physical equipment items, generally the concern of mechanical engineers,
> the materials, generally the concern of chemists,
> the processes, generally the concern of chemical engineers,
> the workers, generally the concern of industrial psychologists,
> the management, generally the concern of itself and management scientists,

that is, each element, each with an individual discipline, is *usually* compartmentalised in and by its speciality.

The view taken here was that all those elements of a chemical production unit or factory form a "system". In such a system each element interacts with the others[2]. If the contribution of one element to system results is below whatever standard is required of it, then the overall standard of the entire system will be reduced. In the system of a chemical production unit quantity and quality are determined by the interaction of the five elements listed above.

The approach taken, therefore, in the overview and research investigation was to consider the above five elements within the chemical industry, their relationship to each other, and the interactions between them, with the aim of forming and testing a model representing management and technical safety in a chemical manufacturing firm.

The above led to a review of models found in the literature, the Sociotechnical Pyramid by Technica (showing five "tiers" of components or elements leading to an accident)[3], the Tweeddale Safety Balance Model (which displays the various elements of technical or process safety as a three-dimensional structure, rather like a "mobile" room decoration)[4], and the Bignall-Fortune Formal System Paradigm (how an organisation is influenced by the wider external system, and how the organization operates internally, for example, to monitor performance and to make decisions)[3]

With the background established for developing a model to suit this research the author examined several alternatives. The proposed model would show the elements which make the industry hazardous and the elements which militate against those hazards, in a sequence which is consistent with their relationship to each other. The selected starting point for the model was whatever causes the inherent hazard in the industry.

The primary hazard in the chemical industry resides in the materials, because materials are a hazard even if only in storage, with no processing or other activity being performed. The raw materials, the intermediates, and the finished products present the primary independent hazard element.

Processes were considered next. They present an inherent hazard, secondary to materials because they act on the materials and cannot be caused to occur without the materials. They were therefore positioned next to materials as another inherent hazard and the second element to be put into the model.

Having determined the sequential ranking of the inherent hazards the relationship of other elements which should compensate or balance the inherent hazards was considered.

The technology was taken as the third element. This position in the model was selected because the technology has a relationship with the processes and with management, but is related more closely to processes than to management. Technology was not ranked ahead of materials and processes as it is not an inherent hazard. It is an external or subsidiary hazard. Its effect may be compensatory (that is, to counteract the hazards inherent in materials and processes) or contributory (that is, to exacerbate the inherent hazards in some manner).

Another reason for this third ranking for technology was one of the interactions considered between elements. This was that technology affects processes more directly than materials, and acts on materials through processes. Technology should reduce the hazard inherent in materials by controlling processes. Thus, an appropriate level of technology, as the third element, would help to balance inherent hazards by interaction with processes. Similarly, an inappropriate level could actually reinforce or even magnify inherent hazards, also by interaction with processes.

The next element taken, as the fourth item, was the human presence element. This was ranked next to technology. The reasoning was that human presence is related to technology through the definition of technology (system design, operation and maintenance as well as hardware), which implies that some human activities are components of the technology. Any action by human presence on the inherent hazards, processes or materials, would be through the technology. Also, as with the ranking of the third element (the technology) one of the interactions considered between variables was that although an appropriate level of human presence, as the fourth element, would help to balance inherent hazards through the technology element,an inappropriate level could actually reinforce or even magnify inherent hazards by action through the technology element.

Management was the final, fifth, element to be included in the model. The logical position for management is next after human presence, with which it has a stronger relationship than with the other elements. Human presence is related to management, for although management is a set of functions all those functions are performed by people, hence the relationship with human presence. Management also relates to technology, because management has a role in making decisions which select the level and type of technology; however, this relationship occurs through the human presence element.

While management is considered to be the most effective element to compensate for the inherent hazards, by making corrections for any hazard increase from technology or human presence, management can only perform that compensating role via the human presence element and the technology element, in series. Management may also increase hazard, if incorrect or inappropriate.

