THE MANAGEMENT OF ORGANISATIONAL CHANGE

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The explosion at Flixborough in 1974 drew the attention of the process industries to the need to control modifications to plant, in order to identify and forestall possible adverse consequences. Changes to processes were soon treated in a similar way. Several decades elapsed, however, before it was realised that changes in organisation can also have unforeseen effects and that they should be systematically studied before they take place. This paper describes a number of incidents in which the immediate causes were technical but the underlying or root causes were changes in organisation, including changes in relationships with contractors. Some of the points to be considered in the management of organisational change are discussed.

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I feel so strongly about [knowledge] because of the horror I have for wrong medicine; because of the horror I have for changes which waste painfully learnt knowledge; because of the horror I have for plans which acknowledge the need for money capital but underplay the need for knowledge capital. – George Muir[1]

The explosion at Flixborough, UK in 1974 and other incidents drew the attention of the oil and chemical industries to the need to control changes to plants and processes. Many publications, including references 2, 3 and 4, have described accidents that have occurred because no one foresaw the results of such changes and have suggested ways of preventing such accidents in the future. Only in recent years, however, we have realized that changes in organization can also have unforeseen effects and should also be scrutinized systematically before they are made. In the UK this is now a legal requirement in high hazard industries[5] though it seems to be enforced rigorously only in he nuclear industry.

A common organisational change is to eliminate a job and distribute the jobholder's tasks amongst other workers. Although the jobholder is asked to list all his or her duties, sometimes one or two are missed, especially those carried out by custom and practice and not listed in any job description. For example, someone may have built up a reputation as a "gatekeeper", someone who knows how to get things done, where scarce spares may be squirreled away and so on. Another person may be the only fitter who really understands the peculiarities of a certain machine. Only after they have left are their distinctive contributions really recognised. Such changes are not "like for like".

The following are some examples of the unforeseen effects of major changes, one temporary but the others intended to be permanent.

ADMINSTRATIVE CONVENIENCE VERSUS GOOD SCIENCE

My first example, from James Lovelock's autobiography, *Homage to Gaia*[6], shows what happened when "administrative convenience ruled and good science and common sense came second", though the results were a decline in effectiveness rather than safety. He was working in a government-funded research centre that employed chemists and biologists. It was amalgamated with another similar institution some distance away. To the administrators it seemed sensible to move all the chemists to one site and all the biologists to the other as this would avoid the need to duplicate the services that each group required. The administrators did not realise, and did not listen to those who did, that research benefits from informal day-to-day contact between people from different disciplines. Both institutions declined. As we shall see, in the section on Longford, a similar loss of communication occurred when the professional engineers were moved from a plant to the company's head office.

AN INCIDENT ON AN ETHYLENE PLANT

The plant was starting up after a turnaround. At 2 am on the day of the incident the shift team started the flow of cold liquid to the demethaniser column. A level should have appeared in the base of the column two hours later. It did not, but problems elsewhere distracted the shift team and they did not notice this until 7 am. By this time the temperature at the top of the column was –82ºC instead if the usual –20ºC and the level in the reflux drum rose from zero to full scale in 10 minutes. This should have told the shift team that the column had flooded, had overflowed into the reflux drum and would now be filling the flare knock-out drum (see Figure 1). However, neither of the two high level indicator/alarms on this drum, set at 8% and 22% of capacity, showed any response.

It was 12 noon before anyone had a thorough look at the column. They found that the wires leading from the column level indicator were disconnected and that the valves between the knock-out drum and its level indicators were closed. Both vessels were shrouded with scaffolding and the state of the wires and connections was not easily seen. Liquid was now entering the flare stack. It failed as the result of low temperature embrittlement and was followed by a fire.

The immediate causes of the incident were the failures to restore the isolations of the level instruments before start-up and the slowness of the shift teams to realise what was happening. The underlying causes were far deeper and were due to both short-term and long-term changes in organization.

