Harpur Hill, Buxton
Derbyshire, SK17 9JN
T: +44 (0)1298 218000
F: +44 (0)1298 218590
W: www.hsl.gov.uk

HEALTH & SAFETY LABORATORY

The Causes of Major Hazard Incidents and How to Improve Risk Control and Health and Safety Management: A Review of the Existing Literature

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Project Leader: **Julie Bell**

Author(s): **Julie Bell & Nicola Healey**

Science Group: **Human Factors**

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EXECUTIVE SUMMARY

Introduction

The Health and Safety Executive (HSE) commissioned the Health and Safety Laboratory (HSL) to carry out a review of the existing literature on the causes of major hazard incidents and the relevant control measures and behaviours that can prevent incidents occurring. This research is an important first step in taking forward Social Science support for the Major Hazards Strategic Programme. The research is needed to take stock of the existing evidence base, identify gaps and suggest how these gaps might be addressed by further research.

The objectives of the review were to:

1. Scope what existing research literature is available to address specific questions relating to the understanding and control of major hazard accidents;
2. Review and report on how far the existing evidence can provide answers to the research questions;
3. Assess the quality of existing research evidence and provide comments on the overall quality of the evidence base and the robustness of individual studies;
4. Identify gaps in the existing evidence base and suggest how these gaps might be addressed;
5. Make recommendations on what style of interventions HSE should be pursuing in light of the research evidence.

Main Findings

1. The existing evidence base

Underlying causes of major accidents and associated control measures

- There is significant and robust information about, and common agreement on, the probable and underlying causes of major accidents and incidents in the major hazard industry.

- There is an extensive, good quality evidence base for the control measures needed to prevent major hazard incidents. Establishing and maintaining a positive safety culture is the focus of this work and is based on findings detailed accident investigations and analytical studies from across industry.

- While the theory of what is required is comprehensive the translation of this knowledge into practical solutions and interventions, to prevent major accidents, is limited. Therefore, the evidence base cannot be considered robust.

Behaviours associated with major accidents and how to change them

- There are behaviours that need to be changed in all the major hazard industries, but there is insufficient evidence to draw any conclusions about what those specific behaviours are, or how this is different (if at all) between hazardous industries.

- Management commitment to safety and the perceived pressure for productivity is highlighted in a thorough, qualitative investigation of the rail industry. This experience also may be relevant to major hazard industries but, notwithstanding findings from the offshore industry, this has not been investigated sufficiently to be certain.

- There is research on how to change behaviour but this is limited, based on small-scale studies and focused on individual behaviour and leadership styles.

- Training is not generally an effective way of changing behaviour but can be of use in specific circumstances e.g. simulation of emergency responses.

- The means for changing behaviour has been researched but the evidence base is not robust and does not provided a conclusive view on the most effective ways to change safety behaviour.

- A better understanding of the specific behaviours to be changed is essential before the research on how to change behaviour can be sufficiently developed.

Organisational change and major accidents

- There is circumstantial evidence, from case study examples, to indicate a link between organisational change and accidents. It is, therefore, an issue for the management of health and safety by major hazard industry and should be part of the safety management system. An example from the chemical processes industry shows that change can be effectively managed through the development of management change guidelines for changing key safety tasks.

Additional requirements for preventing major hazard incidents

- No papers were identified that explicitly addressed the issue of additional requirements for preventing major hazard incidents beyond those for "ordinary" health and safety incidents. Research to understand the differences between major hazard and non-hazard industries in the management of risk may help to address this gap in knowledge.

- Generally, however, the literature on the control of human factors in the major hazard industry points to a focus on organisational factors (via safety culture) more than individual behaviours, while the non-major hazard sectors seem to focus on changing individual behaviours, through techniques such as behavioural modification.

Cost benefit analysis

- The review identified one example of reported savings as a result of implementing an effective safety management system. However, few papers of sufficient quality to demonstrate the costs and benefits to industry associated with risk management were identified.

2. Possible gaps in the evidence base

- ***Underlying causes of accidents*** – If consistent and accurate data about the underlying causes of accidents were to be collected, both via HSE reporting systems and internal company systems, a better understanding of the accidents and how to prevent them, could be developed. Work to explore whether there are differences between the causes of accidents in the context of major hazard and non-major hazard industries is also required and would be facilitated by improved data collection.

- ***Application of knowledge*** – Exploration is needed to understand how the principles of safety culture can be made more accessible, in order to turn theory into practice and support real managers (those who need to implement changes) in real situations. Similarly, work is required to understand the effectiveness of interventions that are put into practice and the context in which they work.

- ***Interventions* -** Work is required to understand what interventions have been applied, how effective they have been and the context in which they work. The lack of literature on what has been applied to prevent major hazard accidents also suggests that evaluation work has not been carried out; this should be linked to any work to implement interventions.

- ***Identifying unsafe behaviours and establishing any differences between industries*** – The specific behaviours that need to be modified are not obvious. If the specific behaviours are understood then consideration could be given to appropriate methods of changing behaviour. Linked to this is the need to understand whether there are differences between major hazard and non-major hazard industries.

- ***Approaches to modifying behaviour*** – The effectiveness of behavioural modification approaches in reducing major hazard accidents, for example through safety management systems is not yet determined. Work to explore the potential of behavioural modification approaches in safety management systems is reported to be underway but no evidence of this was found in the review. Follow up work to establish the findings and to investigate how appropriate the progression has been of behavioural modification to safety management systems may be useful.

- ***Understanding the implications of organisational change* -** A clear understanding of the association between organisational change and accidents is lacking. However, it is unlikely that something beyond the principles of effective safety management is needed to control health and safety during times of organisational change in major hazard industries. It is also extremely difficult to establish what constitutes an organisational change for the purposes of research; change is often ongoing and influenced by other factors. For these reasons further research in this area is not a priority.

- ***Establishing the difference between major hazard and non-major hazard accidents* -** Targeted research is needed to address the issue of whether there are additional requirements for preventing major hazard incidents beyond those for "ordinary" health and safety incidents. One way to explore this issue would be to correlate conventional safety accidents with more serious (e.g. nuclear safety) accidents, if there is a correlation between the two, this would suggest that the methods used to control and modify conventional safety would also be applicable to major hazard safety.

- ***Cost benefit analysis*** – Research to understand the costs and benefits of major hazard interventions is required. It is also suggested that industry be encouraged to build this sort of analysis into new interventions, as part of their review and monitoring process.

3. Overall quality of the existing evidence base

- A significant proportion of the research, included in this review, comes from applied research and review papers commissioned by the HSE. Therefore, while this work is of good quality, little empirical, peer reviewed research has been considered directly and a critical analysis of the issues, theories and principles was not possible.

- The majority of the research reviewed is based on small-scale questionnaire studies, case studies and in-depth, qualitative studies. This has resulted in a significant amount of good quality research, and information that has potential to be applied to other industries. However, there are problems applying this apparently specific knowledge to other industries and circumstances; therefore, further research is required to demonstrate the applicability of knowledge across industries.

4. Recommendations for HSE interventions

- The literature search did not identify any relevant literature that was specifically concerned with how HSE should target its resources, or the style of interventions needed to prevent major hazard incidents, to allow conclusions to be drawn. The only conclusion that can be made, based on the literature, is the need for continued influence at the director level, because there is good evidence from two comprehensive review papers of the importance of the director leadership role on health and safety, and the positive effect that Government legislations has on achieving health and safety standards.

- One suggestion, as a result of consultation with HSL staff, is that HSE Inspectors (or other specialists) could be encouraged to act as agents of change for industry. Often where interventions have been attempted by industry they are ineffective because they are initiated by the safety specialists and may not have the necessary level of management support. If HSE could facilitate the progression of initiatives by encouraging the organisation to implement, follow through and evaluate interventions, this could increase the likelihood of success. A suggested approach was to carry out safety culture audits because, while the available audit tools may be less than optimal, they can indicate an agenda for future development on a range of criteria relating to HSE interest. This agenda could then be used to engage with stakeholders to identify what interventions are required for the organisation to improve.

- HSE may benefit from developing a better measure of safety culture, one that could look at health as well as safety and would be free for use by the HSE Inspectorate and Industry, alike.

- It is recommended that the next step for HSE should be to consult with the HSE Offshore, Nuclear and Hazardous Installations Directorates, relevant stakeholders and subject matter experts to gain an understanding of what interventions might be appropriate. The consultation should be designed to look at what they think works, what does not work, what needs to change and what they think could work.

1 INTRODUCTION

1.1 BACKGROUND

1. The Health and Safety Executive's (HSE) major hazards strategic programme is tasked with delivering specific reductions in the frequency of events that could trigger a major incident, by the end of 2007-08. The industries covered by this programme include: nuclear industries, offshore oil and gas industries, and onshore industries including chemical industries, mines, biological agents, explosives and gas supply/pipelines. The railway industry is no longer included, as responsibility for health and safety for this industry transferred to the Office of Rail Regulation on 1st April 2006. The HSC Strategy to 2010 and beyond states that "HSE will continue to work to prevent incidents from those industries which have the potential to cause significant harm, including to members of the public, such as the chemical, offshore, nuclear and railways industries and to maintain our international obligations."

2. The HSE commissioned the Health and Safety Laboratory (HSL) to carry out a review of the existing literature on the causes of major hazard incidents and the relevant control measures and behaviours that can prevent the occurrence of incidents. This research is an important first step in taking forward Social Science support for the Major Hazards Strategic Programme. The research is needed to take stock of the existing evidence base, identify gaps and suggest how these gaps might be addressed by further research.

3. The review will help HSE to identify what safety related behaviours and associated health and safety management systems need to be changed, and by whom, to prevent major hazard incidents. The main focus of the literature review is on the aspects of human behaviour that could trigger a major incident and how this behaviour can be improved to reduce the likelihood and consequences of such incidents. The review will also look at literature to identify the underlying causes of accidents and the factors that impact on human behaviour in the major hazards sectors. Research into the most effective ways of changing behaviour and systems is also discussed.

1.2 OBJECTIVES

The more detailed objectives of the study are to:

a) Scope what existing research literature is available to address the following questions:
    - What are the probable causes that have been attributed to major hazards incidents in the different industries e.g. nuclear industries, offshore oil and gas industries, and onshore industries?
    - What are the underlying causes of major hazard incidents in the different industries e.g. nuclear industries, offshore oil and gas industries, and onshore industries?
    - What are the relevant control measures and behaviour needed to prevent major hazard incidents in the different industries e.g. nuclear industries, offshore oil and gas industries, and onshore industries?
    - What are the safety related behaviours e.g. by employers, company directors, middle management, employees, duty holders etc. which need to be changed in the different industries to prevent major hazard incidents?
    - Is there any evidence that organisational change factors e.g. outsourcing, and changes to the size of organisations can impact on effective risk control and health and safety management? If so, how can these risks be reduced or managed?

- What are the most effective ways of changing behaviour – does this vary for different stakeholders e.g. employers, employees, duty holders etc?
- Are there additional requirements for preventing major hazard incidents beyond those for “ordinary” H&S incidents?
- Where should HSE target its resources to have the most impact e.g. at which levels of an organisation should you try to influence to have the most impact on behaviour?
- Are the probable causes of major hazard incidents readily identifiable through current reporting systems to HSE? e.g. RIDDOR etc. If not, what changes should be made to current reporting systems?

b) Review and report on how far the existing evidence can provide answers to the research questions. This should draw together and synthesize the existing evidence and clearly identify key messages;

c) Assess the quality of existing research evidence and provide comments on the overall quality of the evidence base and the robustness of individual studies;

d) Identify gaps in the existing evidence base and suggest how these gaps might be addressed;

e) Make recommendations on what style of interventions HSE should be pursuing in light of the research evidence.

2 METHODOLOGY

A review of the existing literature was conducted to collate key papers listed by HSE, applied research reports (e.g. Contract Research Reports for HSE) and authoritative reviews of the topic areas from the wider literature. The review is not a systematic one but the library, database and Internet searches were thorough and included attempts to look at unpublished work, conference papers and the international literature. The HSE Knowledge Centre Search Team searched the OSH-ROM literature database. OSH-ROM includes four leading databases: CISDOC (International Labour Office); NIOSHTIC (United States National Institute for Occupational Safety and Health); HSELINE; and RILOSH (Canada). It covers occupational health and safety with over 350,000 citations since 1960. While not all directly related to major hazards, an Internet search included websites for the following: HSE, United States Nuclear Regulatory Commission (US NRC), International Atomic Energy Agency (IAEA), the Air Accident Investigation Branch (AAIB), the Marine Accident Investigation Branch (MAIB), the Confidential Human Factors Incident Reporting system (CHIRP) and Confidential Incident Reporting and Analysis System (CIRAS).

The following search terms were used to identify appropriate references:

- Human behaviour and major accidents (e.g. what causes major hazard incidents/ accidents looking at both immediate and underlying causes);

- Changing safety behaviour (e.g. what behaviour needs to be changed by whom and what are the most effective ways of changing behaviour);

- Changing organisational safety culture;

- Effective risk control particularly in major hazard industry (including nuclear, offshore oil and gas and onshore industries such as petrochemical plants, explosives, and biological agents.);

- Key safety related behaviours;

- Human versus Mechanical safety (e.g. effective safety management systems);

- Organisational change and safety behaviour (e.g. outsourcing, changes in size and structures of organisations and impact on risk control, and health and safety management);

- Costs and benefits of preventing major hazard incidents/ accidents.

It was necessary to take a pragmatic, but thorough, approach to this review in order to comply with the work timetable; the aim was to identify authoritative reviews without returning to the base literature. However, this was not possible for all of the subject areas and source papers were consulted to check for complete information where it seemed that the review paper had not covered the issue in sufficient detail. Some papers were subsequently found not to be significant or to contain new information, so are not referenced in the body of the report but are included in the Bibliography. Despite the thorough approach to the literature search it is recognised that the review may not be comprehensive and some gaps may exist.

A short summary of each key paper is included in Appendix B.

The results of the literature search have been organised into topics relating to the questions posed by HSE.

3 FINDINGS FROM THE LITERATURE REVIEW

3.1 THE CAUSES ATTRIBUED TO MAJOR HAZARD INCIDENTS

1. In order to understand the nature of accidents, the first question to be addressed by the literature search was “What are the probable causes and underlying causes that have been attributed to major hazards incidents in the different industries e.g. nuclear industries, offshore oil and gas industries, and onshore industries?”

2. To answer this question, case studies were collated from fourteen well-documented major accidents that have been analysed and reported on in, for example, human factors textbooks (each case study is provided in Appendix A). Information was also collated from research papers where a case study approach was taken and/or where accident reports have been analysed to identify the underlying causes.

3. The numerous case studies and analyses of incident reports show that human error influenced by human and organisational factors are implicated as a cause of incidents in the major hazards sector. It is recognised that controls on human and organisational factors are now more important than technology because significant improvements have been made to ensure the increasingly inherent safety of machinery, technology and equipment (e.g. Lee, 1998). In addition, during accident investigation, operators more readily identify and improve on the physical issues than the underlying organisational factors. Advances in the control of human factors/organisational factors influencing error are less well developed, yet they are reported to account for 80-90% of organisational accidents (Reason, 1997).

3.1.1 Relevant Information

1. A summary of each of fourteen major accident case studies is provided in Appendix A. The summaries include a brief description of the accident and information on ***some*** of the immediate and underlying causes that have been attributed to each. Due to time and resource constraints the original incident reports were not consulted; the case study information was collated from accident investigation textbooks and research papers that provided an analysis of each accident.

2. In most cases, the combination of management decisions, specific events and circumstances on the day of the incident is extremely complex and numerous factors contributed to the incident. The following section, therefore, provides a list of ***some*** of the causes of those major accidents and is focused on the contribution of human and organisational factors as underlying causes.

3.1.1.1 Underlying causes of major accidents

1. ***Aberfan Waste Tip Slide (1966) -*** inadequate warning system; inspections were not carried out routinely; inadequate competency of staff; collective neglect of safety by numerous regulatory and governing bodies; failure to learn lessons.

2. ***Flixborough Explosion (1974)*** – inappropriate modifications to plant layout were made without risk assessment; inadequate support of a temporary bypass line; poor site layout; inadequately placed and supported control room.

3. ***Three Mile Island (1979)*** – earlier, inadequate maintenance resulted in critical valves left closed; operators were misled by unclear control panel indicators and layout; failure to correctly interpret plant's status; inadequate training of operators in emergency response meant they were unable to respond appropriately to the automatic shutdown of the reactor.

4. ***Bhopal Toxic Gas Leak (1984)* -** prolonged period of inadequate and insufficient maintenance allowed the site to fall into a poor condition; excessive quantities of non-essential chemicals were stored on site; failure of safety systems; hesitation by operators to raise the emergency warning siren.

5. ***Chernobyl (1986)* -** disregard of procedures to meet local objectives; inadequate training of operators; disarming of the plant's safety mechanisms; and known defects in the safety system were not redesigned or improved***.***

6. ***Challenger Space Shuttle Disaster (1986)* -** essential safety data not collected; the trend in failed 'O'-ring failures was not identified; inappropriate safety testing of equipment; pressure to achieve unrealistic launch schedules; 'acceptance' of risk.

7. ***Columbia Space Shuttle Disaster (2003)*** – failure to learn the lessons of the past; complacency of support team; adoption of cultural traits and organisational practices that were detrimental to safety; organizational barriers to effective communication of safety critical information; excessive pressure to achieve unrealistic shuttle flight schedule.

8. Sinking of the ***'Herald of Free Enterprise' (1987)*** – violation by the crewmember responsible for ensuring closure of the bow doors; poorly organized shifts; inadequate staffing; inadequate emphasis on safety from management; pressure to sail early; 'negative reporting' policy.

9. ***Piper alpha (1988)* -** inadequate communication between shifts regarding maintenance activities; inadequate use of permit to work systems; modification to the design of the platform without adequate risk assessment and planning.

10. ***Clapham Junction Rail Crash (1988)*** – a lack of monitoring and supervision during roll out of a major signalling modification programme; lack of training; sloppy work practices; and excessive working hours.

11. ***Kings Cross Fire (1989)*** – complacency by personnel, including senior management; a lack of smoke detectors beneath escalators; poor housekeeping; inadequate fire and safety related training; a reluctance to call out the fire brigade.

12. ***Kegworth Air Crash (1989)*** – the crew failed to assimilate readings on the engine instrument displays; crew reacted to the initial engine problem prematurely and in a way that was contrary to their training; fundamental acceptance of poorly designed instrumentation; passengers and cabin crew failed to question the flight commander's decision.

13. Grounding of the ***'Exxon Valdez' (1989)*** – inadequate communication between the captain and the third mate, and inadequate safety culture (prevalence for excessive drinking of alcohol among crew).

14. ***Southall Rail Crash (1997)*** – the train's two protection systems were rendered ineffective, one system was broken at the time of the incident and the driver was not trained in the use of the second.

3.1.1.2 Nuclear incidents

1. More recently, there have been significant incidents reported in the nuclear industry but they were recognised sufficiently early to prevent their escalation to a major accident. Ghosh and Apostolakis (2005) discuss two such incidents in a paper on the organisational contributions to nuclear power plant safety. Some of the issues highlighted were:

a) ***Davis Besse Nuclear Power Station Incident (2002)*** – severe vessel head corrosion resulting from inadequate processes for assessing safety of the plant; delayed shut down of the plant; failure to recognise and consider other secondary warning signals in a holistic fashion; inadequate safety culture meant this issue was never identified or dealt with; failure to reflect latest practices within industry; inconsistent and incomplete company policies on safety; incentive programs based on production levels not safety.

b) ***Paks Fuel Damage Incident (2003)*** – fuel damage resulted from inadequate new procedures i.e. the unsafe design and operation of the cooling system; inadequate reporting culture; inefficient monitoring systems; no alarm; inadequate organisational commitment to safety; inadequate sharing of safety information.

3.1.2 Findings from research papers

1. Work by the University of Liverpool (1996) analysed publicly available HSE investigation reports for the contribution of attitudinal and management factors. They found the main underlying causes of accidents in the chemical industry included: ***maintenance errors, inadequate procedures, inadequate job planning, inadequate risk assessments, inadequate training of staff, unsafe working condoned by supervisors/ managers, inadequate control and monitoring of staff by managers, inadequate control and monitoring of contractors working on site,*** etc.

2. Mearns *et al* (2001) looked at safety behaviours linked to accidents and near misses in the offshore industry (Appendix B, Ref 37). They investigated the underlying structure and content of offshore employees' attitudes to safety, feelings of safety and satisfaction with safety measures. Their results suggest that 'unsafe' behaviour is the 'best' predictor of accidents/near misses as measured by self-report data and that ***unsafe behaviour*** is, in turn, driven by perceptions of ***pressure for production***. Those employees, who had reported performing unsafe acts and violations, and those who felt that they were under more pressure to keep production going, were more likely to have been involved in one or more near miss on that installation in the past two years.

3. Keeley (2005) examined a number of incidents from the nuclear, offshore, gas and chemical industries, to determine contributing factors which, had they been picked up by inspection and/or assessment, may have prevented an incident. The underlying causes for most of the incidents reviewed were; ***maintenance procedures***; ***operating procedures***; assessing ***competence***; ***plant inspection***; ***plant and process design***; ***risk assessment***; and ***management of change*** (Appendix B, Ref 50). These causes were similar across the major hazard industries.

4. Work by the Vectra Group Ltd. for HSE (2004) planned to identify the ways in which human factors 'best practice' may be integrated into an offshore maintenance strategy. They noted that incidents resulting from ***maintenance*** are more likely to stem from a human factors-related root cause than engineering ones (60% of all incidents were identified as human factors related).

5. In a research project for HSE to develop human factors methods and associated standards for major hazard industries, Simpson, *et al* (2003) analysed accident case studies and identified five human factors topics that were influencing accidents in the chemical industry. Those topics were: ***procedures***, ***availability of information***, ***communications***, ***emergency planning***, and ***accident investigation.***

6. Ghosh and Apostolakis (2005) investigated the organisational contribution to nuclear power plant safety and discussed the findings of the investigations into Davis Besse Nuclear Power Station Incident (2002) and Paks Fuel Damage Incident (2003). They also reported on two other studies to look at the underlying causes of accidents in nuclear power plants. The first of these reports by the United States Nuclear Regulatory Commission (US NRC) analysed 48 events at US nuclear power plants for human performance contributions and found human errors were included among the root causes in 37 of the events.

7. The second study was by the Organisation for Economic Co-operation and Development's (OECD) Nuclear Energy Agency (NEA) (2003) on recurring events in the nuclear industry. Management and organisational factors that were revealed as root causes in multiple events, and specific behaviours included: deficiencies in ***safety culture*** in general; deficiencies in ***communication*;** deficiencies in work practices such as not following ***procedures***, lack of clear ***work responsibilities***, improper use of ***system diagrams;*** a lack of ***design basis information*** available; ***inadequate management;*** heavy ***workload***; and ***insensitivity*** to shutdown risk activities (Appendix B, Ref 55).

   Ghosh and Apostolakis (2005) note that,

   > "The implicit assumption is that safety culture is clearly a pervasive and important aspect of operations but one whose effect on risk may be difficult to quantify."

8. The Bomel Consortium (2003) conducted a comprehensive review of the factors and causes contributing to major accidents, across all industry sectors, between 1996/97 and 2000/01 (Appendix B, Ref 57). The key issues of concern were identified at three levels in the organisation. At the individual level, **'*competence*'** (linked to 'training'), **'*situational awareness and risk perception*'** (linked to 'communications' and 'availability of information and advice'), and **'*compliance*'** were highlighted as being linked to accidents. At the organisational level, **'*management and supervision*'**, **'*planning*'**, and **'*safety culture*'** issues were highlighted and **'*safety management*'** at the corporate Policy level.

9. Part of the work included an analysis of the results by industry sector (see Appendix B, Ref 57 for details relating to each sector). The industry sectors included in the analysis were, Agriculture and Wood, Construction, Engineering and Utilities, Food and Entertainment, Metals and Minerals, Services, Polymers and Fibres, and Hazardous Installations (including, onshore and offshore oil companies, mining, and chemical processing plants).

   It is noted in the report that,

   "…there is surprising consistency in the dominant failings uncovered across the sectors and across different accident kinds, process environments and employment status…".

10. Schein, 1996 (Appendix B, Ref 60) suggests this across industry consistency may be due to a fundamental difference in the organisational culture of operators, engineers and chief executive officers (CEO). He argues that their different organisational behaviours and assumptions can conflict to have dramatic and catastrophic consequences in the form of major accidents. He provides the example of an aeroplane crash that occurred a few miles short of the runway,

> *"The flight recorder revealed that the flight engineer had shouted for several minutes that they were running out of gas, while the pilot (functioning as the CEO) continued to circle and tried to fix a problem with the landing gear. When the situation was run in a simulator, the same phenomenon occurred; the pilot was so busy with his operational task and so comfortable in his hierarchical executive position that he literally did not hear critical information that the flight engineer shouted at him. Only when the person doing the shouting was a fellow pilot of equal or higher rank did the pilot pay attention to the information. In other words, the hierarchy got in the way of solving the problem."*

3.1.3 Key issues identified

1. The information collated from the major accidents case studies and research papers has shown that the underlying causes of accidents are similar across the major hazard industries. In the majority of major accidents there is a complex chain of events, including organisational policies and decisions, individual behaviours and mechanical or technological failures that, when combined, resulted in the incident. While the individual behaviours that resulted in the accidents are wide and varied, they all relate to human and organisational factors, and many are symptomatic of a poor safety culture. The accidents chosen for analysis date back to 1966 and have occurred as recently as 2003 indicating that, despite attempts to learn lessons, major accidents continue to be a threat. Efforts to map the causes of accidents to the different industry sectors indicate that there is consistency in the dominant failings, and this is true across the major hazard industries and also for non-major hazard industry sectors. This may be due to pervasive differences between organisational groups (operators, engineers and directors) that hinder effective learning and communication.

2. Specific factors contributing to major accidents include:

    - Poor management practices e.g. inadequate supervision
    - Pressure to meet production targets
    - Inadequate safety management systems
    - Failure to learn lessons from previous incidents
    - Communication issues e.g. between shifts, between personnel and management etc.
    - Inadequate reporting systems
    - Complacency
    - Violations/ non-compliance behaviour

- Inadequate training e.g. emergency response, fire and safety
- Lack of competency
- Excessive working hours resulting in mental fatigue
- Inadequate procedures
- Modification/ updates to equipment without operator knowledge and/or revised risk assessments
- Inadequate/ insufficient maintenance
- Maintenance errors

3. Clearly, the analysis of accidents is carried out after the event and with the benefit of hindsight, which can introduce bias to the understanding of the issues. Much of the information known after the event would not have been evident to the individuals whose actions were the immediate precursors to the accident.

3.1.4 Quality of the evidence base

1. There is a significant amount of information available about the probable and underlying causes of major accidents and incidents in major hazard industry. The evidence comes from extensive and detailed investigations of major accidents along with the analysis of smaller scale incidents to look for common causes. Many of the major accidents have been analysed, and re-analysed by researchers to be presented as case studies for model accident causation theories and to develop investigation approaches. Such approaches are presented in good quality papers and books on accident investigation by respected authors. There is common agreement on the causes of the major accidents included in this review, though different emphasis is placed on particular aspects of the incident depending on the specific interests of the reviewer (e.g. maintenance errors or communication breakdowns).

2. There is an implicit assumption, in many of the papers, that the causes of major accidents are comparable across industries and the comprehensive analysis by the Bomel Consortium (2003) and theoretical discussion by Schein (1996) provide support for this view. However, more research is required to substantiate this, to determine whether it is possible to map specific causes to different industries, and if the causes of accidents differ between major hazard and non-major hazard industries.

3.2 CONTROL MEASURES AND BEHAVIOURS TO PREVENT MAJOR HAZARD INCIDENTS

1. Having considered the underlying causes of accidents, the next question was "What are the relevant control measures and behaviours needed to prevent major hazard incidents in the different industries e.g. nuclear industries, offshore oil and gas industries, and onshore industries?" To answer this question, the literature was consulted for both academic reviews and examples of applied research, to not only understand the principles but also what has been effective in practice.

2. The review revealed that approaches to controlling unsafe behaviour in the major hazards sector are focused on issues related to safety culture and how to achieve a positive safety culture. This includes the development of effective safety management systems, the importance of good leadership, the extent of emergency preparedness, and the inclusion of safety in total quality management systems.

3.2.1 Relevant Information

3.2.1.1 Safety Culture

1. A review and discussion of the issues surrounding safety culture, mindfulness and safe behaviour, by Hopkins (2002), noted that safety culture is an attractive idea because it promises a way to overcome the limitations of safety systems. It is not, however, a straightforward idea. Many of those who refer to safety culture, particularly managers, have in mind an organisation whose members are all individually safety conscious. Hopkins cites Reason (1997), as acknowledging that safety culture has implications for the behaviour of individuals, but insisting that the concept be used to describe truly organisational phenomena and not simply the aggregated behaviour of individuals (Appendix B, Ref 59).