The five elements of the proposed model (from highest probability of hazard-causing to highest ability for hazard compensating) are: materials, processes, technology, human presence, and management, all as previously defined. In sequence:

a fundamental, primary, inherent hazard element (materials),

a secondary inherent hazard element (processes),

a tertiary, subsidiary, element (technology) which is closer to the processes element than to the materials element, and not as close to the management element as to the human presence element, and which may increase or decrease total hazard, depending on its features,

a second tertiary, subsidiary, element (human presence) which is closer to the management element than to the processes element, but is close to the technology element, and which may also increase or decrease hazard, depending on how it is used, and

a final tertiary, subsidiary, element (management) which acts on the technology element through the human presence element.

To sum up, a physical system (of materials and processes) with high inherent hazards will be less “forgiving” towards technology, human, and management inadequacies and errors than one which has low inherent hazards. Vice versa, a physical system with low inherent hazards will be more “forgiving” towards technology, human, and management inadequacies and errors than one which has high inherent hazards.

For convenience, the five elements for the model were identified by initial letters, and sequenced, as follows:

Materials (Chemical materials) = C
Processes = P
Technology (system design, operation, and maintenance) = T
Human presence = H
Management = M

Five models using the above five elements were developed by the author. The first was based on the fault tree, which seemed to be an obvious approach, but when constructed and examined it proved to be unsuitable. An event tree model was then constructed, but also proved to be unsuitable. A flow-chart type model was constructed to show a relationship between hazards, technology, and management style, and the results of their interactions. but this also failed to give the require picture. All three thus far did little to show how the various elements can be varied in magnitude.

The fourth model was titled "The Engineering Model" and pictures a beam, balanced on a fulcrum, with "loads" or "weights" bearing on it in various positions. The implications of this model may be explained as follows: given that the inherent hazards from the materials and processes are a certain "weight" on the left-hand end of the beam, then technology, human presence, and management must be of a certain "weight" to maintain the balance, given that they occupy certain "positions" along the balance lever.

