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The contribution of human factors to accidents in the offshore oil industry

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Accidents such as the Piper Alpha disaster illustrate that the performance of a highly complex socio-technical system, is dependent upon the interaction of technical, human, social, organisational, managerial and environmental factors and that these factors can be important co-contributors that could potentially lead to a catastrophic event. The purpose of this article is to give readers an overview of how human factors contribute to accidents in the offshore oil industry. An introduction to human errors and how they relate to human factors in general terms is given. From here the article discusses some of the human factors which were found to influence safety in other industries and describes the human factors codes used in accident reporting forms in the aviation, nuclear and marine industries. Analysis of 25 accident reporting forms from offshore oil companies in the UK sector of the North Sea was undertaken in relation to the human factors. Suggestions on how these accident reporting forms could be improved are given. Finally, this article describes the methods by which accidents can be reduced by focusing on the human factors, such as feedback from accident reporting in the oil industry, auditing of unsafe acts and auditing of latent failures. © 1998 Elsevier Science Limited.

1 INTRODUCTION

In the past, industrial accidents were reported mainly in terms of technological malfunctions and the human element in the cause of the accident tended to be ignored. Since the frequency of technological failures has diminished, the role of human factors has become more apparent. Accidents such as the Piper Alpha disaster[1] illustrate that the performance of a highly complex socio-technical system, is dependent upon the interaction of technical, human, social, organisational, managerial and environmental elements and that these factors can be important co-contributors to incidents which could potentially lead to a catastrophic event. Human factors were deemed to be the root cause of many major disasters, such as Chernobyl, Three Mile Island and Piper Alpha and as such were well-researched by those interested in the human contribution to the causes of accidents, such as psychologists, reliability engineers and human factors specialists[2].

The terms 'human factors' and 'human error' are often exchanged in the offshore oil industry without clear definition as to what is actually meant by these labels. They are often used interchangeably as general terms referring to the cause of an accident being related to people as opposed to a technical fault. The traditional definition of human factors is the scientific study of the interaction between man and machine. This definition was extended in recent years to encompass the effects which individual, group and organisational factors have on safety [3] and is the framework used in the following article. Human errors were defined by Rasmussen[4] as 'human acts which are judged by somebody to deviate from some kind of reference act .. they are subjective and they vary with time.' These are specific acts which can either directly (active errors) or indirectly (latent errors) cause an accident.

Both human errors and human factors are usually studied separately and any relationship between them is often overlooked. This may be caused by the difficulty of the task or because there is still no agreement between the two separate areas as to their precise nature and definition. However, a number of high reliability industries have attempted to combine these two subjects in their accident reporting forms which will be discussed later in this article. A

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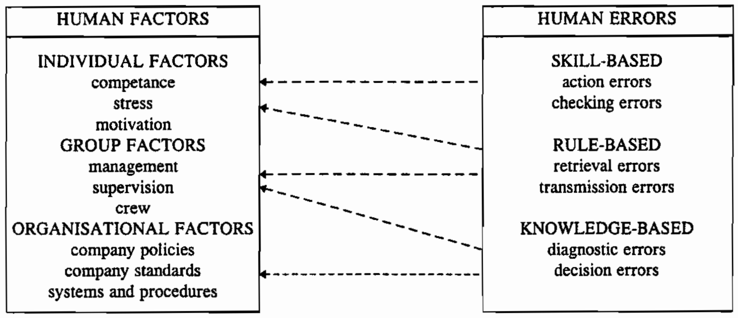

Fig. 1. Framework of the relationships between the underlying causes of accident (human factors) and their immediate causes (human errors).

proposed framework describing the relationships between the underlying human factors and the immediate human errors is given in Fig. 1.

The aim of this article is to begin to improve accident reporting forms by basing the categorisation on a stronger theoretical grounding. This proposes the human error categories based on Rasmussen's skill, rule, knowledge model[4] to determine the immediate cause of the accident, and use human factors categories (organisation, group, individual) to determine the underlying causes of the accidents. This article describes some of the previous literature from human error and human factors research, and it also reviews the human factors categories used in accident reporting from high hazard industries including the UK sector of the offshore oil industry. Finally, suggestions on how to improve the human factors component of accident reporting forms and of ways to reduce accidents using human factors data are presented.

