ICI'S CONTRIBUTION TO PROCESS SAFETY

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ICI's substantial contribution to process safety is described and followed by a discussion of the following:

- The reasons why ICI produced more new process safety ideas than other companies.
- If ICI had never existed, would the same new ideas still have been produced?
- If ICI still existed in its old form, what new ideas might it have been producing now?
- The reasons for ICI's decline and fall, and their similarity to process accidents.

KEYWORDS: company failure, hazards, ICI, process safety, risks

> *Uncertainty creates risk. Risk is the consequence of bad chance. Reducing the uncertainty in a project by better information does not itself reduce the risk but may lead to a different decision. The worst consequence of the new decision may be less disastrous, a smaller risk, than the original decision.*
>
> (ICI, 1970, p. 316)

This paper describes an accident, that is an event that had unforeseen and unexpected results: it led to the end of an independent company, Imperial Chemical Industries (ICI), which had made major changes in process safety, most of which were widely copied.

ICI was formed in 1926 by the merger of the United Kingdom's four largest chemical companies. The dominant partner was Brunner-Mond which had been founded in 1874 by Ludwig Mond and John Brunner to manufacture sodium carbonate in Northwich, Cheshire. After World War I Brunner Mond expanded, producing ammonia and fertilisers at Billingham in North-East England and later, as part of ICI, producing petrol by the liquefaction of coal. Ludwig's son, Alfred, 1st Lord Melchett, became the first chairman of ICI. Brunner Mond attached great importance to safety and what we now call human resources. The company's policies were far ahead of industry as a whole and they became the policies of ICI.

I joined the company at Billingham in 1944 and retired in 1982. My first seven years were spent in the Research Department, the next 16 in production and my last 14 in process safety. The following is a list of the major innovations in process safety made by the company during my time there. All of them were published and made freely available to the process industry as a whole. I was involved to varying degrees in all of them.

1. **Hazard and operability studies** (Hazop). They were developed in ICI in 1963 and the first paper on them was published in 1974 (Lawley, 1974). They have been used extensively by many companies for many years and their success is shown by the fact that four papers on them are being presented at this conference.
2. **Quantitative risk assessment** (QRA) (also known as Hazard Analysis or Hazan). It started in the nuclear industry (Farmer, 1967) but ICI was the first company to apply the technique in the process industries (Kletz, 1971). While all new projects and major modification should be Hazoped, QRA should be used selectively. While the risks of all projects, modifications and operations should be assessed, in most cases a non-quantitative study is sufficient.

   QRA was readily accepted in the UK by industry and the regulators as in the UK we do not have to do everything possible to remove every risk. We have to do only what is "reasonably practicable". If the cost in money, time and trouble, of removing a risk, is far greater than the gain, we can tolerate the risk. In many other counties the pretence is that all risks should be removed, however unlikely that they will occur and however trivial their effects will be.
3. **Inherently safer design**. The Flixborough explosion in 1974 taught us many lessons but the most important of them was missed by the official enquiry and most commentators. The explosion was so big because the inventory of flammable raw materials in the plant was large, several hundred tonnes. It was so large because only about 6 per cent of the raw material fed to the reactors was converted, while the rest had to be repeatedly recovered and recycled. ICI operated a very similar process and it soon occurred to us that the best way of preventing such large explosions was, if possible, to improve the process so that the inventory in the plant was lower (intensification or minimisation). If that was not possible or "reasonably practicable" perhaps we could use less hazardous materials (substitution) or use the hazardous materials in the least hazardous form (attenuation or moderation).

   Of course, such actions have been taken on many earlier occasions but they were isolated occasions. ICI made inherently safer design into a procedure that could and should be applied to every project (Kletz, 1978). Ten years after Flixborough the toxic leak at Bhopal in India underlined the need for inherently safer design, as the material which leaked and killed

thousands was not a raw material or product but an intermediate, which it was convenient but not essential to store. Intensifying the Flixborough process, a stage in the production of nylon, is not easy. ICI started to develop a process but abandoned it when we realised that there was already excess capacity in the industry. At Bhopal it would have been easy to dispense with the intermediate storage and use the intermediate as soon as it was formed.

