

HOW CAN WE DRIVE DOWN INCIDENT RATES BY THE USE OF INCIDENT RECORDS AND DATA BASES?

Eur Ing FK Crawley, Fellow
University of Strathclyde

This paper is written in a provocative manner as another *wake-up call* to the industry as a whole. The challenge is to revert to the more open era of accident information and data dissemination that existed during the 1970s by directing effort, and of necessity money, with the objective of improving the learning process both inside companies and on a global basis.

The paper examines a number of incidents, some of which have not been found in the public forum, that have recurred in the past both globally, inside an industry and worse still recurring inside a company. It also uses the more significant findings from the OECD Workshop on "Lessons Learned" [1] with the objective of identifying some of the reasons for the repetition of causations from an analysis of the past incidents and so to propose some possible means of enhancing and disseminating the already depth of data in the data bases. The OECD Workshop also identified some practical difficulties in Data Mining and proposed some actions. These difficulties included, amongst others, definitions. Further the analysis of real incidents spread over 30 years indicates that there are some organisational problems, which also include, amongst others, dissemination of information to the correct place, its relevance and also internal (management and cultural) issues.

The overall objective of this paper is that it will set the Industrial accident statistics (including that of the Process Industry) on a downward path, without resort to new Regulations.

KEYWORDS: Lessons Learned, Accidents, Incidents, Knowledge, Culture.

INTRODUCTION

To know not what happened before you were born is forever to remain a child.
Cicero

It seems that there is a flaw in the brains of Homo Sapiens which means that they cannot learn from the past. If it were not so children would not receive cuts, burned hands and broken bones. There seems to be a need to experience the incident at first hand!

Likewise in Industry the incidents are often a repeat of ones that have already occurred and have been recorded in the open press (with minor variations). Even worse the incidents sometimes recur with very little variation in the same company. [See section 1.1]. Tony Barrell ex-Chief Executive HSE OSD focused on the management issues quite succinctly [2] "*There is unfortunately an awful sameness. They are always characterised by a lack of forethought and a lack of analysis and nearly always the problem comes down to poor management. It comes back to the fact that it is sloppy* *and ill organised and unsystematic right from the top of the company downwards*". This suggests that more attention should be paid to "software" rather than to added "hardware" [1,2].

The trend in the incident frequencies is not falling as fast as the Regulators had expected when legislation was drawn up [1]. This may be the result of the traditional exponential approach to the irreducible minimum but it may also be the result of many changes inside the Industry. The application of more and more regulation may assist the downward trends but there may be some serious cost implications. The challenge of this paper is to ask the fundamental question:

> "*What can we learn from the lessons of the past and how can we be*"
> *better by "self regulation?*"

There are many reasons why there may be difficulties in learning from the past. As already indicated in the *Preliminary Announcement* of this Symposium the process industry has become "leaner" and it is "changing". The *leaner* approach has many implications, which will be discussed later, but the *changes* are such that Speciality Chemicals, Pharmaceuticals and even Food Processing are replacing the big bulk chemicals of the 1960s and 1970s. This also is discussed later.

THE CHANGES IN THE INDUSTRY

CULTURAL/MANAGERIAL

There is no doubt that all industry has had to become leaner and meaner in order that it can survive. Even so the argument that safety is good business, while basically true, does not seem to be proven by the total cost of the incidents to the company, both positive and negative. In spite of this there is generally a downward trend in incident frequencies but may be not as fast as would be wanted by the Regulator or the Government [3]. The leaner and meaner approach means that the manager has had to devolve more responsibilities downwards (empowerment) to persons who may not have been as highly trained/educated. Likewise, as a result of empowerment the manager becomes more and more divorced from the detail of the process itself and feels less accountable. Empowerment is a good managerial tool but the change has to be managed properly and those empowered must have the correct skills (skills matrix). The empowerment is both a *cultural change* and a change in *management style*, which should be subject to a *Management of Change* Study (MoC). The results of empowerment have been significant and while not the total picture it is believed that it may have contributed to a reduction in the rate of fall of incidents.