2 HUMAN ERROR

2.1 Theories of human error

Human error was studied in some detail by industrial psychologists such as Reason[5], Hudson[6] and Rasmussen[7] whose findings suggest that by endeavouring to conquer, or at least understand human error, its consequences could be reduced. Based on Rasmussen's theory of human performance, Reason[5] categorised errors in terms of: (1) skill-based slips and lapses, (2) rule-based mistakes and (3) knowledge-based mistakes. At the skill-based level, distraction or preoccupation with another task can lead to slips and lapses where monitoring of the task fails. For an error to occur at the rule-based or knowledge-based performance level, attention would not necessarily have to stray far from the problem. Problem solving failures may occur when the incorrect rule is applied (rule-based) or the person is unfamiliar with the problem (knowledge-based). In addition to slips, lapses and mistakes, violations are also unsafe acts which Reason[5] describes as deliberate deviations from procedures deemed necessary to maintain the safe operation of a potentially hazardous system.

The error types used by Reason[5] are based on psychological theories and are designed to describe errors in high risk industries. Although this may sound like an ideal model to use in accident reporting forms, Reason's error types are complex and would need considerable training to understand and use on a regular basis. A more simplistic approach was devised by Kontogiannis and Embrey[8] who summarised human errors into the following six categories.

1. *Action errors*: where either no action is taken, the wrong action is taken or the correct action is taken but on the wrong object.
2. *Checking errors*: the checks are omitted, the wrong checks are made or the correct check is made on the wrong object.
3. *Retrieval errors*: when information that is required is not available, or the wrong information is received.
4. *Transmission errors*: when information has to be passed onto someone else, either no information is sent, the wrong information is sent, or it is sent to the wrong place.
5. *Diagnostic errors*: when an abnormal event arises, the actual situation is misinterpreted.
6. *Decision errors*: when the circumstances were considered but the wrong decision is made.

The first two error categories, 'action' and 'checking' relate to Reason's skill-based slips and lapses, 'retrieval' and 'transmission' errors relate to Reason's rule-based mistakes, and 'diagnostic' and 'decision' errors relate to Reason's knowledge-based mistakes.

Examples of human errors found in the nuclear industry were studied by Rasmussen[7] who categorised 200 significant events into the following human error categories: omission of functionally isolated acts, latent conditions not considered, other omissions, side effects not considered, low alertness, mistakes among alternatives, strong expectation, manual variability, lack of precision, weak spatial orientation, absent-mindedness and familiar association. The results indicate that the majority of errors made in the nuclear industry are omissions and errors which were made previously but were not detected. The research carried out in this area indicates that there is an understanding of the basis of human error, though still little is known about how individual error tendencies interact within complex organisations of people working with high-risk technologies, such as in the offshore oil industry.

2.2 Active versus latent errors

When considering human errors in systems disasters, two kinds of errors can be involved. Firstly, *active errors*, whose effects are generally almost immediate (such as an omission or using the wrong rule) and secondly, *latent errors*, whose adverse consequences may lie dormant within the system for a long time, only becoming evident when they combine with other factors to breach the systems defences (such as design or training)[5]. *Active errors* are most likely to be caused by front-line operators (e.g. control-room crews, production operators), whereas *latent errors* are more likely to be caused by those who are removed from the direct control interface (e.g. designers, high-level decision makers, construction workers, managers and maintenance personnel). In most cases, safety programmes are aimed at the operators, to reduce active failures in order to reduce specific causes which are unlikely to occur in the same combination.

In one of their studies in the nuclear industry, Miller, Freitag and Wilpert[9] found that in 20% of the incidents, outside (contracting or sub-contracting) companies were involved, and for the majority of these cases there was a time lag between the error and the consequence. This indicates that the main contribution from the outside firms did not result in immediate incidents, rather they resulted in incidents which occurred later (i.e. latent errors). Wrong and missing procedures contributed to incidents in 22% of all cases for operators and contractors. In the other half of the cases there was a time lag of more than 15 min and up to 8 h between the error being made and the consequence, where most of these errors were maintenance, again indicating that latent errors play a major role. By identifying both active and latent errors at the work site, it is possible to focus on the actual problem, thereby understanding the basis of the accident or error. The following section focuses on the underlying causes of accidents (or 'human factors'), which also includes latent errors which were described before.

3 HUMAN FACTORS

3.1 The human factors found to affect safety

The underlying human factors found to affect safety have been defined as organisational, group and individual factors[3]. At the *organisational level*, various factors may contribute to an increase in incidents and accidents, including cost cutting programmes and the level of communication between work-sites. At the *group level*, the relationships between members of a work group, and between individuals and their supervisors, have the potential to influence the safety of an installation. In addition, management's leadership, supervision and crew factors can affect safety. At the *individual* level, optimisation of the human-machine interface are evaluated, competence of the individual, perceptual judgements, stress, motivation, health risks (such as work over-load) and the contribution of human error to the probability of accidents are examined.