2. Research in 2005 to develop a safety culture inspection toolkit for the rail industry was based on the five key indicators, as identified by HMRI, known to influence safety culture (Appendix B, Ref 1). These five indicators are: ***leadership, two-way communication, employee involvement, learning culture, and attitude towards blame***. The paper provides a review of the characteristics regarding positive and negative safety culture, the types of behaviour associated with each, and to a limited extent, how this can be achieved. For example, one element of effective leadership is for the ***management's commitment to safety to be highly visibl*****e**; senior managers should demonstrate visibly and repeatedly show their commitment to safety throughout all areas of the organisation. This will create a shared vision of the importance of safety. This can be achieved by the use of **verbal *communications*** (e.g. ***scheduled safety tours***, ***safety briefings***, ***open door policy for safety***) and written safety communication (e.g. statements and newsletters).

3. A review of organisational culture and climate research, by Wiegmann et al (2002), identified five global components or indicators of safety culture. They include: ***organisational commitment, management involvement, employee empowerment,*** **reward *systems,*** and ***reporting systems*****.** The review was conducted on behalf of the aviation industry and it was recognised that despite the fact that the term safety culture was initially associated with the nuclear industry (after the investigation into the Chernobyl incident), safety culture is an issue for the aviation industry too. The investigation of the crash of Continental Express Flight 2574 was one of the first to have attributed safety culture as a causal factor in aviation incidents and Wiegmann et al (2002) note that, while there are numerous definitions of safety culture, there were several points of similarity across industries. These are detailed in Appendix B, Ref 58 and include, "The safety culture of an organization has an impact on its members' behaviour at work."

4. A recent publication by the Flight Safety Foundation (2005) further demonstrates the relevance of safety culture to the aviation industry by featuring a paper on a 'just culture' (one of the four characteristics of safety culture as defined by Reason). The paper provides an overview of what is meant by a just culture, with the aim of increasing awareness in the international aviation community of the benefits of creating such a culture. They also provide information on the implementation of a just culture in aviation organisations, share

lessons learned and provide initial guidelines that might be helpful for those who might benefit from the creation of a just culture.

5. It is recognised that different organisations will be at a different stage in their development of safety culture and work for HSE has attempted to develop a model to assess safety culture maturity (Appendix B, Ref 17). The maturity model is based on the assumption that safety performance improves with increasing levels of safety culture maturity but there is no hard evidence to support this. The model proposes five levels of safety culture maturity, these are ***emerging***, ***managing***, ***involving***, ***cooperating*** and ***continuous improvement***. There are ten elements to the safety culture maturity model that have been adapted from HS(G) 48, these are:
    - ***Management commitment*** and ***visibility***;
    - ***Communication***; ***productivity versus safety***;
    - ***Learning organisations***;
    - ***Safety resources***;
    - ***Participation***;
    - ***Shared perceptions*** about safety;
    - ***Trust***;
    - ***Industrial relations*** and ***job satisfaction***;
    - ***Training***.

6. The importance of leadership at all levels in the organisation (i.e. directors, managers, supervisors and team leaders) for creating and promoting a positive safety culture is the subject of a number of papers. The area seems to be one of the most well developed and understood areas for influencing safety culture in general, and behaviours specifically. However, Bomel Consortium (2003) reported that the changing work environment has implications for increasing pressure on managers and supervisors, which in turn impact on health and safety. The reported included the following recommendation;

    "…drivers (on managers and supervisors) and implications need to be understood more fully in specific industrial contexts, to develop indicators and guidance on optimal management and supervision provision from both health and safety and productivity viewpoints".

7. O'Dea and Flin 2003 (Appendix B, Ref 6) published a key review paper on the role of managerial leadership in determining workplace safety outcomes. The report reviews the evidence for the associations between leadership and safety, and specifically looks at what characteristics of leadership work best to influence safety behaviour. The key factors associated with positive safety outcomes are summarised in the paper and have been copied into Appendix B, Ref 6. It includes for example, at the senior management level factors such as ***attitudes to safety***, which should be demonstrated by safety being viewed as integral to competitiveness and profitability. At the middle management level factors such as ***commitment to safety***, which should be demonstrated by allocating ***adequate resources*** for safety. At the supervisory level factors such as ***supportive supervision***, which includes ***openness on safety issues***, ***initiating safety discussions***, ***providing feedback*** and ***fairness*** are highlighted. At the employee level factors such as ***worker autonomy*** (with specific and reasonable responsibilities, authority and goals) is considered important.

8. That management is the key influence of an organisation's safety culture was also confirmed in other reviews of the literature, such as that by Collins, 2002 (Appendix B, Ref 9). This review also noted that ***employee' perceptions of management's attitudes*** and ***behaviours towards safety, production and issues*** such as ***planning and discipline*** were the most useful measurement of an organisation's safety culture. It was also noted that the

literature on bonus schemes suggests that financial incentives to improve productivity or to compensate for working in hazardous conditions can lead to safety being compromised because they may be seen as an inducement to take risks. Such schemes may be seen as either an incentive to work faster and potentially commit unsafe acts, and/or encourage the non-reporting of accidents to ensure a bonus.

9. A leadership resource pack was developed for the HSE, Offshore Safety Division (OSD) as a contract research report (Appendix B, Ref 18). The pack was intended as a source of knowledge and good practice to demonstrate how positive leadership can drive a health and safety agenda alongside business considerations. The pack includes examples of health and safety leadership behaviours, such as: a high degree of ***enthusiasm***, ***clarity in how health and safety is discussed in the business***, ***demonstrable knowledge*** of good practice within operations, and ***participation and execution of advance training techniques and practices***. These behaviours are supported with best and poor practice examples of management behaviour. Examples of best practice behaviour include: ***"Senior managers lead safety briefings and regularly include health and safety matters in other briefings and presentations"***, ***"Senior managers all commit to receiving regular updated health and safety training"*** and ***"Senior managers follow health and safety procedures and practices at all times".***

10. An earlier paper (Appendix B, Ref 19) looked at which aspects of supervisor behaviour are associated with effective safety management in the oil and gas industry. It was found that a supervisor's behaviour had a significant impact on subordinate safety behaviour. Particular behavioural aspects were: ***valuing subordinates, frequency of visiting worksite, work group participation, communicating the importance of safety***. It was suggested that the subordinates of supervisors who display these behaviours most frequently are less likely to be involved in an accident. It was noted that while these four factors are not sufficient to manage safety effectively, they do distinguish good supervisors from excellent ones.

11. Despite the focus on the importance of leadership, a paper by Schein (Appendix B, Ref 60) suggests that more fundamental work is required to understand the influence of organisational culture on unsafe behaviour (at both the individual and organisational level) and accidents. He argues that operators, engineers and chief executive officers (CEO) have their own organisational cultures, with different organisational behaviours and assumptions that can conflict to hinder organisational learning. Effective organisational learning requires not only innovations and new processes but also their adoption and diffusion to other parts of the organisation. If the different elements of the organisation cannot communicate effectively then successful organisational learning will tend to be short-run adaptive learning (doing better at what they are already doing) or, if they are genuine innovations, they tend to be isolated and eventually subverted and abandoned.

12. The papers described above are a small sample of the many applied research papers that have focused on the importance of safety culture to control and modify unsafe behaviour and reduce the propensity for incidents. Intrinsically linked to a positive safety culture is an effective safety management system; this is because one way to achieve an effective safety culture is through a successful safety management system. A number of references were identified that focused on safety management systems and accident prevention.

3.2.1.2 Safety management systems

1. HSE guidance on Successful Health and Safety Management outlines the common characteristics of a successful health and safety management system approach (Appendix B,

Ref 24), broadly defined as ***policy, organising, planning, measuring performance, reviewing performance and auditing*** (POPMAR). These principles are applicable to all organisations but the guidance notes, "*the extent of action required will vary with the size of the organisation, the hazards presented by its activities, products or services and the adequacy of its existing arrangements*."

2. Hurst *et al*, 1996 (Appendix B, Ref 48) provide examples of ideal, good and poor safety management systems at chemical process sites in four European countries. The work is focused on tools to assess safety culture and does not describe any specific 'behaviours' but, like many other papers, does show that the tools can be used to predict self-reported accident rates and reflect the different safety cultures within sites; therefore tools can be used to identify strengths and weaknesses for each site in terms of safety.

3. Research reported in 1995 (Appendix B, Ref 49) focused on the organisation of human factors in the major hazard sector, the specific aim of the work was to explore whether the nuclear industry could learn anything from other industries in the application of human factors in safety management systems. The result of the research was a checklist of good practice under the titles of ***Senior management commitment; Communication; Safety management systems and organisational complexity; Measurement of safety; Operational feedback; Proprietary tools; Modification and evolution of proprietary systems; and Organisational structure***. The practicalities of each of these elements are listed in the summary (Appendix B, Ref 49) and include, for example on communication, the importance of communicating regularly with the workforce on safety matters and the need to monitor the effectiveness of communications etc. However, while the key points for an effective safety management system are provided, the precise behaviours to achieve effective communication are not discussed.

4. The European Agency for Safety and Health at Work.1996-2001 (Appendix B, Ref 56) produced a short book to describe case studies on the effective implementation of Occupational Safety and Health Management Systems (OSHMS) from a range of companies across Europe. They noted that quantifiable objectives relating to the introduction of an OSHMS could only be observed in a few cases. Companies that defined such objectives mostly referred to the 'zero accidents' strategy. Those companies that had defined quantitative targets achieved a reduction of accidents at work. They also noted an increase in employees' motivation, even though this is not measured in a quantifiable way; many companies believe that productivity rises with the implementation of OSHMS. The main advantages that were reported were:

   - Systematic root analysis of hazards, risks and incidents;
   - Strong awareness of hazards and risks;
   - Improved transparency concerning internal processes;
   - Better communication among employees;
   - Stronger motivation and identification of employees with their company;
   - A more extensive and integrated point of view in the sense of the working environment;
   - Better measuring of the occupational safety and health performance.

3.2.1.3 Behavioural approaches to safety management and Tools for the assessment of human factors

1. Work to apply behavioural approaches to safety management within reactor plants (Cox *et al* (2004) (Appendix B, Ref 46) listed the main factors thought to influence safe behaviours as: ***Human factors*** (including person-environment fit), ***Personal characteristics*** (age, gender, experience), ***Established norms of behaviour***, ***Attitudes and climate***, ***Attitudes and perception of risk***, ***organisation and environment***, ***Perception of long-term versus short-term benefits***, ***Motivation*** and ***Trust***.

2. A tool developed to assist both HSE Inspectors and staff on chemical plants in assessing the management of human factors, provides some evidence of the factors thought to be important for controlling unsafe behaviours. The work by Simpson *et al* (2003) (Appendix B, Ref 8) describes guidance on five human factors topics that were selected following the application of an incident analysis process, to identify the human factors that were influencing accidents in the chemical industry. The topics identified were: ***Procedures, Availability of information, Communications, Emergency planning and Accident investigation.*** The topics are presented as Assessment Principle Statements with explanatory text and a suggested question set to allow an examination of each of the Assessment Principles. There are also guidance notes to expand on and exemplify the questions and a scoring procedure. The questions, particularly those for gathering evidence/for operators, give an indication of the sort of behaviours that might be associated with good management of human factors issues. For example, when exploring the issue of "Procedures", one of the suggested questions is,

   "*Is there evidence that staff are involved in the writing/review of procedures?*"

   The accompanying explanatory text states,

   > *"Many of the problems which arise with procedures do so because they have been written by some one who may well know the engineering/technology involved but is not involved with the actually day-to-day operation. Assumptions that may seem sensible and reasonable to the author may be far from the case in day-to-day reality…"*

   The number of Assessment Principles and associated question sets means that the full list of behavioural questions cannot be included in this review or summarised in the Appendix; the reader is, therefore, referred to the original paper.

3.2.1.4 Features of safety management systems

1. The literature review also identified research into specific aspects of a safety management system and ultimately the safety culture, which may inform the control measures and behaviours needed to prevent major accidents. For example, Larken *et al*, 2001 (Appendix B, Ref 15) carried out work for HSE that identifies the factors related to effective emergency responses (based on simulation training). The specific aims of the work were to develop a framework model of emergency management and then apply it to the development of performance indicators for the assessment of emergency preparedness in the major accident hazard industry.

2. The work involved an assessment of emergency performance, at each of 11 major hazard sites, in terms of their performance relative to the risks posed, and relationships between features of the site preparedness and their subsequent level of performance in exercises. Six

features were found to be particularly representative of quality of practical performance. These were: ***senior management commitment***; ***emergency philosophy***; ***emergency management team structure***; ***information management system***; ***exercise regime***; and several specific features of ***team preparedness*** – continuity in membership of ***emergency teams***; training in ***command and control***; ***competence assurance of emergency managers***; and ***professional coaching*** of management teams during exercises.

3. A second example is that of work to assess the safety of staffing arrangements for process operations in the chemical and allied industries (Appendix B, Ref 14). The work was carried out because of increasing concern that reduced staffing levels could impact the ability of a site to control abnormal and emergency conditions, potentially resulting in an incident. Six principles were established to test staffing arrangements based on a literature search and case studies, they were:

- There should be ***continuous supervision*** of the process by skilled operators.
- ***Distractions*** such as answering the telephone, talking to people in the control room, administration tasks and nuisance alarms ***should be minimised*** to reduce the possibility of missing alarms.
- Additional ***information*** required for diagnosis and recovery ***should be accessible***, correct and intelligible.
- ***Communication links*** between the control room and field should be ***reliable***.
- Staff assisting in diagnosis and recovery should be available with ***sufficient time*** to attend when required.
- Operating staff should be allowed to ***concentrate*** on recovering the plant to a safe state.

The work highlights the specific controls required to ensure that the safe behaviour needed to maintain control of processes during abnormal and emergency conditions can be achieved.

3.2.1.5 Combining total quality management with health and safety

1. A report looking at the integration of total quality management systems with the management of health and safety (Appendix B, Ref 23) found that those organisations where health and safety performance is perceived to be more critical to the overall success of the business tended to be more advanced in the application of total quality management to the management of health and safety. They identified the reasons why organisations choose to adopt total quality management in the management of health and safety, these included:

    - A high level of ***identity with and understanding*** of the subject of health and safety ***at the executive level;***
    - A ***high intrinsic value*** for the ***safety*** and welfare of its stakeholders exists within the business;
    - ***Customers demand*** that the business adopts similar values, standards and practices as their own;

- Strategic goals of ***‘business excellence’*** as recognised by external assessment bodies require that a consistent management approach be adopted throughout the business;

- It is perceived that ***health and safety performance*** is ***critical*** to the overall ***success of the business.***

2. The authors also highlight the barriers to the use of total quality management in the management of health and safety (see original report for full details):

   - ***People factors*** – e.g. leadership style, leadership at executive level, health and safety is primarily to comply with legislation and does not generate income or profit, personal fears and assumptions, negative attitude, low calibre of safety personnel etc.

   - ***Process factors*** – e.g. inadequate processes for developing, deploying and reviewing health and safety policy, difficulties measuring performance, inappropriate measures, ineffective & inadequate communication etc.

   - ***Organisational factors*** – e.g. overbearing culture of compliance, difficulties controlling contractors, changing business priorities etc.

   - ***External factors*** – size of business perceived to be too small to warrant the ideal approach to health and safety, nature of the business is such that health and safety is not seen as critical to success of business etc.

3.2.1.6 An industry example of effective safety culture

1. Finally, Walker and Maune, 2000 (Appendix B, Ref 43) have published an industry example of how an effective safety culture can be achieved and the benefits to all involved. The paper is a case study of a project to build a new chemical processing plant that was completed on time, below budget and with an exemplary safety record (in 13million construction hours: one lost-time injury recorded and two reportable injuries). The report states that $3million in avoidable costs were saved when compared to the ‘typical project’. The report describes the process by which the following key elements were achieved:

   - A visible, proactive and extraordinary vision and commitment to safety at all levels;

   - World-class safety processes and best practices;

   - A culture that valued workers and focused on protecting people.

2. For example, the company developed an executive sponsor leadership team to create the vision, remove barriers, supply resources and sustain the commitment to safety. To achieve this, the group:

   - Publicly stated its commitment to the established safety vision;

   - Performed monthly executive sponsor meetings, with a half day devoted to safety issues;

   - Monthly construction site walks to acknowledge safe behaviours;

   - Conducted unannounced contractor work camp visits and audits;

- Formed a workable, results-focused owner/ contractor safety partnership.

3. They also introduced a number of initiatives such as safety awareness training, defensive driver training, feedback for sponsors, posters, visuals, project newsletters, small incentives such as raffle tickets for larger prizes and pre-paid phone cards to immediately reward positive behaviours.

4. The report provides details (too numerous to be included in this review) of all aspects of the development of the safety culture from the company's choice of contractors (e.g. contractors had to provide proof of their safety record and agree to adopt a specified safety management programme) through to behaviours of individual workers (e.g. stopping work if it is viewed as unsafe, etc.). These management actions and employee behaviours are applied examples of the key principles identified in the research literature.

5. This example was typical of the sort of papers identified that reported to consider the costs and benefits associated with interventions to control the risk of major hazard accidents. The information, while claiming benefits associated with effective safety management, was not a true cost/benefit analysis. No research was found to systematically evaluate the costs/benefits of effective safety management.

3.2.2 Key issues identified

1. One important factor and the most researched control measure for human factors/organisational issues is the role of ***leadership*** throughout the organisation. An employee's perceptions of ***management's attitudes and behaviours towards safety***, production and issues such as planning and discipline are a measure of an organisation's safety culture. The important factors in effective leadership include: ***a high degree of enthusiasm, clarity in how health and safety is discussed in the business, demonstrable knowledge of good practice within operations, visiting worksite, work group participation, communicating the importance of safety***.

2. Other influential factors that have been identified include: ***communication***, ***feedback***, ***procedures***, ***employee involvement*** in the organisation, and ***worker autonomy*** with specific and reasonable responsibilities, authority and goals, ***availability of information***, ***emergency planning*** and ***accident investigation***.

3. In many cases, the specific behaviours are not discussed in the literature; this may be because the precise behaviours are too wide-ranging and unpredictable to be specific (as evidenced by the major accident case studies). However, by ensuring that industry is aware of the value of controlling and monitoring the higher-level categories of behaviours the unknown, specific unsafe behaviour that precedes the accident may be prevented.

4. Baumont *et al* (2002) conducted a European wide review of organisational factors, their definition and influence on nuclear safety. The paper notes that a list of organisational factors together with their definition can provide some insights, but is difficult to use in day-to-day management activities. It was suggested that further research was needed where real managers describe their actual problems and real solutions. (Appendix B, Ref 54).

3.2.3 Quality of the evidence base

1. There is an extensive theoretical evidence base for the control measures and behaviours needed to prevent major hazard incidents; much of the knowledge is based on accident

investigations and establishing what, if done differently, would have prevented the accident. An important development was the investigation into the Chernobyl incident, during which the issue of safety culture became prominent. Work since then has produced a substantial body of applied research exploring the link between safety culture and accidents; this work includes the identification of the key issues needed to establish a positive safety culture. The development of tools, based on this knowledge, has shown that it is possible to identify areas for improvement in safety culture and behaviour in particular organisations, and even to predict accident rates.

2. The importance of an effective safety management system as part of the general safety culture has also received considerable attention and examples of good management practice were found in the literature search. However, there is some suggestion that more needs to be done to make the theory of safety culture more accessible to those who need to implement changes, in order to turn theory into practice and support real managers in real situations.

3. There may be work underway by and on behalf of the relevant HSE directorates that was not identified from the review of published literature, so it is recommended that this be explored via stakeholder consultation.

4. No research was identified, as part of this review, which provided an adequate cost/benefit analysis of interventions to control the risk of major hazard accidents. This is a complex area and one that HSE has attempted to address, however, due to time constraints it was not possible to pursue the issue as part of this report.

3.3 SAFETY RELATED BEHAVIOURS THAT NEED TO BE CHANGED TO PREVENT MAJOR HAZARD INCIDENTS

1. Linked to the question of what are the relevant control measures and behaviours needed to prevent major hazard incidents in the different industries, is the question of "What are the safety related behaviours e.g. by employers, company directors, middle management, employees, duty holders etc which need to be changed in the different industries to prevent major hazard incidents?" This area of the literature seems less well developed than that relating to control measures, but there is some research that can be drawn upon.

3.3.1 Relevant Information

1. Work by Weyman *et al*, 2004 (Appendix B, Ref 4) explores the practical implications of factors known to influence safety culture in the context of the UK rail industry. This comprehensive paper identifies a number of areas of organisational behaviour that need to change; these may be applicable to major hazard industries.

   - First, it was found that despite wide recognition in the industry of the importance of senior management commitment to safety culture, some ***variability was reported with regard to the visible, active, involvement of senior managers***, and the extent to which this commitment was perceived as genuine by the front line staff.

   - Secondly, the strong industry ***focus on high performance*** and loss avoidance has resulted in the potential for tensions and trade-offs in the day-to-day decision making over safety and performance by middle management.

- Thirdly, the rail industry has a ***strong blame culture***, and in light of recent major accident investigations there are concerns about litigation (both personal and organisational). The prevailing contractual arrangements and the operation of a performance regime exacerbates this situation.

- Fourthly, the strong focus on blame has the potential to reduce employee preparedness to report near-miss accidents, and to lead to a focus on immediate rather than underlying causes in incident investigations. This can have implications for ***organisational learning and risk management strategies***.

2. Work by O'Dea and Flin (2003) on the role of managerial leadership in determining workplace safety outcomes (Appendix B, Ref 6) provides evidence from a review of the empirical literature on the importance of leadership in effective safety management. They note that, while offshore installation managers are increasingly aware of best practice in safety leadership and the behaviours that are likely to be the most influential in promoting more positive employee behaviours, many find it ***difficult to translate this knowledge into practice***. They go on to suggest that leadership training programmes may be appropriate if they are based on training needs analysis, have sufficient theoretical grounding and are evaluated.

3. Work in the nuclear industry, for example that by Lee (1998), Harvey, *et al*. (2002) and Takano *et al* (2005) to develop tools to evaluate safety culture has shown that there are safety culture issues to be addressed. Harvey *et al* (2002) found that safety culture may differ across different departments or plants within an organisation and Takano *et al* (20050 found evidence of staff '*not connecting potential accidents to their own work ways*' and *'regarding safety as an organisational concern, not an individual one'*.

4. A paper by Mearns *et al* (2001) describes the use of a self-report questionnaire to consider the human and organisational factors in offshore safety. It was found that unsafe behaviour such as rule breaking and risk taking behaviour was related to perceptions of pressure for production. This pressure came from workmates, supervisors and management who also take chances and violate safety regulations for the same reasons. Specific examples of unsafe procedures are incorporated in the questionnaire's safety behaviour scale and include:

    - I ignore safety regulations to get the job done;
    - I break work procedures;
    - I bend the rules to achieve a target;
    - I get the job done better by ignoring some rules;
    - Conditions at the workplace stop me working to the rules;
    - I take shortcuts that involve little or no risk.

    For a full list of unsafe behaviours included in the questionnaire please see Appendix B, Ref 37.

5. A preliminary investigation by Williams (1997) to assess and reduce the likelihood of violation behaviour, notes that violation or non-compliance behaviour can have a detrimental effect on safety. High profile examples include incidents such as the Bhopal

chemical leak, Chernobyl, the sinking of the Herald of Free Enterprise, and the Clapham Junction rail crash. The aim of the work was to,

> *"…obtain some understanding of the probability of non-compliance behaviour and circumstances in which otherwise compliant behaviour might become non-compliant and vice-versa."*

6. The key influences on behaviour were reported to be the ***presence of a group***, a ***person's status*** or a person who is judged to be in ***authority***, the likelihood of the ***violation behaviour being detected*** and the amount of ***inconvenience*** associated with maintaining compliant behaviour.

7. In the course of the research, Williams (1997) identified some factors that explicitly reduce the likelihood of violation behaviour for example, following ***best practice management theories***, making ***compliance an easy option*** and the ***importance of managers*** who lead by example, are seen in action and delivery actions that are consistent with health and safety policies (Appendix B, Ref 53).

3.3.2 Key issues identified

1. The literature search provided evidence (e.g. from investigations into safety culture) that there are behaviours that need to be changed in all the major hazard industries, but there is insufficient evidence to draw any conclusions about the specific behaviours that need to be changed, or how this is different (if at all) between hazardous industries.

2. The reported experiences from the rail and offshore industries show that, while there is awareness of best practice, the application of that theory is variable, and front line staff question senior management commitment to safety. The focus on high performance has contributed to this perception because of the 'inevitable' tension between safety and performance resulting in unsafe behaviour. This focus on performance and associated pressures was also noted in the offshore industry where there was some evidence of the individual unsafe behaviours that correlate with accident rates.

3. The need to reduce the likelihood of non-compliance and violation behaviour is also clear, but, like most of the unsafe behaviours associated with accidents, a positive safety culture and effective safety management system seem likely to be influential in achieving compliant behaviour.

3.3.3 Quality of the evidence base

1. Only eight studies were identified and are included in this report, but all provide applicable, good quality, applied, qualitative research. While this is insufficient to allow firm conclusions about the behaviours that need to be changed in the various major hazard industries, it is a rich source of information and a solid basis for further investigation. There is persuasive evidence that organisational factors need further attention in the nuclear, offshore and rail industries, and an indication from the rail industry of what might be required. Work to consider the quantification of violation behaviour in probabilistic safety assessments has drawn on violation research data, from a wide variety of sources, to show that such behaviour is predictable and, therefore, preventable.

2. Further work focusing on an analysis of specific behaviours, at the director, organisational and individual levels and how these groups interact is needed. This could be targeted to consider how, if at all, this differs between major hazard industries and non-major hazard industries.

3.4 THE MOST EFFECTIVE WAYS OF CHANGING BEHAVIOUR

1. The next HSE question to be addressed is, "What are the most effective ways of changing behaviour and does this vary for different stakeholders e.g. employers, employees, duty holders etc?" The control measures and changes to behaviour needed to prevent major hazard incidents have been discussed in earlier sections; this section focuses on research that has been carried out by the major hazard industries to modify, or otherwise influence, safety behaviour.

3.4.1 Relevant Information

3.4.1.1 Behavioural modification approaches

1. One element of the safety culture work is focused on changing workers attitudes towards safety, but it is suggested by some researchers that the causal link between safety attitudes and behaviour is weak (Appendix B, Ref 16). They have focused on behavioural modification approaches to directly target unsafe behaviours in the workplace because it is thought that the link between behaviour and attitudes is much stronger; if you can change behaviour then attitudes follow. The basic features of behavioural modification programmes are: ownership, definition of safe/ unsafe behaviours, training, observation, establishing a baseline, feedback, reinforcement, and goal setting.

2. The importance of these features, to the success of behavioural modification programmes, was reiterated in an example from the construction industry (Appendix B, Ref 30). The key safety issues identified in this paper were:

   - It was found that goal setting was successful in reducing the frequency of unsafe acts and that participatory goal setting was more effective than prescriptive;

   - Ownership of the safety programme was important. It was observed that by allowing individuals whose behaviours would be affected by the changes to engage in target selection and setting, enhanced the success of the intervention;

   - It was noted that when safety policy changes, it could have a profound impact upon staff. The removal of targets resulted in a strong negative correlation with safety behaviours increasing the likelihood of an accident over the long term. It is recommended that any behavioural change strategy be designed to be in place over the long term;

   - Training seemed to have little impact upon frequency of unsafe acts.

3. Further work by Fleming and Lardner, 2002 (Appendix B, Ref 11) provides a review of the effectiveness of behavioural modification programmes. The report draws on previous research, reviews and case studies to show that this approach can be extremely effective in reducing accident rates (note: a wide variation in effectiveness was observed) and leading to

safer behaviour. However, the extent of the accidents that may be influenced is not clear; it seems that behavioural modification approaches may be effective in reducing the occurrence of minor injuries, slips and trips but their effectiveness in reducing major hazard accidents is not yet determined. Indeed, one aim of the work was to look at how behavioural modification approaches could be expanded to the health and safety management system including critical risk control behaviour. The authors acknowledge that,

> *"Within the health and safety context, behaviour modification techniques tend to be used to promote the safety behaviours which will prevent individual members of frontline staff being injured, rather than critical behaviours required to manage major accident hazards effectively."*

4. In the absence of published literature to demonstrate how this might be achieved, the researchers focus on the theory of behavioural modification and how it might be applied to those critical health and safety behaviours that are more difficult to observe such as management actions and leadership. A short summary of one of the examples is included in Appendix B (ref 11).

5. Work to apply behavioural approaches to safety management within reactor plants (Cox *et al* (2004) noted that the behaviour change is intimately tied up with the issues of motivation, attitudes, beliefs, learning and trust but in the management of safe behaviour these constructs are interdependent. In applying behavioural modification approaches they had focused on 'conventional' safety; the examples of specific safe behaviours that are identified in the paper relate to the wearing of PPE and to the Chief Executive's walking too close to the edge of the stage while giving a presentation. They do not relate to nuclear safety (Appendix B, Ref 46).

3.4.1.2 Risk communication

1. There has been a large body of work to consider the effectiveness of risk communication to promote safety behaviour. For example, Ferguson *et al* (2003) explored the influence of the design of HSE risk communication leaflets on the use of ear defenders and manual handling with respect to workers' intentions to follow safe working practices (Appendix B, Ref 7). The key findings of relevance to the question of how to change behaviour are:

   - Workers' intentions to adopt safe working practices were influenced by the usability and usefulness of the risk communication leaflets;
   - Communication design is a very important consideration when trying to influence safe working practice;
   - Risk communication presented as 'positives' was generally more influential on intentions to act than negative frames for the current sample of leaflets. However, there was evidence that prior-exposure to negative health outcomes or past-behaviour influenced the effectiveness of positive and negative frames. This indicates that when targeting specific groups for an intervention, information on their prior-exposure and past-behaviour should be taken into account.