SHORT-TERM CHANGES

It was the practice on the plant to work 12-hour shifts instead of the usual 8-hour shifts during start-ups so that there were more people present than during normal operation. On this occasion the operators refused to do so (though they were willing to work overtime if necessary; this would give them more pay than working 12 hour shifts). However, the foremen and shift managers worked 12-hour shifts. They changed shift at 7 am and 7 pm while the operators changed at 6 am, 2 pm and 10 pm. This pattern of work destroyed the cohesion that had been built up over the years within each shift and lowered the competence of the team as a whole.

A report in the local newspaper said that, "A major influence over the behaviour of the operating teams was their tiredness and frustration". A trade union leader was quoted as saying that the management team members were more tired than the operators as they were working 12-hour shifts.

In addition to the usual shift personnel, two professional engineers were also present on each shift but their duties were unclear. Were they there to advise the shift manager or, being more senior in rank, could they give him instructions? Should they try to stand back and take an overview or should they "muck in"? On the day of the incident they did the latter and got involved in the detail of the problems that distracted everyone from the demethaniser.

LONG-TERM CHANGES

So far I have followed the published report on the incident[7] but there had also been more fundamental changes. The incident shook the company. It had a high reputation for safety and efficiency and the ethylene plant was considered one of its flagships – one of the least likely places where such a display of incompetence could occur, so what went wrong?

About seven years earlier there had been a major recession in the industry. As in many other chemical companies drastic reductions were made in the number of employees, at all levels, and many experienced people left the company or retired early. This had several interconnected results.

- Operating divisions were merged and senior people from other parts of the company, with little experience of the technology, became responsible for the ultimate control of some production units.
- There was pressure to complete the turnaround and get back on line within three weeks. This pressure came partly from above but also from within the team, as the members were keen to show what they could do. They should have aborted the shutdown to deal with the problems that had distracted everyone during the night but were reluctant to do so.
- There were fewer "old hands" on the plant who knew the importance, when there were problems, of having a look round and not just relying on the information available in the control room. A look round would have shown ice on the demethaniser column.
- Delayering had produced a large gap in seniority between the manager responsible for the ethylene plant and the person above him. This made it more difficult for the ethylene manager to resist the pressure to get back on line as soon as possible. Previously an intermediate manager had acted as a buffer and prevented commercial people and more senior managers speaking directly to the start-up team. Also, he would probably have aborted the start-up. Senior officers, not footsoldiers, order a retreat.

The company had an outstanding reputation for openness but was reticent about this incident and no report appeared in the open literature, apart from the local newspaper, until about twelve years later, after the company had sold the plant.

THE LONGFORD EXPLOSION

On 25 September 1998 a heat exchanger in the Esso gas plant in Longford, Victoria, Australia fractured, releasing hydrocarbon vapours and liquids. Explosions and a fire followed, killing two employees and injuring eight. Supplies of natural gas were interrupted throughout the State of Victoria and were not fully restored until 14 October. There was no alternative supply of gas and many industrial and domestic users were without fuel for all or part of the time that the plant was shut down[8,9,10,11].

The purpose of the unit in which the explosion occurred was to remove ethane, propane, butane and higher hydrocarbons from natural gas by absorbing them in “lean oil”. The oil, now containing light hydrocarbons and some methane and now known as “rich oil”, was then distilled to release these hydrocarbons and the oil, now lean again, was recycled. The heat exchanger that ruptured was the reboiler for the distillation column. The cold rich oil was in the tubes and was heated by warm lean oil in the shell.

As the result of a plant upset the lean oil pump stopped. There was now no flow of warm lean oil through the heat exchanger and its temperature fell to that of the rich oil, –48°C (–54°F). The official report describes in great detail the circumstances that led to the pump stopping. However, all pumps are liable to stop from time to time and the precise reason why this pump stopped on this occasion is of secondary importance. Next time it will stop for a different reason. In this case one of the reasons was the complexity of the plant. It had been designed to recover as much heat as possible and this resulted in complex interactions, difficult to foresee, between different sections. (Complex plants have complex problems.)

