An engineer's view of human error

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Third edition

Trevor Kletz

The theme of this book:

Try to change situations, not people

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Foreword to the third edition

In this book I set down my views on human error as a cause of accidents and illustrate them by describing a number of accidents that have occurred, mainly in the oil and chemical industries. Though the book is particularly addressed to those who work in the process industries, I hope that it will interest all who design, construct, operate and maintain plant of all sorts, that it may suggest to some readers new ways of looking at accident prevention and that it will reinforce the views of those readers who already try to change situations rather than people. It is intended for practising engineers, especially chemical engineers rather than experts in human factors and ergonomics, and I hope it will be of particular interest to students.

Although human factors are not specifically mentioned in the Institution of Chemical Engineers' publication *Accreditation of University Degree Courses — A Guide for University Departments* (November 1996), they are essential if the course is to 'develop an awareness of the necessity of safe design', which is included. Many of the accidents I describe can be used as the raw material for discussions on the causes of accidents and the action needed to prevent them happening again, using the methods described in the Institution's safety training packages, collections of notes and slides on accidents that have occurred. Some of the incidents are included in the package on *Human Error* and other packages.

Some readers may wonder why I have added to the existing literature on human error. When so much has been written, is there need for more?

I felt that much of the existing literature is too theoretical for the audience I have in mind, or devoted to particular aspects of the problem. I felt there was a need for a book which would suggest to engineers how they might approach the problem of human error and do so by describing accidents which at first sight seem to be the result of human error. My approach is therefore pragmatic rather than theoretical, and influenced by engineering methods. Thus I have:

- questioned the accepted wisdom;
- started with situations as they are rather than as we would like them to be;
- judged possible actions by their effectiveness;
- suggested actions based on the best current information, as in industry we often cannot postpone decisions until more information is available.

I do not claim any great originality for the ideas in this book. Many of them are to be found in other books such as *Man-Machine Engineering* by A. Chapanis (Tavistock, 1965) but while that book is primarily concerned with mechanical and control equipment, this one is concerned mainly with process equipment.

Not all readers may agree with the actions I propose. If you do not, may I suggest that you decide what action you think should be taken. Please do not ignore the accidents. They happened and will happen again, unless action is taken to prevent them happening.

Thanks are due to the many friends and colleagues, past and present, who suggested ideas for this book or commented on the draft — without their contributions I could not have produced this book — and to Mr S. Coulson who prepared the illustrations for Chapter 14. Thanks are also due to the many companies who allowed me to describe their mistakes and to the Science and Engineering Research Council for financial support for the earlier editions.

In the second edition I added three new chapters, on 'Accidents that could be prevented by better management', on 'Errors in computer-controlled plants' (as people, not computers make the errors) and on 'Some final thoughts' and made a number of additions to the existing chapters.

In this third edition I have added more examples of accidents caused by the various types of human error. I have extended the chapters on errors made by managers and designers and now include errors due to their ignorance of various options such as inherently safer design. I have also expanded the chapter on computer control and added an appendix on 'Some myths of human error', widespread beliefs that are not wholly true. John Doe has been joined in his adventures by Joe Soap but the reasons for their errors are very different.

I have often been irritated by authors who use phrases such as, 'as discussed in an earlier chapter', without saying which one. I have therefore included cross-references whenever a topic is discussed under more than one heading.

US readers should note that in the UK 'supervisor' is another name for a foreman while 'manager' is used to describe anyone above the level of foreman, including those who are known as supervisors or superintendents in most US companies.

To avoid the clumsy phrases 'he or she' and 'him or her' I have usually used 'he' and 'him'. Though there has been a welcome increase in the number of women employed in the process industries, the manager, designer or accident victim is still usually a man.

Trevor Kletz
May 2001

Glossary

Some words are used in this book in a specialized sense.

Error

A failure to carry out a task in the way intended by the person performing it, in the way expected by other people or in a way that achieves the desired objective.