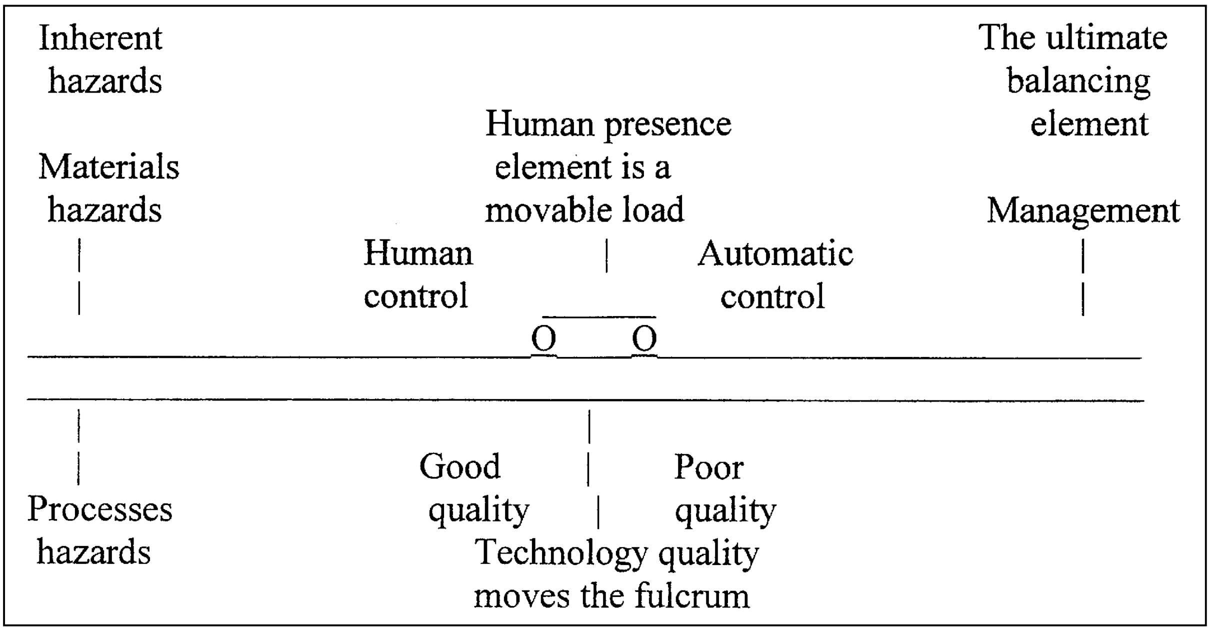

FIGURE 1
AN "ENGINEERING MODEL" OF HAZARD ELEMENTS

If either the materials or processes elements become "heavier" because their hazard contribution has increased then the technology (design, operations and maintenance systems) must be "shifted" to maintain the balance, or human presence must be "moved" (such as by having automatic systems replace human presence), or, finally, make the management system "heavier". Any of those response-actions would restore "balance".

This model appeals to the engineering mind-set because it is both "pictorial" and "functional". It can also be said to have built-in limitations. If hazards increase the human element can only be moved as far as its limiting position in the automatic direction (the limit, not yet achieved, would be total artificial intelligence), and the quality of the technology equally has a limiting value. When those limits are reached, and a balancing condition has not been reached, the only further possible action is to make management "heavier". The model also illustrates the relative fragility of the concept of technical safety by demonstrating the effect of a small increase of "weight" on the left, increasing materials or processes hazard, or the effect of reducing the "weight" of management by a small quantity, or of shifting human presence or technology in the wrong direction by a few millimetres. Any of those actions can be pictured as causing a slow tilting of the beam, until the movement reaches a critical point and the whole system overbalances into a state of hazard consumation.

However, this model only shows an overall, general, picture of the industry, and not an easily-interpretable statement of any particular firm's overall hazard level.

The fifth model, “The Profile Model”, resulted from the search for a model which would provide such an easily interpretable statement of a particular company’s overall hazard level, and was formed by considering the sequence of and possible interactions between the five elements.

The profile model was conceived on a two-axes framework, with a “hazard ranking” on the “y” axis (length proportional to hazard, according to some arbitrary convenient scale) and the five elements distributed equally-spaced along the “x” axis. This could be shown as a histogram, with a vertical bar indicating the value of each element. However, the preferred presentation was to plot the position of each hazard level for a firm and join these together, thus forming a “hazard profile”.

The outline or shape of this profile is an indicator of both the individual and collective effect of the five elements. The position of the points on the y-axis for the individual elements gives an immediate impression of the hazard-value of each element, and also the outline or shape of the line through these points gives an immediate impression of the overall hazard, of a particular firm.

Although many combinations of element values are possible, only four cases appeared to be examples which could be termed “standard classes”, with which actual cases could be compared to rank the overall hazard level. They arise from consideration of a simple matrix of extreme values of the two groups of elements, those forming the inherent hazards, and those forming the subsidiary hazards. The model is illustrated in Figure 2.

		Inherent hazard	
		High	Low
Subsidiary hazard	High	High-High Class 3	Low-High Class 2
	Low	High-Low Class 1	Low-Low Class 4

FIGURE 2
MATRIX OF ELEMENTS AND EXTREME VALUES

From this matrix, the four standard classes of profile are: High-Low (Class 1), Low-High (Class 2), High-High (Class 3), and Low-Low (Class 4).

The four “standard classes” of the profile model reflect, in general, the four possible distributions of scores on each of the five elements (chemicals, processes, technology, human presence, and management) discussed up to this point, following which a method for measuring these elements was devised and produced as a questionnaire.

