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Concept Articles

How We Changed the Safety Culture

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Abstract:

The accident rate in a large chemical company gradually got lower. Then, over a 10-year period there was a large increase in process accidents and fatalities, although the lost-time accident rate, which measures mainly simple mechanical accidents such as trips and falls, remained low. As the fatal accident rate varied from year to year, it took the company several years to realise that there had been a fundamental change and that new approaches were needed. These are described. They reduced the fatal accident rate to a lower level than that achieved before it started to rise. Although all this occurred some years ago, the methods developed to increase process safety are still relevant as, despite changes in technology, a more important factor—human nature—is unchanged.

Introduction: Why Change Was Needed

When people have the tools, the training and the support they need, and it is combined with the freedom and encouragement to find their own solutions, they find the energy, enthusiasm and creativity to get the job done, to get results.

—Robert Gore[1]

Figure 1shows the variation in the fatal accident rate (FAR) of Imperial Chemical Industries (ICI) over a 20-year period, as a 5-year moving average. The FAR is the number of people killed in 10^8 working hours. If you spent all your working life in a company or factory with a thousand employees, the FAR is the number of your fellow workers who would, on average, be killed by an accident at work during your working life. After improving for many years, the rate got worse during the 1960s and then improved (Figure 1). For accidents due to process hazards such as fires, explosions and leaks of toxic gases the rate increased from about 1.4 to 4 between 1960 and 1969 and then fell to about 0.2 by the end of the 1970s. There was also a reduction in fatal accidents due to nonprocess causes during the 1970s, but it was less marked.

All this occurred many years ago, and younger engineers may wonder if it has any relevance to the present day. However, while equipment, particularly control systems, has changed, one factor—human nature—is unchanged. Every accident is due to errors by operators, designers, or managers.[2] Usually people in all three groups have opportunities to prevent the accidents, although this does not mean that they should be blamed as they are usually unaware of what they might have done or had a momentary lapse of attention, something that is inevitable from time to time.

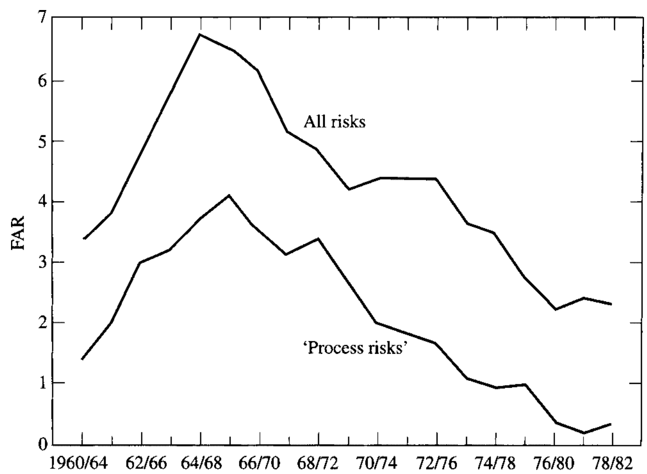

Figure 1. **ICI's fatal accident rate (the number of fatalities in 10^8 working hours, i.e., in a group of 1000 people in a working lifetime, expressed as a 5-y moving average).**

It took some time for ICI staff to realise that the fatal accident rate was getting worse as the data in Figure 1 was not available in that form. The lost-time accident rate, made up mainly of slips, falls, accidents with hand tools, etc. was good, and the first fire or explosion in each major division was treated as an isolated event. The immediate technical causes were put right, but there was no suggestion that the management systems, as we would now call them, were poor. The second major incident raised a few doubts, and the third made it clear beyond doubt that something was fundamentally wrong. We are all reluctant to admit that something is seriously wrong in our organisation as a whole until the evidence is overwhelming.

The main reason for the increase in serious process accidents in the 1960s was probably the introduction of a new generation of plants, larger than earlier ones and operating at higher temperatures. As a result, the consequences of leaks were more serious than in the past.

I was working at the time on production in ICI's Heavy Organic Chemicals (HOC) Division, later renamed Petrochemicals Division, which was based mainly at Billingham and Wilton on Teesside, United Kingdom. We had serious fires, causing loss of life in 1965, 1966, and 1967. The Division Board decided that process safety required an input from someone with

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(1) Anon. *Chem. Ind. Suppl.* **2005**,17 Nov, 4.
(2) Kletz, T. A. *An Engineer's View of Human Error*, 3rd ed.; Institution of Chemical Engineers: Rugby, U.K.,2001.