This definition has been worded so as to include the various types of error listed below. It is consistent with the *Shorter Oxford English Dictionary* which defines error as 'something incorrectly done through ignorance or inadvertence' and as 'a transgression'. Some writers use error in a narrower sense to include only slips and lapses of attention, as defined below.

Mismatch

An error that occurs because the task is beyond the physical or mental ability of the person asked to perform it, perhaps beyond anyone's ability (see Chapter 4).

Mistake

An error that occurs as a result of ignorance of the correct task or the correct way to perform it. The intention is fulfilled but the intention is wrong (see Chapter 3).

Non-compliance or violation

An error that occurs because someone decides not to carry out a task or not to carry it out in the way instructed or expected. The motive can range from sabotage, through 'can't be bothered' to a belief that the instructions were incorrect. In such cases the non-compliance may prevent a mistake (as defined above) (see Chapter 5).

Slips and lapses of attention

An error that occurs as a result of forgetfulness, habit, fatigue or similar psychological causes. Compared with mistakes (as defined above), the intention is correct but it is not fulfilled (see Chapter 2).

The opening words of Tolstoy's *Anna Karenina* are, 'All happy families resemble one another, each unhappy family is unhappy in its own way.' Similarly, there is a right way for every task but each error is erroneous in its own way.

Contents

'... *unlike all other organisms* Homo sapiens *adapts not through modification of its gene pool to accommodate the environment but by manipulating the environment to accommodate the gene pool ...*'
M.T. Smith and R. Layton, 1989, *The Sciences*, 29(1)· 10

'... *there is a belief amongst many engineers and managers that human error is both inevitable and unpredictable. However, human error is inevitable only if people are placed in situations that emphasise human weaknesses and that do not support human strengths* '
Martin Anderson, *IChemE Safety and Loss Prevention Subject Group Newsletter*, Spring 1999

'... *decreasing the amount of human responsibility in the operation of the plant increases the amount of human responsibility in the design of the plant.*'
The Use of Computers in Safety-critical Applications (HSE Books, UK, 1998), page 13

'*If the honey that the bees gather out of so manye floure of herbes ... that are growing in other mennis medowes ... may justly be called the bees' honeye .. so maye I call it that I have ... gathered of manye good autores ... my booke* '
William Turner (1510–1668). Quoted by Frank Lees in *Loss Prevention in the Process Industries*, 2nd edition (Butterworth-Heinemann, Oxford, UK, 1996) and reproduced here as a tribute to one who did so much to further the subject.

Introduction

1

'Man is a creature made at the end of the week ...
when God was tired.'
Mark Twain

1.1 Accept men as we find them

The theme of this book is that it is difficult for engineers to change human nature and therefore, instead of trying to persuade people not to make errors, we should accept people as we find them and try to remove opportunities for error by changing the work situation — that is, the plant or equipment design or the method of working. Alternatively, we can mitigate the consequences of error or provide opportunities for recovery. (When it is possible for them to do so, people are better at correcting errors than at not making them.) I hope the book will remind engineers of some of the quirks of human nature so that they can better allow for them in design.

The method used is to describe accidents which at first sight were due to human error and then discuss the most effective ways of preventing them happening again. The accidents occurred mainly, though not entirely, in the oil and chemical industries, but nevertheless should interest all engineers, not just chemical engineers, and indeed all those who work in design or production. Apart from their intrinsic interest, the accident reports will, I hope, grab the reader's attention and encourage him or her to read on. They are also more important than the advice. I did not collect incident reports to illustrate or support my views on prevention. I developed my views as the result of investigating accidents and reading accident reports. You may not agree with my recommendations but you should not ignore the reports.

Browsing through old ICI files I came across a report dating from the late 1920s in which one of the company's first safety officers announced a new discovery: after reading many accident reports he had realized that most accidents are due to human failing. The remedy was obvious. We must persuade people to take more care.