Ice formed on the outside of the heat exchanger when the flow of warm oil stopped but no one realised that the low temperature was hazardous. Despite long service the operators had no idea that the heat exchanger could not withstand low temperature and thermal shocks and that restarting the flow of warm lean oil could cause brittle failure. More seriously, some of the supervisors and even the plant manager, who was away at the time, did not know this. It was not made clear in the instructions.

The ignorance of the operators does not surprise me. When I was working in production, before I became involved full-time in safety, some operators’ understanding of the process was limited. Trouble-shooting depended on the chargehands (later called assistant foremen) and foremen, assisted by those operators who were capable of becoming chargehands or foremen in the future. In recent years I have heard many speakers at conferences describe the demanning and empowerment their companies have carried out and wondered whether the operators of today are really better than those I knew in my youth. At Longford they were not.

Esso claimed that the operators had been properly trained and that there was no excuse for their errors. But the training emphasised the knowledge that the operators needed to do their job rather than the understanding they needed to deal with unforeseen problems. They were tested after training but only for knowledge, not for understanding. One operator was asked why a certain valve had to be closed when a temperature fell below a certain value. He replied that it was to prevent “thermal damage” and received a tick for the correct answer. At the Inquiry[9] he was asked what he meant by “thermal damage” and replied that he “had no concept of what that meant”. When pressed, he said that it was “some form of pipework deformity” or “ice hitting something and damaging pipework”. He had no idea that cold metal becomes brittle and may fracture if suddenly warmed.

Now we come to the crucial changes in organisation. Two major changes were made during the early 1990s. In the first, all the engineers, except for the plant manager, the senior man on site, were moved to Melbourne. The engineers were responsible for design and optimisation projects and for monitoring rather than operations. They did, of course, visit Longford from time to time and were available when required but someone had to recognise the need to involve them.

In the second change the operators assumed greater responsibility for plant operations and the supervisors (the equivalent of foremen) became fewer in number and less involved. Their duties were now largely administrative.

Both these changes were part of a company-wide initiative and were the fashion of the time. There was much talk of empowerment and reduced manning. The Report concluded that, "The change in supervisor responsibilities… may have contributed by leaving operators without properly structured supervision". It added, "Monthly visits to Longford by senior management failed to detect these shortcomings and were therefore no substitute for essential on-site supervision."

On the withdrawal of the engineers the Report said that it "appears to have had a lasting impact on operational practices at the Longford plant. The physical isolation of engineers from the plant deprived operations personnel of engineering expertise and knowledge, which previously they gained through interaction and involvement with engineers on site. Moreover, the engineers themselves no longer gained an intimate knowledge of plant activities. The ability to telephone engineers if necessary, or to speak with them during site visits, did not provide the same opportunities for informal exchanges between the two groups, often the means for transfer of vital information". None of this was recognised beforehand. Chats in the control room and elsewhere allow operators to admit ignorance and discuss problems in an informal way that is not possible when a formal approach has to be made to engineers at the company HQ. Empowerment can become a euphemism for withdrawal of support. There is a similarity with the changes in the research organisations described earlier.

On one occasion when I was a safety adviser with ICI Petrochemicals Division I was asked to move my small department to a converted house just across the road from the main office block. I objected as I felt that this would make contact with my colleagues a little bit harder as they would a little less likely to drop into our offices.

At Longford there were also errors in design. The heat exchanger that failed could have been made from a grade of steel that could withstand low temperatures or a trip could have isolated the flow of cold liquid if the temperatures of the heat exchanged fell too far. These features were less common when the plant was built than they became 30 years later but they could have been added to the plant. The designs of old plants should be reviewed from time to time. We cannot bring all old plants up to all modern standards – inconsistency is the price of progress – but we should review old designs and decide how far to go. Esso intended to Hazop the plant but the study was repeatedly postponed and ultimately forgotten. Another design weakness was the excessive heat recovery system already mentioned.