It is not so evident that those empowered have the skills that the previous managers once had. In 1969 during the initial commissioning and start-up of an Olefine Plant the level instrumentation, both control and alarm, at the base of the Demethaniser failed to give any indication of level after one hour of initial fed. (The Demethaniser receives a number of feeds of mixed hydrocarbons, the heaviest being Butane, and Hydrogen with temperatures from 273K to 173K.) The mass balance (which was crude bearing in mind that this was the initial commissioning of the column) indicated that there should be some level present but other parameters indicated that a level might not be present. After about two hours the manager aborted that phase of the start up until the instruments were checked and errors corrected. On investigation it was discovered that there was a common mode fault (not in the tappings) [4]. On the same column, on the sister plant, on the same works, in the same company there was a similar event, about 10 years later, but this was not handled as well [5]. The Demethaniser flooded over into the flare drum, in turn this was overfilled and liquid Methane entered a carbon steel flare stack with disastrous consequences. The reports put the causes down to tiredness and frustration. The managers on the first incident had been struck down with 'flu and had been working for about 90 hours per week for three months. They were very tired! But they did handle the situation properly. What was not brought out in the report [5] is that the managers of the second plant had empowered the top line of the Plant Supervisors, who were not academically qualified, and had divorced themselves from the routine detail of operation. In the final analysis no one was able to carry out the simple diagnostics and the team developed a "mind set" before and during the incident.

Another example of cultural change is to be found in a fire resulting from poor isolation for maintenance standards [6]. A new operational site was being established inside a company. The teams were made up of two groups, one had experience of high-pressure small bore piping and the other lower pressure large bore piping. The first group locked closed valves before maintenance and the second slip-plated joints before maintenance without first necessarily locking the valve closed. In the cultural change on the new site the locking off was not adopted with the large bore piping and due to the piping size the slip plating was stopped. As a result, during maintenance on a pump a suction valve was left open, fluids were released, ignited and a serious fire resulted. Three persons were trapped and died. The sequence of events was almost identical to those on Piper Alpha [7]. Small changes can compound to cause major incidents. The change from state A, the original isolation philosophy, to state B the adopted isolation philosophy, was not covered by a MoC or was it not thought through (1.4)?

Culture and management are inter-related. A flaw in the corporate management is a flaw in the corporate culture.

LEARNING FROM THE PAST ("MEMORY FADE")

A second implication of leaner is that the manager has less time to follow up the incidents of the past and to learn the lessons in those incidents. Possibly of more concern is that in the drive for promotion the detail is not really important, provided the tour is survived without any blemish on the dossier. This is compounded by the lack of a detailed handover to the new job incumbent. There is a secondary effect from poor hand-overs and not learning the lessons, that is the accumulative knowledge, is not recycled or it is forgotten, and therefore there is a dilution of the local knowledge. This results in the "truth" that the corporate memory has a "half-life" of only 10 years. In the days where lean and mean was not a requisite for productivity there was a portion of time that could be set against Professional Development such as lessons learned from the past. Too often the messages are just forgotten. The messages from the reference [4] could equally have been that as level measurement had been compromised the plant was operating outside the boundaries or envelope studied in the HAZOP, so before the plant was allowed to continue in operation full MoC Study should have been initiated. This was done in [4] but not in [5]. In the recent incident in Texas City, Texas [8] a Fractionator was operated with a high base level, again outside the operating envelope. The final disturbance was probably initiated by operating outside the base temperature operating envelope, the base temperature was significantly higher than normal probably the result of suppressed boiling due to the imposed static head of fluid. The final eruption was probably the result of a form of "roll over". (Nothing to do with the Lottery). The report notes that just before the ignition a vehicle engine was heard to "race", that is it was being over fuelled by fuel in the ambient air. There are now a number of examples of ignitions caused by internal combustion engines, particularly diesel engines, which do not require spark ignition. The first example (petrol) was at Feyzin in 1966 [9] a second (diesel) was in ICI in 1968 [10] and a likely third (diesel) was in BP in 1989 [11]. Nothing appears to have been learned.