Since then people have been exhorted to do just this, and this policy has been supported by tables of accident statistics from many companies which show that over 50%, sometimes as many as 90%, of industrial accidents are due to human failing, meaning by that the failure of the injured man or a fellow-worker. (Managers and designers, it seems, are not human or do not fail.) This is comforting for managers. It implies that there is little or nothing they can do to stop most accidents.

Many years ago, when I was a manager, not a safety adviser, I looked through a bunch of accident reports and realized that most of the accidents could be prevented by better management — sometimes by better design or method of working, sometimes by better training or instructions, sometimes by better enforcement of the instructions.

Together these may be called changing the work situation. There was, of course, an element of human failing in the accidents. They would not have occurred if someone had not forgotten to close a valve, looked where he was going, not taken a short-cut. But what chance do we have, without management action of some sort, of persuading people not to do these things?

To say that accidents are due to human failing is not so much untrue as unhelpful, for three reasons:

(1) Every accident is due to human error: someone, usually a manager, has to decide what to do; someone, usually a designer, has to decide how to do it; someone, usually an operator, has to do it. All of them can make errors but the operator is at the end of the chain and often gets all the blame. We should consider the people who have opportunities to prevent accidents by changing objectives and methods as well as those who actually carry out operations (see Appendix 2, item 1, page 261).

(2) Saying an accident is due to human failing is about as helpful as saying that a fall is due to gravity. It is true but it does not lead to constructive action. Instead it merely tempts us to tell someone to be more careful. But no-one is deliberately careless; telling people to take more care will not prevent an accident happening again. We should look for changes in design or methods of working that can prevent the accident happening again.

(3) The phrase 'human error' lumps together different sorts of failure that require different quite actions to prevent them happening again (see Section 1.3, page 4).

If all accidents are due to human errors, how does this book differ from any other book on accidents? It describes accidents which at first sight seem to be due wholly or mainly to human error, which at one time would have been followed by exhortations to take more care or follow the rules, and emphasizes what can be done by changing designs or methods of working. The latter phrase includes training, instructions, audits and enforcement as well as the way a task is performed.

It is better to say that an accident can be prevented by better design, better instructions, etc, than to say it was caused by bad design, instructions, etc. Cause implies blame and we become defensive. We do not like to admit that we did something badly, but we are willing to admit that we could do it better.

I do not say that it is impossible to change people's tendency to make errors. Those more qualified than engineers to do so — teachers, clergymen, social workers, psychologists — will no doubt continue to try and we wish them success. But the results achieved in the last few thousand years suggest that their results will be neither rapid nor spectacular and where experts achieve so little, engineers are likely to achieve less. Let us therefore accept that people are the one component of the systems we design that we cannot redesign or modify. We can design better pumps, compressors, distillation columns, etc, but we are left with Mark I man and woman.

We can, of course, change people's performance by better training and instructions, better supervision and, to some extent, by better motivation. What we cannot do is enable people to carry out tasks beyond their physical or mental abilities or prevent them making occasional slips or having lapses of attention. We can, however, reduce the opportunities for such slips and lapses of attention by changing designs or methods of working.

People are actually very reliable but there are many opportunities for error in the course of a day's work and when handling hazardous materials we can tolerate only very low error rates (and equipment failure rates), lower than it may be possible to achieve. We may be able to keep up a tip-top performance for an hour or two while playing a game or a piece of music but we cannot keep it up all day, every day. Whenever possible, therefore, we should design user-friendly plants which can tolerate human error (or equipment failure) without serious effects on safety, output or efficiency[3].

1.2 Meccano or dolls?

Let me emphasize that when I suggest changing the work situation, I am not simply saying change the hardware. Sometimes we have to change the software — the method of working, training, instructions, etc. Safety by design should always be the aim, but sometimes redesign is impossible, or too expensive, and we have to modify procedures. In over half the accidents that occur there is no reasonably practical way of preventing a repetition by a change in design and we have to change the software.

