MANAGING HUMAN FAILURE IN MAJOR HAZARDS: PRACTICAL APPLICATIONS

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This paper outlines recent experience of the HSE's Human Factors Team in assessing human factors issues on major hazard installations. It presents the 'Top Ten' human factors issues that have arisen out of inspection and audit of major hazard sites and from assessment of COMAH safety reports. Although the experiences and lessons learned are taken mainly from the onshore chemical and oil industries, they apply equally to other complex systems.

Our involvement on major hazard sites reveals that most duty holders do not adequately address human factors. Three serious concerns are (i) an imbalance between hardware and human issues, (ii) focussing on the human contribution to personal safety rather than to the initiation and control of major accident hazards and (iii) focussing on 'operator' error at the expense of management failures. Where human failures are addressed, we have found a number of common weaknesses in the approaches taken that reduce the impact of the assessment.

However, following targeted inspection and awareness-raising in the industry, the profile of human factors and effective consideration of these issues is steadily increasing. We are beginning to see the results of these efforts reflected in contact with sites. We will continue to work with major accident sites and industry bodies to develop and share emerging best practice.

INTRODUCTION

Human failures are implicated in the majority of serious accidents in hazardous industries. Some recent examples include Bhopal, Texaco Milford Haven, Chernobyl, Piper Alpha and Flixborough to name a few. As technical safety measures improve, we can expect the significance of human factors in major accidents to increase.

To help address these issues, the UK Health & Safety Executive (HSE) set up a new Human Factors Team in the Hazardous Installations Directorate in 1999. This Team provides site inspectors with specialist advice and support during inspections, investigations and enforcement; as well as preparing industry guidance on human factors issues. The Team is composed of a balanced mix of experienced field inspectors, psychologists and ergonomists.

The focus of the Team's activities is on those sites that fall within the scope of the Control of Major Accident Hazards Regulations 1999 (COMAH), although we are also active in the railway industry. Over the last three years, the team has become involved at numerous chemical sites across the whole of the UK, including most oil refineries.

In addition to our inspection and assessment activities, we develop guidance and standards, train field inspectors, set policies for the field, manage applied research and promote human factors to industry (either directly or through intermediaries such as the Institute of Petroleum, Institution of Chemical Engineers and the Chemical Industries

Association). We are also involved in the European Commission PRISM network co-ordinated by the European Process Safety Centre (EPSC), the aims of which are to develop and disseminate best practice guidance on human factor topics.

WHAT WE MEAN BY 'HUMAN FACTORS'

The HSE document HS(G)48[1] presents a simple introduction to generic industry guidance on human factors. This guidance provides a useful definition:

> *'Human factors refer to environmental, organisational and job factors, and human and individual characteristics, which influence behaviour at work in a way which can affect health and safety'*

This definition includes three interrelated aspects that must be considered – the job, the individual and the organisation. In other words, human factors is concerned with what people are being asked to do, who is doing it and where they are working. Human factors interventions will not be effective if they consider these aspects in isolation. The scope of our interventions thus includes organisational systems and is considerably broader than traditional views of human factors/ergonomics.

It is deficiencies in either of these three areas, or in the interactions between them, that lead to human performance problems. There are three types of human failures that may lead to major accidents:

- **Errors** are physical actions that were not as intended;
- **Mistakes** are also errors, but errors of judgement or decision-making;
- **Violations** differ from the above in that they are intentional (but usually well-meaning) failures, such as taking a short-cut or non-compliance with procedures.

The likelihood of these human failures is determined by the condition of a finite number of 'performing influencing factors', such as time pressure, workload, competence, morale, noise levels and communication systems. Given that these factors influencing human performance can be identified, assessed and managed; potential human failures can also be predicted and managed. In short, human failures are not random events.

THE ROLE OF THE HUMAN FACTORS SPECIALIST

Our involvement is usually instigated at the request of the local site field inspector where they have a concern or where there has been an accident with a human factors aspect. Furthermore, our contribution to the assessment of COMAH Safety Reports and railway safety cases may lead us to follow up issues identified in the assessment.