2. Work by Petts *et al* (2002) to develop a methodology to design and evaluate effective risk messages identified 16 generic principles for the design of risk messages (see Appendix B, Ref 12). These included:

- The need to focus not only on what people believe, but why and how they reduce risks;
- The need for risk information to answer key questions – i.e. what can it do to me? How might this happen? How can I protect myself?
- The need to base risk information on what people already know and believe;
- The need to present risk information in lay language and respond to the needs of those whose first language is English.

However, the research looks at the change in perception after the provision of amended risk communication literature, not whether that perception was translated into a change in behaviour.

3. The literature provides mixed messages on the influence of training on changing safety behaviour; generally it is not considered to have a significant impact on unsafe acts (e.g. Duff *et al* 1993 on the Construction Industry). For training to be effective it has to: target specific training needs; be delivered as part of an effective safety culture, which means that the aims of training are agreed before the training is initiated; be subjected to ongoing monitoring of the outcomes; and be regularly evaluated to ensure its value. It can be useful in specific circumstances for example, training in emergency responses (based on simulator training) but performance in these circumstances is influenced by the frequency, realism and detail of the emergency exercises (Larken, 2001).

4. Interestingly, a conference paper on the integration of process safety and personnel safety in Japan reported on how employees had been 'requested to take care' (Saka, 2001). All employees were asked to take responsibility towards safety and accident prevention and to make continuous efforts, with a positive attitude toward that objective in their daily work (Appendix B, Ref 40). There may be value in exploring the concept, however the paper did not report on the results achieved using this approach.

3.4.1.3 Leadership

1. In a review of the literature on director leadership of health and safety, Shearn and Miller (2005) reported the factors known to influence directors' behaviour. These were: compliance with ***legislation***; fear of loss of ***reputation***; the perception that effective health and safety management is ***good for business***; ***health and safety standards*** of other companies; and ***moral responsibility***.

2. The Bomel Consortium, 2003 (Appendix B, Ref 57) also highlighted the influence of other companies on corporate behaviour. They note that an effective route for improvement measures was seen to be through the ***business supply chain*** because customer demands are responded to by businesses.

3. In turn, ***effective leadership*** from senior management (including directors) through to team leaders (supervisors) have been highlighted as an essential part of good health and safety management because of their influence on personnel (see Section 3.2.1.1 Safety Culture).

4. Research by Fleming (1999) for HSE on effective supervisory safety leadership behaviours in the oil and gas industry found that different factors appear to drive safety behaviour (encouraging others to work safely) than drive risk-taking behaviour (taking short cuts). ***Positive safety behaviour*** can be encouraged by ***increasing the status of safety*** on the installation and by supervisors' creating a supportive environment. ***Risk taking behaviour*** can be reduced by ***creating a learning culture*** on the installation and by supervisors'

communicating the importance of safety, setting a positive example and visiting the worksite frequently. (Appendix B, Ref 19).

3.4.2 Key issues identified

1. This literature review did not identify sufficient evidence to provide a conclusive view on the most effective ways to change safety behaviour; it is very likely that more than one approach is needed. There is insufficient information to comment on whether there are different effective ways of changing behaviour for different stakeholders e.g. employers, employees, duty holders etc.

2. The information that is available focuses on three main areas:

   - Behavioural modification approaches that seem suitable for conventional safety in both major and non-major hazard industries. They may even have applicability to safety management systems in both types of industry but they have yet to be validated for this purpose.

   - The key principles of effective risk communication to ensure that safety messages are understood; whether the messages are acted upon are less clear.

   - The role of safety culture, particularly the role of managers because of their ability to influence organisational culture and personnel safety behaviour;

3.4.3 Quality of the evidence base

1. The research to determine the most effective ways to change safety behaviour is limited; much of the research has focused on individual behaviours. For example, there is noteworthy research into behavioural modification techniques providing evidence that they can work with the right structure, approach and context. There is also a body of evidence looking at how information is effectively conveyed, and some of this has focused on the communication of risk.

2. Research into behavioural changes at the organisational level is lower quality, being restricted to how to foster effective leadership and do not seem to address how to make wider organisational changes, other than via positive safety culture. Fleming and Lardner (2002) note that work to explore the potential of behavioural modification approaches in safety management systems is underway but this review did not identify any published findings on their realisation. Further work could investigate how appropriate the progression into the major hazards context has been.

3. It seems that more specific information about the behaviours that need to be changed is essential before the best approaches for modifying that behaviour can be determined. There is some information available about the various techniques and approaches to organisational and individual learning that could be applied once the behaviours have been identified but this also needs further investigation; the evidence base is not robust.

3.5 IMPACT OF ORGANISATIONAL CHANGE FACTORS ON EFFECTIVE RISK CONTROL AND SAFETY MANAGEMENT

1. An additional question raised by HSE was, “Is there any evidence that organisational change factors e.g. outsourcing, and changes to the size of organisations can impact on effective risk control and health and safety management? If so, how can these risks be reduced or managed?” This is an issue that is of relevance to all of the major hazard industries.

3.5.1 Relevant Information

1. A literature review was the first of three pieces of work for HSE on the effects of business re-engineering, aimed at considering whether organisational changes did have an effect on industrial health and safety (Appendix B, Refs 26, 27 & 28). The review did not identify any formal research that explicitly examined the wider effects of reorganisation on health and safety, such as the impact on major hazard safety. It was concluded, however, that there are examples where reorganisation has contributed to major accidents involving multiple fatalities. It was also noted that reorganisation can be a stressful process and suggested that health and safety standards can be affected in both positive and negative ways.

2. In follow on work, a best practice model of business re-engineering and health and safety management was developed (Appendix B, Ref 28) and offered as a means by which the unforeseen effects of organisational change may be mediated. The model involves the development and application of issue identification skills, followed by change impact analysis and subsequent performance review. The study recommends,

   “… the level of risk inherent in each task should dictate reach, proliferation and source of rules. For example, for low risk tasks it is recommended that there be minimal supervisory control with an emphasis placed upon the individual to identify and implement safety rules and behaviours. However, if the task is identified as high risk, the level of supervisory control should increase relative to risk level and with it the degree of behavioural automation”.

3. The study also recommends that senior management should be responsible for implementing a health and safety strategy that recognises and reflects the impact that organisational change can have of safety levels. Although the study cites examples of accidents that have occurred post organisational change there is little statistical evidence to support this supposition.

4. The third piece of research on business re-engineering and health and safety management, considers case studies from a range of industries that have been through or continue to go through organisational changes, including: rail, power, chemical, nuclear and aviation. The report includes learning points and examples of what makes for effective H&S management during change, points which overlap with HS(G)65 (HSE, 1997). The points emphasised indicate that the management of organisational change requires the same attention as the safety management system for normal and emergency operations; it is important to recognise at an early stage that any organisational change can have the potential to impact health and safety management.

5. This finding is supported by work in the nuclear industry by the Nuclear Energy Agency, Organisation for Economic Co-operation and Development (2004), who report that

modifications at nuclear power plants are controlled through the use of written procedures. Large modifications are generally found to lead to fewer health and safety problems than smaller ones because they are given more attention and resources, recognising that there may be a major hazards impact on health and safety. Smaller modifications can be more problematic because they are less likely to be recognised as a potential safety issue.

6. Work by Weyman *et al* 2004 (Appendix B, Ref 4) looking at the organisational dynamics and safety culture in the UK rail industry, commented on the perceptions of rail staff following privatisation. Initially, it was characterised as a period of general upheaval, uncertainty and confusion, particularly with respect to roles and responsibilities. This blurring of responsibilities has the potential to result in accidents because of the potential for both inter-organisational communications problems as well as a lack of priority being given to safety. Participants in the study reported that the performance regime, which resulted from privatisation, tended to induce sector businesses to focus on partisan interests that acted to the detriment of the integrated operation of the network. The focus on performance and the attribution of blame to underperformance was widely considered to run counter to the establishment of harmonious relationships between the rail sector businesses.

7. Research for HSE, by Henderson *et al* (2002), considered management of change issues associated with the remote operation of process plants. They note that many companies focus on the technical control elements of such changes and neglect consideration of the human factors issues associated with this change. The work provides a list of benefits and problems (see Appendix B, Ref 10) associated with changes to remote operations; many of the principles are transferable to other industries. For example, reduced manning levels can mean reduced costs but also create potential problems due to increased workload and difficulty covering sickness and absence.

8. Notably, none of the sites attributed potential accidents to the organisational change problems they had encountered, but the literature shows they are likely to be contributory factors. The paper also lists the potential impacts of change based on a survey of companies and case studies, for example,

   - New automatic safety systems resulted in over reliance at one plant because the operators believed the system would protect them. However, the automatic system had activated and resulted in a drum being filled with liquid that was not discovered until some days later;

   - With more work areas, operating teams did not always have a broad enough experience base to consistently cover every work area;

   - Management concentrated on production issues surrounding the new product and had not appreciated the impact of installing the new control system; insufficient training had been provided for the operating system.

9. Work by Keeley (2005) to examine the underlying causes of past incidents from the nuclear, offshore, gas and chemical industries identified the management of change along with other factors such as maintenance procedures; operating procedures; assessing competence; plant inspection; plant and process design; and risk assessment (Appendix B, Ref 50).

10. Finally, a paper presented at conference by Fryman (2001) (Appendix B, Ref 42) reported on the successful management of change at a chemical processing plant that had faced almost constant changes in the previous last two years due to demands for cost reduction. Key to the successful management of the process was the development of management of

change guidelines for changes in key safety job tasks. The steps for the Management of Change Guidelines for Key Safety Job Tasks are listed as:

- Inventory of key safety job tasks for the current job;
- Inventory of key safety job tasks for the new/revised job;
- Undesirable impacts of changes in the key safety job tasks for new/revised job;
- Action tracking;
- Post change review.

11. When defining job tasks, they developed not just a job description or major area of responsibility but also the key job tasks (e.g. leading Hazard & Operability, HAZOP studies, tracking open action items, scheduling the reviews etc), ensuring that staff had awareness of their new responsibilities, had the competency to meet those responsibilities but also had the time to fulfil their new responsibilities.

3.5.2 Key issues identified

1. The literature reviewed does not contain evidence of a strong link between organisational change, health and safety issues and accidents but there is circumstantial evidence from case study examples to indicate a link. Therefore, major hazard industry should consider change as part of their management of health and safety until evidence can be found to prove otherwise. The management of health and safety during times of organisational change should be via the safety management system and effective management comes from having plans and risk assessments in place, developed with employee involvement, and communicated to the workforce.

2. It is noted that when making changes there is often a tendency to focus on the changes to technology and neglect to appreciate potential detriment to human factors issues. There is also a need to be aware of implications of small-scale modifications to sites, as well as the large ones.

3. An example from the rail industry highlights the characteristics associated with organisational change and potential incidents, this includes: general upheaval, uncertainty and confusion among staff, particularly with respect to roles and responsibilities. Another example, this time from the chemical process industry shows how change can be managed well.

4. The literature reflects awareness that organisational change can have a detrimental effect on health and safety if not managed correctly, but that change can also be an opportunity to improve.

3.5.3 Quality of the evidence base

1. There is a vast and well established literature available on the theory and practical implementation of organisational change, that has not been included in this literature review, the general principles of which can be applied to the major hazard setting. However, there is little evidence linking change to accidents and this is circumstantial; it is

not clear whether the intuitive view, that change is associated with accidents, can be substantiated.

2. A better understanding of the association between organisational change and accidents is needed. It is also not clear whether something beyond the principles of effective safety management is needed to control health and safety during times of organisational change in major hazard industries.

3.6 ADDITIONAL REQUIREMENTS FOR PREVENTING MAJOR HAZARD INCIDENTS

The literature review was also to consider whether there are additional requirements for preventing major hazard incidents beyond those for "ordinary" health and safety incidents?

3.6.1 Relevant Information

1. As noted in Section 3.2.1.2, the principles of successful health and safety management systems are applicable to all organisations but *"the extent of action required will vary with the size of the organisation, the hazards presented by its activities, products or services and the adequacy of its existing arrangements."* (Appendix B, Ref 24). Therefore, it might be expected that there are differences between how major hazard installations manage risk compared with other industries (e.g. differences in the level of detail and degree of quantification needed in risk assessments). This review, however, did not identify any papers that explicitly considered the issue.

2. Generally, the literature on the control of human factors in the major hazard industry points to a focus on organisational factors more than individual behaviours, while the non-major hazard sectors seem to focus on changing individual behaviours, through techniques such as behavioural modification. Behavioural modification approaches, which have been demonstrated to be influential in reducing the occurrence of minor injuries, slips and trips in, for example, the construction industry (Duff *et al* 1993) and in the nuclear industry when focused on 'conventional' safety such as the wearing of PPE (Cox *et al* 2004), do not seem to have been applied and tested for the management of safety systems.

3. A paper presented at conference by Kiyotsugu Saka (2001) (Appendix B, Ref 40) on the integration of process safety and personnel safety in Japan suggests a different point of view and states that,

   > *"Poor process safety and poor personnel safety is a common combination. One does not see a company with good process safety and poor personnel safety, or vice versa. It is because they are under the same management. A strong occupational health and safety management system will help in promoting both safety issues"*

4. The paper reports on a Zero Accident Campaign that began 25 years ago to tackle personnel injuries when all employees were 'requested' to take responsibility toward safety and accident prevention and to make continuous efforts with a positive attitude toward that objective in their daily work. The paper refers to a set of tools for employers and employees called 'Finger Pointing and Call' but it does not provide any details.

3.6.2 Key issues identified

1. The literature search did not identify any papers that explicitly addressed the issue of whether there are additional requirements for preventing major hazard incidents beyond those for "ordinary" health and safety incidents. The principles of successful health and safety management systems are applicable to all organisations but major hazard installations are likely to manage risk differently to other industries, because of the potentially high consequences of failure. It seems probable that major hazard industries focus on organisational factors more than individual behaviours, while the non-major hazard sectors seem to focus on changing individual behaviours. This may be because individual unsafe behaviours are less obvious in the context of a nuclear processing plant compared with a construction site, for example.

3.6.3 Quality of the evidence base

The literature search did not identify any targeted research to address the issue of whether there are additional requirements for preventing major hazard incidents beyond those for "ordinary" health and safety incidents. One way to explore this issue would be to correlate conventional safety accidents with more serious (e.g. nuclear safety) accidents, if there is a correlation between the two, this would suggest that the methods used to control and modify conventional safety would also be applicable to major hazard safety.

3.7 UTILITY OF CURRENT REPORTING SYSTEMS TO IDENTIFY PROBABLE CAUSES OF MAJOR HAZARD INDCIDENTS

1. Major hazard incidents are generally reportable under either the Reporting of Injuries, Diseases and Dangerous Occurrences Regulations (RIDDOR, 1995) if they involve significant injuries or fatalities, or meet the classification criteria for dangerous occurrences or gas incidents, or under the Control of Major Accident Hazard Regulations (COMAH, 1999 & as amended by the COMAH (Amendment) Regulations 2005) for sites that come under these regulations due to the quantity, type of storage and nature of hazardous substances present on the site.

2. In this review, limited research has been identified that explores the issue of the utility of current reporting systems to identify the probable causes of major hazard incidents. HSE CRR 81, 1996 (Appendix B, Ref 25) includes accident summaries, and notes that, while there is little detail in the accident reports to identify underlying causes, as the reports generally focus on the immediate causes, some conclusions can nonetheless be drawn. In particular, it is possible to determine the main human factors issues that are identified as causal factors in a number of accidents. These included: maintenance errors; inadequate procedures; inadequate job planning; inadequate risk assessments; inadequate training of staff; unsafe working condoned by supervisors/managers; inadequate control and monitoring of staff by managers; and inadequate monitoring of contractors working on site.

3. A number of previous studies by HSL concerned with the analysis of accident causation in non-major hazard industries had generally similar findings. Previous HSL research involving detailed examination of RIDDOR reports has been carried out in a number of different sectors including: the paper industry (Horbury and Bottomley, 1998); the rubber industry (Bottomley, 1998); the foundries industry (Dickety *et al*. 2002); and the food retail

sector (Dickety, 2001a). A similar methodology was also used in a study to identify causative factors of workplace transport accidents (Dickety, 2001b). A common finding of all these studies was that the presence of causal information (including both immediate and underlying causes, but particularly in relation to underlying causes) in the accident reports was generally very limited. However, in spite of this, the analysis and interrogation of aggregate accident/incident data made it possible to generate detailed accident profiles, identify some underlying causes, and identify themes and trends in accident causation. It was possible to identify causal factors from analysis of groups of accidents that would not be apparent from separate analysis of individual incidents in isolation (Gadd *et al*. 2005).

4. Other relevant HSL studies in non-major hazard industries have been concerned with exploration of other issues affecting the quality of reported information. Two significant problems that need to be taken into account when carrying out analysis of accident data are under-reporting and Standard Industry Classification (SIC) mis-classification (Gadd *et al*. 2005). Under-reporting is a problem in many sectors of industry, and this is significant, since, if reporting levels are low, the accident data will not provide the full picture of accidents that have occurred and analysis of such data may be of limited use in determining the real problem areas (Gadd *et al*. 2005). Analysis of accident data is also made less accurate as a result of SIC mis-classification, although the extent to which this is a problem in the major hazard industries is not known. Studies including analysis of either levels of reporting or problems with SIC mis-allocation and the implications for estimating accident rates have been carried out by HSL in the following sectors: the paper industry (Horbury and Bottomley, 1998); the cotton industry (Collins and Bottomley, 2001a); the clothing industry (Collins and Bottomley, 2001b); the manufacturing sector (Daniels *et al*, 2006); and the services sector (Daniels *et al*, 2006).

5. The strength of the current reporting systems appears therefore not to be in the quality of the information that is captured on individual incidents, but in the opportunity they provide for subsequent analysis and interrogation of aggregate accident/incident data, as this enables greater understanding of accident causation. The benefits of the analysis and interrogation of aggregate accident data would be even greater if the quality of the reported information was improved.

6. To have maximum utility, an effective reporting system would encourage reporting (resulting in low levels of under-reporting), and would capture causal information (including both immediate and underlying causes) in a consistent format that is readily searchable and retrievable (Gadd *et al*. 2005).

3.8 WHERE HSE SHOULD TARGET ITS RESOURCES

1. HSE asked the question, “Where should HSE target its resources to have the most impact e.g. at which levels of an organisation should you try to influence to have the most impact on behaviour?” The literature search did not identify any relevant literature to specifically help address this question, or on the style of interventions needed to prevent major hazard incidents, to allow conclusions to be drawn. The only evidence to emerge came from the review of director leadership on health and safety; here it was found that compliance with legislation, fear of loss of reputation and health and safety standards of other companies was influential in relation to directors' behaviour (Shearn and Miller, 2005). Similarly, O’Dea, and Flin’s (2003) review of leadership in determining workplace safety outcomes stated that their results:

"…have important implications for government safety policy, they reject the notion that current regulatory mechanisms are ineffective in motivating corporate governance of safety and confirm the notion that the motivation to achieve good health and safety standards are linked primarily with regulatory requirements and that government regulations are necessary in order to protect employees against excessive levels of workplace risk"

2. However, a number of previous studies by HSL have been identified that include consideration of interventions for the prevention of non-major hazard incidents. This includes: studies to investigate the underlying causes of accidents in various manufacturing industries (paper, rubber and foundries) in order to inform the setting of targets and strategies for accident and ill-health reduction (Horbury and Bottomley, 1998; Bottomley, 1998; and Dickety *et al*. 2002); an analysis of slip, trip and fall accidents in the food retail sector (Dickety, 2001a); and a study to identify causative factors of workplace transport accidents (Dickety, 2001b).

3. The extent to which the interventions for prevention of non-major hazard accidents suggested in these studies would also be appropriate for the prevention of major hazard accidents is difficult to determine. In some cases, the suggested interventions are either sector specific or very much focussed on occupational health and safety problems, and hence may not have much relevance to the control of major hazards. In other cases, the suggested interventions are more general in style, and may have wider applicability. For example, Dickety *et al*. (2002) identified the need for increased supervision, extra training, better maintenance management and better management of production pressures. A number of practical steps for improving the overall safety culture within foundries were also outlined. The findings from Horbury and Bottomley (1998) were broadly similar. In this research, the following areas were identified as contributing to a good safety culture and low accident rates: good supervision; the capability to stop production if a situation is deemed unsafe; compliance with procedures; operators prepared to tackle unsafe behaviour by others; and management addressing safety at a strategic level within the production dynamics.

4. Consultation with HSL colleagues on the question of where HSE should target its resources, suggested that HSE Inspectors (or other specialists) could be encouraged to act as agents of change for industry. Often where interventions have been attempted by industry they are ineffective because they are initiated by the safety specialists and may not have the necessary level of management support. (The importance of leadership and management ownership of issues in influencing safety culture and behaviour of employees has been highlighted in this review.) If HSE could facilitate the progression of initiatives by encouraging the organisation to implement, follow through and evaluate interventions this could increase the likelihood of success. A suggested approach was to carry out safety culture audits because, while the available audit tools may be less than optimal, they can indicate an agenda for future development on a range of criteria relating to HSE interest. This agenda could then be used to engage with stakeholders to identify what interventions are required to improve.

5. HSE may benefit from developing a better measure of safety culture, one that could look at health as well as safety and would be free for use by the HSE Inspectorate and Industry, alike.

6. It is also suggested that recommendations with respect to the most effective styles of intervention for the prevention and control of major hazard accidents could be determined through a 'stakeholder consultation' exercise. Such an exercise could be used to collate the

suggestions and experiences of human factors specialists within HSE (and ORR) as to: what intervention tools are currently available and being used; what sorts of interventions have been observed to work in practice; what other sorts of interventions are considered likely to work; and whether there are differences in the sorts of interventions that are effective in different situations, and the reasons for any differences. This is a suggested next step for HSE research.

4 CONCLUSIONS

4.1 THE EXISTING EVIDENCE BASE

4.1.1 Underlying causes of major accidents and associated control measures

1. There is significant information about, and common agreement on, the probable and underlying causes of major accidents and incidents in major hazard industry. The evidence comes from extensive and detailed investigations of major accidents, along with the analytical studies of smaller scale incidents to look for common causes. Many of the major accidents have been analysed, and re-analysed by researchers to be presented as case studies for model accident causation theories and to develop investigation approaches. Such approaches are presented in good quality papers and books on accident investigation by respected authors.

2. Similarly, there is an extensive, good quality evidence base for the control measures needed to prevent major hazard incidents; much of the knowledge is based on accident investigations and establishing what, if done differently would have prevented the accident (Section 3.2). Safety culture has become the central focus of this work and there is a substantial body of literature exploring the link between safety culture and accidents. The assessment tools that are based on this knowledge show that it is possible to identify areas for improvement in safety culture and even to predict accident rates. The importance of an effective safety management system as part of the general safety culture has also received considerable attention and one excellent example of good management practice was found in the literature search (Section 3.2.1.6).

3. While the theory behind the causes of accidents and how to prevent them is comprehensive, the translation of this theory into practice is lacking. Therefore, evidence to show that application of this knowledge will prevent accidents, is also lacking.

4.1.2 Behaviours associated with major accidents and how to change them

1. The literature search suggests that there are behaviours that need to be changed in all the major hazard industries, but there is insufficient evidence to draw any conclusions about what those specific behaviours are, or how this is different (if at all) between hazardous industries. Evidence from an excellent, comprehensive study of the rail industry shows that, while there is awareness of best practice, the application of that theory is variable, and front line staff question senior management commitment to safety.

2. The need to reduce the likelihood of non-compliance and violation behaviour is also clear, and like most of the unsafe behaviours associated with accidents, a positive safety culture and effective safety management system seem likely to be influential in achieving compliant behaviour.

4.1.3 Organisational change and major accidents

1. The literature reviewed did not provide evidence of a strong link between organisational change, health and safety issues and accidents but there was circumstantial evidence from

case study examples to indicate a link. Therefore, change is an issue for the management of health and safety by major hazard industry and should be part of the safety management system. There is a tendency for organisations to focus on the changes to technology, to fail to appreciate potential human factors issues, and to disregard smaller changes.

4.1.4 Additional requirements for preventing major hazard incidents

1. The literature search did not identify any papers that explicitly addressed the issue of whether there are additional requirements for preventing major hazard incidents beyond those for "ordinary" health and safety incidents. Generally, the literature on the control of human factors in the major hazard industry points to a focus on organisational factors more than individual behaviours, while the non-major hazard sectors seem to focus on changing individual behaviours, through techniques such as behavioural modification. The principles of successful health and safety management systems are applicable to all organisations but major hazard installations should manage risk differently to other industries. The potentially high consequences of failure mean that an increased level of detail and degree of quantification needed in risk assessments is needed by major hazard industry.

4.1.5 Overall quality of the existing evidence base

1. A significant proportion of the research, included in this review, comes from applied research and review papers commissioned by the HSE. Such work was, for example to identify contemporary views on the topic or to design assessment tools for use by HSE Inspectors. Therefore, while this work is of good quality, little empirical peer reviewed research has been considered directly and a critical analysis of the issues, theories and principles was not possible.

2. Due to the complex and intangible nature of topics such as safety culture, safety behaviours, and management influence, the majority of the research reviewed is based on small-scale questionnaire studies, case studies and in-depth, qualitative studies. This has resulted in a significant amount of good quality research, and information that has potential to be applied to other industries. However, there are problems applying this apparently specific knowledge to other industries and circumstances; therefore, further research is required to demonstrate the applicability of knowledge across industries.

4.2 POSSIBLE GAPS IN THE EVIDENCE BASE AND SUGGESTIONS FOR HOW THEY COULD BE ADDRESSED

1. Despite the thorough approach to the literature search, it is recognised that this review may not be fully comprehensive and some gaps may exist. It is also recognised that the review is limited by focusing on publicly available information; there may be work in progress by, and on behalf of, the HSE Offshore, Nuclear and Hazardous Installations Directorates that is not included. The implications of initiatives such as 'LearnSafe' and 'Step Change' also have not been considered. It is, therefore, recommended that any knowledge gaps suggested by this report be verified by consultation with appropriate HSE representatives. Further, there are a number of subject matter experts who could meaningfully contribute to the discussions.

The following are suggested for further consideration:

a) ***Underlying causes of accidents*** – If consistent and accurate data about the underlying causes of accidents were to be collected, both via HSE reporting systems and internal company systems, a better understanding of the accidents and how to prevent them, could be developed. Further work could then explore whether there are additional requirements for preventing major hazard incidents beyond those for "ordinary" health and safety incidents.

b) ***Application of knowledge*** – Exploration is needed to understand how the principles of safety culture can be made more accessible, in order to turn theory into practice and support real managers (those who need to implement changes) in real situations. Current work by HSL for HSE to explore the barriers to learning lessons may go some way towards addressing this point (Keeley *et al*, work in progress). The success of the safety culture toolkit, which was developed for the rail industry (2005), could be evaluated and the concept expanded to other industries.

c) ***Interventions -*** Work is required to understand what interventions have been applied, how effective they have been and the context in which they work. The lack of literature on what has been applied to prevent major hazard accidents also suggests that evaluation work has not been carried out; this should be linked to any work to implement interventions. An analysis of the interventions that have been applied in non-major hazard industry could identify those appropriate for application to the major hazard sector.

d) ***Identifying unsafe behaviours and establishing any differences between industries*** – The specific behaviours that need to be modified are not obvious. If the specific behaviours are understood then consideration could be given to appropriate methods of changing behaviour. Linked to this is the need to understand whether there are differences between major hazard and non-major hazard industries. One way to explore this issue would be to correlate conventional safety accidents with more serious (e.g. nuclear safety) accidents, if there is a correlation between the two, this would suggest that the methods used to control and modify conventional safety would also be applicable to major hazard safety.

e) ***Approaches to modifying behaviour*** – The effectiveness of behavioural modification approaches in reducing major hazard accidents, for example through safety management systems is not yet determined. Work to explore the potential of behavioural modification approaches in safety management systems is thought to be underway (see Fleming and Lardner, 2002 Section 3.4.1.1) Follow up work to establish the findings and to investigate how appropriate the progression of behavioural modification has been to safety management systems in major hazard industry may be useful.

f) ***Understanding the implications of organisational change -*** A clear understanding of the association between organisational change and accidents is lacking. However, it is unlikely that something beyond the principles of effective safety management is needed to control health and safety during times of organisational change in major hazard industries. It is also extremely difficult to establish what constitutes an organisational change for the purposes of research; change is often ongoing and influenced by other factors. For these reasons further research in this area is not a priority.

g) ***Cost benefit analysis*** – Research to understand the costs and benefits of major hazard interventions is required. It is suggested that industry be encouraged to build this sort of analysis into new interventions, as part of their review and monitoring process because retrospective analysis is extremely difficult to do accurately.

4.3 RECOMMENDATIONS FOR HSE INTERVENTIONS

1. The literature search did not identify any relevant literature specifically concerned with how HSE should target its resources, or the style of interventions needed to prevent major hazard incidents, to allow conclusions to drawn. The only conclusion that can be drawn from the literature is the need for continued influence at the director level, because there is good evidence from two comprehensive review papers of the importance of the director leadership role on health and safety, and the positive effect that Government legislations has on achieving health and safety standards.

