

HOW NOT TO INVESTIGATE AN ACCIDENT

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For many years many of us have been advising our colleagues on ways of preventing accidents or reducing their seriousness and probability. We have had some success but there are still too many accidents, so this paper describes some of the actions we should not take.

1. Don't think of a possible, or even probable, cause and then look for evidence that supports it. This is the greatest error.
2. Don't quote human error as a cause.
3. Don't blame individuals except in exceptional cases.
4. Don't report that a recent accident has never occurred before.
5. Don't keep reports secret.
6. Don't forget that the actions are the most important part of a report.
7. Don't say that a recent accident will never happen again.
8. Don't interview witnesses in the head office.

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For many years many of us have been suggesting to our colleagues ways of preventing accidents or reducing their seriousness and probability. We had some modest success but there are still many accidents. So this paper discusses some of the most serious errors that investigators make.

ERROR 1: THE WORST ERROR IS TO THINK OF A POSSIBLE CAUSE AND THEN LOOK FOR EVIDENCE THAT SUPPORTS IT

There are two ways of solving problems of all sorts, including finding the causes of accidents.

- (a) We collect and consider all the relevant data and, if necessary, carry out some experiments.
- (b) We think of a possible cause and then look for data that supports this cause and perhaps devise experiments that will support it. We fail to see that there may be a better solution, that some evidence points the other way or that our solution has unwanted side-effects. We develop a fixed mental attitude called "mind-set" (or "groupthink" if it is believed by a number of people).

This second way is not science. It can "prove" that almost any cause is the right one. Some scientists and engineers use method (b) but it is used far more often by politicians and the police. A newspaper report stated that a member of the government, I forget who, had appointed someone to find evidence that supported her views. The newspaper reported this as a fact, without any comment, as if it was a normal action.

To quote (John Humphrys, 2008), "Most of us want our beliefs to be confirmed rather than proved false, and we will disregard any inconvenient evidence. And that seems to apply no matter how clever you are. Sigmund Freud once said:

'To begin with it was only tentatively that I put forward the views I had developed . . . but in the

course of time they gained such a hold of me that I can no longer think in any other way. Our belief becomes a part of what we and who we are.'

Edward De Bono (1983) writes, "Even for scientists there comes a point in the gathering of evidence when conviction takes over and thereafter selects the evidence".

Unlike the politician, these writers developed mind-sets unintentionally. Nevertheless, mind-sets are often so strong that debate is futile. If two or more people have different mind-sets on the same subject, the result is confrontation rather than compromise or concession.

Here is an example of a mind-set: a low-pressure refrigerated ethylene tank was provided with a relief valve set at a gauge pressure of about 1.5 psi (0.1 bar), which discharged to a vent stack. After the construction had started it was realized that cold gas coming out of the stack would, when the wind speed was low, drift down to ground level, where it might be ignited. The stack was too low to be used as a flarestack — the radiation at ground level would be too high — and it was not strong enough to be extended. What could be done?

Someone suggested putting steam up the stack to disperse the cold vapour. This seemed a good idea, and the suggestion was adopted (Figure 1).

As the cold ethylene gas flowed up the stack, it met condensate flowing down. The condensate froze and completely blocked the 8-in.-diameter stack. The tank was over-pressured and ruptured. Fortunately, the rupture was a small one and the escaping ethylene did not ignite. It was dispersed with steam while the tank was emptied.

In retrospect, it seems obvious that ethylene gas at -100°C might cause water to freeze but the design team were so hypnotized by their solution that they were blind to its deficiencies. After the tank was repaired, the vent stack was replaced by a flarestack.

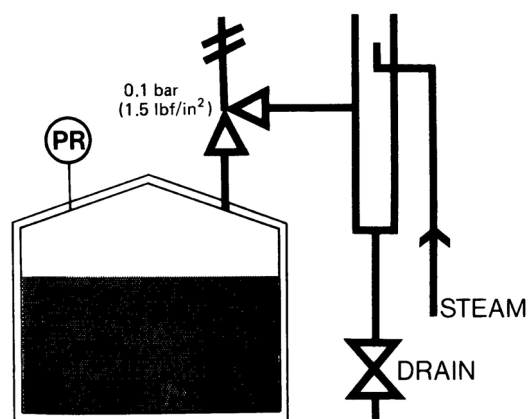


Figure 1. The condensed steam flowing down the stack was frozen by the rising cold ethylene gas

Miller (1978) writes: “If a theory is persuasive enough ... scientists will accommodate inconsistent or anomalous findings by decorating the accepted theory with hastily improvised modifications.”