The firms which operate major facilities such as oil refineries are in the Class 1 category, with (rather obviously) high-hazard materials and processes and low-hazard management (that is, management which by its nature presents a low hazard). Many small batch process firms were found to have low-hazard materials and processes and management systems which presented a relatively high-hazard, but with the low-level inherent hazards there was no need for higher-level management systems.

Ninety companies were contacted with a request that they might reply to a questionnaire which would quantify their element values. Thirty-one replied and the results were:

Class 4 (Low hazard materials + Low hazard management) : 22.
Class 1 (High hazard materials + Low hazard management): 4.
Class 4/Class 1 (Mixed low-low and high-low) : 3.
Class 2 (Low hazard materials + High hazard management) : 1.
Class 3 (High hazard materials + High hazard management): 1.

Of the above only one plant was a cause for concern: the one Class 3, which had no low hazard management to balance the high hazard materials and other elements. Several years later that factory was destroyed by fire.

DISCUSSION FROM THE RESEARCH

The chemical industry in the Sydney region is made up of a few very large firms and a large number of smaller ones. The concentration of the industry into the large firms is increased when one recognises that some of the smaller firms are part of a larger company group, even though they are operated under an independent name.

There is a large gap between the large number of small firms and the small number of large firms and several differences have been made apparent. The smaller firms tend to use less hazardous materials and less hazardous processes than large firms.

The smaller firms tend to use lower-level technology (which, by the definition which has been used, included some aspects of management) than large firms, to use people more to monitor and control the processes, and to have fewer tertiary-trained people in the higher levels of organisation, than large firms. Finally, the smaller firms tend to be less well organised at the management level than the large firms.

The impression one might obtain from the comments above is that small firms are high-risk enterprises, poorly managed, and capable of causing chemical disasters with great ease. However, when the whole ‘system picture’ is taken (for example, using the hazard profile) by considering *all* the elements, it does appear that most of the small firms are as ‘safe’ as large firms because they have less hazardous materials and processes. Or, phrasing that the other way around, the large firms which have the more hazardous materials and processes are as safe’ as the small firms because they have higher-level management elements.

Hence, although simple comparative words have been used occasionally in the above, the lower-level (high-value) technology, automation, and management is not necessarily ‘bad’. The results suggest very strongly that the level of these elements needed in any situation depends on the level of the inherent hazards. The companies investigated were ranked on a hazard-scale for each of the elements, using values of the elements in the hazard profile model, and the hazard profile of each company surveyed was presented. The profile of each company surveyed was compared with the standard cases. The comparison has indicated whether the company is acceptable on the hazard rating, and whether there is any conceivable probability of a disaster (bearing in mind that *any* ‘probability’ may be far from a certainty).

Comparison of sets of hazard profiles indicated a value of each element which *could* be taken as a safe limit or criterion, under specified conditions, an unexpected result. However, combination of these values of the elements into an overall hazard-rating, stated as one number, was rejected as not feasible at this time. Use of the hazard profile, as a whole, is the only form of hazard rating seen to be useful at this time.

CONCLUSIONS FROM THE RESEARCH

An analytical procedure was devised and applied, and the statements of the hypothesis were satisfied.

The majority of the companies investigated appeared to have a system of elements which is reasonably safe. In particular, most of the managements suit the other four elements of the companies, although a few were found which would benefit by improving some elements.

Although the investigation has indicated that most of the firms examined in the Sydney region are assessed as "safe" for one reason or another (low materials or process hazard, or good technology, appropriate human presence or good management) the freedom of many from being involved in a disaster still depends, to a very large extent, on the low probability of such random events.

THE INVESTIGATIONS (IN THE PRESENT)

During the years since finishing the research many accident investigations have been performed, and some of these add to the above conclusions. Citations for these investigations cannot be given, as details of the information may relate to legal proceedings, therefore only a very general outline of each is stated. As the general content of this paper relates to the chemical industry the first examples will be those which have caused injuries directly by chemicals, then examples of fires and explosions

1. Some members of a family were killed, and others were severely injured, when the gas supply to a fire was interrupted during the night.

