To err is human...

but organisations make mistakes too. By understanding the cause of errors, accident, incident and near-miss investigations can be more effective. Ronny Lardner and Mark Fleming tell us more

EARLIER THIS year the Health and Safety Commission issued a discussion document on proposals to introduce a new duty on employers to investigate the cause of workplace accidents. There was support for goal-setting legislation, further guidance, and promotion of root-cause investigation of the fundamental causes of accidents and incidents.

So what are the implications for chemical engineers? The 80:20 accident causation rule of thumb (80% human and organisational causes; 20% technical causes) suggests hard-won technical knowledge will need to be supplemented with an insight into how human and organisational factors can cause or contribute to accidents or unplanned incidents. Although this short article cannot provide all the answers, it seeks to whet the appetite for this complex field of knowledge, and point interested readers in the right direction.

The basic problem is that we all can and do make errors, regardless of how well-trained and motivated we are. This human fallability exists throughout the organisation, and extends beyond front-line workers involved at the time of an incident to include management responsible for work organisation, equipment design, organisational priorities and the like.

Box 1: Underlying causes of accidents

A NUCLEAR industry study identified the following underlying organisational, team and individual causes of accidents:

	% of accidents
Deficient procedures or documentation	43
Lack of knowledge or training	18
Failure to follow procedures	16
Deficient planning or scheduling	10
Miscommunication	6
Deficient supervision	3
Policy problems	2
Other	2

Models of human and organisational error

The HSE discussion document on accident investigation notes that when accident investigations are carried out, they frequently "concentrate on determining the immediate technical causes, and often stop when there is someone to blame for the event (often those closely involved with the circumstances), failing to get to the underlying causes".

So what determines when a halt is called in the search for root causes? It seems people have 'stopping rules' in their search for explanations, which are guided by the underlying model or paradigm of human behaviour and error they hold. Four major error paradigms have been distinguished [1] (see Box 2). Which paradigm(s) do you subscribe to?

All of these error paradigms have some merit. However the uncritical adoption of one paradigm to the exclusion of others is likely to result in human and organisational root causes of accidents and incidents being missed, as in the example in Box 3[2].

Box 2: Error paradigms

Error paradigm	**Basic assumptions**	**Solutions**
1. Engineering error	• people are an unreliable component in the system	• remove people from the system via automation • improve human reliability through good workplace and interface design
2. Individual error	• poorly motivated people commit unsafe acts, or break rules and procedures	• discipline those involved • reward safe behaviour • reduce organisational pressures to violate rules and procedures
3. Cognitive error	• human error occurs due to a mismatch between individual capabilities and the demands of the job	• match people with demands of job • ensure job and workload is do-able
4. Organisational error	• poor management decisions create conditions which influence likelihood of error	• examine adequacy of management • audit safety management systems

Useful tools

To help the non-specialist systematically uncover root human and organisational causes, and learn from such incidents, help is available. Larger organisations may employ or retain human factors specialists. Generic, commercially-available human error root-cause analysis techniques exist, as do versions tailored to specific industries. For those without such resources, or wishing an introduction to the topic, the following may be useful.

HSE's *Successful health and safety management* guidance[3], Appendix 5, contains an approach to analysing immediate and underlying causes of accidents, including human and organisational contributions such as individual behaviour, control, cooperation, communication, competence, and arrangements for monitoring and review.

More detail on how 'human factors' – job, individual and organisational – can influence health and safety are provided in a recent HSE publication *Reducing error and influencing behaviour* [4]. Significantly for the accident investigator, this publication includes a detailed account of the human contribution to accidents, and examples of solutions implemented to address human factors aspects influencing accidents, near-misses or potential health problems. A human factors checklist which can be used preventatively, without waiting for an accident to occur, is also included on pages 54–55.

Box 3: Two ways of investigating an accident

TWO fitters slackened the bolts on the wrong flange of a double-bodied valve. This caused the valve to fall apart and release flammable material. An initial investigation revealed the fitters were unfamiliar with this type of valve, and recommended a verbal reprimand to the fitters to "take more care".

Question: What error paradigm was operating during this initial investigation?

Further investigation indicated the fitters had been retrained as part of a multi-skilling exercise, and their original expertise was in electrical engineering. This more in-depth investigation identified the need to examine:

- the adequacy of training;
- the way jobs were allocated so they were only given to those who were competent;
- the operation of the permit-to-work system which should have ensured the pipework was isolated and drained before work started.

Question: What type of error paradigm was operating during the subsequent investigation, and how might this influence the likelihood of a recurrence?

During the second investigation, a less restricted set of stopping rules meant the emphasis on blame was replaced by learning how to avoid similar incidents in future.