At present, most engineers are men and as boys most of us played with Meccano rather than dolls. We were interested in machines and the way they work, otherwise we would not be engineers. Most of us are very happy to devise hardware solutions. We are less happy when it comes to software solutions, to devising new training programmes or methods, writing instructions, persuading people to follow them, checking up to see that they are being followed and so on. However, these actions are just as important as the hardware ones, as we shall see, and require as much of our effort and attention.

One reason we are less happy with software solutions is that continual effort — what I have called grey hairs[1] — is needed to prevent them disappearing. If a hazard can be removed or controlled by modifying the hardware or installing extra hardware, we may have to fight for the money, but once we get it and the equipment is modified or installed it is unlikely to disappear.

In contrast, if a hazard is controlled by modifying a procedure or introducing extra training, we may have less difficulty getting approval, but the new procedure or training programme may vanish without trace in a few months once we lose interest. Procedures are subject to a form of corrosion more rapid and thorough than that which affects the steelwork. Procedures lapse, trainers leave and are not replaced. A continuous management effort — grey hairs — is needed to maintain our systems. No wonder we prefer safety by design whenever it is possible and economic; unfortunately, it is not always possible and economic.

Furthermore, when we do go for safety by design, the new equipment may have to be tested and maintained. It is easy to install new protective equipment — all you have to do is persuade someone to provide the money. You will get more grey hairs seeing that the equipment is tested and maintained and that people are trained to use it properly and do not try to disarm it.

1.3 Types of human error

Human errors occur for various reasons and different actions are needed to prevent or avoid the different sorts of error. Unfortunately much of the literature on human error groups together widely different phenomena which call for different action, as if a book on transport discussed jet travel and seaside donkey rides under the same headings (such as costs, maintenance and publicity). I find it useful to classify human errors as shown below. Most classification systems are designed primarily to help us find the information. I have used a system that helps us find the most effective way of preventing the accidents happening again.

- Errors due to a *slip* or momentary *lapse of attention* (discussed in Chapter 2).

The intention is correct but the wrong action or no action is taken. We should reduce opportunities for errors by changing the work situation.
- Errors due to poor training or instructions (discussed in Chapter 3). Someone does not know what to do or, worse, thinks he knows but does not. These are called *mistakes*. The intention is carried out but is wrong. We need to improve the training or instructions or simplify the job.
- Errors which occur because a task is beyond the physical or mental ability of the person asked to do it, perhaps beyond anyone's ability (discussed in Chapter 4). There is a *mismatch* between the ability of the person and the requirements of the task. We need to change the work situation.
- Errors due to a deliberate decision not to follow instructions or accepted practice (discussed in Chapter 5). These are often called *violations* but *non-compliance* is a better term, as people often believe that the rule is wrong or that circumstances justify an exception. We should ask why the rules were not followed. Did someone not understand the reasons for the instructions, were they difficult to follow, have supervisors turned a blind eye in the past? There is fine line between initiative and breaking the rules. Note that if the instructions were wrong, non-compliance may prevent a mistake (as defined above).

Chapter 6 discusses those errors made by managers, especially senior managers, because they do not realize that they could do more to prevent accidents. These errors are not a fifth category but are mainly due to ignorance of what is possible. Many managers do not realize that they need training and there is no-one who can tell them. Today it is widely recognized that all accidents are management failings: failures to reduce opportunities for error, failures to provide adequate training and instruction, failures to ensure that people follow the rules, and so on. Chapter 6, however, looks at management failures in a narrower sense.

The boundaries between these categories are not clear-cut and often more than one factor may be at work. Thus an error might be due to poor training compounded by limited ability (a mismatch) and the fact that the foreman turned a blind eye on previous occasions, thus winking at non-compliance.