4. **Management of change**. Another lesson learned from Flixborough was the need for a system for the management of changes to plants and processes. ICI saw the need and set up such procedures before the explosion at Flixborough. Later, changes in organisation were also studied in a similar way.
5. **The causes of accidents, including human factors**. As early as the 1960s, long before most other companies, ICI staff realised that it was superficial to blame most accidents on operators or other frontline workers and that supervisors and managers could have taken actions which would have prevented the accidents or made them less likely to occur. Such actions included better design, changes in methods of working and not turning a blind eye to previous failures to follow instructions. Typical of the time was the experience of one factory in April 1969, where there were 30 minor accidents. Over half were recorded by the immediate supervisors of the injured men as caused by "human failing". However, the accidents were discussed individually with the supervisors and in all but two cases they agreed that there was something they could do to prevent the accident happening again.
6. **Improving the preparation of equipment for maintenance**. A disproportionate number of accidents were, and still are in many companies, due to poor systems for preparing equipment for maintenance or to failures to follow the systems. ICI improved both, particularly in those divisions that handled large quantities of hazardous materials or handled them at high temperatures and pressures.
7. **Systematic attempts to remember the lessons of the past**. The actions included widespread circulation of accident reports both inside and outside the company, recycling of information, regular discussion of recent and past accidents, a monthly Safety Newsletter and a computer-based index of accident reports and other safety data. These actions have still not been adopted by many other companies where accidents are investigated, reported and then forgotten and training is unsystematic. The computer-based index lapsed in the 1980s recession. When, in the late 1990s, I asked if I could get a copy I was told that it could not be found and, if it could be found, it could not be opened. However, the Newsletters are now available on the Institution of Chemical Engineer's web site and can be downloaded without charge. To download. go to www.icheme.org and follow the links "Safety", "Safety Newsletters", "More Details" and "Newsletters 1–100".

I am not suggesting that ICI was perfect. We had many accidents, but at least we learned from them, not just the immediate technical or human causes but the need for the underlying changes listed above. Not all parts of the company were as good as the best divisions, partly because the divisions had considerable autonomy, the head office controlling only rates of pay and major capital expenditure.

WHY DID ICI, MORE SO THAN OTHER COMPANIES, MAKE THESE CHANGES?

ICI was not dominated by committees. When I became a full-time safety advisor there was no safety committee to tell me what I should do. Committees can be a barrier to innovation. If they are considering a change someone is likely to express reservations and the Chairman will then say, "I think we should give further consideration to these comments". This, I think, is the reason why so many official reports, including those on Flixborough and Bhopal, miss important messages (see item 3 above).

In contrast, ICI's policy, never written down, was to pick who they thought was the right person for a job and give him or her the freedom to achieve his or her objectives in what he or she thought was the most effective way. In every organisation there are actions that employees, at each level, can clearly do on their own authority and actions that they clearly can't. In between there is a grey area where, if you ask for permission, it may be refused or postponed, but if you just go ahead nothing is said. In ICI the grey area was much wider than in most companies. (See the last book listed at the end of this paper.)

A good boss allows his subordinates to use their freedom in the gray area but he watches what they do and comments on it if necessary. One of the best bosses I ever worked for, during my time in production, was notorious for the amount of detail he wanted to know. But I still felt that I was making the decisions and telling him the results.

I do not think that I and my colleagues were more knowledgeable about safety than our opposite numbers in other companies. In fact, most of us, being new to the subject, were not aware of much of the accepted wisdom on safety and did not feel bound by it. We felt free to innovate. To quote Einstein, "Imagination is more important than knowledge".

WHAT WOULD HAVE HAPPENED IF ICI HAD NOT EXISTED?

I think the seven changes listed above would have come about but later in time, perhaps even decades later. I think this because none of the ideas was a complex one such as calculus, relativity or quantum theory. In contrast, the changes in safety all seem almost obvious in retrospect. Many people must have said, "Why did we never think of that?"

WHY DID ICI COME TO AN END?

In the 1980s ICI Pharmaceuticals Division was about one-third of the company's capital but provided about two-thirds of the profits. It wanted to raise more capital for expansion. By dermerging from ICI and renaming itself as Zeneca, it became much easier to do so and after demerging it soon raised the extra capital. A few other products besides pharmaceuticals became part of Zeneca and were later sold. Later, Zeneca merged with the Swedish company Astra to form AstraZeneca. Pharmaceuticals Division was very different in many ways from the rest of ICI so these changes made sense.

ICI's normal practice was to breed its own leaders but in the 1950s an outsider, a former civil servant, was appointed as executive chairman. It was widely accepted in the company that this appointment was not a success. The man concerned is chiefly remembered for a long and unsuccessful campaign to buy Courtaulds. Perhaps this had been forgotten, as after demerging Zeneca, ICI appointed an outsider as managing director and later as chairman. He was previously head of Unilever's chemicals division.

The rest of ICI, once Pharmaceuticals had gone, was mainly bulk production of commodity chemicals and their sales and profits were very irregular, up in some years and down in others. For a long time it had been the company's policy to gradually increase their involvement in speciality chemicals, by acquisitions and natural growth, as they were less subject to such changes in sales and prices. When Unilever decided to sell their chemicals division, ICI's new managing director saw an opportunity to increase ICI's involvement in a big way. He, and the Board, decided to borrow the money needed to buy his former "toy" and pay for it by selling most of ICI's bulk chemical plants.