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a scientific or engineering background and experience of the technology. It could not be left to the existing safety officers who were mainly former foremen, retired army officers, and graduates in nontechnical subjects. They dealt competently with the everyday types of accidents but not with process safety. I was asked to undertake the job and started on 1 January 1968. It was a most unusual appointment at the time for someone with my experience, and if the reason for my appointment had not been so obvious, I would have wondered what I had done wrong. Looking back, I could well have repeated Winston Churchill's remark when he became prime minister in 1940, "I felt ... that all my past life had been but a preparation for this hour and this trial."[3] (not that I wish to compare myself with Churchill).

Within a few months of my appointment there were two more major incidents, an explosion and a fire on the Wilton site, on plants operated by other divisions and, because HOC had some responsibilities for the site as a whole, I was involved in the investigation of them both. These events showed that there was a need for change in the company as a whole, not just in HOC Division although it was some time before everyone realised this.

The rest of this paper describes the actions I and my team—there were never more than eight of us, including the secretaries—took between 1968 and my retirement from industry in 1982. Although strictly speaking my responsibilities were confined to HOC/Petrochemicals Division, we did influence other divisions, especially those with plants at Wilton, and many of them followed our example and appointed experienced chemists or engineers as safety advisers.

ICI was much larger in the 1970s than it is now. It employed 120,000 people in the United Kingdom alone. Petrochemicals Division employed about 10,000, so it was a fairly large organisation itself, with considerable autonomy. The main Board of ICI controlled major capital expenditure and what we now call human resources, including rates of pay; however, on technical matters the divisions were free to go their own ways.

Few Committees

I was helped by the fact that HOC/Petrochemicals was not overloaded with committees. There was no safety committee to decide policy, to tell me what I should do, or to draw up a strategic plan full of text boxes and connecting lines. The practice was to give someone a job and leave them free to get on with it. I soon realised that if I was at a meeting and said what I was intending to do, someone was sure to express doubts, and the chairman would then say that we should give the subject further consideration. So I said what I had done, not what I was going to do. I was helped by the ICI culture in which there was a large grey area between what one could obviously do and what one could not. In this area, if one asked permission, it might be refused, but if one went ahead, 19 times out of 20 nothing was said. I was also helped by the fact that following the serious fires I had the full support of the Board, and everyone knew this.

The downside of this ICI freedom was that people who were so inclined could stop doing things on their own initiative as well as starting things, as I was to discover after I retired from industry and some of my innovations gradually lapsed.

There were two aspects to the job which I will discuss separately: deciding what advice to give and then persuading people to follow it. We did not have a safety management policy although I drew up a list of aims. In my view one should not start any activity by writing a policy. We deal with various problems as best as we can in the light of various aims and constraints.[1] Looking back we see a common pattern. That is our policy. By writing it down we then turn what has become the common law of the company, its custom and practice, into the statute law. For example, I persuaded individual design engineers to include leak detectors for combustible gases in their designs, and I also encouraged people to fit them on some existing plants. In time, it became the accepted practice and was ultimately written into the division's design codes.

The Advice

The first decision I had to make was to set my priorities as I could not do everything at once. It was clear that I should concentrate on process safety (a term that was not then widely used[2]) as the accidents that led to my appointment were process accidents and the old-style safety officers were still there to worry about the lost-time accident rate, the everyday accidents, hard hats, safety footware, and so on. But which process risks were the most serious? My answer was to estimate the FAR of the people carrying out potentially hazardous jobs and then concentrate resources on those which exposed the people carrying them out to the highest risks. I called this procedure, which the U.K. Atomic Energy Authority had already used, hazard analysis or Hazan, although now quantitative risk assessment (QRA) is the more common name. It was the subject of my first substantial paper on process safety to be published.[4] Whenever possible the estimates of FAR were based on experience, but sometimes we had to estimate figures from the known failure rates of components.

It soon became apparent that a weakness in Hazan, probably the most serious one, was making sure that all the hazards were taken into account. If not, we wasted time and effort calculating some risks with ever greater accuracy while greater risks remained unseen. Hazard and operability studies or Hazop, developed in ICI a few year earlier, were our favoured way of identifying hazards, and we encouraged their use. Bert Lawley, an expert Hazop team leader, became a member of my group.

I tried to eliminate some of the inconsistencies in our safety practices. For example, the system for the testing of relief valves was good, but there were two exceptions. First, open vents were not included although they are, in effect, relief systems, of the simplest possible type. Soon after I was appointed, two men were killed when a choked vent caused a vessel to rupture. In the works where this occurred, a system for the inspection of such vents was immediately set up, but the message had to be passed to the other works and to other divisions. The other exception was bursting discs which, we discovered after a serious leak, were sometimes installed upside down or on the

(3) Churchill, W. S. *The Gathering Storm* ; Cassell: London, 1950;Preface.