Tasks are sometimes divided into skill-based, rule-based and knowledge-based. Skill-based actions are highly practised ones carried out automatically with little or no conscious monitoring. Knowledge-based actions are carried out under full conscious control, because the task is non-routine or unfamiliar; they take longer than skill-based ones as each step has to be considered. Rule-based actions have been learned but have not been carried out often enough to become automatic; the degree of conscious control is intermediate.

Note that the same action may be skill-based for one person, rule-based for another and knowledge-based for a third. The errors in my first group — slips and lapses of attention — are errors in skill-based tasks. Those errors in my second group — mistakes — that are due to poor training are mainly errors in knowledge-based tasks; those that are due to poor instructions are mainly errors in rule-based tasks. Violations can be any of these types of error.

Chapter 7 describes some of the attempts that have been made to quantify the probability of human error. However, these methods apply only to the first sort of error. We can estimate — roughly — the probability that someone will have a moment's aberration and forget to open a valve, or open the wrong valve, but we cannot estimate the probability that he will make a mistake because the training or instructions are poor, because he lacks the necessary physical or mental ability, or because he has a 'couldn't care less' attitude. Each of these factors can contribute from 0 to 100% to the probability of failure. All we can do is assume that they will continue in the future at the same rate as in the past, unless there is evidence of change. People often assume that these errors have been eliminated by selection, training, instructions and monitoring, but this is not always true.

Chapters 8–12 examine some further accidents due to human failing, but classified somewhat differently:

- accidents that could be prevented by better design;
- accidents that could be prevented by better construction;
- accidents that could be prevented by better maintenance;
- accidents that could be prevented by better methods of operation;
- accidents in computer-controlled plants.

Finally Chapter 13 looks at legal views and at the question of personal responsibility. If we try to prevent errors by changing the work situation, does this mean that people who make errors are entitled to say, 'It is your fault for putting me in a situation where I was able to make a mistake?'

1.4 Two simple examples

The various types of human error may be illustrated by considering a simple everyday error: forgetting to push in the choke on a car when the engine has warmed up (a rare error today when most cars have automatic choke). There are several possible reasons for the error:

- It may be due to a lapse of attention. This is the most likely reason and similar errors are discussed in Chapter 2.

- With an inexperienced driver the error may be due to a lack of training or instruction; he or she may not have been told what to do or when to do it. Similar errors are discussed in Chapter 3.
- The error may be due to a lack of physical or mental ability — unlikely in this case. Such errors are discussed in Chapter 4.
- The error may be due to the fact that the driver cannot be bothered — the hired car syndrome. Similar errors are discussed in Chapter 5.
- If I employ a driver, I may leave everything to him, take no interest in the way he treats the car and fail to investigate the reasons why my engines wear out so quickly. These management errors are discussed in Chapter 6.

If the error is due to lack of training or instruction then we can provide better training or instruction. There is not much we can do in the other cases except change the work situation — that is, provide a warning light or alarm or an automatic choke (now usual). The latter adds to the cost and provides something else to go wrong and in some such cases it might be better to accept the occasional error. Examples of situations in which automatic equipment is not necessarily better than an operator are given in Chapter 7.

As another example of the five sorts of error, consider spelling errors:

- If I type *opne* or *thsi* it is probably a slip, overlooked when I checked my typing. Telling me to be more careful will not prevent these errors. Using the spell-checking tool on my word processor will prevent many of them.
- If I type *recieve* or *seperate*, it is probably due to ignorance. If I type *wieght* it may be the result of following a rule that is wrong: 'I before e, except after c'. Better training or instructions might prevent the errors but persuading me to use the spell-checking tool would be cheaper and more effective.
- If I write *Llanfairpwllgwyngyllgogerychwyrndrobwlllantysiliogogogoch* (a village in Wales), it is probably because it is beyond my mental capacity to spell it correctly from memory. (Can you spot the error? Answer on page 10.)
- If I type *thru* or *gray*, it is probably due to a deliberate decision to use the American spelling. To prevent the errors someone will have to persuade me to use the English spelling.
- If I work for a company, perhaps the managers take little or no interest in the standard of spelling. They may urge me to do better but do not realize that they could do more, such as encouraging me to use the spell-checking tool.