Exxon has a high reputation for its commitment to safety and for the ability of its staff. Was Longford a small plant in a distant country that fell below the company's usual standards or did it indicate a fall in standards in the company as a whole? Perhaps a bit of both. Exxon did not require Esso Australia to follow Exxon standards and the Longford plant fell far below them. Exxon were fully aware of the hazards of brittle failure but their audit of Esso did not discover the ignorance of this hazard at Longford. On the other hand, the removal of the engineers to Melbourne and the reductions in manning and supervision were company-wide changes. It also seems that in the company as a whole the outstandingly low lost-time accident rate was taken as evidence that safety was under control. Unfortunately, the lost-time rate is not a measure of process safety.

RAILTRACK

When British Railways was privatised and split into a hundred companies, Railtrack owned the track, signalling and stations, but other companies owned the trains, another group of companies operated them and British Railway's former maintenance groups became independent contractors. This left Railtrack without any engineering expertise or the ability to monitor its contractors.

This produced many interface problems between the various companies who had different objectives. For example, Railtrack had to compensate the train operating companies whenever trains were delayed and this made Railtrack reluctant to increase the time available for maintenance. There was also a literal interface problem, as responsibility for the rails and the wheels lay with different organisations. "Both sides of the wheel/rail interface may be operating within their respective safety based Standards, but the combined effect of barely acceptable wheel on barely acceptable rails is unacceptable".[12] This led to the rolling contact fatigue of the track (also called gauge corner cracking), the Hatfield train crash in October 2000 and the consequent upheaval while hundreds of miles of rail were replaced.

The engineering principle involved is hardly new. In 1880 Chaplin showed that a chain can fail if its strength is at its lower limit and the load is at its upper limit.[13] The Hatfield crash did not occur because engineers had forgotten this but because there were no engineers in the company's senior management.

OUTSOURCING

A marketing manager in a company that manufactured ethylene oxide foresaw a market for a derivative. The company operated mainly large continuous plants while the production of the derivative required a batch plant. The derivative was wanted soon and the company did not want to spend capital on a speculative venture. The manager therefore looked for a toll manufacturer. He found one able to undertake the task and signed a contract with them without consulting any of his technical colleagues. The toll manufacturer was very competent but was located in a built-up area. When it was realised that ethylene oxide was being handled there, this gave rise to some concern even though the stock on site was moderate.

A few years later the buildings were demolished as part of a slum clearance scheme. The HSE then refused permission for new ones to be built in their place. Before the local authority could develop the site they had to pay the toll company to move to a new location.

This incident occurred some years ago, before the CIMAH Regulations came into force. It probably could not happen today, but is a warning that outsourcing, of products or services, is a change that should be systematically considered before it takes place.

MULTISKILLING

Multiskilling presents specific problems, illustrated by the Flixborough explosion. The site was without a mechanical engineer for several months, as the only one – the works engineer –had left and his successor had not arrived. Arrangement had been made for a senior engineer from one of the owning companies to be available when needed but the men who designed and built the temporary pipe that failed did not realise that these tasks were beyond their competence and did not see the need to consult him[14]. Similarly, in many plants there is now no longer an electrical engineer but the control engineer is responsible for electrical matters. An electrical engineer is available for consultation somewhere in the organisation but will the control engineer know when to consult him? Will he know what he doesn't know?

The same applies at lower levels. Will the process operator who now carries out simple craft jobs be able to spot faults that would be obvious to a trained craftsman?

One of the underlying causes of the collapse of a mine tip at Aberfan in South Wales, which killed 144 people, most of them children, was similar. Responsibility for the siting, management and inspection of tips was given to mechanical rather than civil engineers. The mechanical engineers were unaware that tips on sloping ground above streams can slide and have often done so[14].