2. Cleaning contractors were made ill, hence injured, by aerosol insecticide, automatically-sprayed before they entered premises to perform their work.

3. Garbage collectors were made ill, hence injured, by fumes emitted from garden chemicals picked up from domestic bins, after the plastic containers were crushed and the chemicals were mixed by the compacting mechanism.

No reason could be found for the gas fire being extinguished and gas continuing to flow, but that's what happened, and the house became flooded with old-fashioned town gas containing carbon monoxide which caused the fatalities and injuries.

The strange feature of the second case is that the property-owners did not coordinate with the firm which installed the automatic spraying system to ensure there was sufficient time for the aerosol to settle or disperse before the cleaners arrived. Alternatively, the owners should have specified spray timing to suit the cleaners' times. And somewhere in the negotiations the owners should have been informed that the sprayed material could cause illness while it was floating in the air, before it settled on the floor and furniture. So the worst feature seemed to be that the system suppliers didn't tell the owners that several hours should elapse before anyone should enter. Or, if they did, the owners didn't pay attention.

The third case, involving the garbage truck, gets down to the difficulty manufacturers have in telling end-users what to do with the products. In general, materials such as those in the case should not be put into garbage bins but should go to waste collection depots, and of course the manufacturer can "design" the label to provide that information on the label. But can the manufacturer ensure that the end-user *follows* such information? Probably not. More to the point, can anyone be at all sure the manufacturer can ensure the end-user actually *reads* that information? Very probably not. Indeed, that case illustrates the sad conclusion that accidents will continue to happen.

Fire, a reaction between a combustible material and oxygen, is a very useful phenomenon and is, almost certainly, a major factor in humans developing civilised society.

However, sometimes fire is uninvited, and occurs because we forget we're surrounded by one of the necessary reactants.

1. At a tyre retreading factory, rubber dust ignited in the exhaust duct.

2. At a plastics manufacturing factory, polystyrene flakes ignited in an air-conveyor duct.

3. Solvent used to wash machined components was spilled when hoses failed by chemical softening, and was ignited by a nearby gas fire, part of the process system.

4. A spill of vegetable oil in a store was covered by an absorbent material, and left overnight for the spill to be soaked up. During the night the mixture of oil and material spontaneously ignited and damaged the building and contents.

5. A paint store ignited when a door hinge was being repaired by welding.

The first four cases caused property damage, the fifth seriously injured one person and slightly injured two others.

The most probable source of ignition in the first case was a spark caused by the wire brush, used to grind the tyres, striking a nail in a tyre, which happened often, and finally the time came when all the right conditions were present and the duct contents ignited. Tests with rubber particles showed they are hard to ignite as a quantity, but finely divided and suspended in an air stream they apparently did, just a matter of getting the right air-to-fuel ratio. A higher air flow rate might have made the mixture too lean. and ignition might not have occurred.

In the second case the source of ignition was probably static electricity, generated by the plastic flakes being conveyed by an air steam through a duct system. It's well known that hydrocarbons will generate static electricity (even liquid hydrocarbon falling freely through air), and as the duct assembly and connected equipment were not earthed it was just a matter of time before a sufficient electrostatic discharge occurred. Tests showed this material was also hard to ignite as a discrete quantity, and again dispersion in an air stream must have been a telling factor.

The third case involved modification to an existing system, an experiment trying to improve the operating conditions by installing a filtering circulation system. In haste, the job was given to a contractor not qualified for the work (he was an ordinary plumber) and he used rubber hoses which softened, hence became slippery, in contact with the solvent. Incidentally, in this case there was no doubt about ease of ignition, the solvent was a typically volatile hydrocarbon liquid. A hose came loose during the morning tea break when no-one was present, solvent sprayed around, and the nearby gas fire ignited it

The fourth one is hard to explain, all one can say is there are cases of vegetable oil, when mixed with some type of dispersed material, have become hot and have ignited surrounding materials. In fact, that happened in a store building at one firm where the author worked, and one can only assume the same happened in this case. This sort of fire is, strictly, an exotherm case, but not resulting in an explosion like the ones mentioned below, only a fire.