Mind-sets are not always absurd. They can be plausible but incorrect; they may have been the right cause on an earlier occasion. Politicians, the press and the public have some knowledge about science and engineering but, to quote Mark Twain, “It ain’t what you don’t know that gets you into trouble. It’s what you know that ain’t so.”

Young children often have original ideas as they have not yet developed mind-sets.

ERROR 2: QUOTING HUMAN ERROR AS A CAUSE

There are lots of books and papers on human error but the adjective is unnecessary. All errors are human errors. Someone, usually a manager or supervisor, has to decide what to do; someone, often a designer, has to decide how to do it; someone, usually an operator or maintenance worker has to do it, and all of them can make errors. When the term “human error” is used the writer or speaker usually means an error by the do-er. Sometimes an investigator will say that an accident was due to equipment failure rather than human failure but equipment has no choice. Equipment failure is due to errors in design, manufacture, installation, maintenance or operation, often more than one of these.

An example: in 1989, in a polyethylene plant in Texas, a leak of ethylene exploded, killing 23 people. The leak occurred because a line was opened for repair while the air-operated valve isolating it from the rest of the plant was open (Figure 2). It was open because two compressed air hoses, one to open the valve and one to close it, had been disconnected and then replaced wrongly. The accident, some might say, was due to an error by the person who re-connected the hoses. This is an error waiting to happen, a trap for the operator, a trap easily

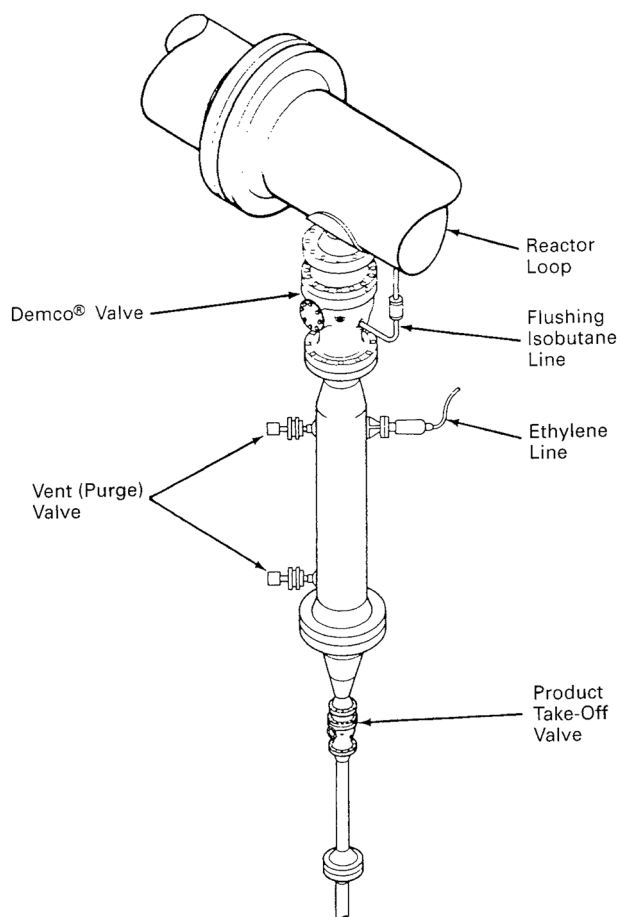


Figure 2. The Demco valve was open when everyone thought it was shut. As a result there was a large leak of ethylene when a maintenance team dismantled the vessel below the Demco valve

avoided by using different types or sizes of coupling for the two connections. This would have cost no more than the error-prone design.

Many similar accidents have occurred, some on medical equipment since at least 1867. But do not blame the designer instead of the operator. Why did he or she produce such a poor design? What was lacking in his or her training and the company standards? Was a safety engineer involved? Was the design Hazoped? Why did the operating team not notice the hazards and change the fittings? Reports rarely look for these underlying causes.

While I was writing this paper the BBC reported that an incident in a hospital was not due to human error but to a system error. System and organisational errors are euphemisms for management errors as only managers can change systems. Accident investigators do not like to blame their bosses, so they blame systems or institutions rather than those who designed or tolerated the systems. Newspaper and BBC reporters unthinkingly swallow the reports.