As less time is now becoming available for training so both the ability and the opportunity to learn are reduced. Continued Professional Development is key to learning, not only about the past but improving the person themselves. While CPD is a professional requisite it is of note that it is not a requirement for retention of membership of an Engineering Institution. Such CPD tools in Loss Prevention do exist, one example is a symposium such as this, another are the Loss Prevention Bulletins (IChemE) and yet another is the family of IChemE Training Packages. Unfortunately, these need to be read, or to be lead in the case of the workshops, all of which is time consuming and is contrary to lean and mean.

The other side of the problem is that there is not always an effective mechanism for capturing knowledge and recycling it into the corporate memory. Historically part of this was carried out by Engineers in the form of Codes and Standards. But the manager left 10 years ago! Keeping these Codes and Standards up to date is not necessarily compatible with leaner.

Unfortunately many Engineers are now out-sourced: in the 1990s many very capable persons were given "golden opportunities" to leave companies. They took with themselves a sizable severance term, an immediate pension and much of the corporate memory and so also shorten the corporate memory "half-life" to below 10 years. The change in culture coupled with the loss of memory has the potential to make the company more vulnerable to the repeat incident. Knowledge has to be captured and held. The problem is also compounded by the move to Engineer, Procure, Install and Commission (EPIC) projects. The EPIC route may not be able to capture the culture of the company, which is a component of the safety performance. Further the contractor may be a very capable designer but may have a limited operational experience; this imposes a higher load on the asset owner's monitoring process through the Safety Studies and HAZOPs.

One example of "corporate memory fade" is to be found in the multiple press reports of the recent fine of a major Exploration & Production company for a double fatality in 2003 as a result of a gas release in a "Condeep" leg (concrete based as opposed to steel supporting structures). More recently there has been an announcement of a Fatal Accident Inquiry into the incident. There was a previous event in the same company in 1984 [12] under almost identical circumstances. In this case there were three fatalities due to smoke and Carbon Monoxide inhalation. (The actual location of the incident was given as Sullom Voe in [12] but in reality it was over 150 km away). In the interim period, common to the industry, there had been a significant downsizing, which had affected the whole industry, and knowledge had left the company.

NOT MY PROBLEM (NUTME – NOT UP TO ME)

The leaner and meaner approach, coupled with the changes inside the industry (later) means that there is less opportunity to interface with other companies, as happened in the 1970s, and to share experiences or to read the incident reports prepared by parties such as HSE.

With the changes from the bulk chemicals, where due to size alone the potential was greatest, to the smaller processes the lessons learned do not seem to be treated as interchangeable and there is a parochial approach that there is nothing to be learned as there is no way that the specific incident could have happened in the newer industries. This denies the benefits of technology transfer. It is true that certain processes require specific skills and knowledge but the IChemE Training Packages, referred to earlier, show clearly that no one industry can stand in isolation. Therefore it is essential that all accidents be analysed by all branches of industry, not only the chemical industry but also all branches of engineering and technology, to determine what lessons can be gleaned and are relevant to those individual industries. Finally the relevant lessons must be learned and the corrective actions put in place. One of the difficulties in relating to the various reports from various industries may well be the lack of reader knowledge of the industry in question; this is not an acceptable excuse, competent engineers and scientists should be able to dissect the incident from the first industry and then draw out the causes and the specific lessons for the second industry. The lack of interfacing means that lessons learned in one industry are not translated to another. It is also evident that some of the problem is the tendency of some industries to be introspective and not outward looking.

> "*And therefore never send to know for whom the bell tolls: it tolls for you*".
>
> John Donne

The following statement, the likes of which are heard too often, illustrates the parochial attitude:

> "It is not really relevant! What has Flixborough or The Ramsgate Walkway Disaster got to do with the water industry?" [13 & 14]

The simple answer to this question is that both contained elements of:

1. Poor Management of Change (In [13] changes were at the site construction stage and in [14] it was at the concept stage).

2. A lack of detailed analysis of the degrees of freedom of the final installation.
3. From 2 above, both structures were inherently weak and with a high probability of failure.

All of these lessons are relevant to any other industry. This emphasises the need for technology transfer.