The fifth, the paint store, was ready-made for a fire - - - what happened was a real vapour cloud explosion-fire, in fact, partly confined. The welder said solvent fumes were evident before the work started, but management insisted the repair had to be done, and ignition occurred when an arc was struck for the second time.

The first two of these explosion cases are incidents the author has investigated, and the third was discussed at an in-company meeting which the author attended.

1. A truck driver was killed when an acetylene bottle exploded, when he was loading it manually onto the truck.

2. An employee opened a pit in the footpath to get access to cables, leaking LPG-town gas exploded, and the employee was injured.

3. There was loss of control of an exothermic process, the reaction progressed beyond containment pressure, the vessel burst disc opened, and the contents were sprayed over a neighbouring property.

The damage caused by the first case above was so major (the driver's body and most of the truck were both virtually destroyed) that no-one can know what caused the acetylene to explode. However, it was probably due to the bottle being bumped during loading onto the truck, so that the porous material within was broken or dislodged and the acetylene was no longer finely distributed. A record was found of a similar case, years ago, in the USA, when a bottle on the tray of a truck exploded as the truck went over a bump in the road.

The gas leak, in the second case, which lead to the explosion, was due to lack of maintenance of the town's infrastructure, in this case the part which was the responsibility of the gas supplier. The ownership of the system had changed hands at least once, pipes (using different materials at different time) had been laid underground, and there was plenty of evidence that much of the piping was corroded.

The third case, fortunately, didn't hurt anyone, although it frightened the plant operator who was largely responsible for the exothermic process, and it lead to acrimonious conflict between the two neighbouring firms. This one was bad enough, but nowhere near as bad as one in New Zealand several years ago, one which spewed out thousands of litres of partly-reacted chemicals and fouled a suburb.

One may question whether that was really an "explosion". It's classified it as such, because it was a sudden release of pressure, with considerable energy behind it. However, classifying exotherms is tricky, and not all lead to explosions, for example, example (4) above, which only led to an ordinary, open, fire.

Design assumptions can lead to accidents. I have been informed of a case which involved a long tunnel-like machine which produced and packaged an item which is a domestic consumable. The machine was built with a series of doors for inspection and adjustment, all fitted with micro-switches to isolate the drive if a door was opened. But during one shift a fitter opened a door to make adjustments, gimmicked the micro-switch so the machine would run, and put his fingers into a toothed belt drive. Guards and other protective devices needed, but they can often be defeated. After that accident I'm told, the micro-switches were replaced with a light beam across each doorway.

There is, also, an injury case recently described to me of a bucket elevator which was caused to run forward by an imbalance of buckets when some were being replaced. Why did it run forward? Well, design practice with these machines installs an anti-runback device, because when a bucket elevator stops the rising buckets are often full (and the decending buckets are empty) so there is then a tendency for the whole system to run *backwards.* However, no-one ever thought an out-of-balance situation would be caused by buckets being missing on the *rising* side, which could make an elevator run *forward.* This one did, and it removed much of the fitter's lower arm.

Finally, here is a case to illustrate that we don't need high technology, not even old-fashioned electricity, to injure, or even to kill someone. This case, given to me by a lawyer friend, reflects on that.

A young man was employed as a labourer at an abattoir southwest of Sydney. His job was to clean up scraps from the floor and put them in a rubbish bin, He wasn't involved in the actual cutting work, which was performed by skilled personnel. As he passed by one of those cutting up the carcases sliced through what he was working on, and, rather like the way a golfer "follows through" after impacting the ball, had his knife move on from the cut in what one might term "a follow-through-flourish".