However, the spell-checking tool can be misused and can introduce errors. The following, copied from various sources, probably occurred because someone misspelled a word, either through ignorance or as the result of a slip, and then accepted whatever the computer offered, on the assumption that the all-powerful computer could not possibly be wrong. They illustrate the way computers (and other tools) can be misused when we do not understand their limitations.

- *Tumble dryer, vertically unused.* (From a classified advertisement.)
- *The opera is in three parts. The first is an appeal to density.* (From a concert programme.)
- *Concrete arched lentils.* (From a newspaper report.)
- *Bedsit with separate fatalities.* (From a classified advertisement.)
- *Classic old brass and copper geezer.* (From a classified advertisement.)
- *Should you have any queers please contact this office.* (From a letter from a building society.)
- *A wonderful conversation of a period house to create four homes.* (From an advertisement.)
- *A red box containing assaulted tools worth £100 was stolen ...* (From a newspaper report.)

1.5 Accident investigation

The output from an accident investigation may tell us much about the culture of the company where it occurred. If it has a blame culture, people are defensive and not very forthcoming. It is difficult to find out what has happened and the true causes may never be found. In addition, when actions are discussed, the design engineer, for example, will try to show that the accident could not have been prevented by better design. People from other departments will behave similarly. In a blame-free environment, however, the design engineer will suggest ways in which better design (or changes in the design procedure, such as more use of Hazop or inherently safer design) could prevent a repetition. Each person will consider what he or she might have done to prevent the accident or make it less likely.

If we wish to find out why accidents occurred and find ways of preventing them happening again, we need a sympathetic attitude towards people who have committed so-called violations, have made slips, had lapses of attention or not learnt what their training was supposed to teach them. It is a small price and is worth paying.

This applies to everyone. We should not blame the workman who for one reason or another failed to take action that could have prevented an accident. We should ask why he did not take that action and make recommendations accordingly. (Possible reasons are discussed in the following chapters.)

Similarly we should not blame the senior manager who failed to take action that could have prevented an accident, but ask why. The reason is usually not wickedness but failure to foresee the actions he might have taken (see Chapter 6 and Sections 13.3–13.5, page 227).

Unfortunately a desire to blame someone for misfortunes seems to be deeply engrained in human nature. For example, amongst the Australian Aborigines, rites were performed often at the grave or exposure platform of the dead to discover the person to be blamed for the 'murder'. Since death was not considered a natural event a cause for it was always sought in the evil intentions of someone else, usually a member of another local group[4].

We are much the same and are ready to believe that every accident is someone's fault, especially the person at the 'sharp end'. In 1998 a plane, flying low in an Alpine Valley, broke the cable of a cable railway, causing many deaths. At first the pilot was blamed for flying too low but the inquiry showed that his altimeter was faulty, so he was much lower than he thought, and that the cable railway was not marked on his map. Nevertheless, television pictures showed relatives of those killed expressing their outrage at his acquittal. As with every accident, many people had an opportunity to prevent it. Why was the altimeter faulty? Was it poor design unsuitable for the application, or poor maintenance? Why was the railway not shown on the map? Was an old edition in use? And so on.

1.6 A story

The following story illustrates the theme of this book. A man went into a tailor's shop for a ready-made suit. He tried on most of the stock without finding one that fitted him. Finally, in exasperation, the tailor said, 'I'm sorry, sir, I can't fit you; you're the wrong shape.'

Should we as engineers expect people to change their (physical or mental) shapes so that they fit into the plants and procedures we have designed or should we design plants and procedures to fit people?

We know that they cannot change their physical shape. If a man cannot reach a valve we do not tell him to try harder or grow taller. We provide a step, move the valve or remove the need for the valve. But some people expect others to change their mental shape and never have slips or lapses of attention. This is as difficult as growing taller. We should instead change the design or method of working to reduce the opportunities for error.