2. A number of previous studies by HSL have been identified that include consideration of interventions for the prevention of non-major hazard incidents. The extent, however, to which the interventions for prevention of non-major hazard accidents suggested in these studies would also be appropriate for the prevention of major hazard accidents is difficult to determine. It is recommended that the appropriateness of these interventions be explored.

3. One suggestion is that HSE Inspectors (or other specialists) could be encouraged to act as agents of change for industry. If HSE could facilitate the progression of initiatives by encouraging the organisation to implement, follow through and evaluate interventions this could increase the likelihood of success. A suggested approach was to carry out safety culture audits because, while the available audit tools may be less than optimal, they can indicate an agenda for future development on a range of criteria relating to HSE interest. This agenda could then be used to engage with stakeholders to identify what interventions are required for the organisation to improve.

4. HSE may benefit from developing a better measure of safety culture, one that could look at health as well as safety and would be free for use by the HSE Inspectorate and Industry, alike.

5. It is recommended that the next step for HSE should be to consult with the HSE Offshore, Nuclear and Hazardous Installations Directorates, relevant stakeholders and subject matter experts to gain an understanding of what interventions might be appropriate. The consultation should be designed to look at what they think works, what does not work, what needs to change and what they think could work. The consultation could also be widened beyond the issue of interventions, to consider what other research might be beneficial and would compliment ongoing work.

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6 APPENDIX A: MAJOR ACCIDENT CASE STUDIES

The following case studies were compiled with the aim of highlighting ***some*** of the common contributory factors attributed to major accidents. Due to time and resource constraints the original incident reports were not consulted; the case study information was collated from accident investigation textbooks and research papers that provided an analysis of each accident. The case studies, therefore, do not represent a comprehensive account of all aspects of the incidents and focus on the human and organisational factors associated with each incident.

6.1 OFFSHORE

6.1.1 Piper Alpha Explosion

6.1.1.1 Summary

In 1988, an explosion and subsequent fire on a North Sea oil and gas platform resulted in 167 people being killed.

During the day shift, staff had removed a pressure safety valve from the relief line of the pump. The valve had been replaced with a blank flange. The blank fit was not tight enough, and when unaware night shift staff then attempted to restart the pump, condensate (light oil) leaked through, causing the explosion (Reducing error and influencing behaviour HS(G) 48).

6.1.1.2 Primary causes

The flange placed over the valve was a temporary measure and was inadequate to deal with operational gas pressures. Staff in the control room were unaware of any work that had been done in this area, as the Permission To Work (PTW) certificate had been lost. They subsequently activated the valve and caused a massive system pressure overload. Condensate escaped from the piping and ignited causing a large explosion.

6.1.1.3 Underlying causes

A combination of basic communication failures, occurring at shift handover, and a lack of commitment to the permit-to-work system (concerning the valve maintenance), resulted in the night shift staffs' ignorance regarding the valve removal.

These failures and weaknesses had been identified during previous inspections, and subsequently judged to have been improved, signifying that the regulatory processes employed were inadequate.

As Piper Alpha was never designed to pipe gas as well as oil, the new gas pipes were installed wherever there was room. Unfortunately, the lines affected by the explosion were located next to the control room and the resultant explosion rendered essential disaster management impossible. Although the emergency stop button was pressed, no alarm was sounded throughout the rig and the fire suppression system was never activated. The deluge system that pumped water from the sea into sprinklers located throughout the station could only be activated from the control room as it was switched off to allow divers to work below the rig. The fire spread unchallenged and eventually ruptured a gas riser causing a massive explosion that engulfed the whole platform.

Inadequate fire containment and corroded sprinklers on the gas platform, along with the associated difficulties in escaping or evacuating the North sea platform meant the lives of rescuers were also at risk in the incident.

The emergency procedures specified staff were to congregate in the galley area in the event of an incident. The lack of any alternative announcements resulted in staff making their way there. Unfortunately, the accommodation area was in the direct path of the resultant fireball, and many staff members, who followed the emergency procedures, died.

6.1.1.4 Reaction and Going Forward

The company that owned Piper Alpha, Occidental Petroleum Caledonia (OPC), issued multiple statements in the immediate aftermath of the accident. In each they referred to their excellent safety record to date and outlined that Piper Alpha had been signed off as safe. As the investigation continued it became obvious that, although Piper Alpha had indeed been inspected, its approval was a damning indictment of the inspection system rather than a certificate to ensure worthiness.

The Cullen enquiry made a number of sweeping recommendations to the offshore industry, all of which were accepted. As a result of good will and an acceptance of the need to change the industry also became a test bed for human factors and safety research allowing development of safety culture surveys. Most significant organisational safety culture measurement tools have, in part, been developed on the work completed through partnerships between researchers and the offshore industry. The offshore industry body is also participating with the HSE to develop 'Stepchange', a policy that aims to reduce the number of accidents taking place on rigs and in refineries. An interesting element of this is the accident and near miss reporting system developed online that allows individuals to log incidents with or without personal information being made public.

6.1.2 The grounding of the Exxon Valdez

In March 1989, whilst changing course to avoid iceberg fragments, the steel hulled oil tanker the Exxon Valdez went aground on Bligh Reef, emptying its cargo of 37,000-tonnes of crude oil, and contaminating 149 kilometres of coastline.

Although no humans were killed by the incident, thousands of animals and organisms perished instantly, whilst many others died over the following time period. Meanwhile fishermen, property owners, businesses and communities were also negatively affected by the spill.

6.1.2.1 Primary causes

The tanker did not change course in enough time, and went aground on Bligh Reef, rupturing the hull of the tanker.

6.1.2.2 Underlying causes

It is unclear whether the tankers' late change in course is attributable to the Captain giving the delayed command to alter the tankers course, or the Third Mates' delay in taking action. However, inadequate/unclear communication is clearly evident (as opposed to navigational errors.) An inadequate safety culture was identified showing prevalence for excessive drinking of alcohol among crew (including before a shift).

6.1.2.3 Interventions

- Key changes included requiring double-hulled tankers and installing better vessel-tracking systems. However, this has itself introduced problems, such as those associated with how to inspect double-hulled tankers.
- Reduced crew work hours.
- Crack down on alcohol use and improved tug escorts.

6.1.3 The sinking of 'The Herald of free enterprise'

6.1.3.1 Summary

In 1987, a car ferry, the 'Herald of Free Enterprise' overturned killing 188 people when it was allowed to leave port, despite a failure to ensure the bow doors were properly secured.

Water began entering the car deck, filling quickly due to a combination of the internal shape and size and a lack of bulkheads. Despite the calm sea, the influx of water quickly affected the ship's stability, until eventually the ship capsized, (Reason, 1990; Reducing error and influencing behaviour HS(G) 48)

6.1.3.2 Primary causes

Due to a sequence of failures, the Herald of Free Enterprise was allowed to leave port with both her inner and outer bow doors open. The crewmember responsible for ensuring closure of the bow doors was absent from his post as the ferry left port. There were no other indicators as to the status of the bow doors.

6.1.3.3 Underlying causes

Poorly organized shifts in combination with a lack of staff monitoring meant that the crew were unaware that the member responsible for ensuring the bow doors were securely closed was absent from his post; reportedly asleep, or that his assistant had not assumed his role.

Requests had been made for bow door warning indicators to be installed on the bridge, so that the status could be checked from this remote location. Despite these requests, no such indicators were installed.

The car ferry was poorly designed, with its top-heavy structure and inadequate means of removing water from the flooded deck. There was also the significant omission of bulkheads, resulting in the shift in the ferry's stability.

Management failed to emphasise safety adequately, instead pressuring crews to sail early. In order to speed operations up, safety was likely to be compromised, as crew members were likely to follow procedures inaccurately.

A ‘negative reporting’ policy was also employed. This meant the crew were to assume that all was well unless anything was heard to the contrary. A positive reporting policy should have recognised the status of the bow doors, potentially preventing this incident.

6.2 NUCLEAR

6.2.1 Three Mile Island Radioactive Leak

6.2.1.1 Summary

In March 1979, during maintenance work on the turbine in one of two pressurised water reactors, water was introduced to the instrument air system. The leak, approximately one cupful of water, affected the air pressure of the valves connecting to the feed water pumps, causing them to shut down. The loss of the pumps’ action resulted in reduced water flow to the steam generator, tripping the turbine.

Heat from the primary cooling system could not be transferred to the secondary system following loss of the pumps’ action. Emergency feed water pumps were automatically activated, circulating water from an emergency storage tank into the secondary system. However, this system failed due to closed valves erroneously left shut during earlier maintenance work.

The heat of the reactor core increased as the cooling system failed. Hundreds of alarms were activated that were visible to the control room operators. A further automatic safety device was activated ‘scramming’ the reactor. The resultant decaying radioactive materials continued to produce heat, further increasing core temperature and pressure.

In response to the increased pressure, a power operated relief valve (PORV) was opened to release water through the plant’s pressuriser. The PORV was supposed to flip closed following the pressure relief. However, the PORV failure to automatically close following recovery from a reactor trip was not recognised by operators, therefore delaying recognition of the extent of the plants situation (Reason, 1990; HS(G)48; www.nrc.gov/reading-rm/doc-collections/fact-sheets/3mile-isle.html).

6.2.1.2 Primary causes

The panel display showing the relief valve switch of the pressuriser as selected ‘closed’ was displaying incorrect information. The valve was stuck open, but operators, despite the switch only activating the opening and shutting mechanism of the relief valve, did not consider the possibility that display information was incorrect. The display was, therefore, unable to communicate information resulting from the independent failure of this mechanism, thereby delaying the plant recovery time.

6.2.1.3 Underlying causes

Two days before the incident, the feed water storage tank valves had been left closed during routine maintenance operations. Although this was recognised as occurring previously, no steps had been taken to prevent recurrence. This caused considerable damage to the reactors radioactive core by preventing the cooling of the plant’s core temperature and pressure.

Inadequate control room instrumentation meant operators commonly deduced the level of coolant in the core using the readings from other instruments. Operators also failed to recognise that the relief valve on the pressuriser was open.

Numerous operators also failed to read the core temperature accurately, therefore failing to realise the true extent of the plant's situation for a further two hours. Only when a replacement shift supervisor arrived were the true readings accurately interpreted.

Automatic implementation of the first safety system (i.e. the tripping of the turbine) was not enough to render the plant safe. It simply solved one problem, whilst simultaneously causing a secondary set of abnormal circumstances, in this instance the lack of pumps resulted in the overheating of the reactors core.

Inadequate training of operators in the suitable emergency response meant they were unable to respond appropriately to the unplanned automatic shutdown of the reactor.

6.2.2 Chernobyl

6.2.2.1 Summary

In 1986, whilst testing on the fourth reactor (of four) of a nuclear plant, numerous operators and electrical engineers disregarded safety procedures and disabled successive safety mechanisms in order to meet their local objective, testing a new voltage generator.

The lack of safety systems, in combination with the testing occurring whilst the reactor was run on low power resulted in a loss of control over the chain reaction in the reactor. As operators took action to shut the reactor down, a peculiarity in the design caused a power surge. A steam explosion and a fireball ensued, blowing the heavy steel and concrete lid off of the reactor, breaching containment.

A small amount of the reactor core was released, contaminating the atmosphere with radioactive material. Thirty people died instantly, and over a hundred thousand had to be evacuated from the surrounding areas. (Reason, 1990; Kletz, 1993; HS(G) 48)

6.2.2.2 Primary causes

Although the incident was the accumulation of seven unsafe acts, the most notable was when operators incorrectly decided to continue the testing of the voltage generator when the power level fell below acceptable outputs, despite this being strictly against procedure.

6.2.2.3 Underlying causes

The characteristics of the reactor meant it was particularly unstable at low power, leading to runaway reactions. Despite it being strictly against procedures for the reactor to be run at below 20% power, operators made the decision to disable the appropriate safety systems in order to continue testing.

The presence of a poor safety culture prevented known defects in the safety system, such as the peculiarity with the reactor design from being redesigned or improved. This resulted in operators continuing with testing activities despite the power level falling due to another error.

This could also account for the testing task itself, which was considered likely to initiate non-compliance to procedures.

The development of the incident was facilitated by operators whose actions, including disarming the plants safety mechanisms, were due to inadequate training, and resulted from their lack of knowledge regarding the plant's inherent design flaws.

The lack of an adequate 'containment structure' also contributed to the extent of the effect following the disaster. The radioactive material was able to travel, contaminating numerous other countries as well.

Unbeknown to the plant operators, a design flaw in that specific type of reactor meant that the nuclear reaction was liable to speed up, as a result of the internal environment of the reactor. This was exaggerated when the reactor was running at a low power output, making the reactor unstable and highly dangerous.

6.2.2.4 Reaction and Going Forward

The IAEA Chernobyl accident investigation report provided the first use of the term safety culture to describe an umbrella of organisational and human factors that relate directly to the relative safety of an institution or organisation. Errors were rife at Chernobyl ranging from the lack of experience of those in charge (mainly submarine reactors rather than civil) through to the collective understanding of the equipment (Dosimeter readings were dismissed rather than acted upon immediately after containment was lost). It was the consideration and therefore combination of these elements, however that made the Chernobyl investigation unique. Although the term safety culture has evolved over time the initial recognition of human factors and how they might be included in the process of accident investigation was unique to the IAEA investigation and represented a milestone in human factors research.

Recent research has indicated that initial assessments made concerning accident causation may have been unfounded. Although much blame was placed at the feet of the reactor operators for their behaviour both prior to and during the accident, it is now alleged that a systematic reactor fault may have been instrumental in the incident development. This is significant as it highlights the role and responsibilities of incident investigators, even more so when investigations are taking place in politically sensitive environments.

6.2.3 Davis Besse Nuclear Power Station

6.2.3.1 Summary

In spring 2002, during its 13th refuelling outage (13 RFO), the reactor pressure vessel (RPV) head, where the heated nuclear core of the reactor is held, at the Davis Besse Nuclear Power Station (DBNPS) was found to have sustained significant corrosion damage. As an integral component of the reactor's coolant pressure system, the state of the RPV was inherent to plant safety.

A nozzle leakage, identified as a problem at two other plants, and suspected at Davis Besse had caused the US Nuclear Regulation Commission to make preparations to close the DBNPS for a full investigation. However, it was agreed to postpone the investigation (to coincide with the 13 RFO) following provision of additional information by DBNPS.

During the 13 RFO, 5 of the 69 nozzles were found to be cracked, with 3 nozzles found to have complete cracking. This allowed Boric acid (present in the cooling water, and used to absorb surplus neutrons) to make contact with, and corrode the reactor vessel. The corrosion was significant enough to have raised the plant's risk of a meltdown and the potential release of radioactive material (Ghosh and Apostolakis, 2005).

6.2.3.2 Primary causes

Despite corrosion and cracking of the reactor vessel being an accepted possibility, the plant investigations frequently carried out were inadequate for determining whether this was occurring. Therefore the condition had been allowed to progress, untreated and unacknowledged for several years.

6.2.3.3 Underlying causes

Nuclear Regulatory Commission (NRC) inspections at the plant and operators' performance assessments had failed to collect accurate and complete information relating to plant safety conditions.

NRC inspectors who were aware of other secondary warning signals (i.e. excessive clogging of the containment filters) did not recognise the significance of such an indication, and therefore failed to consider or communicate these in a holistic fashion. The inadequate safety culture meant this issue was never identified or dealt with, and had the operating plan been upheld, the plant would have continued to operate without recognition of the corrosion, potentially leading to an incident occurring.

The corrective action plan was found to be inadequate, failing to reflect the latest practices within industry, and aimed at reacting to system symptoms, as opposed to treating the causes of the problem. Symptoms were categorised as low priority, and so inadequate corrective actions were taken.

The company's policies on safety were also inconsistent and incomplete, resulting in a failure to adequately analyse the safety implications of the systems being used. Meanwhile, the Boric Acid Corrosion Control Procedure and In-service Test Program were not complied with adequately.

Incentive programs were also found to reflect the inadequate safety culture, by awarding monetary incentives to senior levels of the organisation, based on production levels as opposed to safety.

6.2.4 Paks Fuel Damage Summary

6.2.4.1 Summary

During an ex-core cleaning exercise of the fuel's corrosion deposits, in spring 2003 a fuel damage incident was recorded at a power plant in Hungary. The fuel was cleaned in a pool of constantly circulating water in order to keep the temperature down. However sufficient cooling was not maintained due to deficiencies in the cooling system, and the water was able to reach boiling, and stay there for several minutes before it was discovered. By this time damage to the fuel had been sustained (Ghosh and Apostolakis, 2005).

6.2.4.2 Primary causes

The capacity of the cooling water pump was inadequate for the intended purpose, whilst the location of the inner vessel outlet resulted in regular clogging due to corrosion deposits. It was also recognised that the system layout allowed water to bypass the cooling tank (and therefore fuel), failing to contribute to the cooling power of the system. However this was never appropriately addressed and the combination of factors resulted in the eventual overheating of the cooling system.

6.2.4.3 Underlying causes

Around 30 fuel elements were severely damaged, some from the initial cooling failure, but others from recovery actions such as the influx of cold water that resulted in thermal shock.

Problems with implementing new procedures (delays in opening the fuel cleaning tank following the processing of earlier batches) were not reported due to an inadequate reporting culture. It was also found that the cooling chamber lacked an efficient monitoring system and there was no alarm, so personnel were not made instantly aware of a system malfunction.

Investigations by the Hungarian Atomic Energy Authority and the International Atomic Energy Agency (IAEA) found that weaknesses in the plants safety management and safety culture had led to an inadequate organisational commitment to safety, resulting in an aggressive schedule for design, fabrication, installation, testing and operation of the fuel cleaning system.

No evidence was found to suggest that the unsafe design and operation of the cooling system had ever been challenged. This was despite analysis which showed boiling could occur in 9 minutes if cooling power was lost.

Inter-organisational communication between units was only encouraged between managers, thus limiting the opportunities for personnel who would be instrumental in emergency preparedness and response, from sharing information.

6.3 CHEMICAL

6.3.1 Flixborough Explosion

6.3.1.1 Summary

In March 1974, at a chemical factory in England, a temporary bypass pipe was implemented to circumvent reactor vessel number 5 (in a series of six) which had been removed for repair following detection of a cracked shell. Approximately two months later, this inadequately supported temporary pipe failed, freeing 50 tons of hot cyclohexane into the atmosphere. This highly volatile gas mixed with the air and on contact with an ignition source the gas exploded killing 28 people (a low mortality rate due to the explosion taking place at the weekend), and partially demolishing the plant (www.hse.gov.uk/comah/sragtech/caseflixboroug74.htm).

6.3.1.2 Primary causes

The inadequate support of the temporary bypass line allowed the pipe to ‘squirm’ with a rise in pressure. This movement allowed the temporary pipe to shift, releasing the cyclohexane.

6.3.1.3 Underlying causes

The plant was modified despite the lack of an adequate assessment of the potential consequences. Therefore, inadequate repair measures were taken, the integrity of the bypass line was never fully investigated, and no drawings were ever produced.

The site layout was poor, failing to consider the positioning of occupied buildings. Meanwhile the control room lacked the necessary structural reinforcements, resulting in the windows shattering and the roof collapse.

6.3.2 Bhopal Toxic Gas Leak

6.3.2.1 Summary

In December 1984, a toxic gas leaked from an Indian pesticide production plant after a maintenance worker failed to isolate sections of the plant whilst cleaning. This in conjunction with the failed defence of six safety systems, and numerous latent failures resulted in the poisonous gas escaping from the plant. The gas spread throughout the surrounding areas, which were mostly dominated by shanty housing, killing over 2000 people, and injuring a further 200,000.

(Reason, 1990; Kletz, 1993; HS(G)48; www.hse.gov.uk/comah/sragtech/caseuncarbide84.htm).

6.3.2.2 Primary causes

Failure of the maintenance worker to isolate the pipes whilst flushing them out allowed water to pass into a connected storage tank. The storage tank (tank 610) held vast quantities of the intermediate methyl isocyanate (MIC). The influx of water caused an exothermic reaction, resulting in the temperature rising to over 200ºC and causing the pressure within the storage tank to rise. This resulted in the lifting of a relief valve on the storage tank, releasing the poisonous gas into the atmosphere.

6.3.2.3 Underlying causes

Prior to the gas release, operators identified the increased pressure of the tank. A MIC leak was also reported near the vent gas scrubber (VGS). Heat could also be felt radiating from the tank, and attempts were made to switch the VGS on, however this was inoperable.

At the time of the incident the hazards associated with manufacturing highly toxic chemicals such as MIC were not fully understood. This was evident in the finding that 10 times the required daily amount of the intermediate MIC was stored on site, as a matter of convenience, despite this being non-essential.

Critically, the plants numerous safety systems designed to prevent a MIC leak failed due to the systems being neglected on management belief that the risks had decreased with the ceasing of production. The prolonged period of inadequate and insufficient maintenance allowed the site to fall into a poor condition.

During the early stages of the incident, operators also hesitated in using the warning siren system, eventually deploying the siren when the leak became severe.

There is still confusion as to the exact chemicals released into the atmosphere that day, partly due to the company's reluctance to admit them. This has contributed to the continuing environmental impact the plant's operations and the disaster have caused.

6.3.2.4 Reaction and Going Forward

Although Bhopal has been recognised as one of the worst recorded accidents worldwide in terms of lives lost, the companies directly involved are still debating blame and deferring compensation. Union Carbide India and eventually Union Carbide itself accepted a limited liability, however these companies were subsequently purchased by Dow Corning who have refused to accept liability for the disaster.

Bhopal may have come about as a result of an unplanned hazardous chemical release but the seeds of this disaster were sown well before the event:

- ***Site selection*** –the site was in close proximity to a dense population centre;
- ***Skill set*** – Bhopal may have provided cheap labour, however, the same pressures that reduced labour costs (excess of workers) also forced qualified individuals from the area to find work. As a result Bhopal offered a limited pool of labour with a low skill set; staff were unsure how to respond to the accident;
- ***Technology*** – Union Carbide have subsequently been shown to have been using technology that was "untested and unproven" in their site in Bhopal;
- ***Reports*** – various warning signs were ignored concerning inadequate safety measures. Later investigation found that senior staff were either unaware or unwilling to act upon scientific recommendations;
- ***Fail-safe equipment*** – the fail safe equipment in place was either inadequate (water curtain) or inoperable (flame towers, gas scrubbers, emergency shutdown switch).

Overall, it was the accumulation of factors that caused this incident. Each one of the points above may have caused smaller accidents but these points combined resulted in a disaster of massive proportions. An over arching model of safety culture takes into consideration many of the issues raised above (senior staff attitude to safety/maintenance of safety equipment/job security) and will be discussed in more detail when offshore incidents are considered.

6.4 RAIL

6.4.1 King's Cross Fire (Underground)

6.4.1.1 Summary

In November 1987, 31 people were killed when a fire broke out at King's Cross underground station. The fire originated when an ignition source came into contact with flammable debris that had collected under the running tracks of the escalator.

Fifteen minutes later the ticket hall was evacuated, and the large metal gates closed. Approximately four minutes after this a flashover occurred engulfing the area in flames and intense heat (Reason, 1990; HS(G) 48; www.railwaysarchive.co.uk).

6.4.1.2 Primary causes

The direct cause of the fire was probably a lighted match or cigarette, which was dropped onto the running tracks of the escalator by a passenger.

6.4.1.3 Underlying causes

A smoking ban at the station, implemented in 1985, had resulted in passengers lighting up whilst on the escalators, as they prepared to leave the station. This had led to a number of 'smoulderings' (smaller fires which were assumed to be less of a threat) in the last few years.

Grease and dust had been allowed to accumulate on the escalator running tracks due to organisational changes that had resulted in poor housekeeping. Along with the wooden escalators this provided the ideal seed bed for the fire to spread.

The lack of any previous fires on escalators had encouraged a false sense of security amongst staff. This even extended up to higher management, and was reflected in the emergency procedures, even down to the use of the term 'smoulderings' to classify such incidents.

Inadequate fire and safety related training of the staff, in combination with a lack of smoke detectors beneath escalators, and staffs' reluctance to call out the fire brigade all contributed to the perpetuation of the incidents seriousness.

6.4.2 Clapham Junction Rail Crash

6.4.2.1 Summary

In December 1988, 35 people were killed, and hundreds more injured when a packed commuter train passed a defective signal, on route to Waterloo station. The train continued into the back of a second busy commuter train, causing it to veer off the tracks and into a third oncoming train. This incident did not result from the common SPAD incidents, as wiring errors by the signalling technician meant that the signal was incorrectly showing green (HS(G) 48; www.railwaysarchive.co.uk).

6.4.2.2 Primary cause

A new signalling system was being implemented, and following alterations to the Clapham Junction signal box, a signalling technician failed left two wires incorrectly connected to the same terminal of a relay.

The live wire was then able to make contact with the old circuit, which should not have contained any current, preventing the signal from turning to red, resulting in an incorrect green signal and causing the system to fail.

6.4.2.3 Underlying cause

There were a number of underlying causes that contributed to this incident. Most predominantly was the lack of monitoring and supervision, which according to the official report *'did not confine itself to…immediate superiors'*. This was compounded by the lack of training, despite the need being recognised, up to three years preceding the incident.

Sloppy work practices were blamed for the loose wires that were left in place. This had evolved into an established work method for saving time, despite similar wiring errors being made a couple of years previously.

The signalling technician responsible for the wiring oversight had worked for 12 hours on the day of the incident, with only a five minute break in that time. It is recognised there were no effective systems for monitoring or restricting excessive working hours.

6.4.3 Southall Rail Crash

6.4.3.1 Summary

In 1997, seven people died and 150 were injured when a Great Western train, on route to Paddington collided with a freight train (www.hse.gov.uk/railways/southalleast/index.htm).

6.4.3.2 Primary causes

The primary cause of the incident was the driver’s inattention. This allowed the train to pass through two signals that should have warned the driver of the impending obstacle, the freight train blocking the track up ahead.

6.4.3.3 Underlying causes

The initial driver error was compounded by faulty safety equipment. The Great Western train had both the basic ‘Automatic Warning System’ (AWS) and a second more advanced pilot version ‘Automatic Train Protection’ (ATP) installed. The AWS was broken at the time of the incident and the driver was not trained in the use of ATP, rendering both systems ineffective.

6.5 AIR

6.5.1 Challenger space shuttle disaster

6.5.1.1 Summary

In late January 1986, NASA flight 51-L was destroyed in a total loss explosion just following take off. Failure of the O-ring seal had resulted in the release of a stream of ignited fuel, which caused the shuttle to explode (Reason, 1990; HS(G) 48)

6.5.1.2 Primary causes

The immediate cause of the eventual explosion was a split, which developed shortly after the launch, in the O-ring seals between the lower two segments of the shuttle’s starboard solid rocket booster (SRB). This allowed fuel to leak, eventually igniting.

6.5.1.3 Underlying causes

Safety, Reliability and Quality Assurance staff failed to collect essential safety data. They, therefore, neglected to identify the trend in O-ring failures, experienced by more than half of the fifteen missions preceding Challenger.

The shuttle's SRB manufacturer had expressed concern as to the circumstances in which they were deployed. The specification rendered them unsafe to operate at temperatures below 53º Fahrenheit, as is the case during take off. The SRB was not tested in an accurate, launch authentic situation.

Constraints on resources meant that spare parts were kept in short supply, whilst pressure was put on staff to achieve unrealistic launch schedules. This also resulted in the 71% reduction of safety and quality control staff prior to the disaster.

The evolution of a culture where a certain level of risk was expected, even so far as to be deemed 'accepted' meant that such deviances were normalised, and as a result numerous warning opportunities were missed prior to the disaster.

6.5.1.4 Reaction and Going Forward

The Rogers commission was formed to report on the major causes of the Challenger accident. Interestingly, the organisational safety culture at NASA came under serious criticism with commission members citing this as a major accident antecedent. Examples of poor safety culture ranged from inadequate risk identification and management procedures through to an organisational structure that did not allow for the individual concerns of independent contractors to be heard.

NASA embarked on a radical overhaul of their safety assessment procedures with the explicit goal of raising standards. A safety committee was established and allocated independent status concerning launch/no launch decisions.

The Challenger disaster also provided academics with concrete proof concerning the impact that a defective safety culture can have upon a high-risk environment. The accumulation of unresolved issues concerning safety allowed human factors specialists such as Reason to suggest a Swiss Cheese model of accident causation, and, more importantly, allowed researchers to point at possible methods of behaviourally addressing safety culture issues.

NASA was accused of failing to learn the lessons of the past after the Columbia disaster in 2003.

6.5.2 Columbia space shuttle disaster

6.5.2.1 Summary

During the re-entry sequence, an American shuttle experienced a breach of its Thermal Protection System (TPS). This breach allowed superheated air to penetrate the insulation, melting and weakening the aluminium structure. The aerodynamic forces in operation, ultimately, caused a total loss of control. All seven crewmembers died as a result of the disintegration of the shuttle (caib1.nasa.gov/news/report/pdf/vol1/chapters/introduction.pdf (Executive Summary); caib1.nasa.gov/news/report/volume1/chapters.html)

6.5.2.2 Primary causes

Shortly after the launch of the shuttle a section of insulating foam separated from the bipod ramp of the external left tank. This struck the left wing as it fell, causing the eventual TPS breach. Despite engineers' suspicions, only minor investigations were carried out, neglecting to identify the missing foam or the impact damage.