The point of the knife entered the young man's body in the chest, on the left side, and penetrated his heart. He died. Paramedics arrived within minutes of frantic phone calls made. They revived him, bundled him into the ambulance and headed for the hospital. On the way to the hospital - - - he died again. The paramedics revived him. He was whizzed into casualty and a surgeon started repairing the damage, in the middle of which -- - he died again. The surgical team revived him again, and patched him up, then finalised the repair work, and as far as we know he is now still alive.

The two features which come out of this case are ---

First, the low level of technology involved in killing him. How many tools are at a lower level in the technology scale than a knife? Any? Well, maybe a few. A knife doesn't even need to be made from steel, it can be made from flint or some other mineral. The Aztecs made very sharp knives from obsidian, a volcanic rock. So, as I've said, low-tech stuff can be equally as deadly as what we think of as high-tech, and engineers need to remember that. On another side of technology, one may assume the young man is glad surgical technology is at the level it is.

Second, the level of chance (or, in more elegant language, the value of the probability) in what happened. Talk about someone being at the wrong place at the wrong time! A fraction of a second, or a spatial difference of a few centimetres, and it would have been a near miss, followed by some highly-flavoured remarks from both sides. But those sorts of margins are what we are often seeing, in accident cases. If we look at this case as a classic risk, it's high consequence-low probability, with the use of low-level technology, and the probability is so low most would say it's not reasonable to consider it as possible. Minor injuries occur all the time in abattoirs, not fatalities.

THE RECENT AUSTRALIAN CASE

In September, 1988, at Longford, where the Bass Strait oil and gas refinery part-owned and operated by Esso is located down south in Victoria, out from the town of Sale, we had a major fire and explosion which killed two and reduced the supply of gas for the whole state of Victoria to a mere trickle for some weeks.

There has been an equally major enquiry, a Royal Commission, and the findings have been published[5], showing among other problems that there were operating faults and proper maintenance practices were not followed. The report of the Commission was quite strange in one respect, it focused overwhelmingly on the technical factors, but a follow-up volume[6] dealt with the organisational aspects.

What happened? The precise failure occurred in one of the three gas plants GP1),

around the absorber tower, through which light oil is circulated to scrub the denser hydrocarbons out of the gas stream, leaving principally methane. The night before the incident the flow of mixed gas-and-oil crude from the Bass Strait platforms had been unusually high in liquids, which raised the liquid level in the bottom of the tower. This level should have been controlled by increasing the heat input, but the steam control valve was misbehaving so manual control was being used, but ineffectively, so the level continued to rise, finally entering the outlet at the bottom of the absorber tower and chilling the rich oil stream leaving the tower. The pumps supplying the oil stream to the top of the tower automatically shut down.

The reboiler heat exchangers became very cold, showing external frost, and started to leak. Then the circulation pumps were restarted, bringing hot oil into the chilled exchangers, and one failed with a brittle fracture, releasing a mixture of liquid and gas hydrocarbons, which rapidly found a source of ignition, setting off an explosion and subsequent fire. The location of the fire, under some major cross-plant pipelines (something Kletz warned about years ago), forced a complete shutdown of all three of the gas plants. In late winter Victoria was without gas for heating and cooking.

The management blamed the operators, particularly the one in the control room at the time. All that was blown up extensively by the media, and led to this author having the following letter published in the major Sydney newspaper:

> This note follows from my letter last year (Herald, 1st October, 1988) which referred to the explosion and fire at Longford and recent reports concerning the enquiry on that event.
>
> The manner in which Esso has laid the cause of the event at the feet of employees relates to a comment I have made several times in the past, sometimes formally at conferences, and occasionally informally in company.
>
> What I have noted, when reviewing man-made disasters in my research, is that management behaviour is like that attributed, rightly or wrongly, to surgeons. It's said of the latter that they can bury their mistakes. If we take that a step further, we may say they bury them in the ground.
>
> Likewise, management can bury their mistakes. Not in the ground, but in the organisation structure. Top management can point down to line management, who can point to supervision, who can point to workers.
>
> I doubt this burial practice fertilises or otherwise improves the organisation structure.