(4) Kletz, T. A. In *Major Loss Prevention in the Process Industries*;Symposium Series No. 34;Institution of Chemical Engineers: Rugby, U.K., 1971, p75.

wrong side of their supports. Once installed incorrectly it was difficult or impossible to see that this had occurred.

Despite these anomalies, the protection of vessels against excessive pressure was generally good, but protection against increased temperature was poor and little understood. When vessels or pipes burst because they were too hot, the reaction of almost everyone, including technical staff, was to ask "What's wrong with the relief valve? Is it damaged, or is it too small?" Most pressure vessels are tested at 1.5 times their design pressure but can usually withstand 4 times their design pressure before they rupture. In contrast, vessels and pipes can withstand only a small rise in absolute temperature. For example, if a furnace tube is subjected to 10% increase in absolute temperature (note, absolute not Celsius), its creep life may be drastically shortened, and it may fail after months rather than years of use.

The 1967 fire, the most serious of the three that led to my appointment, was due to the neglect of the procedures for the preparation of equipment for maintenance; as a result, improving these procedures and checking that they were being followed was an important task. Much of this work was done by two auditors that I was able to recruit. I called them surveyors, as rather than having a quick look at everything, they looked at key aspects in detail. They looked at the permit-to-work books and also at the people carrying out the job to see whether they were actually taking the precautions specified; they witnessed the routine testing of every trip and alarm, looked at every sample point and the way it was used and at every piece of flameproof electrical equipment, some of which was dismantled in their presence.

The explosion at Flixborough in 1974[5] drew attention to the need of a system for the management of change. Before any change is made to the equipment or to the process, such as a change in operating temperature or catalyst strength, the proposal should be critically analysed, to see if there could be any problems, and then approved by the professional level of management. We had already recognised the need for such a system, but the explosion gave it added urgency. The need to consider changes in organisation in the same way was not recognised until long afterwards.

A more important consequence of Flixborough was the recognition of the desirability of designing inherently safer plants—those in which hazards are removed rather than controlled—whenever this is reasonably practicable.[6] This proved to be a much harder idea to sell than Hazan, Hazop, or the control of modifications. Even today, while process safety experts are familiar with the concept and most engineers have heard about it, many do not realize its full potential.

Persuasion

Many of the serious accidents that occurred during the 1960s were very similar to others that had occurred 10 or more years earlier.[7] The earlier ones had been investigated, reports were written, changes were made, and then the reports were filed and forgotten. The people closely involved remembered them, but their successors did not, and after 10 years most of the people on a plant have changed. Many of the old reports were hard to find, but even if they had been readily available and recirculated, reading is not a good enough method of communication to change people's actions. Unless it is relevant to our immediate problems, we soon forget what we have read.

The best method of persuasion is one-to-one discussions with people, and I did a lot of that; however, the number of people one can influence in that way is limited so I put a lot of effort into two other methods, described below.

In 1968 I started a monthly Safety Newsletter and sent copies to 30 colleagues, mainly those working in the safety field. The newsletter contained information on accidents and new developments that I thought would be relevant to their current problems. Gradually, over the next 14 years, the circulation grew spontaneously. I did not advertise it, but added people to the list at their request. By the time I retired, the circulation was several thousand, including all ICI divisions, many outside companies, universities, and the Health and Safety Executive. ICI had a very liberal attitude to the dissemination of safety information, and I was allowed to publish many papers or present them at conferences. I attended the annual Loss Prevention Symposia of the American Institute of Chemical Engineers for many years and learned a lot from them as, initially at least, they were well ahead of us in process safety.

Within ICI, the newsletter was seen by directors, managers, foremen, and in some works, operators. Some other companies photocopied it and distributed it widely. The contents came to consist mainly of reports on accidents of general and technical interest from ICI and also from other companies, supplied in exchange for the newsletters. I did not copy the original reports but rewrote them to bring out the essential messages. Many later newsletters were devoted to specific themes, such as accidents due to plant modifications, preparation for maintenance, static electricity, and human error. After I retired, I edited many items from old newsletters and published them in a book, *What Went Wrong?*;[8] now in its fourth edition, I have added many later reports and written a second volume, *Still Going Wrong*.[9]

My second method of getting my ideas across was by series of discussions on accidents that had occurred both in ICI and elsewhere.[10] A talk may convey the message of an accident better than the written word, especially if it is illustrated by slides of the damage. The recommendations can be explained, and the audience can comment on them and point out any problems. I used to give such talks, many years ago, when I was a manager and not a safety adviser. One day the training manager asked, "Instead of telling people what happened and