Unfortunately ICI found it much harder than expected to sell these plants and had to accept lower prices than it had hoped to get, thus landing the company with a large debt. The company had to sell some old ICI plants it had intended to keep and then sell some of those it had bought from Unilever. Finally, the Dutch company AkzoNobel bought the reemnant that was left. By this time the number of employees had reduced from 120,000 in the UK in the mid-1970s to a total of 10,000. The name Imperial Chemical Industries still exists as that of one of AkzoNobel's subsidiaries, though some of the former ICI plants are now in other parts of AkzoNobel.

There are a lot of similarities between this account and many of the process accidents described in books and papers, including my own. The earlier result of bringing in an outsider for the top job had been forgotten or dismissed as no longer relevant. More seriously, no one seems to have asked the obvious questions, "What will happen if we cannot get enough money from the sale of ICI's bulk chemical plants to get us out of debt?" and "What is the probability of this happening?" It seems there was no study similar to a Hazop or a risk assessment, qualitative or quantitative. Any engineer or scientist who made a major change to plant equipment or operation without asking these questions would be considered incompetent. Yet in the commercial field major changes are often called bold or resolute.

WHAT WILL WE MISS IN THE YEARS TO COME?

We know what ICI did in the 80 or so years of its existence, especially in the last half of the 20th century. What innovations would it be making in the 21st century if it had not been for the actions of the directors who killed the goose that laid the seven golden eggs (and a few smaller ones)? We shall never know. However, AstraZeneca have inherited some of ICI's culture and practices. If Zeneca, rather than the other part of the demerged company, had kept the ICI name we might have agreed that ICI had gone from strength to strength after the demerger.

When, in 1969, I wrote my first internal ICI paper on what we now call quantitative risk assessment I called it "risk analysis". I was then reminded that ICI had produced a book (ICI, 1970) which dealt with quantitative ways of estimating the commercial risks of a project, and called it risk analysis. I therefore called the new technique – new to the company and the industry – "hazard analysis", soon abbreviated to "Hazan". I expect that ICI's commercial staff and Boards have long forgotten the book, if they ever saw it. Here are some quotations from it:

> I*t is a common experience that some things can be forecast with greater experience than others. But you can never be completely confident. And a forecast is a conjectural estimate of something future, however soundly it is based on what has gone before. And a conjecture is a formation of opinion on insufficient grounds! Hence confidence in a forecast depends largely on how much one knows about what has gone before... and how far ahead into the future one is trying to forecast*
>
> (page 267)

> *A forecast is a conjectural estimate of something future and is generally based on some knowledge of the past. Confidence in a forecast depends on the relevance and extent of knowledge of the past, experience of the forecaster, and how far ahead the forecast extends*
>
> (page 282)

> *Good decisions depend on people with imagination. flair and sound judgement and the value of these qualities is greatly enhanced by a grounding in modern methods of assessing projects.*
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> (From the Foreword by Sir Peter Allen, Chairman of ICI at the time of publication; page vi).

After an accident HSE often criticise a company for not complying with their own standards and advice.

ICI is not the first company to come to an end because a forecast turned out to be wrong. However, if the Board had copied all or perhaps just some of the practices of their engineers and scientists, the company would still be with us today. They could have:

- Looked systematically for all that might go wrong, as in a Hazop.
- Estimated the probability of these events occurring, as in a quantitative risk assessment.
- Followed a systematic procedure for the management of proposed changes.
- Looked for less risky and inherently safer ways of achieving their objectives, such as gradual change.
- Learned the lessons of the past.

I have seen no detailed obituary of ICI. All I have seen in the newspapers and technical press are a few reminiscences by former employees.

The lesson we can learn from this paper is that many other activities, such as banking, business and law making, would benefit by copying the methods developed in the process industries to prevent accidents. Many of the laws and regulations approved by Parliament never achieve the expected results.

An American lady who spent a year in England in 1957 wrote afterwards that the English "like cautious experiment rather than radical change, and if this predilection sometimes muddles them up, costs them money and slows them down, at least it spares them the disillusionment that can follow the collapse of some grandiose scheme (Beadle, 1961)." Another failure to learn a lesson from the past.

AFTERTHOUGHT

> *All the text books will tell you, stretching back over two decades, that most acquisitions fail to create value for anyone other than the selling shareholders, and that three years after the event the buying company is suffering remorse: they just wish they had never done it.*
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> Sir John Banham (former director-general of the UK Confederation of British Industry), *Daily Telegraph* (London), 11 Aug. 2005.

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