ERROR 3: BLAMING INDIVIDUALS

The Texas accident just described illustrates the error of blaming individuals. As already stated some people would blame the man who replaced the two hoses the wrong way round. But we all have moments when we aren't fully alert and make slips. The designer of the equipment could be at fault but was he or she using company standards or practices in which case the author of the standard was at fault? Or the person responsible for checking from time to time that standards were OK. The people who checked the design could have prevented the explosion, as could the supervisor or manager of the plant, either of whom could have modified, at a trivial cost, what they had taken over. Many of the operators or maintenance workers who used the hoses, or just looked at them, must have realised that they could be interchanged. Did they report this? If they didn't, was it because they expected that no one would listen to them? If so, the culprit is the factory manager who had, deliberately or unintentionally allowed a "don't want to know" culture to develop. The investigation uncovered other faults which suggest that this could be the case. Altogether there were dozens, perhaps scores of people who, if they were honest enough, could have said after the explosion, "I could have prevented it." But the managers have the greatest responsibility. A shop steward has written:

Sole responsibility should be placed fairly and squarely on the shoulders of the Departmental Manager. He should go about with his eyes open instead of sitting in his office, to be able to note unsafe and dangerous practices or work places, and get something done about them as soon as possible. If he gives instruction on these matters he should enforce them (Hynes, 1971).

ERROR 4: REPORTING THAT SUCH AN EVENT HAS NEVER OCCURRED BEFORE

The underlying cause of the explosion at Buncefield, UK in 2005 was that all the people and organisations involved in design, operations and maintenance believed that cold petrol vapour had never exploded in the open air. They were unaware that such explosions had occurred in Newark, New Jersey in 1983 (Anon., 1983; Henry, 1985; Kletz, 1986), Naples, Italy in 1995 (Russo *et al.*, 1999), St. Herblain, France in 1991 (Lechaudet, 1995) and elsewhere. Other examples can be found by searching Google for "gasoline spills".

If just one person at Buncefield had known about just one of the incidents I have mentioned, had realized that a similar incident might occur at Buncefield and had drawn this to the attention of his colleagues, then the explosion might not have occurred.

If the designers or operators had carried out a search for incidents that had occurred on installations similar to the one they were designing or operating, then the explosion

would probably not have occurred. Not carrying out such a search was a dereliction of duty by all of the many the organisations involved.

Another example: In the US, in June 2009 and February 2010 there were explosions because flammable gases were dispersed into confined spaces (Ossmann *et al.*, 2010). Two similar incidents occurred in the UK in 1981 and 1984, both were reported in HSE publications (1982) and (1985) and in books and both were forgotten (or never noted).

ERROR 5: KEEPING THE REPORT SECRET

There are four reasons why we should publish our accident reports:

- (i) The first reason is moral. If we have information that might prevent an accident, then we have a duty, morally and legally, to pass on that information to those who might have a similar accident.
- (ii) The second reason is pragmatic. If we tell other people about our accidents, then in return they may tell us about theirs, and we shall be able to prevent them from happening to us. If we learn from others but do not give information in return, we are "information parasites," a term used by biologists to describe those birds, for example, that rely on other species to give warnings of approaching enemies.
- (iii) The third reason is economic. Many companies spend more on safety measures than some of their competitors and thus pay a sort of self-imposed tax. If we tell our competitors about the action we took after an accident, they may spend as much as we have done on preventing that accident from happening again.
- (iv) The fourth reason is that if one company has a serious accident, the whole industry suffers in loss of public esteem and there are demands for more legislation, which will affect the whole industry. To the public and politicians we are all one. To misquote the well-known words of the poet, John Donne:

No plant is an Island, entire of itself; every plant is a piece of the Continent, a part of the main. Any plant's loss diminishes us, because we are involved in the Industry: and therefore never send to know for whom the inquiry sitteth; it sitteth for thee.

Some companies are nevertheless reluctant to publish their reports because they do not want others to know how foolish they have been or because they wish to keep their processes secret. Experience shows that it is always possible to publish without disclosing confidential data. In my books and papers I do not mention the location of an accident unless it has already been given in the title of a published report.

Remember that we are here today to learn from each other what more we can do to prevent people being killed or

injured (and to prevent damage) and that alone is reason enough to publish.