6.5.2.3 Underlying causes

The inadequate design of the Bipod ramps was fundamental to this particular incident. Little consideration was given to the aerodynamic loadings the ramps were exposed to during launch, and the use of foam, which is not considered a structural material, only contributed to the unsuitability. Additionally, a level of complacency had evolved following previous failure of the ramps, which had resulted in no serious damage.

The complacency had resulted in a confidence based on past success, instead of a focus on sound engineering practices. The official report also uncovered other 'cultural traits and organizational practices detrimental to safety' that were allowed to develop.

The shuttle flight schedule was considered unrealistic, and put excessive pressure on planned launches to go ahead. The deadlines were not regularly re-evaluated to ensure their continuing viability.

Organizational barriers to effective communication of safety critical information were identified by the official incident report, along with 'stifled professional differences of opinion' and a lack of integrated management across the various program elements.

6.5.2.4 Reaction and Going Forward

As mentioned previously, NASA has faced some considerable criticism concerning a perceived failure to react to the issues raised in the Challenger investigation. The Columbia investigation board again cited safety culture as causal and made recommendations intended to address these issues going forward. Since the Columbia disaster NASA has followed more explicit rules governing launch/no launch decisions resulting in a serious reduction in the number of missions scheduled and completed. An emphasis has now been placed upon a new design of reusable aircraft that can be designed from the ground up with safety in mind.

6.5.3 Kegworth Air Crash

6.5.3.1 Summary

In January 1989, 47 people were killed when a Boeing 737, on its return flight from Heathrow to Belfast, experienced engine vibration and smoke. The crew acted to stabilise the situation until an emergency landing could be performed, however the measures taken failed and the passenger craft hit the ground, coming to a final standstill on the westerly embankment of the M1, at Kegworth.

6.5.3.2 Primary causes

The initial smoke and vibration experienced by the crew was the result of a fan fracturing in the No. 1 engine. Using their knowledge of the aircraft, its air conditioning system and instrumentation the order was mistakenly given to throttle back (shut down) the No. 2 engine.

Unfortunately, this action coincided with a reduction in engine vibration, confirming an erroneous belief. This resulted in the loss of power (i.e. the good engine), and sole reliance on the damaged engine.

6.5.3.3 Underlying causes

The crew failed to assimilate the readings on the engine instrument display prior to throttling the No. 2 engine. The official incident report states that the crew therefore *'reacted to the initial engine problem prematurely and in a way that was contrary to their training'*.

The reduction in noise and vibration that coincided with the throttling of the No. 2 engine persuaded the crew that the defective engine had been correctly identified. Meanwhile, the flight crews' workload remained high throughout the subsequent landing preparations, preventing follow up appraisals of the situation.

The poorly designed layout of engine instrument displays had previously been accepted, however recent adjustments had resulted in the instruments now using LED displays for engine indications. No additional alerting system was fitted to identify the defective engine to the pilots.

Passengers and cabin crew also failed to question the commander's announcement or bring the discrepancy, which referred to the 'right' engine despite them witnessing smoke from the left engine, to the attention of the crew.

6.5.3.4 Reaction and Going Forward

The extensive Air Accident Investigation Branch (AAIB) report that followed Kegworth outlined technical and human factor failures that lead to and worsened the disaster. Recommendations were varied, from correct brace position training (taken up by industry) through to reverse facing seating (not taken up for passenger comfort reasons). The most telling recommendation, however, concerned the passage of information throughout the cabin. As witnessed in other air accidents it was recognised that the authority of the Commander should not come at the expense of common sense. Many passengers and crew correctly identified the burning engine but failed to raise this when the other unit was shut down. Everyone is susceptible to error, even the most experienced Commanders. It was recommended that flight deck culture should allow for error to be addressed in a secure environment with the aim of improving standards and therefore safety levels.

6.6 COAL MINING

6.6.1 Aberfan Coal Waste Tip Slide

6.6.1.1 Summary

In 1966, 144 people (mostly children) were killed when a portion of a coal waste tip slid down the mountainside, in South Wales. The tip collapsed onto the small mining village, crushing a local school (Kletz, 1993).

6.6.1.2 Primary causes

It was well known by locals that the tip had been located on an underground spring, as well as on a sloping mountainside. In addition, two days of heavy rain preceding the incident had loosened the slag piles, resulting in the eventual tip slide.

6.6.1.3 Underlying causes

Visibility was at approximately 50 yards due to mountain fog. Although the tipping gang on the mountainside saw the tip begin to slide, many people down in the village saw nothing. The lack of an adequate warning system also contributed to the resultant devastation.

Inspections were not carried out routinely, and the company also failed to employ adequately competent people.

Forty years previously a similar incident had taken place elsewhere. Despite the causes having been investigated and published, the information was not applied to Aberfan, and the incident was allowed to repeat. However it is also worth noting that such literature was not as widely available as other mining-related literature due to a perceived distinction between the hazards associated with mining as opposed to the 'peripheral' issue of tips.

The Tribunal of Inquiry identified a 'pervasive institutional set of attitudes, beliefs and perceptions', which resulted in a collective neglect of safety regarding the tip by numerous regulatory and governing bodies.

The National Coal Board also failed to take responsibility for the tip slide by denying all knowledge of the underground spring situated beneath the tip. The official enquiry revealed this was not the case.

7 APPENDIX B: SUMMARY OF REVIEW PAPERS

Ref 1: A review of safety culture and safety climate literature for the development of the safety culture inspection toolkit. Human Engineering 2005. HSE CRR 367

Summary

- A focused review and summary of the main findings from the safety culture literature, based around the five key indicators (identified by HMRI) that are known to influence safety culture: leadership, two-way communication, employee involvement, learning culture, attitude toward blame.
- Uses data/ recommendations from accident enquiries as well as academic and applied research.
- Focused on effective safety culture, how to create and maintain safety culture and the characteristics of both positive and negative safety cultures from cross-industry research.
  - E.g. A blame culture is characterised by staff trying to conceal errors, employees feeling fearful and reporting high stress levels. Employees are not recognised or rewarded thus lacking motivation and errors are ignored or hidden.

Details of each indicator are included in the report and the summary of each point is copied here:

Leadership

- Safety versus Performance priority: senior management should give safety a high status within the organisation's business objectives, and safety is prioritised in all situations. This can be demonstrated by providing sufficient:
  - H&S budget
  - Opportunities for safety communication
  - Health and safety training
  - Support to personnel
  - Manpower (including health and safety specialists)
- High visibility of management's commitment to safety: senior managers should demonstrate visibly and repeatedly their commitment to safety throughout all areas of the organisation. This will create a shared vision of the importance of safety. This can be achieved by:
  - The use of verbal communications (e.g. scheduled safety tours, safety briefings, open door policy for safety)
  - The use of written safety communication (e.g. statements and newsletters)
- Safety management system: organisations should have effective systems in place for the management and co-ordination of safety; a strategic safety leadership team should lead this.

Two-Way Communication

- Top-down communication: effective communication from management to staff is the key to successful health and safety leadership. This can be achieved by:
  - A visible safety policy statement
  - Emphasis on safety issues and procedures via newsletters, videos warning sheets etc.
  - The communication of major accident risks

- Safety reporting: communicating a problem or concern is only one step in the route towards a good safety culture. Feedback mechanisms should be in place to respond to the reporter (if required) concerning any actions taken.
- Horizontal communication: the organisation should provide a system for the effective transfer of information between individuals, departments and teams. In practice, appropriate safety information is available when required.

Employee involvement

- Active employee participation is a positive step towards preventing and controlling hazards. The main points have been summarised as:
- If the workforce feel that they are responsible for their own safety, and that of others, they are likely to feel a sense of involvement within the company
- Ownership for safety can be increased by providing effective training, and opportunities for employees to be responsible personally for areas of safety (do you mean physical areas?)
- Safety specialists should play an advisory or consultancy role
- It should be easy for staff at all levels to report concerns about decisions that are likely to affect them, particularly during an organisational change
- Feedback mechanisms should be in place to inform staff about any decisions that are likely to affect them.

Learning culture

- The existence of a learning culture enables organisations to identify, learn and change unsafe conditions
- An organisation should allow all employees to be involved in proactively contributing ideas for improvement
- Continuous review and self-monitoring of organisational processes is a positive step towards a successful learning culture, as it allows the success of improvement initiatives to be monitored, as well as providing a means for increasing employee involvement in safety
- In-depth analysis of accidents, and good communications, with provision for feedback and sharing of information enable a learning culture to develop
- All levels of the workforce should be included in safety culture surveys when they are administered in an organisation. This helps to increase employees' involvement in the company and provides the opportunity for issues of concern to be raised. Feedback regarding the outcomes of the survey, and any actions taken should be disseminated throughout the company.

Attitude towards blame – the existence of a just culture

- Organisations should move from a blame culture to a just culture, or one of accountability
- Incident investigators should have a good understanding of the mechanism of human error, and a system should be in place that enables the full set of lessons to be learnt from accidents and near misses
- Management should demonstrate care and concern towards employees
- Employees should feel they are able to report issues and concerns without fear they will be personally blamed or disciplined as a result of coming forward
- Confidentiality should be maintained throughout the course of the investigation.

Evidence of poor safety culture include: lack of ownership; isolationism; lack of learning; unwillingness to share safety information or co-operate; failure to deal with the findings of independent external safety reviews; lack of management commitment.

Strengths

- Good overview of key papers, research papers and accident enquiries.
- Focused on learning from major accidents as well as research.
- Prepared with a view to applying the knowledge (Development of the HMRI safety culture inspection toolkit).
- Provides evidence of the characteristics regarding positive and negative, the types of behaviour associated with each, and to a limited extent, how behaviour can change.

Weaknesses

- Focused on rail industry, but some knowledge is transferable, and the report draws upon other industries experiences to some extent.
- Focused on five key indicators identified by HMRI. There may be additional indicators of higher priority to other industries, however this is not clear from the paper.

Ref 2: Development and validation of the HMRI safety culture inspection toolkit – Human Engineering HSE CRR 365

Summary

- Documents the development of a tool based on the earlier literature review.
- Includes case studies: the tool is used to explore safety culture in railways. The case studies show that despite top-level initiatives, the messages regarding safety culture do not always permeate down sufficiently, and that a 'blame culture' rather than a 'just culture' is still prevalent.

Strengths

- Applies knowledge gathered in Ref.1 literature review.

Weakness

- Not directly relevant to the current work.

Ref 3: Director Leadership of Health and Safety Shearn, P. and Miller, M. HSL 21/ 2005

Summary

The report provides a literature review of the role of company director leadership in health and safety. A summary is provided of why director leadership is important i.e. essentially because it promotes health and safety as a matter to be taken seriously by the workforce. While there is little empirical evidence regarding this role, the report does discuss research literature and case studies relating to whether directors actually lead health and safety in practice, how this is done and what has been achieved. The paper also considers the factors that influence directors' behaviours e.g. legislation, reputation, financial benefits/ considerations and moral responsibility.

Strengths

- Review of literature, so draws upon findings from other research that is of interest to the current work.
- Provides a summary of why the director leadership role is important and also looks at the limited evidence about how this works in practice.
- List of references of use to current work

Weaknesses

- Lack of empirical evidence means that the conclusions and recommendations are limited

Ref 4.

Organisational Dynamics and Safety Culture in UK Train Operating Companies Weyman, A., Pidgeon, N., Jeffcott, S. and Walls, J. HSE R67.159

Summary

This is a comprehensive paper covering both academic findings from previous literature and qualitative research to explore safety culture in train operating companies (TOCs). It looks at the principles of good safety culture and explores how TOCs compare to the ideal. It explores the influences on safety culture in the rail industry, the pressures on TOCs, and the barriers to effective safety culture. The work reports on the perspective of senior representatives of stakeholder groups within the UK rail industry, and that of groups of over 500 staff at all levels drawn from a sample of 4 different TOCs (case studies).

Key messages summarised under the following headings:

- Impacts of the post-privatisation industry structure (inc. references to impact on H&S; skill loss and implications on working hours)
- Senior management commitment to safety
- Performance pressures and performance loss
- Blame culture and risk aversion
- Compliance and rule following
- Rolling stock maintenance
- Organisational learning

Strengths

- Comprehensive work, drawing upon knowledge from key researchers in the area
- Extensive interviews/ focus groups with stakeholders and rail industry staff
- Clear research methodology including interview/ focus group protocols.

Weaknesses

- Rail industry focus (but does draw on oil and gas industry research from Rhona Flin etc.)

Ref 5

Human Factors Guidance for Selecting Appropriate Maintenance Strategies for Safety in the Offshore Oil and Gas Industry. Burton, MJ, Stephens, PJ, Hickling, EM, Gaskell, E. (Vectra Group Ltd.) HSE RR 213/2004

Summary

The aim was to identify the ways in which Human Factors 'best practice' may be integrated into an offshore maintenance strategy. A question set was developed to aid both inspectors and industry in ensuring that maintenance strategies address key human factors issues.

3 stages to the research or report:

1. Identifying key issues reported in the literature related to the development and delivery of maintenance in the offshore oil and gas industry

2. Collation and assimilation of available data about human factors in maintenance

3. Translation of the issues identified in the literature and discussions with industry representatives into a question set

Key issues that emerged relating to maintenance errors:

- Design
- Environmental constraints
- Learning from experience
- Risk assessment/ hazard awareness
- Resources/ staffing/ roles and responsibilities
- Competency/ training
- Supervision
- Communication

Incidents/ accidents resulting from maintenance are more likely to stem from a human factors-related root cause than engineering one (60% of all incidents were identified as human factors related).

Strengths

- Informed by academic literature and industry discussion

Weaknesses

- Based on accidents reported via RIDDOR so lacked detail to explore some of the key elements e.g. role of supervision

Ref 6

The Role of Managerial Leadership in Determining Workplace Safety Outcomes. O'Dea, A. and Flin, R. HSE CRR044/2003

Summary

This is a comprehensive review of the theoretical and empirical literature that examines the role of managerial leadership in determining organisational safety outcomes. It notes that failures at managerial levels were at least as important as technical failure and human error in causing accidents such as Three Mile Island, Herald of Free Enterprise, Piper Alpha, and the Kings Cross fire. It explores the role of senior (or corporate) level managers, middle level managers (including site managers) and supervisors (also known as front line managers or team leaders). The unique contribution of each level to organisational safety outcomes is explored and the paths of influence between them are examined. There is too much relevant information to summarise here as the review covers all the relevant papers and key findings in the area (below is a copy of the summary table provided by the authors). However, it is made clear that leadership at all levels is crucial in determining effective safety culture and therefore, reducing the risk of accidents.

The information draws on research from across industry but predominantly relating to major hazards.

<u>Summary of factors associated with positive safety outcomes</u>

Senior Management Factors

- Attitudes to safety
    - Safety viewed as integral to competitiveness and profitability
    - Perceived importance of statutory compliance
    - Leadership style
    - Transformational leadership
    - Charisma
    - Trust
    - Commitment to developing trusting relationships with subordinates

Management Factors

- Commitment to safety
- Resources given to safety
- Safety program, policies and procedures
- Involvement in safety
- Visibility at worksite
- Informal communications with workers
- Retaining personal responsibility for safety
- Priority of safety
- Work planning and scheduling
- Safety practices intrinsic to production
- Leadership style
- Decentralisation of power
- Decisiveness
- Transformational leadership
- Interactions
- Co-operation between workers and management
- Informal contact between workers and management
- Multiple communication vehicles

- Communications
- Open door policy by management
- Feedback to employees
- Humanistic management practices
- Appreciating employees
- Demonstrating concern for employees
- Health promotion policies and practices

Supervisory factors

- Supportive supervision
- Openness on safety issues
- Initiating safety discussions
- Providing feedback
- Fairness
- Supervisor involvement
- Regular safety meetings with workers
- Involvement in safety programs and training
- Involvement in inspections and investigations
- Supervisor autonomy
- Supervisory influence in decision making
- Supervisory control
- Participative supervision
- Participative style
- Emphasis on the importance of teamwork
- Valuing the work group
- Recognition of safety as a major part of the job
- Trust in subordinates

Employee factors

- Worker involvement
- Involvement in decision-making
- Willingness to approach management
- Involvement in safety programs
- Worker autonomy
- Specific and reasonable responsibilities, authority and goals
- Worker risk perception
- Awareness of the risks
- Individual responsibility
- Support for safety
- Worker cohesion
- Workgroup integration
- Group standards and norms
- Positive team spirit
- Worker motivation
- Safety initiative
- Rule compliance

Strengths

- Good summary of theoretical and applied research findings.
- Includes evidence of the association between management and safety outcomes.
- Key behaviour that is associated with promoting safety behaviour throughout the organisation

- Notes that the path of influence between corporate level decision makers and site level managers is not well researched, so the nature or extent of the influence of senior managers behaviours and styles of leadership on middle and front line managers is not well understood.
- Includes a table to summarise the factors associated with positive safety outcomes.
- Provides a model of leadership factors influencing safety outcomes.

Weaknesses

- The authors note that the model is descriptive rather than explicative. It does not show how the different elements interact with each other to determine safety outcomes. Only recently have such inter-relationships been examined empirically. While some inroads have been made in identifying the paths between individual elements, future research needs to go further in uncovering these paths.

Ref 7

Effective Design of Workplace Risk Communications
Ferguson, E. Bibby, P. Leaviss, J. and Weyman, A. HSE CRR 093/2003

Summary
Work to explore the influence of the design of risk communications (i.e. HSE risk communication leaflets on the use of ear defenders and manual handling) with respect to workers' intentions to follow safe working practices. Three design features were explored,

1. Usability – how easy is the material to read, remember and comprehend?
2. Usefulness – is the material relevant to the target audience?
3. Message framing effects – what is the influence of presenting the same risk information as positives or negatives? (The general health promotion literature suggests that messages that are appropriately framed for the target behaviour, and are also useable and useful will have an impact on behavioural intentions).

The work resulted from the increasing emphasis on enabling employees to take responsibility for their own safety through the uptake of safe working practice. Occupational risk communications are produced to allow employees to be well informed on relevant health issues and in so doing have the relevant knowledge to adopt safe working practice. However, this information is not always acted on appropriately.

The effectiveness of a risk communication can be demonstrated though its influence on intentions to follow safe practice.

Findings that are relevant to current work:

1. Workers' intentions to adopt safe working practices were influenced by the usability and usefulness of the risk communication leaflets. This effect of usability and usefulness was in addition to the effects attributed to demographic factors and perceptions of risk and worry. Therefore communication design is a very important consideration when trying to influence safe working practice.
2. Risk communication framed as 'positives' were generally more influential on intentions to act than negative frames for the current sample of leaflets. However there was evidence that prior-exposure to negative health outcomes or past-behaviour influenced the effectiveness of positive and negative frames. This indicates that when targeting specific groups for an intervention, information on their prior-exposure and past-behaviour should be taken into account.

Strengths

- Investigates thoroughly the effects, usability, usefulness and uptake of risk communication, in the form of HSE information leaflets.

Weaknesses

- Focused on one approach to modifying safety behaviour

Ref 8

Development of Human Factors Methods and Associated Standards for Major Hazard Industries. Simpson, G., Tunley, C. and Burton, M. HSE CRR 081/2003.

Summary

The report described work to develop guidance on five human factors topics. The guidance is designed to assist both HSE Inspectors and staff on chemical plants in assessing the management of human factors issues. The topics were selected following the application of an incident analysis process, which provided an informed overview of the Human Factors issues that were influencing accidents in the chemical industry.

Topics were:

- Procedures
- Availability of information
- Communications
- Emergency planning
- Accident investigation

The next stage of the work was to provide guidance in each of these areas. A literature review identified issues, which needed to be considered in the guidelines but the review provided very little information that could be directly used.

The result is a set of Assessment Principle Statements with explanatory text and a suggested question set to allow an examination of each of the Assessment Principles. There are also guidance notes provided to expand on and exemplify the questions and a scoring procedure.

So, for example, one of the ***Assessment Principles*** for '***Procedures***' is "***There is a systematic approach to ensuring the appropriateness of procedures***", there is explanatory text "Writing good, effective and reliable procedures is a difficult and potentially, time consuming task. It is essential therefore that the procedures are appropriate to the operation being controlled and that unnecessary procedures are excluded as early as possible."

There are then a number of ***management questions***, e.g. Is there a process to ensure the procedures are practical and up-to-date? With more explanatory text, "It should be accepted good practice that the operators (or maintenance staff) who will be required to use the procedures will have been involved in their development and/or given the opportunity to test their practicality before they are enshrined as mandatory requirements".

There are then ***evidential/ operator questions***, e.g. is there evidence that staff are involved in the writing/ review of procedures? With more explanatory text, "many of the problems which arise with procedures do so because they have been written by some one who may well know the engineering/ technology involved but is not involved with the actual day-to-day operation. Assumptions that may seem sensible and reasonable to the author may be far from the case in day-to-day reality…"

The number of question sets associated with each of the Assessment Principles means that the full list of behavioural questions cannot be included in this review, and the reader is referred to the original paper. However, the headlines for each of the Assessment Principles are included below:

Assessment Principles

Procedures

1. There is a systematic approach to determine which safety critical operations/ tasks need written procedures
2. There is a systematic approach to ensuring the appropriateness of procedures
3. There is a comprehensive system to ensure the systematic use of procedures
4. Procedures are an integral part of the Change Management Process

Availability of information

1. Information is easily accessible and understandable
2. There is a process in place to ensure that changes and modifications to the operation of the plant do not adversely affect the quality of information available
3. Findings from accident/ incident reviews and emergency exercises are used to improve information needs provision
4. There is a system in place for relaying current operational information/ status

Communications

1. There is a process to identify the communications requirements for the safe operation of plant
2. Communication routes are clearly defined
3. The roles and responsibilities for infrequent events and/ or abnormal/ degraded operations have been effectively communicated

Emergency planning

1. There is a designated and recognised chain of command to deal with emergency situations
2. There is good corporate awareness of potential emergency situations
3. There is provision for controlling of the plant once an emergency arises

Accident/Incident Investigation

1. There is a systematic approach to accident investigation
2. There is process for selecting and training the investigation team
3. The accident investigation process is comprehensive
4. Issues arising from an investigation and systematically addressed

Strengths

- Focused on the Chemical industry
- Identifies the key human factors issues associated with accidents in the chemical industry (n=5 accidents)
- Good analysis of accidents that can be used to inform current work

Weaknesses

1. Not clear where the details for the guidance came from. States that the literature review did not provide information that could be directly transcribed. "The general information gained from the literature review plus the thinking which had underpinned the development of the framework, was used in a series of meetings to develop a structure for the Guidelines…"

Ref 9
Safety Culture: A review of the Literature. Collins, AM. 2002
HSL 25/2002

Summary
Report focuses on research published since 1998. The work had two aims:

- To review the main features of safety culture and safety climate within the existing academic and applied literature.
- To explore the links between safety culture and safety performance.

The report covers the same issues as the O'Dea and Flin report 2003 but is not as comprehensive.
Main findings included:

1. Management identified as the key influence of an organisation's safety culture.
2. Employees' perceptions of management attitudes and behaviours towards safety, production and issues such as planning and discipline were the most useful measurement of an organisation's safety culture.
3. Different levels of management may influence health and safety in different ways.
4. The key area for any intervention of an organisation's health and safety policy should be management's commitment and actions towards safety.
5. A number of studies have found the presence of subcultures within an organisation.
6. Literature on bonus schemes suggests that financial incentives to improve productivity or to compensate for working in hazardous conditions can lead to safety being compromised.

Strengths

- Literature review of papers since 1998.
- Conclusions in agreement with O'Dea and Flin 2003.

Weaknesses

- Not as comprehensive as O'Dea and Flin's review

Ref 10
Human Factor Aspects of Remote Operation in Process Plants. Henderson, J., Wright, K. and Brazier, A. HSE CRR 432/2002

Summary
The study looks at remote operations of process plants. It considers management of change issues, particularly noting that many companies focus on the technical control elements of changes to remote operations and neglect to consider the human factors issues associated with this change (which can be considerable). The work provides a list of benefits and problems associated with changes to remote operations, many of which are transferable principles for other industries.

Notably, none of the sites attributed potential accidents to the problems they have encountered but the literature shows this is an issue they should consider.

The study lists the potential impacts of change on the company based on a survey of companies and case studies.

Strengths

- Work based on case studies and a survey of companies who have, are going through or are planning a change to remote operations.

Weaknesses

- Fails to make the link between change and accidents

Ref 11.
Strategies to Promote Safe Behaviour as a Part of a Health and Safety Management System. Fleming, M. & Lardner, R. HSE CRR 430/2002

Summary
Reports on:

- The theory underpinning strategies to promote safe behaviour
- The key elements of programmes to promote safe behaviour that are currently in use
- How to use behavioural strategies to promote a wider range of critical health and safety behaviours
- How to integrate behavioural strategies into a health and safety management system

Describes the basis of current behavioural modification programmes and looks at evidence that they work (not major hazards), they tend to be focused on frontline/ observable staff and behaviour. The report looks at how behavioural modification would be expanded to the health and safety management system including critical *risk control behaviour – see original* report for details of worked examples.

"Within the health and safety context, behaviour modification techniques tend to be used to promote the safety behaviours which will prevent individual members of frontline staff being injured, rather than critical behaviours required to manage major accident hazards effectively."

"There is strong research evidence that behaviour modification is effective in changing a range of behaviours within organisational settings. Within a safety context, the research shows that behavioural safety programmes can alter frontline employees' behaviour, reduce accident rates and improve the safety climate. Surprisingly, no publications were identified which demonstrated the effectiveness of a behavioural modification intervention in promoting critical risk control behaviours or safety leadership behaviours."

Strengths

- Good overview of behavioural modification programmes
- Provides a model for use with health and safety management systems
- Uses an example of a permit to work system to demonstrate how behavioural modification could work in critical risk control behaviours

Weaknesses

- Lack of evidence re: major hazards industries or critical risk control behaviours (but this is due to lack of information in the literature at the time.)

Ref 12

Development of a Methodology to Design and Evaluate Effective Risk Messages. Petts, J., McAlpine, S., Homan, J., Sadhra, S., Pattison, H., and MacRae, S. HSE CRR 400/2002

Summary

This research used a mental-models approach to understand individuals' knowledge, beliefs and attitudes and to compare these with those of experts. The research involved firms working in the electroplating sector (specifically small firms) because they have well known, accepted and significant occupational risks, defined controls and a range of formal information and guidance available in the workplace.

Questionnaire results confirmed the view that platers have a poorer understanding of the potential long-term effects than the acute/short-term effects. They have a very good knowledge of the latter, based on experience and are aware of the importance of personal protective equipment to deal with the acute risks of burns etc. Experts place greater emphasis on the seriousness of the long-term as opposed to the short-term risk.

There was overall agreement that information in lay language is needed.

The mental-models approach was known to present a number of problems, not least in undervaluing lay knowledge and beliefs, in assuming that expert beliefs are rational and in not addressing behavioural and organisational issues.

16 generic principles were listed for the design of risk messages aimed at overcoming the deficiencies of the mental-models approach.

One of the 9 recommendations made included investigation of the impact of knowledge and beliefs on behaviour.

Strengths

- Combination of case studies and survey work referred to
- Identifies key principles for the design of risk communication messages

Weaknesses

- Looks at change in perception post provision of amended risk communication literature, but not whether that perception was translated into a change in behaviour
- Authors deemed the methodology to be inappropriate for generalisation to other industries without significant work to make it applicable.

Ref 13
Risk Perception Leading to Risk Taking Behaviour Amongst Farmers in England and Wales. DJ Knowles, ADAS. CRR 404/2002

Summary

- Postal survey of 900 farmers in England and Wales
- Accident data was not found to be a reliable source for targeting change and interventions
- Literature reviews showed little work had been done on the perception of risk and risk taking behaviour in an agricultural context
- A Roving Safety Representatives scheme runs (ran?) in Agriculture sponsored by the HSC and run by ADAS that went well and shows that farmers will participate in a scheme. Part of its success could be attributed to the farmers desire for free advice.
- Farmers are scared of visits by the HSE and would prefer fear-free advice.
- Many of the respondents considered the hazards associated with farms to be inherent and unavoidable, with implications for their management.
- Comments on HSE include:
    - HSE should impart knowledge
    - HSE information is too academic
    - Information needs to be presented in a more culturally acceptable manner
    - Improvement Notices are perceived as being about increasing bureaucracy rather than improving safety.
    - Farmers would like to understand the rationale behind legislation, and have access to more case studies.

Strengths

- Identifies farmers perceptions and needs
- Provides suggestions to changes in the way that HSE communicates with stakeholders (but does not state whether or not these would be effective).

Weaknesses

- No list of references
- Attitude survey only
- Does not seem to deliver its title
- Only bit on risk taking behaviour is a question of key violation but no explicit link to perception.

Ref 14
Assessing the Safety of Staffing Arrangements for Process Operations in the Chemical and Allied Industries. HSE CRR 348/2001

Summary
A number of chemical sites are taking steps to reduce staffing levels in their operating teams. There is concern that this could impact on the ability of a site to control abnormal and emergency conditions and may also have a negative effect on staff performance through an impact on workload and fatigue etc. This work was to develop a practical method that organisations could use to assess their required staffing levels and the impact on safety of any reductions in operations staff.