Our objectives range from obtaining an overview of the site's approach to human factors to undertaking an in-depth investigation of a particular human factors issue. Generally, our involvement on site varies from one to five days, depending on the nature of the intervention, although in certain cases this may be extended. When on site, we undertake several activities, including:

- Interviewing a cross-section of personnel, from Directors/senior management to front-line operators and their representatives;
- Reviewing documentation not obtained prior to the visit;
- Verification inspection (i.e. comparing what we have been told with what we observe);
- Initial feedback to site personnel.

Where necessary, we provide opinion on formal enforcement action by the site field inspector, i.e. improvement and prohibition notices, or prosecution. Following our visit, we will prepare an inspection/audit report for the field inspector and possibly revisit the site to present our findings/recommendations and agree a way forward. We will monitor progress through contact with the field inspector and may revisit the site for further inspection as necessary.

Human factors is often seen as a rather nebulous concept and so it is convenient to break the subject down into a series of discrete topics. As a result of our site visits and assessment of COMAH safety reports, a small group of topics has emerged and we promote these as our 'top ten':

1. Organisational change and transition management
2. Demanning and staffing levels
3. Training and competence
4. Organisational and safety culture
5. Alarm handling
6. Fatigue from shiftwork and overtime
7. Compliance with safety critical procedures
8. Safety critical communications (e.g. shift handover)
9. Ergonomic design of interfaces
10. Maintenance error.

Although general HSE guidance on human factors is available [HS(G)48], the Human Factors Team have a programme of producing guidance specific to the above topics. For example, a free information sheet is available on alarm management. Forthcoming guidance will include organisational change, competency, fatigue and human factors in design. We have also assisted with the production of guidance published on the Institute of Petroleum website[2].

EXPERIENCE OF REGULATING MAJOR HAZARD SITES - POSITIVE ISSUES

The Human Factors Team has a distinct advantage of having visited a broad sample of Major Accident Hazard (MAH) sites over the past three years, enabling us to construct a picture of best practice in human factors in the process industry. We are therefore able to facilitate the sharing of what works and what doesn't across the industry, through published guidance, seminars and individual site contact.

Clearly, the efforts of the Team in promoting these issues are beginning to reveal themselves in our contact with MAH sites. For example, some sites have addressed issues that we have raised at regional one-day events held in conjunction with industry bodies and associations (including consideration of the top-ten topics listed above). This has been

reflected in the structure and content of their COMAH safety report submissions and in information available on site inspections.

As our capabilities are increasingly recognised within HSE, we are now finding that we are becoming involved at an earlier stage of the design lifecycle. For example, we are being consulted prior to site modifications (including proposals for organisational change) and are also involved in specifications for human factors in the design of new process plants. This opportunity to be involved at such an early stage will increase the impact of our involvement.

Although our approach has been new to many sites, we have received positive feedback following our interventions. For example, some sites apply the lessons learnt from an intervention to other installations in the company. Other sites have commented that we have provided them with a different perspective on their organisation, not obtained from previous 'independent' audits.

Although our interest is in safety improvements, several companies have experienced significant quality and productivity gains following human factors interventions. For example, at one site, the analysis of procedures and task design led to reduced start-up times.

Once their awareness has been raised, some sites have clearly embraced the issues and are developing their in-house capability in human factors. We are seeing an increasing number of companies having a human factors champion on site, who acts as an 'intelligent customer' in dealings with the competent authority and external consultants. This person should be highly visible, have influence, a link to various project teams and access to human factors technical advice and support where necessary.

Over the past couple of years or so, we have recognised that the major hazards industry is readdressing the balance between hardware and human factors. Given that the regulation of these issues has developed rapidly since the formation of a dedicated team of specialists, we expect that 'emerging best practice' will continue to develop across the industry.

MANAGING HUMAN FAILURES - THREE SERIOUS CONCERNS

Although many MAH sites are managed by multi-national, blue-chip companies, the experience of the Team is that their consideration of human factors issues could be significantly improved. Three main failings apparent in relation to human factors are discussed in detail below. These weaknesses have all been observed at numerous installations and are common threads rather than isolated occurrences.

CONCERN 1: FOCUS ON ENGINEERING ISSUES

Despite the growing awareness of the significance of human factors in safety, particularly major accident safety, many sites do not address these issues in any detail. Their focus is almost exclusively on engineering and hardware aspects, at the expense of 'people' issues. From reading many safety reports it would appear that these sites are unmanned, such is the lack of reference to human performance aspects.