ERROR 6: NOT REALISING THAT THE ACTIONS ARE THE MOST IMPORTANT PART OF A REPORT

The purpose of an accident investigation is to recommend what should be done to prevent it happening again. If the recommendations are not clear and easily found the knowledge for which the company has paid a high price, in human suffering as well as money, is wasted. Yet keywords and indices in books and databases normally list the equipment and substances involved and the result of the accident, such as fire, explosion or toxic release, but often the changes made or recommended are not listed.

For example, an explosion occurred on a plant that handled manganese dust. The published report, entitled "Manganese Mill Dust Explosion", was thorough and described the actions taken afterwards (Senecal, 1991). The keywords were *dust*, *explosion*, and *manganese*. Readers who were interested in dust explosions, especially in metals, will have read the paper, but most others will not. They will have missed an important message that was included in the paper but had nothing to do with dusts or explosions. The explosion occurred because a maintenance team isolated a power supply but did not realise that they were also isolating the power supply to the safety equipment. Labels should list the equipment connected to each power switch or valve, if it is not obvious.

Another example: an operator noticed a small leak of hot nitric acid vapour from a small hole on a pipe weld. Radiography showed that there was significant corrosion of the weld and of the equipment below it. A temporary patch was fitted to the leak, and plans were made to replace the condenser and pipe at a turnaround scheduled to take place a few months later.

Full marks to the plant staff for writing a report on the incident and circulating it widely within the company, but the report left many questions unanswered:

Was the original welding to the standard specified?

Was a positive materials identification program in force when the plant was built, and were the pipe, welding rods, and condenser checked to make sure that they were made from the correct grade of steel? Was a suitable grade specified?

Without the answers to these questions the opportunity to prevent similar accidents in the future was lost.

The actions recommended in a report can be changes in design, procedures and/or organisation. The last includes selection and training of suitable people for jobs at all levels and procedures for checking that procedures are being followed. Reductions in numbers of operators, often described as empowerment, may be a euphemism for loss of support.

I once read a conference paper describing an accident in which the writer, after the heading, "Actions", wrote, "No need for any as the plant is damaged beyond repair and will not be replaced". It did not occur to him at the time that other plants and people might benefit from the lessons that could be learned. This sentence was removed and more information added when the paper was printed in the conference proceedings (Pipkin, 1964).

ERROR 7: SAYING THAT THE RECENT ACCIDENT WILL NEVER HAPPEN AGAIN

This is often said after a serious accident, more often by politicians and directors than by those who work in factories. For example, following a major explosion in Texas, a well-known investigator said:

It is my sincere hope and belief that that our report will establish a new standard of care for corporate boards of directors and CEOs throughout the world. . . . The boards of directors of oil and chemical companies should examine every detail of their process safety programs to ensure that no other terrible tragedy occurs.

Of course, we hope it will never happen again but similar remarks have been made after every major accident. Major accidents are often repeated in the same company after about ten years. After that time most of the staff have left the company or moved to other jobs in it. No one remembers the accident or the reason why certain equipment or procedures were introduced. Someone keen to improve efficiency, a very creditable aim, asks why are we following a time-consuming procedure or using cumbersome equipment. Nobody knows, so the equipment is removed or the procedure is changed and the accident happens again. Never remove equipment or change a procedure unless you know why they are there.

One reason why we do not remember what has happened before is that "most papers have a life of less than five years. After that time, only a small proportion is ever referred to again" (Jones, 2010).

ERROR 8: INTERVIEWING WITNESSES IN THE MAIN OFFICE

This seems a minor error compared with those described above but it may make it harder to gain all the information needed to establish the causes of an accident. Most plant operators and maintenance workers never visit the main office block. If they are called there, they are in unfamiliar territory and have a suspicion that they have been brought there to be carpeted. If the investigators meet on the plant those who work there are on their own territory and are more relaxed, more likely to offer facts rather than just answer questions. To gain the most from the interview the investigators, instead of questioning the interviewee, should allow him or her to describe their own views. The

investigators should realise that they may already have developed a mind-set, and may be tempted to ask “yes or no” questions in support of their mind-set, as discussed in Error 1. We have ended as we began.

AFTERTHOUGHT

Many people claim that deliberate decisions to spend less money on safety, even when hazards are recognised, is a major cause of accidents. I do not agree, though obviously there are some companies who do this.

If so, what are the major causes of accidents?

They are: ignorance, incompetence, forgetfulness, complacency, not noticing or ignoring alarms or abnormalities, following habits or custom and practice, and reading only summaries or PowerPoints instead of detailed reports; in short, all the bad habits which all of us have to varying extents.

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