1.7 Research on human error

The Third Report of the UK Advisory Committee on Major Hazards[2] and many other reports recommend research on human reliability and make some suggestions. While there is undoubtedly much we would like to know, lack of knowledge is not the main problem. The main problem is that we do not use the knowledge we have. Accidents, with a few exceptions, are not caused by lack of knowledge, but by a failure to use the knowledge that is available. This book is an attempt, in a small way, to contribute towards accident reduction by reminding readers of facts they probably know well and reinforcing them by describing accidents which have occurred, in part, as a result of ignoring these facts.

Table 1.1 summarizes the four types of accident and the corresponding actions needed. They are discussed in more detail in the following chapters.

Table 1.1 Types of human error and the action required

Error type	Action required
Mistakes — Does not know what to do	Better training and instructions / CHAOS
Violations — Decides not to do it	Persuasion / CHAOS
Mismatches — Unable to do it	CHAOS
Slips and lapses of attention	CHAOS

CHAOS = Change Hardware And / Or Software

References in Chapter 1

1. Kletz, T.A., 1984, *Plant/Operations Progress*, 3(4): 210.
2. Advisory Committee on Major Hazards, 1984, *Third Report, The Control of Major Hazards*, Appendix 13 (HMSO, London, UK).
3. Kletz, T.A., 1998, *Process Plants: A Handbook for Inherently Safer Design* (Taylor and Francis, Philadelphia, USA).
4. Australian National Commission for UNESCO, 1973, *Australian Aboriginal Culture*, page 44.

The correct spelling of the village in Wales (see page 7) is:

Llanfairpwllgwyngyllgogerychwyrndrobwllllantysiliogogogoch

Accidents caused by simple slips

2

'I haven't got a memory, only a forgettory.'
Small boy quoted on Tuesday Call, BBC Radio 4, 6 December 1977

'It is a profoundly erroneous truism, repeated by all books, and by eminent people when they are making speeches, that we should cultivate the habit of thinking what we are doing. The precise opposite is the case. Civilisation advances by extending the number of important operations which we can perform without thinking about them.'
A.N. Whitehead

2.1 Introduction

This chapter describes some accidents which occurred because someone forgot to carry out a simple, routine task such as closing or opening a valve, or carried it out wrongly — that is, he closed or opened the wrong valve. The intention was correct; he knew what to do, had done it many times before, was capable of doing it and intended to do it and do it correctly, but he had a moment's aberration.

Such slips or lapses of attention are similar to those of everyday life and cannot be prevented by exhortation, punishment or further training. We must either accept an occasional error — probabilities are discussed in Chapter 7 — or remove the opportunity for error by a change in the work situation — that is, by changing the design or method of working. Alternatively we can, in some cases, provide opportunities for people to observe and correct their errors or we can provide protection against the consequences of error.

Note that errors of the type discussed in this chapter — errors in skill-based behaviour — occur not in spite of the fact that the man who makes the error is well-trained but because he is well-trained. Routine tasks are given to the lower levels of the brain and are not continuously monitored by the conscious mind. We could never get through the day if everything we did required our full attention, so we put ourselves on auto-pilot. When the normal pattern or programme of action is interrupted for any reason, errors are liable to occur.

Those interested in the psychological mechanisms by which slips and lapses of attention occur should read J. Reason and C. Mycielska's book on everyday errors[1]. The psychology is the same. Here, as engineers, we are not concerned with the reasons why these errors occur, but with the fact that they do occur and that we can do little to prevent them. We should therefore accept them and design accordingly.

Note that the unconscious mind, as used here, is not the same as the Freudian unconscious, a place of preventive detention, where we hold captive thoughts that would embarrass us if they became conscious. In contrast the non-Freudian unconscious is a mechanism which does not require consciousness to do its job. It is rather like a computer operating system running quietly in the background, or an auto-pilot[25].