One of the potential problems that should be addressed is the excessive use of Quantified Risk Assessment in the general field of risk assessment. The numeric approach, while appropriate in many cases, tends to divorce the engineer or scientist from the qualified assessment which uses the common sense approach of asking, "*What could go wrong? How can we prevent it? How can it be mitigated it if it cannot be prevented?*" As a result the critical analysis of day-to-day risks is left to the Risk Assessor and once again those who should have examined the databases for lessons in day-to-day issues do not learn. This problem applies not only to operations but also design where the problems are not analysed in detail, and, as the designer is not able to make the final decision based on an analysis of evidence, the resolution is left to the HAZOP team to decide! (The HAZOP team do not have the authority to decide, so the problem is recycled to source.)

NOT THOUGHT THROUGH AND "I DID NOT KNOW THAT"

As discussed earlier the knowledge gained in one industry does not belong to that industry but industry as a whole. In one incident a new reflux drum, five times larger than the previous one, was to be installed in the original structure. The vessel was hydro tested at the workshop and the piping was hydro tested on site. It was decided to carry out a site composite hydro test but no one had considered the static loads on the structure [15a]. Clearly there was a poor defence in depth as there were deficiencies in both the design department and in the audit of the design through a MoC. Even the most junior engineer would have asked "*What about the stresses*?" The structure collapsed under the hydro test and it is fortunate that it was so as if it had collapsed under duty the consequences would have been significant.

On a more frivolous (not truly safety) topic a company was short of steam at a pressure of 13.5 bar. At that time the British Railways were converting from Steam haul to Diesel haul and Steam Locomotives, which had boiler pressures of 15 bars, were available from the scrap yard. A series of engines were lined up and the steam bonnets connected to the steam main. Ex-British Rail Firemen fired the coal but, for fairly obvious reasons, they were not required to rake away the ash from a moving engine as it was not in their job description but someone had forgotten that these engines were static! The wooden sleepers burned out and the engines settled onto the ballast. Then the fire bars burned out due to clinker build up and poor cooling [15b].

Figure 1 shows a simple elevation of two conical roofed storage tanks at different elevations attached to a single vent stack [16]. The orientation is as viewed on the plant, Tank A was at a higher elevation than tank B. (The more observant readers will have noted the error set for the reader with the lettering given right to left! See also [6] Page 288.)

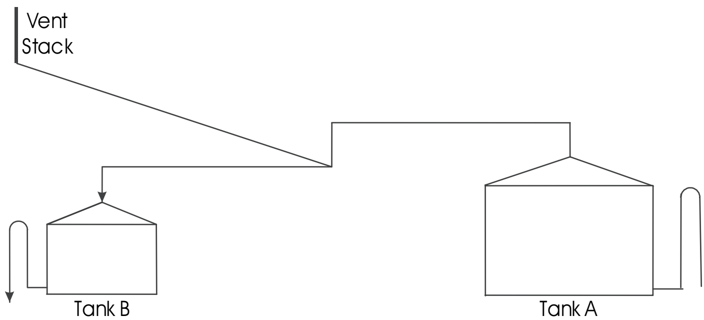

Figure 1.

Tank A acted as a buffer tank, fed by water under split-level control from elsewhere in the process. Water from tank A was then pumped to a second process. Tank B also handled wastewater but was not connected to the first process other than by the common vent. The level control of tank A was not satisfactory and after some years it was decided to operate the tank using the overflow to spill excess water to the sewer. In addition to this change over the previous 5 years the throughput through tank A had reached 50% over the design basis. The modified process worked perfectly well until there was a localised power failure which tripped out the pumps removing water from tank A. The hydraulic jump coupled with the high loading on the overflow resulted in water passing over the overflow into the vent header and then down into the tank B. There was a semi-stable flow regime which persisted for some hours producing a slight positive pressure at the roof of tank A. When the supervisor realised what was happening the feed into tank A was stopped, the pressure regime at the top of tank A changed to sub atmospheric and the roof collapsed inwards. The tank was reinstalled, if a bit bent a few days later, but on deeper analysis it was found that the process could be re-configured and tank A could be removed from service. The root cause of the incident was the change in the operational control, which in turn was compounded by the steady increase in throughput. The increase in throughput, on its own, should have required a review of the overflow capacity.