(5) Kletz, T. A. *Learning from Accidents*, 3rd ed.; Gulf Professional: Oxford, U.K., 2001;Chapter 8.
(6) Kletz. T. A. *Process Plants: A Handbook for Inherently Safer Design*; Taylor and Francis: Philadelphia, PA, 1998.
(7) Kletz, T. A. *Lessons from Disaster: How Organisations Have No Memory and Accidents Recur*; Institution of Chemical Engineers: Rugby, U.K., 1993.
(8) Kletz, T. A., *What Went Wrong? Case Histories of Process Plant Disasters*, 4th ed.; Gulf Publishing: Houston, TX, 1998.
(9) Kletz, T. A. *Still Going Wrong: Case Histories of Process Plant Disasters and How They Could Have Been Avoided*; Gulf Professional: Boston, 2003.
(10) Kletz, T. A. *Educ. Chem. Eng.* **2006**, *1*, 55.

what they ought to do, why don't you ask them to tell you?" From this chance remark, similar to a single stone setting off a landslide, my colleagues and I developed a training method that we used for a half-day almost every week throughout my 14 years as a safety adviser and which continued after I retired from industry.

The usual participants were a group of 12–20 managers and engineers from the works and from the Engineering Design, Technical, and Research Departments, varying from new graduates to heads of departments. Senior foreman also attended from time to time. Nobody had to come; they came because they thought the time would be well spent. The size of the group was important. If more than 20 people were present, the quieter ones did not get much opportunity to contribute to the discussions; if less than 12 were present, the group was not always of critical mass, in the atomic energy sense, and the discussion did not always take off. Some of the works-safety advisers arranged similar discussions for their foremen and process operators.

I started by describing the technique. Those present were the accident investigation team, a rather large one, and I was all the people they might wish to question rolled into one: the people on the job, the manager, the designer, and the technical experts. I then briefly described an accident and, whenever possible, illustrated it by slides of the damage and diagrams of the plant or equipment. The group then questioned me to establish the rest of the facts, those that they thought important. I answered questions truthfully, but as usually happens in accident investigations, I did not answer questions I was not asked.

After they had established the facts, the group went on to say what **they thought** should be done to prevent it happening again. Because the group had developed the recommendations, they were more likely to remember them and were more committed to them than if they had merely been told what they ought to do. Sometimes everyone agreed on the actions; at other times there was a lively discussion.

The discussions led, gradually, to an improvement in accident investigations. More attention was paid to weaknesses in a management and design, and there was less tendency to say that operators should take more care.

Compared with a lecture, the discussions are slow, but more is remembered. We usually spent at least an hour, perhaps half the morning, on a major incident, although all the information conveyed could probably be covered (although not remembered) in 20 minutes talking or 10 minutes reading. However, the success of any training method is the amount that the recipients remember and follow up, not the amount that the trainer covers. We usually spent the rest of the morning on several less complex incidents, and the discussions continued over an informal lunch.

Although the discussions took longer than a lecture, they achieved more in the time available than discussions in syndicates. The discussion leader can prevent the discussion following paths that lead nowhere and can prevent people riding their hobby horses for too long.

People's actions are influenced by antecedents such as training and instructions and by the consequences they expect to follow. Most safety management emphasises the antecedents. The discussions emphasised the consequences. I did not start, for example by describing the procedures for preparing equipment for maintenance but instead described accidents that occurred because the procedures were poor or not followed and let those present say what changes they thought should be made to equipment and procedures.

Each programme ran for the best part of a year, different people coming each week. The following year, we discussed different accidents, but some of the old modules (as we called them) were repeated from time to time for the benefit of newcomers. Most of the technical staff attended year after year, and the discussions gradually increased their knowledge of safety and changed their attitudes towards it.

Most of the modules had a common theme such as the following:

- preparation for maintenance
- over- and under-pressuring of vessels
- fires and explosions
- human error
- failures of alarms and trips
- furnace fires and explosions
- plant modifications
- major accidents that have been repeated

After each module had run its course, I summarised the accident reports and the recommendations made during the discussions in a booklet which was sent to all those who had attended and often to others as well.

Many of the notes and sets of slides that we used were published by the Institution of Chemical Engineers in their series of Safety Training Packages although the packages have now been updated by the addition of later incidents.

Leading (or attending) these discussions is much harder than giving (or listening to) a lecture and I was usually fairly tired by lunchtime. Many people come to a safety meeting expecting a quiet rest and are at first surprised to find that they are expected to contribute. After the discussion leader has outlined the first accident and asked the group to do the detective work and find out why it happened, there may be an awkward silence. The discussion leader should sweat it out. In time someone will talk. Some discussion leaders find this difficult, start talking themselves and what should be a discussion degenerates into a lecture.