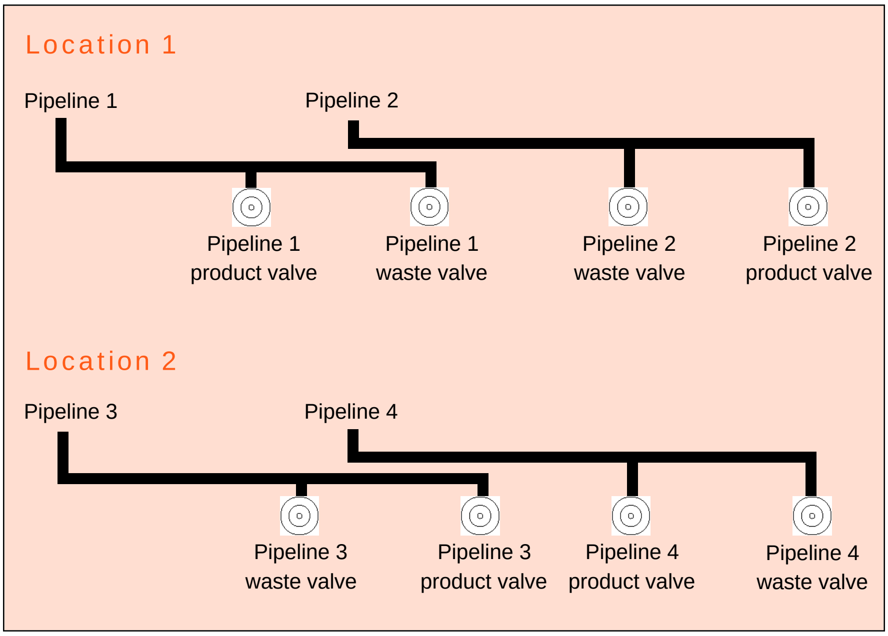
Case study: The application of human factors root cause analysis

THREE very similar incidents occurred over a two-year period in a petrochemicals process plant. On each occasion a series of valves had been wrongly aligned, resulting in contamination of pipework and unintended cross-contamination of raw materials, finished product and waste by-products.

The first two incidents had resulted in a series of procedural, training and plant design recommendations. Following the occurrence of the third very similar incident, management suspected an unknown factor was contributing. The present author reviewed what was known about all three incidents, and visited the work site.

All three incidents involved the erroneous operation of two pairs of two valves, which were replicated at two nearby locations. These eight valves were designed as shown in Figure 1.

Can you spot the potential for error?



▲ *Figure 1: An error designed to happen*

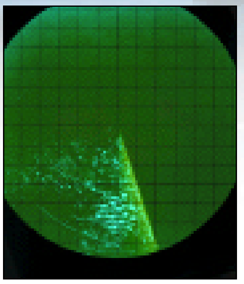
At location 1, pipeline 1, the product valve is on the left and waste is on the right. This layout is transposed for the adjacent pipeline 2. Furthermore, at the nearby location 2, the valve layout is the exact opposite to location 1. It is therefore very easy for operators to apply the right action (open/close a valve) to the wrong object (product valve instead of waste valve, or vice versa) due to the very confusing valve layout. Human error theory predicts this is most likely to happen when our attention is diverted, or we are preoccupied by other things. Indeed this is what happened in two of the incidents described. Many readers will recognise the every-day nature of this phenomena. How many of us have, when preoccupied or distracted at home, placed the milk in the oven instead of the fridge, or poured hot water into the sugar bowl instead of teapot, or similar?

Experienced operators and plant managers were not aware of the confusing layout, and had not noticed the potential for error.

Having identified the missing human factors root cause in the three incidents, recommendations could be made to address each of the error paradigms described in Table 1.

- In the short-term, warn operators of poor design, and likely consequences (individual/cognitive error paradigm)
- Improve valve layout to remove confusion, and physically prevent problematic valve line-ups (engineering error paradigm)
- Include human factors expertise in future accident investigation teams, specify human factors input to design of new plant, and raise awareness of human factors issue amongst senior managers (organisational error paradigm)

Learning from near-misses



Another useful human factors technique for uncovering root causes is 'near-miss' (or near-hit) reporting schemes. Rather than passively waiting for an accident/ incident to happen, near-misses are reported to a confidential, trusted source for analysis and identification of steps necessary to prevent a recurrence. The best-known examples are in the aviation and aerospace industries. These techniques rely on individuals' willingness to report incidents they may have been personally involved in, so will not thrive where a blame culture exists.

Investigation of near-misses must overcome any limiting error paradigms used not just by investigators, but also by the person filing the report. In our case study, the person responsible for turning the valve in the third incident believed they were entirely to blame, and had considerable difficulty accepting they were essentially programmed to fail by those who had designed the system years before. Thus an early task in implementing near-miss reporting is to widen everyone's conception of accident causation. ■

Forthcoming HSE root cause analysis tool

PREVIOUS work by HSE has developed both a model for health and safety management (HSG 65) and a methodology for costing accidents (HSG 96). Current HSE research has made the link between these two publications by developing and testing a refined and simplified method of costing accidents and a new root cause analysis tool. The root cause analysis tool is based on an organisational model, which leads the accident investigator back to failures in high-level elements of how the organisation is managed. This work will be published by HSE in early 2000.

Ronny Lardner and Mark Fleming can be contacted at The Keil Centre, 5 South Lauder Road, Edinburgh EH9 2LJ UK, tel +44 131 667 8059, fax +44 131 667 7946, email ronny@keilcentre.co.uk

References

1. 'The Causes of Human Error', by Lucas, D. in Redmill, F. and Rajan, J. (1997) *Human factors in safety-critical systems* Oxford: Butterworth Heinemann

2. Adapted from *A new duty to investigate accidents: Health and Safety Commission Discussion Document*, HSE Books (1999)

3. *Successful health and safety management* (1997) Suffolk: HSE Books

4. *Reducing error and influencing behaviour* HSG48 Suffolk: HSE Books £11.50

HSE publications can be obtained by contacting HSE Books on tel +44 1787 881165 and fax +44 1787 313995