Among the many points which came out in the Commission's report were these: several years earlier Esso had removed engineering staff from Longford (remember one of the factors behind Flixborough?), GP1 which failed was interconnected in many ways with gas plants GP2 and GP3 (does that sound like Piper Alpha?), and the operators lived quite consistently with live alarms (rather like at Three Mile Island?). In addition to those dreadfully familiar items, a HAZOP had not been performed on No. 1 gas plant, and there were training deficiencies. One of the results of the inadequate training was operators allowed departures from safe process conditions to maintain gas output for commercial reasons; so what seems to have been prominent in the minds of those involved in running the gas plant was the need to keep the gas supply going, by expediencies. And, related to training, Exxon, the parent company, had warned all its member-companies, world-wide, of the risk of low-temperature brittle failure.

CONCLUSION FROM INVESTIGATIONS AND LONGFORD

The eleven investigation cases described above have been sorted into categories: six strongly management-related, three related to lack of information (which could be management-related), one probably due to inadequate training (almost certainly management-related), and one never explained (the gas fire). The injuries in the tunnel-wrapping machine and the bucket elevator were due to design failings (management related), and the abattoir case appears to be the only pure-mischance observed.

The conclusion from all those observations (plus many not recorded here) is that management can very easily be a component in the migration from hazard to incident.

The conclusion from the Longford case is even stronger, supported by the report by the Royal Commission, which pointed at management as a substantial contributor to what happened.

AN OVERALL CONCLUSION

Having reached the point where the author has implicated management as a major factor behind incidents which damage property, and injure and kill people, we should ask ourselves: why is it so? Why does management become a hazard? Is it due to ignorance? Or complacency? Or apathy? Or something else?

The ignorance factor is a strong possibility. The "something else" which has been observed, here, is many of those appointed as industry heads are managing what they do not understand, while those who understand are not allowed to manage as they can. We have, as a recent example of that, the appointment of the retired group managing director of a major bank as chairman of a major chemical firm, for which there may be sound financial reason but one may wonder whether leadership from the top will understand plant-related hazards. Perhaps there was a good reason for that appointment but it's likely the new man will be managing what he understands only imperfectly, maybe does not understand at all.

The complacency factor is also a strong possibility. If nothing has happened for years and years it's rather reasonable to believe nothing will ever happen. At Longford GP1 had been operating for about forty years with no history of imminent disaster, so who would expect what happened on 25th September, 1998?

Apathy, we consider, is unlikely in its usual defined form of not caring, but if we extend it more broadly to include not caring *enough,* of being negligent, then there are certainly examples which agree with that, such as the omission of the HAZOP for GP1, proposed for 1995 but indefinitely deferred.

These become combined, though secondary, when the primary concern of the organisation, hence of the management, is the bottom line, profit. Or, more urgently, survival in the face of competition, which was not the case with Longford, Esso had a near-monopoly, or other external pressure such as customer relations, concerning which Hopkins[6] stated:

> Process upsets which may have had minor commercial consequences were dealt with thoroughly.

The combination of ignorance, complacency and apathy with pressure from the marketplace has been observed in the more "ordinary" cases described above.

A REMEDY? (FOR THE FUTURE)

The only path available to remedying the hazard of management is via information from the past, and a review of the incidents, all of which is analysis of the past. The way from that to the future must be the overall lesson that managers, whether involved in new products, operations, maintenance, or other industrial activities, need to place the correct people in the places which demand those people. But to have that happen we must have high-level managers who accept that those demands exist and are then prepared to face the cost of appointing the right people.

This repeats an old adage: that safety begins at the top. How do we apply it?