There are a number of lessons in this rather simple incident:

1. There was not an adequate MoC before the incident when throughputs were increased and the control was changed.
2. There was not a MoC for changing from a semi-stable regime back to the original regime.
3. A protective system (such as an overflow) should not be used as a control device. This increases the potential for common mode failure – which occurred in this case.

All of these are lessons which seem to require learning on a routine basis.

On a lighter topic a new Manager could not see the reason why Methanol had to be injected into an Ethane/Ethene Splitter, so, after 7 years of it being a Standing Instruction the practice was cancelled without any thought as to why it was so. (7 years is approaching the memory half-life!). Within a few days the reason for the practice became very clear and it was re-instated. (The hydrogenation process, which came before the Splitter, produced both water and Benzene as bi-products, both froze at the operating temperature of the Splitter.) Or was it a variation of section 1.2 or the next issue?

KNOWLEDGE IS NOT READILY OBTAINED

There are databases but when they are examined that data may be, and often is, incomplete. This is exemplified by the inaccuracies in [16]. The need to maintain confidentiality for fear of litigation and/or job security can lead to inaccuracies in the records or data, although the true story associated with [16] is now recorded; the version used in the LPB was suitably adjusted for reasons of confidentiality. As time has moved on the true story can now be told.

It is also clear that there is some under-recording of information. To a degree this is being addressed by RIDDOR [17] but it is not necessarily true in other Nation States in EU. Different companies (and Countries) may be interpreting "dangerous" in many ways; hence it is possible that a specific incident may not perceived to be "dangerous" in one company or country but not another. In [2] there was reference to a previous fatality on Piper Alpha in the early 1980s where an electrically heated gas heater exploded. That incident is not to be found in the databases nor is an incident on another offshore oil platform where a heat exchanger was over-pressured due to leaking tubes. An article in the Press some years later is believed to show a (poor) photo of the incident probably taken by a contractor [18]. Yet the two incidents were known to a number of persons working in the industry. In the first case a high temperature shut down used the same electrical contact as the heating circuit, eventually the contacts welded closed. In the second the pressure relief valve had been isolated from the heat exchanger following maintenance and when the tubes were found to be leaking the low-pressure side was isolated before the high-pressure side.

In another incident [19], caused by a piping modification in a blowdown header at a flare drum resulted in a regular, periodic, series of minor explosions in the flare stack with a period of a few minutes. The pilot lights were left ignited and some hydrocarbons were still left in the flare drum. The natural chimney of the flare stack drew air across the fluids and the resultant gas mix was ignited at the pilot. No injury or damage resulted but the potential was high. As a minimum precaution the isolation of the pilot burners would have prevented this event.

As a means to illustrating the potential problems with the interrogation of databases it is of note that when the IChemE Hazards Database was re-examined to identify the incident referred to in [12] with a greatly increased set of fields it produced "No Matches". This is not meant to be a criticism of this or any other database but it might indicate that data may be recorded but it may not be as easily accessed or acquired as might be expected and that key words must be correctly allocated and defined.

OECD MEETING IN KARLSKOGA, SWEDEN, 2004

This meeting titled "Workshop on Lessons Learned from Chemical Accidents and Incidents" discussed a number of the topics already mentioned. At the meeting were about 60 delegates from around the world. Some 25 papers were presented but there were no formal proceedings of papers but there was a formal report [1]. The conclusions were quite numerous but the following are the more significant.

In the overview paper there were four significant conclusions:

1. That based on two databases . . . the Process Accidents do not appear to be decreasing at the rate that might be expected.
2. That the lessons already learned could have prevented a large majority of process accidents. Sic. (But by definition were not applied.)
3. That inadequately designed and/or executed Process Management Systems are at the "root cause" of the failure to use lessons learned. (As stated in [2].)
4. That improved industrial use of lessons learned to prevent accidents required development of approaches that:
   - Reduced the firm's and practitioner's "cost" of learning and staying aware of pertinent lessons.
   - Captured management attention by transforming lessons into emotional reminders of major process accident consequences.