THE CONTROL OF MANAGERIAL MODIFICATIONS

As with changes to plants and processes, changes to organisation should be subjected to control by a system, which covers the following points:

- Approval by competent people. Changes to plants and processes are normally authorised by professionally qualified staff. The level at which management changes are authorised should also be defined.
- A guide sheet or check list. Hazard and operability studies are widely used for examining proposed modifications to plants and processes before they are carried out. For minor modifications several simpler systems are available[2]. So far as I am aware, only one similar system has been described for the examination of modifications to organisations[15]. Some questions that might be asked by those who have to authorise them are suggested below.
- Each modification should be followed up to see if it has achieved the desired end and that there are no unforeseen problems or failures to maintain standards. Look out for near misses and for failures of operators to respond before trips operate. Many people do not realise that the reliability of trips is decided on the assumption that most deviations will be spotted by operators before trips operate. We would need more reliable trips if this were not the case.
- Employees at all levels must be convinced that the system is necessary or it will be ignored or carried out in a perfunctory manner. The best way of doing this is to describe or, better, discuss, incidents such as those described above, which occurred because there was no systematic examination of changes.

SOME POINTS TO BE COVERED IN A GUIDE SHEET

Define what is meant by a change: Exclude minor re-allocations of tasks between people but do not exclude outsourcing, major re-organisations following mergers or downsizing or high level changes such as the transfer of responsibility for safety from the operations or engineering director to the human resources director. Accidents may be triggered by people but are best prevented by better engineering[16].

A recent survey in the US showed that nearly half the companies that replied to a questionnaire on the management of change said that they included organisational change[17]. However, they may not include the full range of such changes.

Some questions to ask are:

- How will we assess the effectiveness of the change in the short and long-term?
- What will happen if the proposed change does not have the expected effect?
- Will informal contacts be affected (as at Longford)?
- What extra training will be needed and how will its effectiveness be assessed?
- Following the change, will the number, knowledge and experience of people be sufficient to handle abnormal situations? Consider a number of past incidents in this way.
- If multiskilling is involved, will people who undertake additional tasks know when experts should be consulted? See the Section on Multiskilling.

Except for minor changes, these questions should be discussed by a group, as in a hazard and operability study, rather than answered by someone on their own. “None” or “not a problem” should not be accepted as an answer unless backed up by the reasons for this answer.

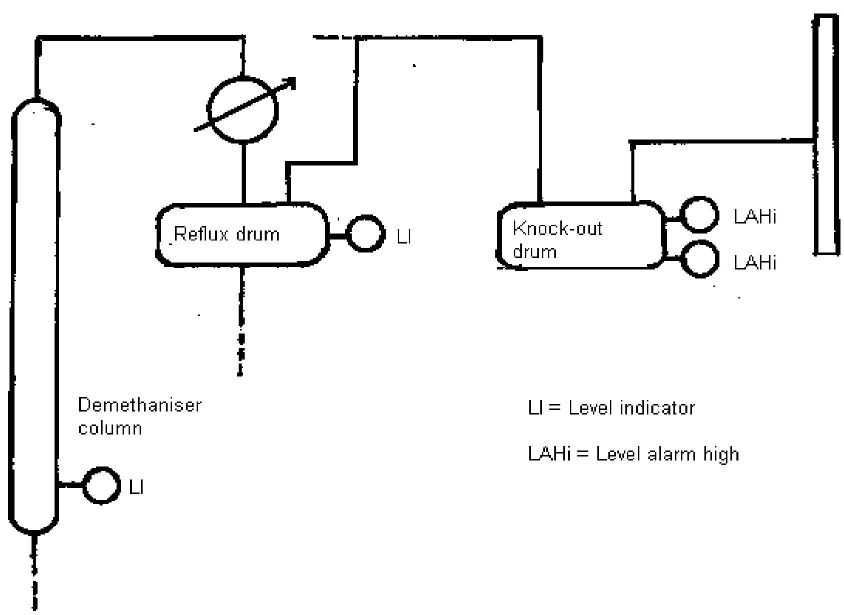

Figure 1. The level indicator on the column and the level alarms on the knock-put drum were out of order. The column filled with liquid which over-flowed into the to drum and then into the stack

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