6 principles were identified to test staffing arrangements:

- There should be continuous supervision of the process by skilled operators.
- Distractions such as answering phones, talking to people in the control room, administration tasks and nuisance alarms should be minimised to reduce the possibility of missing alarms.
- Additional information required for diagnosis and recovery should be accessible, correct and intelligible.
- Communication links between the control room and field should be reliable.
- Staff required to assist in diagnosis and recovery should be available with sufficient time to attend when required.
- Operating staff should be allowed to concentrate on recovering the plant to a safe state.

Strengths
- Practical method developed through literature research, case studies and piloting.
- Developed focus on process industries but probably transferable to other sectors.
- Highlights if staff levels are too low

Weaknesses
- Focused on staffing arrangements
- Not able to calculate a minimum or optimum number of staff.

Ref 15

Performance Indicators for the Assessment of Emergency Preparedness in Major Accident Hazards. Larken, J., Shannon, H., Strutt, J.E. and Jones, B.J.HSE CRR 345/2001

Summary

Work to develop a framework model of emergency management and apply it to the development of performance indicators for the assessment of emergency preparedness in the major accident hazard industry.

A detailed description of 11 major hazard sites of varying sizes and complexities was built up, recounting the hazards, environment and risks, explaining the processes, plans, people and facilities that were in place to deal with the possibility of an accident.

Performance of each site was assessed in terms of their performance relative to the risks posed, and relationships between features of the site preparedness and their subsequent level of performance in exercises.

Six features were found to be particularly representative of quality of practical performance. These were: senior management commitment; emergency philosophy; emergency management team structure; information management system; exercise regime; and several specific features of team preparedness – continuity in membership of emergency teams; training in command and control; competence assurance of emergency managers; and professional coaching of management teams during exercises.

The frequency, realism and detail of emergency exercises have also been shown to impact on performance.

Strengths

- Emergency response behaviour – directly relevant to major hazard accidents
- Benchmarking framework used, so provides examples of best and worst practice with associated indicators of performance.

Weaknesses

- Recognises that a significant limitation of the project is that the simulation environment is not identical to an actual emergency incident environment.
- States data was collected from ‘Major Hazard Sites’ but does not specify industries.

Ref. 16
Behaviour Modification to Improve Safety: Literature Review. HSE OSR 003/ 2000 The Keil Centre

Summary
Written as a guide to improving safety by modifying behaviour. Not an exhaustive account of behavioural modification but explains the main principles with examples from a range of offshore and onshore industries. A significant percentage of accidents can be directly linked to unsafe behaviour that occurred near to the time of the accident. It is thought that by reducing unsafe behaviour, it is possible to reduce non-injury accidents, minor injuries and major injuries.

Notes the causal link between attitude and behaviour is weak, however the causal link between behaviour and attitudes is much stronger. If we change our behaviour but not our attitudes, we feel uncomfortable (cognitive dissonance). We tend to resolve this by changing our attitude to be consistent with our newly adopted behaviour.

Basic features of behavioural modification programmes: ownership, definition of safe/ unsafe behaviours, training, observation, establishing a baseline, feedback, reinforcement, goal setting, and review. The best programmes resulting in successful outcomes were those that utilised all of these components. Training alone achieved mixed results, and where successful only modest improvements were illustrated. The addition of graphical feedback, goal setting and support from management and peers produced significant additional gains.

Factors that influence the likelihood of success:
1. Programme initiation and implementation
2. Programme maintenance
3. Organisational structure
4. Recognition of barriers and pitfalls
5. Workforce concerns - need workforce ‘buy-in’
6. Management and organisational issues
7. Programme suitability and implementation

Strengths
- Good overview, written for non-specialists; very accessible
- Guidance for offshore industries
- Uses evidence from a range of industries to demonstrate the benefits of such programmes

Weaknesses
- No details of the unsafe behaviours that were targeted by organisations. The implication is that behaviours to be targeted need to be identified by each organisation and that different behaviours need to be targeted in each company.
- A description of ‘how to’ rather than applied examples or case studies detailing behaviours

Ref 17
Safety Culture Maturity Model. HSE OSR 049/2000 Flemming, M.

Summary
A short report to describe the development and the processes involved in developing the draft Safety Culture Maturity Model

Ten elements of the safety culture maturity model

- Management commitment and visibility
- Communication
- Productivity versus safety
- Learning organisations
- Safety resources
- Participation
- Shared perceptions about safety
- Trust
- Industrial relations and job satisfaction
- Training

Five levels of safety culture maturity

Level one: Emerging
Level two: Managing
Level three: Involving
Level four: Cooperating
Level Five: Continuous improvement

"It is important to note that while it is assumed that safety performance improves with increasing levels of maturity, there is no hard evidence to support this assumption. The assumption is based on research that compared high and low accident organisations, which revealed that lower accident organisations tended to display the features associated with higher levels of maturity. It is possible that these organisations had lower accident rates for reasons that were not measured in these studies."

Intended to develop the safety culture maturity model into a diagnostic tool.

Strengths

- Short paper to describe the five levels of safety culture maturity.
- Not specific to any one industry.

Weaknesses

- Descriptive only

Ref 18
Development of a Leadership Resource Pack HSE OSR 098/2000 Ernst & Young

Summary

The report describes the development of a ‘Leadership resource pack’ for the Offshore Safety Division (OSD). A resource pack intended as a source of knowledge and good practice examples to demonstrate how positive leadership can drive a health and safety agenda alongside business considerations.
Includes examples of health and safety leadership behaviours: High degree of enthusiasm, clarity in how health and safety is discussed in the business, demonstrable knowledge of good practice within operations, and participation and execution of advance training techniques and practices (more details are provided in the paper).

Also gives Best and Poor Practice examples of management behaviour, for example, “Senior managers lead safety briefings and regularly include health and safety matters in other briefings and presentations”, “Senior managers all commit to receiving regular updated health and safety training”, and “Senior managers follow health and safety procedures and practices at all times”.

Strengths

- Includes examples of behaviours associated with best H&S leadership practice
- Includes case studies to consider how senior managers consider H&S issues in their business.

Weaknesses

- An applied paper, so no justification for the approach

Ref 19
Effective Supervisory Safety Leadership Behaviours in Oil and Gas Industry HSE OSR 065/1999

Summary
A study building on an earlier study by Mearns *et al* (1997), looking at which aspects of supervisor behaviour are associated with effective safety management. Supervisor's behaviour had a significant impact on subordinate safety behaviour, particular aspects were:

Valuing subordinates	
Supervisor makes it clear to each of their subordinates that they value their contribution to the team. Supervisors show concern for team members' welfare.	Subordinates that indicated that their supervisor valued their contribution also reported higher levels of safety behaviour. Subordinates that indicated that their supervisor showed concern for their welfare also reported higher levels of safety behaviour.
Frequency of visiting worksite	
Supervisor visits the worksite three or more times a shift	Non-accident subordinates report that their supervisor visits the worksite more frequently than subordinates that have had an accident.
Work group participation	
Supervisor involved workgroup members in risk assessments	Non-accident subordinates report that their supervisors involve them in risk assessments more often than subordinates that have had an accident.
Communicating the importance of safety	
Supervisor attends pre-job safety meetings and tool-box talks Supervisor has difficulty motivating subordinates to work safely Supervisor encourages safe working by setting a good example	Subordinates that indicated that their supervisor frequently attended pre-job safety meetings also reported less risk taking behaviour. Subordinates that indicated that their supervisor did not have difficultly motivating them to work safely also reported less risk taking behaviour. Subordinates that indicated that their supervisor encouraged safe working also reported less risk taking behaviour.

It is suggested that the subordinates of supervisors who display these behaviours most frequently are less likely to be involved in an accident.

These four factors are not sufficient to manage safety effectively. They are aspects of safety management in addition to all the other safety critical tasks performed by supervisors. However, they do distinguish good supervisors from excellent ones.

Different factors appear to drive safety behaviour (encouraging others to work safely) than drive risk-taking behaviour (taking short cuts). Positive safety behaviour can be encouraged by increasing the status of safety on the installation and by supervisors creating a supportive environment. Risk taking behaviour can be reduced by creating a *learning culture on the* installation and by supervisors communicating the importance of safety, setting a positive example and visiting the worksite frequently.

This also applies in a two-way relationship, where the supervisor's ability to change their safety leadership behaviour is influenced by that of the subordinates.

Mearns *et al* (1997) Study 8 factors identified as important: valuing subordinates; awareness of subordinates feelings; frequency of visiting worksite; motivation for visiting the worksite; work group participation; abdication of responsibility for subordinates safety; pressure to get the job done/ focus on production; safety communication.

Strengths

- Data is collected from supervisor's self reports, subordinate's self reports and views from management i.e. 360 degree feedback
- Qualitative with good exploration of specific behaviours

Weaknesses

- Small sample size
- Qualitative nature of research.

Ref 21
Summary Guide to Safety Climate Tools HSE OSR 063/1999

Summary
This is a comprehensive look at climate tools but it is not really the right paper for this review because it does not establish the link between safety climate maturity and accident records – this has probably been done in another paper.

This report is intended to fulfil three main criteria: to act as a summary of HSE funded safety climate tools, to compare fore mentioned safety climate tools and finally to identify, if possible, tools that correctly capture the safety climate maturity level of an organisation. A number of safety climate tools are considered:

Health and Safety Climate Survey Tool (HSE)
Offshore Safety Climate Questionnaire (Aberdeen University)

- Human and organisational factors in offshore safety (1996)
- Factoring the Human into Safety (1999)
- Computerised Safety Climate Questionnaire (1997)

Safety Climate Assessment Toolkit (Loughborough University)
Safety Climate Questionnaire (QUEST)

The tools are assessed on a variety of levels, ranging from validation methods and support from tool developer through to potential applicability of the tool in other sectors. In the second section of this report, further analysis takes place item by item to confirm the extent of cross over between tools. It is found, as might be expected, that there exists a high degree of inter-item comparability. The authors also assess the number of items in each tool that could be considered to be investigating safety maturity within the organisation. Here it is found that a limited degree of variance exists with the minimum number of items provided by the Computerised Scale (16 items) and the maximum provided by the Health and Safety Climate Tool (35 items). It is made clear during the completion of this report that the methods used to analyse the safety climate maturity level of each item stem from work previously completed by the Keil Centre (funded by the HSE). This report serves to outline differences that exist in the market regarding safety climate measurement in light of research concerning the importance of organisational safety maturity level. Although this report does not make explicit recommendations concerning which safety climate tool should be used, each tool is rated for a number of factors; the ratings are expressed using a simple * = poor to *** = excellent system. This report does not attempt to investigate the relationship between accident or incident rate and safety climate maturity level, assumptions concerning this model are carried over from previous work. Rather, this study attempts to investigate safety climate maturity level integration into current climate measurement tools and as such advise whether this may represent an area that needs to be addressed going forward to ensure the accuracy of HSE guidance and advice.

Although this paper represents an exhaustive investigation of the safety climate tools available in the market today, it does not comment upon the relationship between safety climate maturity, the variable under investigation, and major accident/incident rates. Without making this correlation explicit, this report can only act as a commentary of what is assumed to be known and therefore does not contribute towards knowledge in this area. It is interesting, however, to recognise that a degree of variance exists between safety climate tools and that this variance may impact upon the longevity of the tool itself.

Strengths

- Overview of safety climate tools

Weaknesses

- Purely descriptive discussion of the tools; no details regarding the behaviours being assessed.

Ref 22

Assessment of the application of risk assessment in the UK mining industry. HSL RAS/98/5

Summary

The aims of this document are to review and comment upon the introduction of risk assessment in the UK mining industry, to evaluate the quality of risk assessment in the UK mining industry and to consider what may constitute best practice in the mining industry going forward. Using a methodology that centred upon site visits, informal interviews and structured interviews within a single site, it was discovered that a risk assessment programme had recently been introduced. Although costly, this programme seemed to be effective in improving risk assessment and subsequent identification behaviours, although, it is recognised that mining represents one of the first industries to adopt a formal risk management policy and so changes may be less pronounced than expected. Findings suggested that risk assessment training provided a good platform for reminding individuals of their responsibilities and helped to establish a culture of continual improvement that may have fallen away prior to training.

Interestingly, it is also recognised that accidents are most likely to occur when behaviours have moved away from those covered by standard risk assessment procedure, normally in response to an unplanned event. In these cases, it becomes necessary to perform ad-hoc risk assessment, however, individuals with responsibility in this area expressed a discomfort with the formal recording of decisions made, even though it was recognised that a learning process was required ensure poor decisions were not repeated. Fears in this area were based mainly upon blame in the event of an accident and this issue was flagged as something that required attention (suggestions varied from raising the profile of the key decision maker through to clarification of supervisory responsibility). Overall, the report recommends that the policies and procedures in place at participating mine are, in the whole, adequate, although a greater emphasis needs to be placed upon formal auditing and management review strategies. In addition, it is recommended that the process of ad hoc risk assessment should be monitored to ensure that those making the decisions receive the full support of their superiors and are aware of the contribution to safety that the reporting of such procedures makes.

Strengths

- Focused on mining industry
- Good methodology

Ref 23
Total Quality Management and the Management of Health and Safety. HSE CRR 153/1997

Summary
Four main aims:
- Identify the reasons why organisations do/ do not link the Total Quality Management (TQM) approach with the management of Health and Safety (H&S)
- Explore the causes and assess the effectiveness of such links where they exist
- In the absence of such links, understand the reason for the absence
- Catalogue areas of good practice

Pertinent finding: those organisations where H&S performance is perceived to be more critical to the overall success of the business, e.g. chemical industry, tended to be more advanced in the application of TQM to the management of H&S.
Reasons why organisations choose to adopt TQM in the management of H&S:
- There is a high level of identity with and understanding of the subject of H&S at executive level
- A high intrinsic value for the safety and welfare of its Stakeholders exists within the business
- Customers demand that the business adopts similar values, standards and practices as their own
- Strategic goals of 'business excellence' as recognised by external assessment bodies require that a consistent management approach be adopted throughout the business
- It is perceived that H&S performance is critical to the overall success of the business.

Also highlights the barriers to the use of TQM in the management of H&S (see report for full details):
  - ***People factors*** – e.g. leadership style, leadership at executive level, the belief that H&S is primarily to comply with legislation and does not generate income or profit, personal fears and assumptions, negative attitude, low calibre of safety personnel etc.
  - ***Process factors*** – e.g. inadequate processes for developing, deploying and reviewing H&S policy, difficulties measuring performance, inappropriate measures, ineffective & inadequate communication etc.
  - ***Organisational factors*** - e.g. overbearing culture of compliance, difficulties controlling contractors, changing business priorities etc.
  - ***External factors*** – size of business perceived to be too small to warrant the ideal approach to H&S, nature of the business is such that H&S is not seen as critical to success of business etc.

Strengths
- Applied research – 24 companies (one can be defined as a major hazard industry - Chemical processes)
- Case study extracts

Weaknesses
- Full case studies not provided)

Ref 24
Successful Health and Safety Management HS(G) 65

Summary
Outlines the common characteristics of successful H&S management.

Principles are applicable to all organisations but the "extent of action required will vary with the size of the organisation, the hazards presented by its activities, products or services and the adequacy of its existing arrangements."

Key elements*:* Policy, organising, planning, measuring performance, reviewing performance and auditing (POPMAR)

Policy:

H&S contribution to business performance
Leaders must develop organisational structure and culture which supports risk control
Resource and plan policy implementation
Systematic identification and control of risk
Understanding of risk control and the need to be responsive to change
Review performance to learn from experiences
Connection between quality and H&S

Organising: Managers lead by example

Control
Clear allocation of responsibility
H&S responsibility to line managers
Accountability for H&S responsibilities
Adequate supervision, instruction and guidance
Payment and reward systems avoid conflict between H&S and production
Co-operation
Employee involvement
Communication
Visible behaviour, written material and face-to-face discussion
Competence
Recruitment, selection, placement, transfer and training

Planning:

Identify objectives and targets for achievements in specific time period
Performance standard for management actions
Performance standards for control of risk – hazard identification and risk assessment
Elimination of risks by substitution
Control of risks by physical safeguards
Risk assessment
Performance standards for control of risks to employees and members of the public
Documentation of all performance standards

Measuring performance:

Active monitoring systems
Reactive monitoring systems
Reporting and response systems
Investigation systems

Auditing:

Maximise learning
Improve H&S performance and further develop H&S policies
Remedial action to deal with specific issues identified
4 key performance indicators

- Degree of compliance with H&S standards
- Identify areas where standards are absent or inadequate
- Assessment of the achievement of specific objectives
- Accident, illness and incident data – immediate and underlying causes, trends and common features

H&S performance assessed externally by comparison with other organisations.

Ref 25

The Contribution of Attitudinal and Management Factors to Risk in the Chemical Industry. HSE CRR 81/1996

Summary
Includes accident (HSE publicly available investigation reports) summaries and notes that although contain little detail in the reports to identify underlying causes, because they focus on the immediate causes, some conclusions can be made.

Main HF issues included:
Maintenance errors, inadequate procedures, inadequate job planning, inadequate risk assessments, inadequate training of staff, unsafe working condoned by supervisors/ managers, inadequate control and monitoring of staff by managers, inadequate control and monitoring of contractors working on site, etc.

Copy of conclusions:

When the current project began there was considerable discussion amongst safety professionals about human factors in safety and the need to go beyond the basic ergonomic considerations. While there was a recognition of this need, little understanding existed as to exactly what these aspects of safety were and, consequently, how to measure them. With out such a measure risk assessment had to rely on generic failure rates as a means of taking human factors of this sort into account.

The project has systematically and successfully identified those aspects in the form of safety attitudes. It has also developed a reliable and tested question set to measure safety attitude. Further, the research has demonstrated the clear relationship between safety attitudes and safety performance.

The measure which has been developed will allow the assessment of safety attitude in a wide variety of chemical companies and sites. The possibility also exists to compare the relative performance of any given site with a normative database. Currently the database comprises those sites included in the present project. However each assessment made in the future may be used to enlarge the normative sample included in the database.

In terms of the original aims of the project, the research has resulted in a usable tool for the quantitative assessment of safety attitude within a site. It thereby allows the incorporation of this aspect of the human factor into decision making and the work of the HSE.

Strengths
- Systematic approach to the development of a safety attitude scale
- Draws on accidents from the chemical industry
- Makes the link between safety attitudes and accidents

Weaknesses
- Focused on attitudes rather than specific behaviours.

Ref 26
Business Re-engineering and Health and Safety Management: Vol. 2 Wright, M.S. HSE CRR 125/ 1996

Summary
Include learning points and examples of what makes for effective H&S management during change, overlapping with HS(G)65

Includes case studies: rail operator, power supplier, chemical manufacturer, quarry company, drinks manufacture and distribution, NHS Trust, aircraft maintenance, nuclear power and mail distributor. All have been through or continue to go through organisational changes.

Copy of recommendations:

HEALTH AND SAFETY BEST PRACTICE GUIDANCE

It is recommended that the following issues are addressed.

(1) Examples of the impact that poorly managed changes can have on health and safety.

(2) Identification of any regulations which require organisation and management changes to be addressed, such as Railway (Safety Case) Regulations.

(3) The need to recognise at an early stage that a proposed or planned change in organisation and management has the potential to impact health and safety.

(4) Definition of a "material change in organisation and management" and the level of scrutiny the change demands. Distinctions to be drawn between minor ongoing organisational changes, such as appointing new director, and fundamental changes such as downsizing, merging departments/jobs and introduction of new styles of management.

(5) The health and safety goals which are sought within reorganisation, such as ensuring reorganisation has at least a neutral impact on safety performance and ideally is used as an opportunity to improve health and safety.

(6) Key health and safety issues to be reviewed, such as staff competence, extent of discretion to be allowed in working practices, contractors and workload of management.

(7) Methods of review of planned or proposed changes

(8) Health and safety planning requirements, such as safety action plans.

(9) Role of review and monitoring during implementation phase of changes.

(10) Types of review techniques available, such as independent audits and review panels.

(11) Role of benchmarking before, during and after changes.

(12) Types of benchmarks available.

(13) Key management actions, such as training needs analysis for new roles, ensuring management have competencies for widened spans of responsibility and revision of procedures to match new structures and culture.

(14) Types of techniques available to help design changes, such as "tight-loose" reviews, task analysis and risk assessment.

Ref 27
Business Re-engineering and Health and Safety Management: Vol. 2: Literature Survey HSE CRR 124/ 1996

Summary
Research to consider whether issues such as delayering, outsourcing, and flexible labour affect individuals and industrial health and safety.

Three main aims:

1. To identify the scale and form of business re-engineering in the UK.

2. The effect that business re-engineering has on health and safety standards.

3. The health and safety issues, pitfall and opportunities associated with business re-engineering.

All the main findings are of relevance to the issue of how and why businesses restructure, e.g. “the mixed results of reengineering projects are attributed to the poor implementation of changes, such as following simplistic goals, failing to train people for new roles, and failure to redesign working methods to match new organisational structures”.

With regard to the effects on health and safety standards: “The survey did not identify any formal research which explicitly examined the wider effects of reorganisation on health and safety, such as the impact on major hazard safety.”

However, main findings included:

- It is possible to identify examples where reorganisation has contributed to major accidents involving multiple fatalities.

- Health and safety statistics published by companies reveal an improvement in overall performance subsequent to reorganisation, even if standards fell during reorganisation in some examples.

- Industry level statistics do not consistently reveal a decline in performance, with most revealing improvements in reported accident and injury rates

Concluded that is it is difficult to reach firm conclusions based solely on current research other than to suggest that reorganisation can be a stressful process and that health and safety standards can be affected in both positive and negative ways.

Recommends further research to establish the links between business reengineering and health and safety.

Strengths

- Extensive literature search focused on business reengineering include examples from industry.

Weaknesses

- Literature based survey only

Ref 28
Business Re-engineering and Health and Safety Management: Vol. 1: Best Practice Model. HSE CRR 123/ 1996

Summary
Emphasis upon the role that organisational change has on accident causation; identifies the unforeseen effects of change across all industries and offers a model of best practice as a means by which these effects may be mediated. An emphasis is placed upon the identification and adaptation of negative behaviours plus the reinforcement of positives. The model involves the development and application of issue identification skills followed by change impact analysis and subsequent performance review. It is recommended that the level of risk inherent in each task should dictate reach, proliferation and source of rules. For example, for low risk tasks it is recommended that there be minimal supervisory control with an emphasis placed upon the individual to identify and implement safety rules and behaviours. However, if the task is identified as high risk the level of supervisory control should increase relative to risk level and with it the degree of behavioural automation. The study uses two examples to emphasise the outcome of poor organisational change management, Philips 66 ($1billion) accident and Hickson and Welch – both of which were preceded by periods of organisational change.

The study recommends that senior management should be responsible for implementing a health and safety strategy that recognises and reflects the impact that organisational change can have on safety levels. Although the study cites examples of accidents that have occurred post organisational change there is little statistical evidence to support this supposition beyond this; possibly this link has been made prior to this study. Overall, the model offered would seem to be workable in most companies although support for organisational change /incident link is not made explicit.

Strengths

- Examining the relationship between organisational change and health and safety, using case study examples

Weaknesses

- Little evidence to support supposition that accidents are associated with organisational change

Ref 29
Further Development of an Audit Technique for the Evaluation and Management of Risk. HSE CRR 66/1994

Commentary
This study forms the second part of a two-section report developed to improve risk management analysis. The report looks at the statistical processes that are required to successfully isolate items for tool development but does not attempt to explain the origin or application of such items. Through investigation, the report recommends a variety of improvements to the procedures that are undertaken when safety questionnaire audits are completed. Most of these improvements focus upon statistical issues and, as such, make little impact upon knowledge of major incident causality.

Ref 30
Improving Safety on Construction Sites by Changing Personnel Behaviour. HSE CRR 51/ 1993

Summary

A comprehensive paper that was commissioned by the HSE to further understanding of potential behavioural change strategies that could be effective in the construction sector, a sector that had been experiencing gradual fatality increase since 1980's into the 1990's. An extensive literature review suggested a behavioural methodology would be effective, specifically behavioural modification through goal setting and measurement. The study authors developed a safety scale through factor analysis of hundreds of items to give a 71-item list of unsafe acts. This was combined with an attitude assessment that used a 24 item perceived safety scale. Whilst the study was underway, researchers introduced goals, rewards and training at differing points and worked to reduce Hawthorn effects as each element was introduced and removed.

Study found that goal setting was successful in reducing the frequency of unsafe acts; also found that participatory goal setting was more effective than prescriptive. There was a requirement for extensive feedback to ensure understanding and commitment to the programme was established. Interestingly, found that training seemed to have little impact upon frequency of unsafe acts and that consistency in safety policy was essential as ground can be lost rapidly if safety policies are removed and reintroduced.

Overall, an excellent paper that can be considered scientifically robust and relevant, even in the current research environment that has moved away from behaviour modification as a method of improving safety performance. Key safety issues identified in this paper:

- Ownership of safety programme – allowing individuals whose behaviours will be affected by changes to engage in target selection and setting shown to improve intervention performance. This topic has been integrated into subsequent safety culture and climate measures such is its importance
- Change – when safety policy changes this can have a profound impact upon staff. Research indicated that removal of targets resulted in a strong negative correlation with safety behaviours increasing the likelihood of an accident over the long term. It is recommended that any behavioural change strategy be designed to be in place over the long term.

Strengths

- Focused on behaviours

Weaknesses

- Not major hazard industry. Elements may be applicable to current work but indirectly due to the fundamental difference in nature of industries

Ref 31
The Development of a Model to Incorporate Management and Organisational Influences in Quantified Risk Assessment. HSE CRR 38/1992

Summary
Commissioned to investigate how organisational, management and human factors might be quantified into risk assessment procedures this paper covers a lot of ground in the search for relevant sources. Focus is maintained on the report into pipe work failure (Technica, 1989) and the subsequent Modification of Risk (MOR) techniques that resulted. Study offers a socio-technical analysis of accident causation that integrates a spectrum of elements ranging from management attitude to safety through to engineering reliability.

Level 1. Engineering reliability
Level 2. Operator reliability
Level 3. Communication
Level 4. Organisation and Management
Level 5. System climate

It is argued that the levels progress from 1 through to 5 with an increasing distance placed between the events that precipitated the accident and the reasoning behind it. As such, the "deeper causes" of accidents become apparent as we move up the model towards system climate. The connection between human factors and accident causation is maintained throughout the paper, incidents such as Piper Alpha, Flixborough and Chernobyl are mentioned and the human input in these incidents are recognised. In addition, the authors look to build upon the work by James Reason concerning "active" and "latent" organisational failures, building these elements into their socio-technical model. There remains, however, an emphasis upon the impact that management can have on accident frequency; the model proposed looks to effective management as the most effective means by which safety behaviours can be controlled. Coupled with this the report also recognises the inherent difficulties of transforming qualitative measurements into meaningful quantitative data, especially in the field of human factors management.

Ref 33. Organisational Management and Human Factors in Quantified Risk Assessment: Report 1HSE CRR 33/1992 (Copied from the original document)

<u>Research Funded by the US Nuclear Regulatory Commission</u>

Eight cause code categories would be useful for the NRCs performance trending program and could be used to identify where problems in a particular area may lead to subsequent effects on the direct performance indicators. Some results are shown in Table 2.5. The definition of each cause code is:

a) Operator errors - personnel errors committed by licensed operating personnel that are the result of such factors as limited experience, fatigue, stress or poor work habits.

b) Personnel errors - errors committed by plant, contractor and other personnel (excluding licensed operators) due to the inability of the individual to perform the job due to factors such as lack of experience, fatigue, stress, poor work habits.

c) Maintenance - errors arising in the upkeep or maintenance of equipment, and the surveillance, testing or calibration of instruments or components.

d) Design/installation - errors committed during design, fabrication, construction or installation, or personnel errors committed due to inadequacies in the design of systems and equipment.

e) Procedure errors - errors due to an inadequacy or deficiency in communicating the appropriate information necessary to perform a task, particularly through written procedures.

f) Administrative control problems - errors occurring during managing or supervising a task.

g) Equipment failure - components or systems that have failed and necessitate repair.

h) Unknown - Cause not known or reported by utility personnel.

Ref 34
Health and Safety responsibilities of company directors and management board members
M Wright, S Marsden, J Holmes, Greenstreet Berman RR135/2003

Summary

- Helps answer the question of whether organisations are already 'directing' health and safety at board level.
- A baseline and follow-up survey conducted of firms employing over 250 employees.
- *FTSE 350 firms are more likely to direct H&S at board level compared to the public sector. Furthermore they are more likely to have a director responsible for health and safety.*
- Local government had the highest levels of health and safety delegation (in particular the NHS).
- The individual deciding whether health and safety warranted board direction was the Chief Executive.
- Factors affecting 'directing health and safety' included:
    - Increased perception of the importance of health and safety;
    - Corporate responsibility;
    - General concern about occupational health;
    - Fear of prosecution.
- Benefits of board direction included:
    - Strong leadership;
    - Shows commitment;
    - Helps to improve health, safety and risk management.

Strengths

- Large sample
- Baseline and follow-up show improvement and stability of the trend
- Shows that within large companies that influencing the board could be key.
- Also, does this suggest that wealth and size are the key issues when looking at effort paid to health and safety?

Weaknesses

- Simply a survey; does not utilise much of the richer data regarding the reasons underlying these findings.
- Only large firms in terms of scope
- No stratification of data according to hazard/risk profile.

Ref 36.