Other conclusions taken from the four other sessions included:

5. Moving from "what went wrong" to "why it happened".
6. The organisational resource constraints may limit how many investigations will be undertaken and how deep they will be.
7. Corporate culture may limit the depth of the investigation (of the incident).
8. For lessons learned to be implemented they have to be communicated to "someone". This meant that different techniques and strategies would have to be developed to reach different departments in the organisation. Two major conclusions that arose were as follows:
9. Further efforts were required to harmonise terminology in databases so that information is compatible and can be transferred as widely as possible.
10. Establish a network amongst databases.

It is slightly surprising that one topic that was not recorded under the conclusions was that of education.

ANALYSIS

The section 1 was written as a personal observation based on experience and the OECD Workshop (section 2) was based on team observations. Many of these conclusions have resonance with the first part of this paper and shows that there are some problems to learning lessons from the past. It is clear that there are a number of potential difficulties arising from the leaner approach. Some are cultural and others are knowledge or education based.

However the conclusions need to be supported by formulated actions which have clear objectives.

The first two conclusions from the OECD Workshop stand. Clearly industry is not learning.

The third conclusion is recognised as a major problem in the field of safety. Not only are the accidents due to poor Management Systems (see also [1]) but also the failure to pass on the knowledge gained. This has been discussed in sections 1.1, 1.2 and 1.3 earlier.

However conclusions 4 and 5 (see also sections 1.2 and 1.3) are probably central to this paper and have deeper significance, which must be addressed in a proactive manner.

Conclusions 6 and 7 must give cause for concerns in all groups, from research to design and then operation (and demolition). Companies must be willing to invest in more detailed investigations.

Conclusion 8 (see also 1.2) is very significant as at present there is the assumption that a lesson will be read and learned. This is a dangerous assumption as this paper shows. A "Knowledge Manager" would be a solution but is counter to the concept of leaner.

Conclusion 9 is really a recommendation, which must be acted upon. Information on incidents is often disguised to avoid litigation, protect the guilty and even to protect the employment of the reporter. Of some serious concern is the use of the "catch-all", human error, as the cause of the incident in the reports. Very often this is actually a flaw in the management where a person is not properly supervised or trained or is under serious home pressures. If the causes of the incidents are open to discussion due to confusion within the definitions it might be necessary to resort to a re-analysis of the reports which will be counter productive. This has already caused some difficulties in a research project [20].

Conclusion 10 is also a recommendation. There is a clear need for information to be uniform and readily accessible.

It is not difficult to see that the problems highlighted in section 1 and the conclusions from the OECD Workshop, supported by Tony Barrell's comments, point to the need for Management Solutions.

ENCOURAGING NEWS

JOINT VENTURES

There is some reluctance for the chemical industry to form "Joint Ventures". The Offshore oil and gas industry has accepted that it costs money to generate knowledge. The industry has carried out a number of joint ventures on many topics with the objective of mutual benefit. Such ventures have included Fire Protection and a greater understanding of the dynamics of confined space explosions, these alone cost over £5M. One in particular which is now in the public forum, is the Design of Relief and Blowdown Systems [21]. This was funded as a joint venture with the work put out to consultancies. The information gained during round table discussions was invaluable. To the surprise of many a number of the problems identified were not unique but were common to many operators. This in itself was a valuable outcome from the study as there was the recognition that some problems were general to the industry. (This is another example of a previous lack of interfacing.) If one industry can do it why not another?

TERTIARY EDUCATION

The main Engineering Institutions have now developed a template for teaching at the Undergraduate level. The HSE have now funded this initiative such that teaching materials can be made available to Academe. The intention is that it should be applicable universally and not be tailored to one industry. The undergraduate teaching will not be a panacea but it might start the realisation that issues must be discussed, analysed and the cause of the problem eliminated. If the problem can not be eliminated then to decide what mitigating features might be added.