The discussions varied remarkably, even though all those present come from the same company and culture. One week the group wanted to redesign every plant; the next group may have preferred to change the procedures. Some groups were interested in the immediate technical causes of an accident; others probed the underlying weaknesses in the management system. The discussion leader can comment on the group's ideas and suggest points for consideration but should not persuade the group to go down roads they do not wish to follow or to come to conclusions they do not agree with.

If any foremen (or former foremen) are present, they are often the first to see why the accident happened. They may not understand the theory, but they have seen similar incidents before. In contrast, young graduates get there in the end but explore many possible scenarios on the way.

I learned a lot from these discussions. My books and papers are scattered with remarks made during them for which I have unfairly received the credit. Many centuries ago a scholar said, “I have learned much from my teachers, more from my colleagues, and most of all from my students”.

After I had retired from ICI, I held similar discussions with an experienced American process safety engineer, Roy Sanders, in a 2-day course organised by the American Institute of Chemical Engineers, but they were less successful than those in ICI. In part this was because we rarely got enough students for a good discussion and also, I think, because people find it easier to communicate with others from their own company than with strangers. Roy and I held a few discussions in companies for their staff only, and these were the most successful.

Some companies have used an alternative type of discussion. Every member of a team is given an accident report and asked to say, at the next meeting, what actions have been taken, or should be taken, to prevent a similar accident occurring in the plant.

Later Developments

Figure 1 stops at 1982. What happened afterwards? The fatal accident rate continued at the low rate shown for a number of years. Then ICI changed its portfolio. It was formed in 1926 by the amalgamation of the United Kingdom’s four largest chemical companies, but then this process was reversed. First, the pharmaceuticals and related businesses were demerged, and then the company decided to concentrate on high-value speciality chemicals rather than bulk ones. It bought Unilever’s speciality chemicals division and sold the large bulk chemical plants. The plants on which Figure 1 is based are now owned by many different companies, and the only major ones still owned by ICI are the paint factories. It is impossible therefore to determine the accident rates on the plants that ICI operated in the 1970s. My impression is that the FAR continues to be low.

Conclusions

I am not saying that the methods my colleagues and I used (described in more detail in ref 11 and some of the other references) will work in every company, but if they are not practicable in your company or on your plant, what are you doing or should you be doing instead? In my view the crucial factor underlying ICI’s improvement was the company’s policy, never written down or formally stated, of picking those they thought were the right people and then giving them the freedom to follow what they thought would be the most effective way of achieving their aims. In ICI good practice was spread by example and diffusion rather than by command. It is important that everyone knows that the “right people”have the support of the directors. I have been a line manager and an adviser and found that, on the whole, colleagues were more willing to follow my advice than my instructions.

Sociologists divide people into “dwellers” and “seekers”. The dwellers like to leave objectives as they are. They may consider better ways of doing things—the stock in trade of engineering magazines—but are reluctant to question the desirability of what they are doing. The seekers, a minority, do question it. We do not want everyone questioning the need for everything all the time, but we do need some seekers to question our aims and actions from time to time. When I first moved to production in ICI in 1951 the senior managers were dwellers. Their main objective seemed to be restraining the enthusiasm of their younger colleagues. This changed after 1958 when HOC Division was formed with many younger people in charge. The culture became one of seeking. If it had not I, and my colleagues would not have been able to do what we did.

If you wish to improve your company’s safety record, do not put in charge someone who will carry out every task he or she is given, however willingly and efficiently, that is, a typical dweller. Look for a seeker who will find and follow up on new ideas.

When I retired from ICI in 1982, I thought I could spend about 5 years on consultancy, but after that my knowledge would be out of date. It did not happen. I still read reports of accidents similar to those described in my newsletters and still see too much readiness to blame the operators. In the 1960s in ICI we might have acted as Exxon did at Longford, Australia, in 1998 and BP (initially) at Texas City in 2005 and looked among the workforce for culprits. By the mid-1970s we were already looking for the weaknesses in our management systems.

The reports on Longford, Texas City, and many other major incidents make one think that many other large companies would benefit by following the path that ICI Petrochemical Division followed from 1968 onwards. However, the first and most difficult step is to recognise that there is a problem. Engineers are good at solving problems. They are not as good at realising and admitting (to themselves as well as others) that there is a problem.

Finally, if there has been a fire and you telephone the head office to tell them, what is the first question they ask? Is it “Was anyone hurt?”, or is it “When will you be back on line?” If it is the latter, then you do not need better operators or better safety engineers. You need better directors.

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