An analysis of safety culture attitudes in a highly regulated environment. Harvey, J. et al. 2002. Work and Stress 2002, Vol. 16, No. 1, 18-36.

Summary

Study looking at safety culture in a nuclear reprocessing site that had recently seem changes at senior management level. The new management was keen to see changes in safety culture and was about to introduce safety training initiatives to enhance attitudes and behaviours. The study was to identify the components of safety culture and to make pre-training comparisons between plants and occupational grades.

They found that the concept of safety culture varied according to whether the employee belonged to the shop floor or management, even to the extent that one measure of culture may be inappropriate for all employees.
Also, safety culture may differ across different departments or plants within an organisation.

Culture is a concept that is better applied at the group than organisational level. Safety cultures are not simply more or less versions of the same thing, but differ fundamentally – shop floor employees may have differing perceptions about what safety behaviours are desirable.

Safety culture factors: Job satisfaction, leadership style, communication, risk taking and awareness, responsibility and commitment, this study also reported complacency and avoidance of responsibility.

Strengths

- Focused case study on part of the nuclear industry

Weaknesses

- No links to safety behaviours made in the study, purely an assessment of safety culture.

Ref 37
Human and organizational factors in offshore safety. Mearns, K., Flin, R., Gordon, R., and Fleming, M. 2001 Work and Stress 2001, Vol. 15, No. 2, 144-160.

Summary
Used a self-report questionnaire to understand perceptions of organisational factors that could have an impact on safety. Investigated the underlying structure and content of offshore employees' attitudes to safety, feelings of safety and satisfaction with safety measures. The work is one of a series of studies trying to establish if the UK Offshore Safety Case Legislation (HSE 1992) reforms have actually had an impact on the offshore environment in terms of changing workers' attitudes, perceptions and behaviour.

Results suggest that 'unsafe' behaviour is the 'best' predictor of accidents/ near misses as measured by self-report data and that unsafe behaviour is, in turn, driven by perceptions of pressure for production.

Safety behaviour scale includes:

- I ignore safety regulations to get the job done
- I carry out activities that are forbidden
- I break work procedures
- I take chances to get the job done
- I bend the rules to achieve a target
- I get the job done better by ignoring some rules
- Conditions at the workplace stop me working to the rules
- Incentives encourage me to break rules
- I take shortcuts that involve little or no risk
- I break rules due to management pressure
- I am under pressure from my work mates to break rules
- I get financial rewards for breaking the rules.

Those who reported carrying out more violations and unsafe acts and those who felt that they were under more pressure to keep production going were more likely to have been involved in one or more near-miss on that installation over the past 2 years.

'Pressure for production' items relate to rule-breaking and risk-taking in order to keep production going and feel under pressure from work mates, supervisors and management to take chances and violate safety regulations, for the same reasons.

Strengths

- Uses established measure of safety culture
- Links behaviour to accident and near-miss rates
- 11 installations involved (return rate of 33% n=722)
- 6 different companies involved

Weaknesses

- May not be transferable to other industries
- Self-report data only

Ref 39.
How to measure the performance of a safety management system in the chemical process industry. Kyo-Shik Park & Young-Do Jo 2001. Making Process Safety Pay.

Summary
This is a brief description of a methodology that has been implemented in Korean chemical industries to measure the performance of a safety management system. The method consists of an index to evaluate the rate of SMS performance.

It is stated that two elements matter - determining what factors influence safety management activities are and how much influence each factor has. However, the paper does not identify what those factors might be.

Strengths

- An attempt to quantify the benefits of safety management systems using financial costs

Weaknesses

- Paper is not clear, e.g. it is not clear what safety management system features are being evaluated using the method
- The method seems inadequate and unsubstantiated

Ref 40
Integration of process safety and personnel safety in Japan: practice in chemical industries. Kiyotsugu Saka. 2001 Making Process Safety Pay.

Summary
This is a short paper presented at conference.

Notes: "Poor process safety and poor personnel safety is a common combination. One does not see a company with good process safety and poor personnel safety, or vice versa. It is because they are under the same management. A strong Occupational Health and SMS will help in promoting both safety issues"

Zero Accident Campaign – began 25yrs ago to tackle personnel injuries.

All employees requested to take responsibility toward safety and accident prevention and to make continuous efforts with a positive attitude toward that objective in their daily work; a voluntary system.

Refers to a set of tools for employers/ employees called 'Finger Pointing and Call' –but no details are provided.

Strengths
- Refers to links between major accidents and personnel injuries.

Weaknesses
- No details of the campaigns/ tools used.
- No substance to what is being reported.
- No information re: behaviours targeted or what has been done to improve accident rates.

Ref 42
Retaining process safety culture in FMC Corporation. Fryman, C. 2001. Making Process Safety Pay.

Summary
This is a short paper presented at conference

Acknowledges that FMC Corporation (Chemical processing plant) has faced almost constant changes over the last two years – job changes made for over 50% of the process safety specialists at 31 worldwide manufacturing plants. A similar situation is evident for plant and division management teams, plant technical support staff, and corporate support staff. Changes are due to demands for cost reduction.

When looking at the impact of personnel changes they have focused on 3 areas: Awareness, competency and time commitments.

Developed "Management of change guidelines for changes in key safety job tasks", which applies to all changes in personnel and their job tasks including:

Placement of people new to their jobs; transfer of people form one job to another; changes in the scope of the job; outsourcing of job tasks to contractors; elimination of jobs and job tasks.

Focused on job tasks not just a job description or major area of responsibility – e.g. " … we may specify that project safety reviews are a major area of responsibility, but until we actually specify the key job tasks (e.g. leading HAZOP studies, tracking open action items, scheduling the reviews etc) we cannot properly communicate the roles and evaluate the competencies and time availability of the person to accomplish those roles"

Steps for the Management of change (MoC) Guidelines for Key Safety Job Tasks are listed:
1. Inventory of key safety job tasks for the current job
2. Inventory of key safety job tasks for the new/ revised job
3. Undesirable impacts of changes in the key safety job tasks for new/ revised job
4. Action tracking
5. Post change review

Strengths
- Describes the implementation of a Management of change program
- Industry example where the need to apply management of change principles to the people and programme changes is recognised

Weaknesses
- No evaluation or results to demonstrate how this approach has worked in practice.
- Simply an explanation of the guidelines they have developed.

Ref 43
Creating an extraordinary safety culture. Walker, E.B & Maune, J.A 2000 Safety Performance. American Society of Safety Engineers

Summary
A report on the safety success of at $650million grass roots Aromax Benzene and Cychlohexane project in Saudi Arabia.

Project completed on time, below budget and with an exemplary safety record – in 13million construction hours one lost-time injury recorded and two recordable injuries.
$3million in avoided cost when compared to the 'typical project'

Describes the process by which the following key elements were achieved:

- A visible, proactive and extraordinary vision and commitment to safety at all levels
- World-class safety processes and best practices
- A culture that valued workers and focused on protecting people

Contractor selection included minimum safety requirements to be stated in contracts. Collectively contractors included nearly $1million in their bids to cover required safety programs.

Tier one
Developed an executive sponsor leadership team – to create the vision, remove barriers, supply resources and sustain the commitment to safety. To achieve this, the group:

- Publicly stated its commitment to the established safety vision
- Performed monthly executive sponsor meetings, with a half day devoted to safety issues
- Monthly construction site walks to acknowledge safe behaviours
- Conducted unannounced contractor work camp visits and audits
- Formed a workable, results-focused owner/ contractor safety partnership

Number of initiatives introduced:
Full time TQM coach provided: Safety awareness training, defensive driver training, feedback for sponsors, posters, visuals, project newsletters.
Site safety reps: small incentives such as raffle tickets for larger prizes and pre-paid phone cards to immediately reward positive behaviours.

Tier Two
World-class safety practices applied for safety performance improvement and proven safety practices of various contractors. All contractors required to adopt a safety program including a number of key elements (as a minimum) – listed in report.

Tier Three
Developed a safety culture based on care and concerns; required a commitment to treat all employees with dignity and respect, and to provide a healthy, safe place to work and live. A culture where employees felt able to report incident/ near misses; stopping work they felt was unsafe; taking responsibility for their safety and that of others.
Conducted ongoing series of interviews with a cross section of the workforce to identify issues, perceptions and barriers; the goal was to assess progress in changing the safety mindset

Strengths

- Industry worked example of how an effective safety culture can be achieved

- Highlights successful working, to time and within budget as well as an excellent safety record
- Highlights management safety behaviours
- Evidence of how an effective safety culture works – e.g. effect on safety behaviour of employees (stopping work if viewed as unsafe etc.)
- Includes references to costs
- Quantifiable results

Weaknesses

- Written as promotion for the company

Ref. 45
Assessment of safety culture at a nuclear reprocessing plant. Lee, T. Work & Stress, 1998, Vol. 12. No 3, 217-237

Summary
The paper describes a survey of attitudes towards safety at the Sellafield site of British Nuclear Fuels.

Notes that enquiries into major disasters (e.g. Bhopal, King's Cross, Herald of Free Enterprise, Clapham Junction, Piper Alpha) have all come up with much the same conclusion. Despite the adoption of the full range of engineering and technical safeguards, complex systems broke down calamitously because the people running them failed to do what they were supposed to do. The final slip, mistake or violation that tripped the disasters was just one connection in a blighted network of responsibilities, diffused throughout the organisation.

There has been little direct research on the organisational factors that make for a good safety culture. However, there is an extensive literature if we make the indirect assumption that a relatively low accident plant must have a relatively good safety culture. The characteristics of low accident plants have been distilled into organisational aspects of safety.

Strategically difficult to transcribe into an action plan – values, attitudes and beliefs are abstract terms**. Behaviours are more concrete than attitudes therefore tend to be targeted for modification but although simple behaviours are more easily measured and modified by managers they are probably not the ones most critical to safety.**

One limitation of behaviour modification is that it is ideally suited only to fairly routine, repetitive work where unsafe behaviours are readily observable. It cannot easily be applied to errors of omission or to the kind of diffuse malpractices that characterise some management.

If using a questionnaire to assess safety culture then action plan can be targeted. The action plan may select from a huge range of organisational changes, awareness campaigns, training improvements, or behaviour modifications etc.

Strengths
- Introduction provides a good overview of issues
- Identified several key principles of good safety culture
- Gives a nuclear view of safety culture that shows it faces the same issues as other major hazard industries

Weaknesses
- Research methodology does not follow from the introduction; fairly standard approach to measuring safety culture

Ref 46

Behavioural approaches to safety management within reactor plants: A preliminary study.
Cox, S., Jones, B. and Rycarft, H. 2004
In: Emerging Demands for the Safety of Nuclear Power Operations. Challenge and Response. Ed. Itoigawa, N., Wilpert, B. and Fahlburch, B.

Summary
The chapter describes the implementation of a behavioural safety programme within the nuclear industry. It is noted that the behaviour change is intimately tied up with the issues of motivation, attitudes, beliefs, learning and trust – in the management of safe behaviour the constructs are interdependent.

Main factors thought to influence safe behaviours:

- Human factors (inc. person-environment fit)
- Personal characteristics (age, gender, experience)
- Established norms of behaviour
- Attitudes and climate
- Attitudes and perception of risk
- Perception, organisation and environment
- Motivation and perception of long-term versus short-term benefits
- Motivation (general motivation?)
- Trust?

Initially, focused on ‘conventional’ safety rather than nuclear safety but has been extended to include other areas inc. environmental management, leadership and nuclear safety – details are not provided in this paper (this is something that can be followed up).

A series of interviews and site visits were conducted to assess employee commitment to behavioural safety and any barriers to continuing success. The paper identifies the key perceived strengths (e.g. increases safety awareness, promotes communication, ownership of solutions etc.), perceived pitfalls (e.g. unreal expectations, requires foundation of trust, more feedback required etc.) and learning potential/ outcomes (e.g. opportunities for communication/ knowledge sharing, direct link between behaviour and consequences etc.). Examples are given of specific unsafe behaviours– two relate to wearing of PPE and the third to the chief executive walking too close to the edge of the stage while giving a presentation (i.e. not nuclear safety examples). Perceived to have improved individual learning capability and facilitated organisational safety improvements within the study organization.

Strengths

- Applied example of behavioural modification
- Highlights strengths and weakness of approach as reported by employees

Weaknesses

- Focused on “conventional” safety (i.e. PPE/ slip, trip & fall accidents) not nuclear/ major hazard safety activities
- Mentions that the program has been extended to include nuclear safety activities but too late to be included in paper.

Ref 47

Development of a Safety Assessment System for Promoting a Safe Organizational Climate and Culture. Ken-ichi Takano, Tadashi Tusge, Naoko Hasegawa and Ayako Hirose. In: Emerging Demands for the Safety of Nuclear Power Operations. Challenge and Response. Ed. Itoigawa, N., Wilpert, B. and Fahlburch, B.

Summary

Describes the applicability and feasibility of a proposed safety assessment system by examining the result from a questionnaire survey. The questionnaire was designed to explore a) safety awareness and behaviour of plant personnel, b) safety management and c) organisational climate and culture.

Lists a number of questionnaire items having a significant regression (<5%) with the facility failure rate, the ones relating to safety awareness and behaviour include for example:

- Giving a colleague a caution if he does not follow rules and procedures
- Taking pride in job
- Taking pride in company
- Feeling satisfied in doing one’s work
- Feeling one’s contribution is important to the workplace
- Always reporting crucial information to the supervisor
- Participating in safety education and training

Lists a number of questionnaire items having a significant regression (<5%) with the labour accident rate. The ones (negative factors) relating to safety awareness and behaviour include for example:

- Preferring to work in a safe workplace
- Not connecting potential accidents to one’s own work ways
- Regarding safety as an organisational concern, not an individual one

Strengths

- Identifies individual experience/ behaviour, safety management principles and descriptions of organisational climate and culture.

Ref 48

Measures of safety management performance and attitudes to safety at major hazard sites. Hurst, N.W., Young, S. Donald, I., Gibson, H., Muyselaar, A. Journal of Loss Prevention in the Process Industry, Vol. 9, No.2, pp. 161-172. 1996

Summary

Paper describes the application of a safety attitude safety questionnaire (SAQ) and a Process Safety Management System (PSMS) Audit tool called PRIMA (Process Risk Management Audit) at 6 major hazard sites in 4 European countries.

Provides examples of the

- 'Ideal' process safety management systems control loop
- 'Good' process safety management systems control loop and
- 'Poor' process safety management systems

Focuses on tools to assess safety culture and does not describe any 'behaviours'. The paper states that there is a correlation between the results from the PRIMA tool and accidents rates and therefore can be successful at predicting self-reported accident rates.

The attitude scales reflect the different safety cultures within the sites, and identify strengths and weaknesses for each site in terms of safety.

Strengths

- Good model used for the research
- Good balance of theory and application

Weaknesses

- Specific behaviours not identified.

Ref 49
The organisation of Human Factors - Safety Management Survey Results.
Green Street 1995 IMC GNSR Human Factors Project HF/GNSR/02 (94/95)

Summary
The report describes work to explore whether the nuclear industry can learn anything from other industries in the application of human factors in safety management systems. Focuses on the practical application of safety management systems rather than the theoretical basis for such systems.

Good practice checklist

Senior management commitment

- Specific measures are required to convince the workforce that their safety is seen as an important issue by management and that head office understand operational safety issues.
- Company policy should incorporate safety goals and objectives in a form that is comprehensible to the workforce, so that they can judge whether that policy is being implemented
- Senior management must be visibly committed to safety; indicators may need to be developed

Communication

- Communicate regularly with the workforce on safety matters
- Monitor the effectiveness of communications

SMS and organisational complexity

- Ensure that the SMS is transparent and that all personnel and contractors understand its basic operation
- Ensure that staff and contractors understand their responsibilities for safe behaviour *and* their role in SMS operation; include it in induction and refresher training.
- Aim for simplicity and consistency in SMS design, with overlap or redundancy only where required
- Keep the safety management organisation simple; design the organisation to match the process rather than other way round
- Take active steps to avoid an ‘us and them’ attitude developing sites and HQ safety functions

Measurement of safety

- Safety management comparisons between sites should employ relative and not absolute measures

- Try to avoid ‘league tables’, in particular where site performance may be hindered by factors such as age of equipment, type of workforce population etc.

- Ensure that efforts to improve safety in areas highlighted by audits are directed towards those areas that will have the most effective impact specific to the organisation

- Specific account needs to be taken of the need to develop and, by inference,? to monitor safety culture.

Operational feedback

- Ensure that all personnel have a basic understanding of operational feedback systems and also know how to feedback any general or underlying safety concerns

- It was noted that organisational complexity delays response to feedback and operational personnel may interpret this an inaction by management.

- Also, culture and peer group pressure may discourage reporting

Proprietary tools

- High level standards and procedures have to drawn up by the company’s central safety management function to ensure consistent use of tools and approach to implementation

Modification and evolution of proprietary systems

- Provide for regular feedback on, and review of, safety management policy, systems and tools

- Feedback and data from different sites should feed into a common company database from which experience can be drawn and the safety management framework evolved and updated

- Allow continuous updating and improvement of the safety management system in the light of operational experience, feedback and experience of running the SMS

- Internal expertise allows proprietary methods to be tailored more readily to specific company requirements

- SMS monitoring and maintenance requires explicit allocation of resources and co-operation between sites and health and safety functions

Organisational structure

- The structure of the safety organisation should be transparent to personnel. Avenues for reporting and allocation of safety responsibilities should be clear and understood.

- It should be evident to all levels of management how the SMS relates to the management process

- Flatter structures encourage personal responsibility for safety

- All personnel should be adequately supported in their role within SMS. This support should ideally be documented as part of the system. Managers should be trained in safety management responsibility

- Effective communication, liaison and interaction is required with other functions within the company which have a role in implementation or facilitation of the application of the SMS.

- Safety objectives and safety related feedback systems should be closely aligned with the Quality Management System

Strengths

- Review of the research area focusing on major hazard industries

- Outlines key points for safety management systems

Weaknesses

- High level factors

- No discussion of specific behaviours

Ref 50.
Development of Criteria for the Breadth and Depth of Major Hazard Inspection. Deborah Keeley. HSL RAS/05/08 2005

Summary
Work to develop criteria, if possible, for the breadth and depth of inspection in the regulation of the major hazard sectors (i.e. hazardous chemicals, gas, nuclear and offshore). One of the tasks was to examine a number of past incidents to determine contributing factors which, had they been picked up by inspection and/or assessment, may have prevented the incident (a selection of incidents from each of the 4 major hazard sectors, Nuclear, Offshore, Gas and Chemical were examined).

Most of the literature was not found to be directly relevant, it contained useful information regarding the identification of key areas/issues in the management of safety.

A number of risk control systems were commonly identified as being significant risk contributors in the literature reviewed and their importance was further demonstrated as they were also found to be underlying causes for most of the incidents reviewed. These are:

- Maintenance procedures;
- Operating procedures;
- Assessing competence;
- Plant inspection;
- Plant and process design;
- Risk assessment; and
- Management of change.

Also provides summaries of a number of incidents; the most common contributor to the incidents reviewed was inadequate maintenance procedures, followed by inadequate inspection, inadequate plant and process design, inadequate risk assessment and inadequate operating procedures. Insufficient information was available, in the reports examined, on actions (especially with respect to inspection) that were taken by HSE prior to the incident.

Strengths

- Good overview of underlying causes of incident

- Findings are based on the literature, accident investigation reports and interviews with HSE Inspectors

Weaknesses

- Top level, does not look at specific behaviours.

Ref 51
Fault-finding in maintenance tasks. Contract HF/GNSR/01 Patrick, J., Halliday, P., Handley, J., and O'Reilly, S. May 1995

Copied from the original.

3.2.2 Analysis of Incidents and Events

There is evidence from studies of incidents and events at both nuclear and other complex industrial plant that maintenance error constitutes a serious problem. It has been noted that in the history of nuclear power plants, an early focus of attention on the central role of operations staff has been supplemented by an increasing awareness of the important role that maintenance staff play in plant operation and safety (e.g. Chockie, Badalamente, Hostick and Vickroy, 1984; Rabhouhams, 1986).

Two particularly well-known studies examining the effects of human error in maintenance on the safety and efficiency of plant operation are those conducted by Rasmussen (1980) and the Institute of Nuclear Power Operations (INPO) (1984).

Rasmussen (1980) analysed 200 cases of 'operational problems' and found that omission errors (the failure to carry out some of the actions necessary to achieve a desired goal) accounted for 34% of all the incidents. He found on further analysis that maintenance related tasks (test and calibration; repair and modification) accounted for 74% of these cases. The root causes of 87 significant events reported to INPO in 1983 were analysed. 182 root causes were identified and 44% of these were classified as human performance problems. Omission errors were found to be the largest category of human performance problems contributing to significant events at nuclear plants. Furthermore, omission errors were most frequently associated with maintenance activities.

In addition to these well known studies, Snieziek (1986), Meclot (1989), Wu and Hwang (1989), Wahlström, Laakso, Norros & Pyy (1989) and Strod (1980) all cite human error in maintenance tasks as a significant factor in incidents.

Snieziek (1986) reports that maintenance error has been found to be responsible for 80% of equipment failures. Meclot (1989) notes that analysis of significant incidents at Electricité de France plants has shown that human error is involved in approximately 40% of cases, although not all of these relate to maintenance. Operations staff were initially implicated as the major contributors to this figure though Meclot points out that more detailed analysis reveals that maintenance personnel also play a significant role and as errors that do not manifest an effect on safety or unit availability are not included in analysis, maintenance error potentially poses a larger problem than is suggested by the available data.

The nuclear industry is not alone in finding evidence of human error in maintenance activities. Evidence of the difficulties posed by fault-finding in maintenance tasks can be found in other domains, for example commercial aviation and the military. Christiansen and Howard (1981) note that 40-50% of the components sent for repair in commercial airline maintenance are not defective and removal and replacement of these items may actually induce errors. Nawrocki (1981) reviewing maintenance in US military installations cites the US Department of Defence estimates that between 30-60% of faults are diagnosed incorrectly.

It is difficult to be certain of the reliability and validity of the attribution of maintenance problems to different types of human error. However even if the above evidence is treated conservatively, it seems to indicate that human limitations, inefficiency and error in maintenance activities do constitute a significant problem.

Ref 52
A framework for the use of key performance indicators of major hazards in petroleum refining. IP Research Report 2005. Energy Institute, London. ISBN 9780852934517

Summary
A framework for the use of KPIs in major hazard industry (petroleum refining); considers 600 potential and 800 actual major hazard accidents and reports and the substantial differences in the frequency of causes between the two categories. So in looking for the most frequent causes to use as a KPI the data from actual incidents was thought to be a better guide. Note that from the various sources analysed the most frequent causes of incidents were not always the same.

One recommendation: Potential incident data should not be used as a KPI. Analysis showed that there are too many differences in the distribution of causes compared to actual incidents and a great lack of consistency between sites. Causes were not HF/ behavioural. Focused on physical causes of accidents.

Aim of the work was to provide a set of KPIs to measure the risk of major hazards in petroleum refining. Analysis of current data showed that it was possible to identify the probable cause but not the underlying cause of accidents e.g. relief valve stuck open or closed, because why the relief valve stuck was not included in the report.

Includes one reference to human error, as a cause of an incident, but does not explore why.

Annex 1 – proposes revisions to the HSE loss of containment data set for refinery RIDDOR voluntary reporting

Underlying cause issues have been added to the list:

- Inadequate inspection of process fluids
- Inadequate operating procedures
- Inadequate design for safety
- Inadequate management/ supervision
- Inadequate hazard analysis/ risk assessment
- Flammable liquid vapour pressure above design
- Sudden vaporisation
- Abnormal high temperature

Ref 53

Assessing and reducing the likelihood of violation behaviour - a preliminary investigation Williams, J.C.1997. Paper presented at Institution of Nuclear Engineers' Conference COPSSA '97

Summary

The paper draws upon a range of research in an attempt to characterise and unify non-compliance data for use within system reliability assessments and probabilistic safety assessments (PSA).

“Regardless of the possibility of an occasionally favourable outcome, therefore, we know that violation or non-compliance behaviour will affect the operation of most man-machine systems from time to time”. Aim of the work is to …”obtain some understanding of the probability of non-compliance behaviour and circumstances in which otherwise compliant behaviour might become non-compliant and vice-versa.”

Influences on behaviour:

- Presence of a group
- A person’s status
- Whether a person is judged to be in authority will also influence the behaviour of others, for better or worse, in a systematic fashion
- Likelihood of detection of violation behaviour
- Amount of inconvenience associated with maintaining compliant behaviour

The work is not restricted to focus on major hazard industries but does include references to major accidents e.g. Bhopal, rail accident at Crowden, offshore, Chernobyl and Challenger.

Violation behaviour is therefore not distinguished by industry; a generic view of violations in an attempt to quantify for inclusion in PSAs.

Strengths

- Drawing together violation data from a number of disparate research domains

Ref 54

Organisational factors; their definition and influcence on nuclear safety.Baumont, G, Wahlstrom, B., Williams, J., Frischknecht, F., Wilpert,B. and Rollenhagen.VTT Research Notes 2067, Technical Research Centre of Finland, 2002, Espoo, Finland, ISBN 951-38-5770-0

Summary

EU collaboration work. Note: the work started 1998 it took 17 months and was not published until 2002. Provides an excellent overview of the situation in the nuclear industry. The position may have moved on to some extent since this work was done but the fundamental issues remain the same.

Causes for human errors can be found in deficient man-machine interface design, communication, procedures and training. Behind these deficiencies however there is often a common cause, organisation and management. The aim of the work was to combine European efforts in research in organisational factors of nuclear safety and to establish a common framework for future research.

Methods to improve safety in the nuclear industry have tended to be mostly technical, but today there is an increased recognition that human and organisational factors also have an important contribution to make in ensuring nuclear safety.

Questions to be addressed:

- How can good and bad operational practices be identified?
- How can organisational factors be included in safety assessments?
- Which methods can be used for detecting weak signals of deteriorating performance?
- How should incidents be analysed with respect to organisational factors to give the largest learning benefit?
- How can organisational performance be collected and assessed in a systematic way?
- How can an organisation be developed in response to changes in its operational environment?
- What are the needs and priorities in further research work in organisational factors?

The common starting point for the partners was that assessment of the influence of organisational factors is very important when reviewing the safety of Nuclear Power Plants (NPPs). This is also based on the observation that incidents and accidents often develop from small events, which are encountered in unexpected ways. Organisation and management is the most important contributing factor both for detecting and removing such hidden deficiencies in the system.

The paper notes that a list of organisational factors together with their definition can provide some insights, but is difficult to use in day-to-day management activities – further work needed where real managers describe their problems and solutions.

Includes a section on a regulatory perspective – "Safety culture has become an important concept in regulatory practices, but the concept is difficult to define accurately in a technical sense. Regulatory pressure on NPP operators to show that their safety culture is good can therefore cause confusion if the process is not progressed in a logical, incremental fashion."

Organisational assessment and development:

1. It is necessary to understand what the important characteristics of organisations are and how they interact.

2. This understanding has to be applied to predict how certain actions are likely to influence organisational performance

3. It is necessary to detect early signals of deteriorating performance to initiate corrective actions before an incident makes the deficiencies obvious.

Understanding organisations: "In trying to understand how organisations operate it is necessary to separate the described formal organisation and the actual way the organisation carries out its work. A common observation from many organisations is that there can sometimes be a considerable discrepancy between the as described and the real organisation."

Good organisational principles: It's not easy to determine to what extent such principles are generic or apply only to some local conditions – all agree that organisational factors make a difference, but there is no consensus on which factors are the most important.

Agreement that:

- Authority to make decisions should be placed at the level where all necessary information is available

- The most junior person should have authority to challenge the basis for judgement and to require a safety first approach to operation

- An organisation has to protect itself and its members from over-confidence

- People in any organisation are strongly influenced by and are very responsive to perceived expectations from the top management.

Strengths

- Good overview of position in the nuclear industry

- Europe wide perspective

Weaknesses

- 8 years old

- Does not provide answers, only questions

- Theoretical under pinning despite the fact that the authors note the need to appreciate management issues in practice.

Ref 55.
Organizational contributions to nuclear power plant safety. Ghosh, S.T. and Apostolakis, G.E. Nuclear Engineering and Technology, Vol.37. No.3, June 2005.

Summary
Notes that human error is an important contributor to accidents and incidents, and that organisational factors play an important role in creating contexts for human errors. Current Probabilistic Safety Analyses (PSAs) do not explicitly model the systematic contribution of organizational factors to safety. The paper is said to present a review of research into the following questions:

- Is there evidence that organisational factors are important in NPP safety?
- How do organisational contribute to safety in NPP operations?
- How can these organisational contributions be captured more explicitly in PSA?

The approach used previous accidents to illustrate the safety implications of organisational deficiencies, some mechanisms by which organisational factors contribute to NPP risk and some of the methods proposed in the literature for performing root-cause analyses and including organisational factors in PSA.