ACTIONS PROPOSED

It is appropriate to give some indications of how these conclusions might be dealt with before giving more of the problems. Changes often appear to be slow but they are significant taken over time, knowledge may be lost and new skills may be required. The changes inside the management structure must be monitored (audited) to ensure that the lines of responsibility are clearly defined and that there is adequate communication between parties. Where problems are found corrective actions must be put in place and the "lessons learned" must be recorded (OECD 2, 3 and 4)

Equally it would be wrong to ignore the "empowerment of persons", where those empowered may not have the correct skills matrix, a point not highlighted in the OECD Workshop. The top-level supervisors of the past may now be working outside their capability and retraining may be appropriate. That retraining should be a condition of empowerment not a result of empowerment. It might also be appropriate for the Engineering Institutions to require some written evidence of CPD, say every 5 years, or evidence of competence before Membership is renewed. The production of evidence of the acquisition of new skills may require much effort. However, there are now many Universities offering Masters and Batchelor degrees by Distance Learning so it may not be as difficult as it might seem. In specific cases, particularly those who are developing the teaching and knowledge sources, or are leaders in their field, the evidence of fulfilling CPD would be in the role that they have taken and the case would stand on merit. It may also be necessary to have some dedicated training organisation where new skills can be developed; this could be funded by industry on a central basis and then be supplied by external bodies or the Engineering Institutions themselves. However it is inevitable that the needs for these skills can only be determined internally so the new bred of Manager must have a new skill to add to the skills matrix, namely the ability to recognise where and when new skills are required for individuals working for him/her before that individual is promoted or empowered.

The need for "root cause analysis" using the "why?" approach (OECD 5) is illustrated by the following simple but real example:

The pump bearing failed.
Why?
There was no oil in the lubricator.
Why?
The operator did not fill then lubricator. (At this point the finger of blame would point at the operator and it would be put down to "human error", see earlier comments on this catch all). But please carry on the questioning!
Why?
There was no oil in store.
Why?
It was not ordered.
Why?
The manager forgot to order it! (The fault or root cause of the problem was now clearly laid at the feet of the Manager).

Too often the reports of incidents can be interpreted in a number of manners and if the information is not displayed in a consistent manner the lessons will be lost.

The ability to carry out full and proper investigations will depend upon a no blame culture and may also require new skills and possibly an increase in personnel (OECD 6 and 7). Incident investigation requires experience and patience which have to be learned. It is implicit that that skill must be available inside the organisation. This is not supported by the leaner approach.

The need for collection and dissemination of knowledge or lessons learned does indicate that there is a requirement for what might be called the "Corporate Knowledge Manager" (CKM) (OECD 8). This person would be the point of focus for all information arriving from external sources and they would then search the information for the relevant lessons, which the CKM would then direct to the correct department or party for action. The role of the CKM would be greatly facilitated by a "non blame culture", including the Regulator, where openness is encouraged and rewarded and fears for litigation or job security are eliminated. The role could be part of another job and not the sole function. One other role of the CKM would be to run suitable reminder campaigns, such as were run by Trevor Kletz inside ICI Petrochemicals Division in the 1970s and 80s, (which eventually became the IChemE Training Packages) where reminders are published at an appropriate frequency.

The unification of definitions (OECD 9) is self-evident. There should be some form of "Glossary of Terms" as, without it, different investigators could be quite easy to reach subtly different conclusions for the same event. The Glossary should be directed at the root causes, which are then interchangeable with other engineers and scientists, and not at the symptoms, which may not be interchangeable.

It might appear that as industry can, when the case is made, work as a team in Joint Ventures. It does appear that a learned body could develop a consistent database without resort to disguised information. The ability to generate a network of databases is an honourable objective but may fall foul of business and language barriers (OECD 10).

Finally the education (and re-education) of all engineers and scientists should focus on the skills of identifying and avoiding the root causes of risks. Without the education or CPD the task will be much harder.

When these actions are reviewed there is a clear challenge to the Managers of Industry that they must be willing to raise the cash for the detailed investigation of incidents, and the collection and dissemination of knowledge both externally and internally. Joint Ventures may be a solution. In addition the skills of all must be enhanced and the managerial role must change to reflect this. The alternative will be more Regulation, which may well be more expensive in the long term!

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