For example, a site may describe alarm systems as being safety-critical and describe the assurance of their electro-mechanical reliability, but fail to address the reliability of the

operator in the control room who must respond to the alarm. If the operator does not respond in a timely and effective manner then this safety critical system will fail and therefore it is essential that the site addresses and manages this operator performance.

Due to the 'ironies of automation'[3], it is not possible to engineer-out human performance issues. All automated systems are still designed, built and maintained by human beings. For example, an increased reliance on automation may reduce day-to-day human involvement, but increases maintenance, where performance problems have been shown to be a significant contributor to major accidents[4].

Furthermore, where the operator moves from direct involvement to a monitoring and supervisory role in a complex process control system, they will be less prepared to take timely and correct action in the event of a process abnormality. In these infrequent events the operator, often under stress, may not have 'situational awareness' or an accurate mental model of the system state and the actions required.

CONCERN 2: FOCUS ON OCCUPATIONAL SAFETY

The majority of MAH sites tend to focus on occupational safety rather than on process safety. Those sites that consider human factors issues rarely focus on those aspects that are relevant to the control of major hazards. For example, sites consider the personal safety of those carrying out maintenance, rather than how human errors in maintenance operations could be an initiator of major accidents. This imbalance runs throughout the safety management system, as displayed in priorities, goals, the allocation of resources and safety indicators.

For example, 'safety' is measured by Lost-Time Injuries, or LTIs. The causes of personal injuries and ill-health are not the same as the precursors to major accidents. Therefore, measures such as LTIs are not an accurate predictor of major accident hazards and sites may thus be unduly complacent in this respect. Notably, several sites that have recently suffered major accidents demonstrated good management of personal safety, based on measures such as LTIs. Therefore, the management of human factors issues in major accidents is quite different to traditional safety management.

In his analysis of the explosion at the Esso Longford gas plant, Hopkins (2000)[5] makes this point very clearly:

'Reliance on lost-time injury data in major hazard industries is itself a major hazard.'

and,

'An airline would not make the mistake of measuring air safety by looking at the number of routine injuries occurring to its staff'.

Clearly, a safety management system that is not managing the right aspects is as effective in controlling major accidents as no system at all.

Performance indicators more closely related to major accidents may include the movement of a critical operating parameter out of the normal operating envelope. The definition of a parameter could be quite wide and include process parameters, manning levels

or the availability of control/mitigation systems. Many performance indicators will be site specific and further examples are given below:

- Number of accidental leakages of hazardous substances;
- Environmental releases;
- Time taken to detect and respond to releases;
- Activation of protective devices;
- Process disturbances;
- Response times for process alarms;
- Process component malfunctions;
- Maintenance delays (hours);
- Number of outstanding maintenance activities;
- Frequency of checks of critical components;
- Number of inspections/audits;
- Emergency drills;
- Procedures reviews;
- Compliance with safety critical procedures;
- Staffing levels falling below minimum targets;
- Non-compliance with company policy on working hours.

It is critical that the performance indicators should relate to the control measures outlined by the site risk assessment and/or detailed in the COMAH safety report. Furthermore, they should measure not only the performance of the control measures, but also how well the management system is monitoring and managing them.

CONCERN 3: FOCUS ON THE FRONT-LINE OPERATOR

In general, most safety activities in complex systems are focussed on the actions and behaviours of individual operators – those at the sharp end. However, operators are often 'set up' to fail by management and organisational failures, a point most adeptly made by Reason (1990)[6]:

'Rather than being the main instigators of an accident, operators tend to be the inheritors of system defects created by poor design, incorrect installation, faulty maintenance and bad management decisions. Their part is usually that of adding the final garnish to a lethal brew whose ingredients have already been long in the cooking' (p.173).

Following incidents such as those mentioned in the introduction to this paper, it has become increasingly clear that we need to consider the role of management and organisational factors, rather than place responsibility solely at the feet of the operator. However, audits rarely consider issues such as the quality of management decision making or the allocation of resources. Furthermore, 'safety culture' is seen as being something that operators have and in major incidents that I have investigated, management have not acknowledged that the development and maintenance of a safe culture lie within the bounds of their responsibility.