People who have made an absent-minded error are often told to keep their mind on the job. It is understandable that people will say this, but it is not very helpful. No-one deliberately lets their mind wander, but it is inevitable that we all do so from time to time.

Can we reduce errors by selecting people who are less error-prone? Obviously if anyone makes a vast number of errors — far more than an ordinary person would make — there is something abnormal about his work situation or he is not suitable for the job. But that is as far as it is practicable to go. If we could identify people who are slightly more forgetful than the average person — and it is doubtful if we could — and weed them out, we might find that we have weeded out the introverts and left the extroverts and those are the people who cause accidents for another reason: they are more inclined to take chances. Section 4.3 (page 85) returns to this subject.

The examples that follow illustrate some of the ways by which we can prevent or reduce slips and lapses of attention or recover from their effects. They include better displays of information, interlocks that prevent an incorrect action being performed, warnings that it has been performed, trips which prevent serious consequences and reducing stress or distraction. Behavioural safety training (see Section 5.3 on page 107) will have little if any effect as slips and lapses of attention are not deliberate. People can be encouraged, before closing a valve, to stop and ask themselves, 'Is this the right valve?', much as we pause and look both ways, before we cross the road. However, slips and lapses are most likely to occur when we are in a hurry or under stress and these are the times when we are least likely to pause.

2.2 Forgetting to open or close a valve

2.2.1 Opening equipment which has been under pressure

A suspended catalyst was removed from a process stream in a pressure filter (Figure 2.1(a)). When a batch had been filtered, the inlet valve was closed and the liquid in the filter blown out with steam. The steam supply was then isolated, the pressure blown off through the vent and the fall in pressure observed on a pressure gauge. The operator then opened the filter for cleaning. The filter door was held closed by eight radial bars which fitted into U-bolts on the filter body. To withdraw the radial bars from the U-bolts and open the door the operator had to turn a large wheel, fixed to the door. The door, with filter leaves attached, could then be withdrawn (Figure 2.1(b) on page 14). Figure 2.2 (page 14) shows two similar filters, one open and one closed.

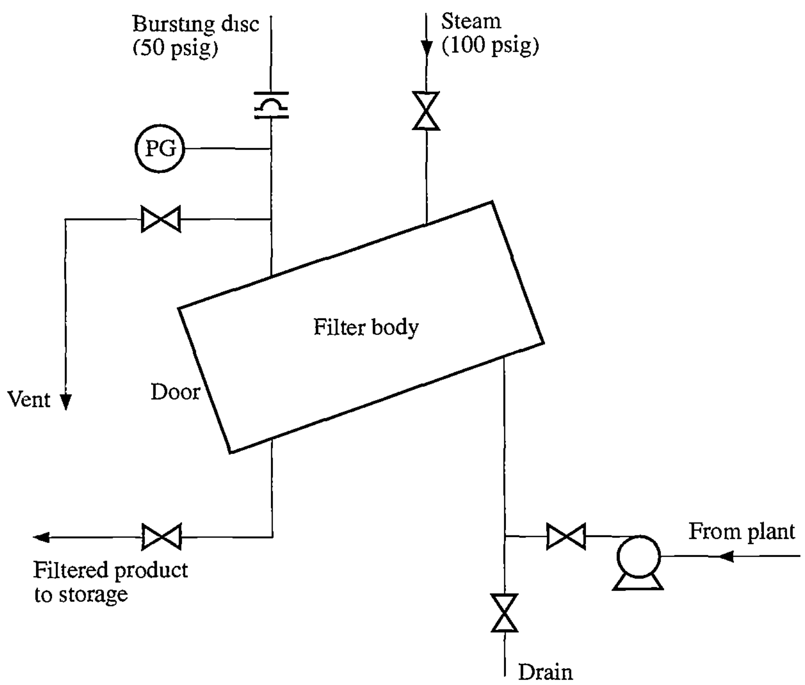

Figure 2.1(a) Filter