Includes 2 more recent accident case studies:

Davies Besse RPV Head Degradation (Spring 2002)

Paks Fuel Damage Event (Spring 2003)

Plus reviews of work to analyse accident data:

1. OECD's Nuclear Energy Agency (NEA) report on recurring events in the nuclear industry. This included a section on recurring management and organisational factors that were revealed as root causes in multiple events, including:

    - Deficiencies in safety culture in general
    - Deficiencies in communication
    - Deficiencies in work practices such as not following procedures, lack of clear work responsibilities, improper use of system diagrams
    - Deficiencies in procedures, instructions, work orders, administrative orders and work control.
    - No common understanding of design basis document review process, lack of design basis information available
    - Failure to act appropriately after the identification of a significant deficiency
    - Inadequate management oversight
    - Heavy workloads and conflicts between personal safety and configuration management

- Insensitivity to shutdown risk activities among multiple organisational units within licensee organisations

2. US Nuclear Research Council (NRC) research analysed 48 events at US NPPs for human performance contributions – in 37 of the 48 events, human errors were included among the root causes.

Provides a lot of information about the underlying causes of accidents.

Conclusions:

There is no doubt that organisational aspects of NPP operating bodies generally affect safety.

Numerous analyses have identified more specifically what aspects of the organisation are important to safety in terms of organisational performance, organisational processes and factors and a safety culture.

The implicit assumption is that safety culture is clearly a pervasive and important aspect of operations but one whose effect on risk may be difficult to quantify.

PSAs are currently incomplete by not including operational factors but how to achieve this is subject to debate that is not resolved in this paper. Organisations are constantly changing, many organisational weaknesses are latent and may not be recognised for a long time. Along the same lines, a signal of potential operational weaknesses may be weak and difficult to interpret. There is a lack of data to tie operational weaknesses systematically to PSA.

Strengths

- Good overview, bringing together many of the issues to be addressed in the current HSE review

- Includes accident data to illustrate the underlying causes of accidents

Weaknesses

- Does not add anything new

- Recognises that organisational issues are important but doesn’t provide any answers about how to address the issues.

Ref 56
The Use of Occupational Safety and Health Management Systems in the Member States of the European Union: Experiences at a company level
European Agency for Safety and Health at Work.1996-2001

Summary
A short book to describe case studies from a range of companies, from across Europe, where strong Occupational Safety and Health Management Systems (OSHMS) have been implemented.

Quantifiable objectives relating to the introduction of an OSHMS could only be observed in a few cases. Companies that defined such objectives mostly referred to the 'zero accidents' strategy. Those companies that had defined quantitative targets achieved a reduction of accidents at work. They also noted an increase in employees' motivation, even though this is not measured in a quantifiable way; many companies believe that productivity rises with the implementation of OSHMS.

Examples emphasise the necessity to declare occupational safety and health as an executive duty.

The main advantages are that they encourage:
- Systematic root analysis of hazards, risks and incidents;
- Strong awareness of hazards and risks
- Improved transparency concerning internal processes
- Better communication among employees
- Stronger motivation and identification of employees with their company
- A more extensive and integrated point of view in the sense of the working environment
- Better measuring of the occupational safety and health performance

Strengths
- Industry examples of where OSHMS has been successfully implemented.
- Includes recommendations from each about how to ensure successful implementation (e.g. change organisational structure, ensure adequate funding etc.)

Weaknesses
- Insufficient details of each scheme
- Little true quantification of the benefits

Ref 57

The Factors and Causes Contributing to Fatal Accidents 1996/97 to 2000/01. Health and Safety Executive Bomel Consortium. C998\01\101R Rev A July 2003 Final Report. HSE Task ID Bom\ 0040

Summary/ selected text copied from paper

The report includes an analysis of accident data that has been reported under RIDDOR, the analysis of paperwork relating to 191 accident investigation reports and workshops were held with representatives from agriculture, construction, hazardous industries, manufacturing and services. The analysis was based on the Model of Influence Network, as follows:

Accident
⇑
Direct level - human performance
⇑
Organizational level
⇑
Policy level
⇑
Environmental level

Situational awareness or risk perception, ***Compliance*** and ***Competence*** were significant immediate contributors to fatal accidents, the more effective route for improvement measures was seen to be through the business supply chain rather than direct. Customer demands are responded to by businesses and it was seen to be important for health and safety requirements to be levered in.

The principal risk control mechanisms emerging to be of concern were ***Safety management***, ***Planning*** (including risk assessments), ***Safety culture*** and ***Management and supervision***. These were reinforced by concerns about Competence, Situational awareness and risk perception and Compliance.

Where formal Safety management systems exist, implementation was said to be weakest in the follow through to ***review, audit and improvement***. Frequent concerns related to the role and relevance of ***Procedures*** in the workplace such that the route of influence for procedures had become uncertain. Concerns with respect to risk assessment aspects of Planning centred on the ***skill level*** required to understand and prioritise risk. There were challenges identified in translating white collar written systems to practical solutions immediately available to the front line workforce as and when required. The issues were seen to be particularly acute for small firms.

Common themes were the need to better understand ***effective mechanisms for Communication*** both to utilise the knowledge and experience of workers in developing appropriate controls and for dissemination. The challenges are comparable whether considering the situation within companies or between HSE and industry.

The principal area of concern across all industries, supported by evidence of reported deficiencies from the FAI files related to Management and supervision.

Reduced levels of Management and supervision, coupled frequently with increasing administrative demands and inattention to required competencies for managers and supervisors in respect of ensuring workforce safety, characterised the issue such that the ability for the role to be effective was questioned. The significant weight of influence from Management and supervision to many of the direct level factors constituting immediate causes of accidents was revealed. The observation was that managers and supervisors may unwittingly be becoming a barrier to disseminating safety advice and information, as opposed to the conduit that senior management envisages.

Competence and Training in general, whilst increased recognition within industry of their significance was acknowledged, the combination of skill-based competencies to undertake a task and competence to work safely were considered to need further attention, particularly to clarify what is required of trainers or on-the-job mentors to deliver effective and lasting safety training.

Another area where the workshops suggested the mechanisms and strength of influence might not yet be wholly recognised by industry, relates to Safety culture. That this is highly dependent on the overall Company culture, its Ownership and control of the processes

For many of the fatal accidents examined, it appeared the person had been unaware of the risks they faced or of the reasonably practicable precautions that should have been available to them (indicating inadequate Situational awareness / risk perception). Underlying this is a general failure for adequate Planning and risk assessment at a level that is practical and meaningful for those carrying out the work tasks. The workshops further expanded on the concerns highlighting the difficulty some individuals and thus organisations have in differentiating hazards from risks, in prioritising their actions accordingly, in translating generic principles to specific circumstances, and the consequent reliance on perhaps inappropriate check lists in an attempt to satisfy risk assessment 'demands'. In such hands, the power of risk assessments to protect workers is being lost. Whilst the work has strongly endorsed established safety management concepts as an effective means for assuring worker safety, it has identified significant concerns and deficiencies in current delivery for which new solutions must be sought.

Recommended Actions

The report presents specific recommendations that can be grouped:

- To understand better the potential mechanisms of influence (e.g. contracting strategy, Incident management and feedback, and Training to deliver Competence to work safely)

- To examine the impact of changing external factors on the quality of influence (e.g. related to Management and Supervision, Inspection and Maintenance, multiskilling/ agency workers etc to ensure Availability of suitable human resources, recreational drugs use and influences on fatigue and alertness

- To revisit health and safety management devices and improve their effectiveness

(e.g. Safety management in terms of continuous improvement, review and audit, Procedures, and planning to include risk assessments that will provide for Situational awareness and Availability of information and advice within the workforce).

Strengths

- Triangulated approach: accident database, incident investigation reports and workshops with subject experts.

- Provides a view that there is insufficient detail in the data provided via RIDDOR for investigating incidents and identifying underlying causes.

- Data collected as part of HSE Inspector accident investigation is not gathered with a view to identifying underlying causes but some insight can be gleaned from witness statements.

- Provides an overview of the immediate causes to fatal accidents and a breakdown of this information by sector

- Compares HID industries with non-HID sectors

Weaknesses (all noted in report)

- Subjective

- Quality incident report data variable

- Sample sizes in some sectors

Additional information (copied from report)

The most common influences evident for the sample of accidents reviewed, were problems with situational awareness; competence; planning; tools, equipment and PPE; safety culture; work environment; safety management and general management; compliance; procedures; and communication issues. This selection suggests that a mixture of human, hardware and organisational factors are the underlying causes in the accident sample. In order to understand the specific deficiencies within each of these broad categories it is necessary to drill down into each factor and examine the nature and frequency of the precise failings highlighted in the review.

The main problems at the direct level include a failure to appreciate the scale of risk associated with the work activity (situational awareness), incorrect or inappropriate actions on the part of the individual who was killed (DP) (competence), violations of adequate procedures (procedures) often to save time and effort, a lack of appropriate tools, equipment and/or PPE or inadequately repaired and poorly maintained equipment / PPE, unprotected height (work environment) and lastly, a tendency for team members to work on individual fronts without sufficient awareness of each others' activities (teamworking).

At the organisational level, emerging trends include planning failures, in the form of complete absence of risk assessments and/or method statements, inadequate risk assessments and inadequate systems of work. Failures identified under organisational safety culture include a tangible lack of management commitment to safety as well as management recognition and acceptance of safety short cuts. Other management failings identified include inappropriate levels of supervision with 'too little' supervision being the most frequent failing along with a lack of enforcement regarding safe practices. At the procedural level, common failings in the sample include a complete lack of any formalised procedures as well as inappropriate work practices/procedures. This failing was related to people carrying out activities in an ad hoc manner that increased the likelihood of an accident. There were also several cases where the written work practices were not appropriate for the job in hand or were not correctly followed. Lastly at this level, communication deficiencies were highlighted including failures in vertical communication between supervisors and staff as well as inadequate communication between different organisations working together.

At the policy level under safety management, the issue of inadequate risk assessment and the resulting inadequate identification of hazards dominates again, followed by inadequate safety policies. It should be remembered that the sector sampling strategy deliberately reflected the SE fatal accidents statistics so that the number of files pulled for each sector is proportionate to the actual fatality statistics for that sector i.e. those sectors with higher fatal accident numbers, such as agriculture and construction, will be represented by a larger number of files than a sector such as HID where very few fatal accidents occur. The result of such sampling is that any global perspective of common causes is biased by the common causes highlighted in the ‘higher-risk’ sectors (as defined by higher fatality numbers). In order to determine whether there are any particular deficiencies that are sector unique it is therefore necessary to drill own into the file review data for each sector. In the following sections these review results have therefore been broken down by sector for comparison purposes

Agriculture and Wood

In the Agriculture and Wood Sector, situational awareness at the direct level and planning at the organisational level are dominant followed by individual competence, safety culture, compliance and levels of management and supervision.

Construction

In the sample of 68 construction accidents reviewed the most frequently identified deficiency is a lack of situational awareness on the part of the person who was killed. Unusually this is closely followed by work environment although this is almost undoubtedly a result of the number of falls from height accidents reviewed in the sample. In falls cases the detailed deficiency ‘unprotected height’ will have been highlighted as an indication of wider work environment failings. Although the work environment factor is a specific issue in construction, otherwise there seems to be a pattern emerging across the sectors. There appears to be a tripartite relationship between situational awareness, individual competence and deficiencies in planning.

Engineering and utlilities

In the review for the engineering and utilities sector, the repeated deficiencies are again predominantly in planning, situational awareness, competence, tools, equipment and PPE, safety management, safety culture, management & supervision, and compliance. Again, as with the other sectors, the key issues with regard to planning are related to risk assessments either being inadequate or non existent with similar deficiencies in relation to method statements. The issue of inadequate risk assessment also associated with respect to Safety Management.

Food and entertainment

In common with other sectors, situational awareness is the dominant deficiency followed by competence, and planning. As discussion in other sectors has shown, planning issues include lack of risk assessments and method statements coupled with inadequate systems of work. Similarly inadequate risk assessment also features in the safety management factor, which is being highlighted in 54% of cases. It appears that the triangulated relationship between situational awareness, competence and planning is also apparent in this sector and the pattern of deficient active risk assessments and the resulting impact is highlighted once more. Following these, dominant factors are issues such as compliance and safety culture.

Metals and minerals sector

In the review of metals and minerals sector files, situational awareness, tools, equipment and PPE dominate with planning, competence and safety management following closely behind these two factors. Again the same pattern is appearing in relation to individuals choosing inappropriate actions, displaying poor levels of situational awareness and organisations having deficient risk assessments. Other common failings include work environment and safety culture.

Services

In the review of services sector files, compliance and situational awareness dominate with management and supervision and safety culture following closely behind and planning, communications and competence ranked joint third. Again the same pattern is appearing in relation to individuals displaying poor levels of situational awareness and organisations having deficient risk assessments (planning). Despite the repeated deficiencies in this sector sample, it is difficult to highlight any real trends due to the small sample size reviewed. However it is interesting to note that, aside from the frequency of compliance issues, nothing particularly new is being identified in relation to this sector of industry and so this adds weight to the theory that there is in fact a pattern of common causal factors emerging.

Polymers and Fibres

From the review completed, both tools, equipment and PPE and situational awareness are most frequently identified as contributory factors with safety management, planning and competence issues ranked joint second. Despite the repeated occurrence of the most common deficiencies in this sector sample, it is very difficult to highlight any real trends due to the relatively small number of accidents reviewed. This is demonstrated clearly by the lack of differentiation in frequency between the factors identified. Despite this constraint, it is interesting to note that nothing new or different is occurring as a frequently repeated deficiency and so this adds weight to the suggestion that common causal patterns are occurring across a wide diversity of different accidents and different industrial sectors.

HID

When reviewing the results of the HID files, similar limitations due to sample size are encountered as when reviewing the sample for engineering & utilities and polymers & fibres. Despite this, it is interesting to observe that although the common failures in competence, compliance, situational awareness, and tools, equipment and PPE are repeated there are some initial differences in the highest ranked factors. Management and supervision as well as procedures are coming out in the top four factors and fatigue is coming out in two of the three of the cases reviewed.

The detailed failings show that under management and supervision there are two issues being picked up. Firstly that there is an inadequate level of supervision, more specifically too little supervision, and the second and not unrelated issue is that there are inadequate levels of work site walkthrough. Although the sample size prevents any robust conclusions being drawn, it is interesting that during the HID workshop the issue of management and supervision was of concern to the participants. In particular the concern was not related to the quality of management and supervision in itself but to whether or not those appointed had sufficient time to do the job properly. This appeared to be a problem right across the board, it was believed that companies have cut back on the numbers of managers and supervisors to such an extent that those competent ones that remain are overstretched and less effective. The net result of such downsizing is that when everything is going smoothly the supervisor can just about cope but, in non-routine emergency situations, or even when work levels increase, then the supervisor's effectiveness is compromised. With regard to procedures, the more detailed findings highlighted indicate either that appropriate procedures were not followed or that they were inappropriate or out of date. This is interesting, as procedures were not thought to be a particularly pertinent issue during the workshop. The picture that emerged from discussion with participants was that the HID industries were highly proceduralised and that although some procedures might get overlooked in day-to-day routine activities, where there are specialised high risk activities then procedures are strictly adhered to and activities are even further controlled through the use of permit to work (PTW) systems. The review seems to suggest the contrary, that procedural issues have been implicated in very serious accidents. However, as previously stated, the sample is so small that it is not appropriate to use these results as evidence to indicate wider problems regarding procedures in the HID industries. Lastly the issue of fatigue is highlighted with particular failings being lack of rest periods and 'work being skill based resulting in people working automatically so prone to mental lapses'. It was acknowledged during the workshop that managers are tending to work longer hours and do more work in those hours. It is not known whether this extends to workers in general, however this might corroborate the 'lack of rest' finding.

Conclusions

Taking a global perspective, there was surprising consistency in the dominant failings uncovered both across the sectors and across the different accident kinds, process environments and employment status categories included in the sample.

Bulleted below are those factors that recur consistently across the files reviewed and can be reported with confidence.

- Situational Awareness, Competence, Planning and Safety Management - The issue of inadequate risk assessments is the most common deficiency identified in the fatal accident files. Whether risk assessment deficiencies are identified overtly under planning or safety management failures, or whether they are implied by the frequency of failings such as 'poor situational awareness' or competence issues such as 'inappropriate actions being taken by the DP', it is clear that failures to assess risk and communicate the findings to the workforce such that they change their behaviour is a common failing across all the sectors reviewed.

- Tools, Equipment and PPE - In several of the accidents reviewed failures in basic standards of Tools, Equipment and PPE were identified with equipment predominantly not available or not to an appropriate standard. This primarily relates to the absence or inadequacy of safety equipment, including PPE and physical guards/barriers rather than operational equipment.

- Management & Supervision, Compliance and Safety Culture – It has been found that managers and supervisors are generally providing inappropriately low levels of supervision and guidance to staff. This is thought to be more as a result of heavy workloads rather than a neglect of responsibility itself. This lack of supervision may be related to the prominence of compliance failures in the review, with cases of violations and bad practice being noted. The fact that such non-compliant and often dangerous behaviour is sometimes tolerated and not addressed by management may also be indicative of wider failings in organisations' safety cultures.

- Work Environment **-** Unprotected height was identified as a detailed failing under work environment in 31% of all cases reviewed and in 59% of the construction accidents reviewed. This is something that should be picked up in risk assessments and appropriate action taken. However, the fact that risk assessments have been highlighted as a deficiency may help to explain why the appropriate action has not been taken.

- Procedures **-** Failures associated with procedures have been highlighted in 42% of the cases reviewed with particular failings being either that there were no written work practices at all, or, that they simply were not appropriate to the context in which they were being applied. Such failings mean people are carrying out work activities in an ad hoc manner, which increases the risk of accidents.

Ref 58

A Synthesis of Safety Culture and Safety Climate Research Wiegmann, D. A. Zhang, H, von Thaden, T. L., Sharma, G, and Mitchell. A.A. Technical Report ARL-02-3/FAA-02-2 June 2002

Summary (N.B. Key text copied directly from the paper)

Defining Safety Culture

Current interest in the term "safety culture" can be traced directly back to the Chernobyl accident in 1986. Since then, numerous definitions of safety culture have abounded in the safety literature. Indeed, our recent review of the literature revealed several diverse definitions of the concept (Wiegmann, Zhang, & von Thaden, 2001). Most definitions originate from articles that have focused on safety culture in industries other than aviation (e.g., nuclear power, mining and manufacturing). Nonetheless, there does appear to be several commonalities among these various definitions regardless of the particular industry being considered. These commonalities include:

1. Safety culture is a concept defined at the group level or higher, which refers to the shared values among all the group or organization members.
2. Safety culture is concerned with formal safety issues in an organization, and closely related to, but not restricted to, the management and supervisory systems.
3. Safety culture emphasizes the contribution from everyone at every level of an organization.
4. The safety culture of an organization has an impact on its members' behaviour at work.
5. Safety culture is usually reflected in the contingency between reward systems and safety performance.
6. Safety culture is reflected in an organization's willingness to develop and learn from errors, incidents, and accidents.
7. Safety culture is relatively enduring, stable and resistant to change.

Defining Safety Climate

Although the debate over the definition of safety culture has not reached unanimous agreement, a similar term "safety climate" has been used frequently in the literature and has added to the confusion. Furthermore, a previous review of the literature (Wiegmann et al., 2001) indicated that, from the time the term was first highlighted by Zohar (1980), the literature has not presented a generally accepted definition of safety climate either. In fact, some definitions of safety climate are almost identical to definitions of safety culture. However, many definitions do have commonalities and do differ from safety culture in important ways. These include:

1. Safety climate is a psychological phenomenon, which is usually defined as the perceptions of the state of safety at a particular time.
2. Safety climate is closely concerned with intangible issues such as situational and environmental factors.
3. Safety climate is a temporal phenomenon, a "snapshot" of safety culture, relatively unstable and subject to change.

Organisational Indicators of Safety Culture; there are at least five global components or indicators of safety culture. They include ***organisational commitment, management involvement, employee empowerment, reward systems, and reporting systems.***

Strengths

- Excellent critical evaluation of the literature

- Excellent summary of the key issues

Weaknesses

- Purely a literature review; no industry experience included

Ref 59
Safety Culture, Mindfulness and Safe Behaviour: Converging ideas?
Working Paper 7 December 2002, Hopkins, A. The Australian National University, National Research Centre for OHS Regulation.

Summary
The paper provides a good overview of the concepts and key literature regarding safety culture, mindfulness and safety behaviour. Hopkins notes "safety culture is one of a number of ideas currently seen as having the potential to move organisations to higher standards of safety." Mindfulness is a second approach that has generated interest and is advocated by Karl Weick and his associates. Safe behaviour is a third idea which very much in vogue. These three concepts are embedded in slightly different literatures, suggesting that they are more distinct than perhaps they are. The purpose of the paper is to discuss the way these ideas converge and to explore their limitations.

Hopkins' conclusions are as follows (copied from the paper):
Safety culture is an attractive idea because it promises a way to overcome the limitations of safety systems. It is not, however, a straightforward idea. Many of those who refer to safety culture have in mind an organisation whose members are all individually safety conscious. Reason, while acknowledging that safety culture has implications for the behaviour of individuals, insists that the concept be used to describe truly organisational phenomena and not simply the aggregated behaviour of individuals. In so doing, he resists the slide towards individualism.

The author argues that mindfulness, is closely related to Reason's culture of safety. In many respects it is no more than a restatement of his ideas in new language. It exhibits the same creative tension in that it refers to truly organisational phenomena, which nevertheless have implications at the level of individual consciousness. Its full potential, however, depends of maintaining its emphasis on organisational characteristics.

Safe behaviour strategies are aimed at culture change. But here the emphasis is unambiguously at the level of individuals and what they do, and the link to the organisational level inherent in the previous strategies is largely missing. Safe behaviour strategies in general aim to transform the behaviour of collections of individuals by creating a culture of compliance with rules and procedures. Only when applied to the behaviour of managers is there a potential for changing organisational practices.

The strategy of promoting risk-awareness among employees is a behaviour-based strategy that transcends other safe behaviour strategies in that it attempts to inculcate individual mindfulness directly. Although a promising development, it is unlikely to succeed unless it is part of a broader strategy of promoting organisational mindfulness or a culture of safety as described by Reason.
Reason's work is clearly pivotal in these developments. It insists on the truly organisational nature of the concept of safety culture and it provides a touchstone against which a variety of related concepts can usefully be evaluated.

Strengths

- An excellent overview and discussion of the literature
- A consolidation of the literature from converging sources

Ref 60
Three cultures of management: The key to organizational learning.
Schein, E.H. Sloan Management Review/ Fall 1996, Pgs 9 – 20

Summary
Review to consider why organisational innovations either do not occur or fail to survive or proliferate. Organisational learning requires not only the invention of new organisational forms and processes but also their adoption and diffusion to other parts of the organisation. Schein argues that organisations have not learned how to manage that process, noting that examples of successful organisational learning tend to be short-run adaptive learning (doing better at what they are already doing) or, if they are genuine innovations, they tend to be isolated and eventually subverted and abandoned.

Postulates that in most organisations there are three different major occupational cultures that do not really understand each other and often work at cross-purposes.

1.Culture of engineering, 2. Culture of CEOs. 3. Culture of operators.

Assumptions of the operator Culture

- Because the action of any organisation is ultimately the action of people, the success of the enterprise depends on people's knowledge, skill, learning ability and commitment.
- The required knowledge and skill are 'local' and based on the organisation's core technology
- No matter how carefully engineered the production process is or how carefully rules and routines are specified, operators much have the capacity to learn and deal with surprises
- Most operations involve interdependencies between separate elements of the process; hence, operators must be able to work as a collaborative team in which communication, openness, mutual trust, and commitment are highly valued.

Assumptions of the engineering culture

- Engineers are proactively optimistic that they can and should master nature
- Engineers are stimulated by puzzles and problems and are pragmatic perfectionists who prefer 'people free' solutions
- The ideal world is one of elegant machines and processes working in perfect precision and harmony without human intervention
- Engineers are safety orientated and over design for safety
- Engineers prefer linear, simple cause-and-effect, quantitative thinking

Assumptions of the Executive Culture

Financial Focus

- Executives focus on financial survival and growth to ensure returns to shareholders and to society
- Financial survival is equivalent to perpetual war with one's competitors

Self-Image: the embattled lone hero

- The economic environment is perpetually competitive and potentially hostile, so the CEO is isolated and alone, yet appears omniscient, in total control and feels indispensable
- Executives cannot get reliable data from subordinates so they must trust their own judgement

Hierarchical and individual focus

- Organisation and management are intrinsically hierarchical: the hierarchy is the measure of status and success and the primary means of maintaining control
- The organisation must be a team, but accountability has to be individual
- The willingness to experiment and take risks extends only to those things that permit the executive to stay in control

Task and control focus

- Because the organisation is very large, it becomes depersonalised and abstract and, therefore, has to be run by rules, routines (systems) and rituals (machine bureaucracy)
- The inherent values of relationships and community is lost as an executive rises in the hierarchy
- The attraction of the job is the challenge, the high level of responsibility, and the sense of accomplishment (not the relationships)
- The ideal world is one in which the organisation performs like a well-oiled machine, needing only occasional maintenance and repair
- People are a necessary evil, not an intrinsic value
- The well-oiled organisation does not need people, only activities that are contracted for.

In many industries, there is enough alignment among the needs of the tasks as defined by the operators, the needs of the engineers for reliable and efficient operations, the needs of the executives for minimising costs and maximising profits, so that the cultures do not clash. But when organisations attempt to learn in a generative way, when they attempt to reinvent themselves because of technologies and environmental conditions have changed drastically, these three culture collide, and we see frustrations, low productively and the failure of innovations to survive and diffuse.

The collision of cultures can have dramatic and catastrophic consequences – major accidents. Schein provides an example of a 'plane crash a few miles short of the runway. The flight recorder revealed that the flight engineer had shouted for several minuts that they were running out of gas, while the pilot (functioning as the CEO) continued to circle and tried to fix a problem with the landing gear. When the situation was run in a simulator, the same phenomenon occurred; the pilot was so busy with his operational task and so comfortable in his hierarchical executive position that he literally did not hear critical information that the flight engineer shouted at him. Only when the person doing the shouting was a fellow pilot of equal or higher rank did the pilot pay attention to the information. In other words, the hierarchy got in the way of solving the problem.

Schein argues that organisations will not learn effectively until they recognise and confront the implications of the three occupational cultures. Until executives, engineers and operators discover that they use different languages and make different assumptions about what is important, and until they learn to treat the other cultures as valid and normal, organisational learning efforts will continue to fail. Powerful innovations at the operator level will be ignored, subverted or actually punished; technologies will be grossly under utilised; angry employees will rail against the impersonal programs of reengineering and downsizing; frustrated executives who know what they want to accomplish will feel impotent in pushing their ideas through complex human systems; frustrated academics will wonder why certain ideas like employee involvement, socio-technical systems analysis, high-commitment organisations and concepts of social responsibility continue to be ignored only to be reinvented under some other label a few decades later.

Schein suggests the following:

1. We must take the concept of culture more seriously than we have. Instead of superficially manipulating a few priorities and calling that 'culture change' we must recognise and accept how deeply embedded the shared, tacit assumptions of executives, engineers and employees are.

2. We must acknowledge that a consequence of technological complexity, globalisation and universal transparency is that some of the old assumptions no longer work. Neither the executives nor the engineers alone can solve the problems that a complex socio-technical system like a nuclear plant, generates. We must find ways to communicate across the cultural boundaries, first by establishing some communication that stimulates mutual understanding rather than mutual blame

3. We must create such communication by learning how to conduct cross-cultural 'dialogues'.

Concludes: we are a long way from having solved the problems of organisational learning, but thinking about occupational communities and the cultures of management will being to structure these problems so that solutions for the 21st century will be found.

Strengths

- Own view developed from own research/ literature
- A different perspective on organisational culture and its implications for accidents

Weaknesses

- Not clear if there is support for the view in research

Ref 61
Flight Safety Digest – A Roadmap to Just Culture: Enhancing the Safety Environment. Vol 24, No. 3. March 2005. Published by the Flight Safety Foundation

Summary
The report was prepared by the Flight Operations/ ATC operations Safety Information Sharing Group of the Global Aviation Information Network (GAIN) with the following objectives:

- Provide an overview of what is meant by a just culture
- Heighten awareness in the international aviation community of the benefits of creating a just culture
- Provide a portrayal of a just culture implementation in aviation organisations and share lessons learned
- Provide initial guidelines that might be helpful to others wishing to benefit from the creation of a just culture

The paper provides a summary of Reason's (1997) work on safety culture and shows how the key messages are applicable to the aviation industry. It draws on experiences of implementation by aviation organisations.

Describes **Four Types of Unsafe Behaviours -** Marx (2001) – not all unsafe behaviours warrant disciplinary action.

- Human error – general agreement that the individual should have done other than what they did. In the course of the action they inadvertently caused an undesirable outcome.
- Negligent conduct – conduct falls below the standard required as normal in the community. To raise the issue of negligence there needs to be an established duty of care on the person and harm must be caused by the negligent action
- Reckless conduct (gross negligence) - is more culpable than negligence. The risk would have been obvious to a reasonable person. It involves a person taking a conscious unjustified risk, knowing that there is a risk that harm would probably result from the conduct, and foreseeing the harm, nevertheless took the risk.
- Intentional 'wilful' violation – when a person knew or foresaw the result of the action, but went ahead and did it anyway.

Goes on to discuss how the industry could determine acceptable behaviours, e.g. using Reason's culpability decision tree. These issues need to be addressed and understood, so that individuals understand their responsibility and organisations can make decisions about behaviours that can be learned from etc.

Strengths

- Good overview of the subject from an aviation perspective
- Discusses the legal implications of individual behaviours