Feedback from audits that we have completed on major hazard sites often reveals areas that require attention in the management system which have not been identified (or reported) in previous audits. Audits of management systems frequently fail to report bad news. For

example, following the Piper Alpha offshore platform fire it is reported that numerous defects in the safety management system were not picked up by company auditing. There had been plenty of auditing, but the inquiry reported that:

'it was not the right quality, as otherwise it would have picked up beforehand many of the deficiencies which emerged in the inquiry'. (Reported in Hopkins, 2000, p.80).

Clearly, in addition to the performance of operators on specific tasks, there is also a human dimension to the decisions made and actions taken in the management of safety itself (for a fuller discussion, see Hurst, 1998[7]).

MANAGING HUMAN FAILURES - COMMON PITFALLS

The above concerns indicate that there is more to managing human failure in complex systems than simply considering the actions of individual operators. However, there is obvious merit in managing the performance of these personnel who play an important role in preventing and controlling major incidents; as long as the context in which this behaviour occurs is also considered.

The accompanying presentation outlines several pitfalls that we have identified when major hazard sites assess human performance. These include:

1. Treating operators as if they are superhuman, able to intervene heroically in emergencies;
2. Providing precise probabilities of human failure (usually indicating very low chance of failure) without documenting assumptions/data sources;
3. Assuming that an operator will always be present, detect a problem and immediately take appropriate action;
4. Assuming that people will always follow procedures;
5. Stating that operators are well-trained, when it is not clear how the training provided relates to major accident hazard prevention or control;
6. Stating that operators are highly motivated and thus not prone to unintentional failures or deliberate violations;
7. Ignoring the human component completely, failing to discuss human performance at all in the risk assessment or safety report/case, leading to the impression that the site is unmanned;
8. Inappropriate application of techniques, such as detailing every task on site and therefore losing sight of targeting resources where they will be most effective;
9. Producing grand motherhood statements that human error is completely managed (without stating exactly how).

DEMONSTRATING THAT YOU ARE MANAGING HUMAN FAILURE

Human performance studies of individual tasks cannot be considered in isolation from wider management and organisational issues. Therefore, in order to demonstrate that human failures are being managed effectively, it is necessary to first of all consider whether the three serious concerns above apply to your organisation. When you are satisfied that the safety management system is balanced (for example, in terms of addressing human factors with

proportionally the same degree of rigour as other issues and addressing big, rare events as effectively as routine injuries), then you can consider the specifics of your approach to managing human performance.

This involves ensuring that you have an audit trail to show, for example, that:

1. You have sufficient numbers of operators who;
    a. are appropriately trained;
    b. supported by the technology;
    c. highly motivated;
    d. who always follow procedures;
    e. under all operating conditions.
2. You have:
    a. identified safety critical tasks, roles and responsibilities;
    b. identified possible human failures associated with these;
    c. and managed these failures, following the hierarchy of control measures.

This audit trail may include a range of demonstrations, for example:

a. assessments of operator workload;
b. details of training needs analysis;
c. records of training and its assessment/evaluation;
d. human-machine interaction studies;
e. analysis of alarm handling;
f. procedures for consultation and involvement of personnel;
g. working time recording systems/fatigue risk assessments;
h. details of scenario emergency training;
i. analyses of communications/information handling requirements;
j. procedure for development of procedures;
k. risk assessments of proposed organisational changes;
l. details of human factors input into procurement policy;
m. root cause analyses for accident investigation;
n. details of safety critical tasks, roles and responsibilities;
o. records of task analyses for critical tasks;
p. records of human error analyses for critical tasks;
q. details of error management decisions.

THE WAY FORWARD

At its inception, the HSE Human Factors Team outlined a strategy which can be summarised as follows:

- Increase awareness of the importance of human factors among UK major hazard sites and the railway industry;
- Improve the integration of human factors in design, risk assessment and safety reports/safety cases;
- Encourage continuous improvement and sharing of good practice;
- Codify knowledge in a useful way for HSE and transfer to field inspectors.

Over the past three years we have made significant progress towards achieving these objectives, including interventions on a large number of major hazard installations across the UK.

However, there remain considerable weaknesses in the approaches taken to human factors on many of the most hazardous sites in the country, operated by some of the world's largest companies. If further major accidents are to be prevented, duty holders are urged to examine whether any of the failings discussed in this paper apply to their organisation.

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