A study by the Institute of Nuclear Power Operations [10] showed that the underlying causes of accidents in the nuclear industry covered organisational, group and individual factors. The underlying factors were broken down into the following categories; deficient procedures or documentation (43%), lack of knowledge or training (18%), failure to follow procedures (16%), deficient planning or scheduling (10%), miscommunication (6%), deficient supervision (3%), policy problems (2%), other (2%). At least 92% of the underlying causes of accidents were caused by people, only a small proportion of the underlying causes were actually initiated by front-line personnel (i.e. failure to follow procedures) and most originated in either maintenance-related activities or in bad decisions taken within the organisational and managerial domains. The following section illustrates each of the underlying factors (organisational, group and individual) with regard to previous research in this area.

3.1.1 Organisational factors

It has been postulated that without a good organisational safety climate to which everyone contributes, it is inconceivable that any organisation has a safe working environment[11]. The organisational climate represents the context in which behaviour occurs and the basis of people's expectations[12]. In a review of research on safety climate, the following factors were found to be related to safety: management commitment to safety, safety training, open communication, environmental control and management, stable workforce, positive safety promotion policy[11]. In addition, the following factors were found to discriminate between factories in terms of safety climate: importance of safety training, effects of workpace, status of safety committee, status of safety officer, effect of safe conduct on promotion, level of risk at the workplace, management attitudes towards safety and effect of safe conduct on social status[12].

In her post-mortem examination of the factors which led to the Piper Alpha disaster, Elizabeth Paté-Cornell explains the technical and organisaional factors as mainly stemming from financial pressures[13,14]. The corporate culture of Occidental gave priority to short-term production goals which were described as leading to a 'reversed safety culture'. Management was under pressure to reduce production costs and thus design, construction, inspection and maintenance costs were all at a minimum. In addition, there was a 'culture of denial' of the serious risks, where management tended to focus on frequent incidents which had the potential to disrupt production rather than focusing on the risk of a catastrophe. Rewards and incentives were given for short-term production figures, which could have encouraged workers to cut corners to get the job finished. There was a high turnover of staff indicating that personnel may not have had the necessary level of understanding of the system which is of particular importance in the case of the system being pushed to its limit. Occidental Petroleum was not the only company which felt these pressures, nor have these pressures disappeared from the offshore oil industry today.

An important part of the manager's role in increasing safety is that they promote learning from past experience. Paté-Cornell[13] described the safety culture on the Piper Alpha as discouraging internal disclosure and communication of bad news which led to small incidents and near-misses being ignored. Lessons could have been learned from an accident which occurred on the Piper Alpha, a year prior to the Piper Alpha disaster, in which one man was killed, caused partially by the failure of the Permit To Work system consisting of a breakdown of communications and an error in shift handover (i.e. similar problems to the Piper Alpha disaster).

Kletz[15] recommended four ways for organisations to learn from past experience: (1) recent and old accidents should be described in safety bulletins and discussed at safety meetings, (2) standards and codes of practice should contain notes on accidents which led to the recommendations, (3) a 'black book' containing reports of accidents with technical interest that have occurred should be compulsory reading for all newcomers and for refreshing memories and (4) accident information retrieval and storage systems should be used as they contain a wealth of useful information.

In conclusion, the literature indicates that the organisational climate is important for a safe working environment, where commitment to safety by senior management at the strategic or policy levels, training, communication, a positive safety promotion policy and learning from past experience are important factors. Therefore these organisational factors need to be incorporated into accident analysis.

3.1.2 Group factors

The following section describes group dynamics which can lead to enhanced or reduced safety. While there maybe some degree of overlap between organisational and group factors with regard to management style, it was included in this section. Thus the subheadings under group factors include the role of middle management, supervision, and crew factors. The notion of teamworking is a large part of working in the offshore oil industry as many operations are managed by crews, shifts and groups working together.

From research into safety culture in the nuclear industry, Lee[16] found that management 'style' may affect the accident rate indirectly through job satisfaction, where a 'humanistic approach', which involves more regard by management for personal and work problems, is likely to be effective. Good communication between the various management, supervisory and worker levels at an informal level is a feature of low accident plants. Excessive pressure for production also creates a shortage of time to complete tasks which leads to 'cutting corners' and more slips and mistakes. Finally, with regular appearances of the management on the 'shop floor' an important contribution could be made to the safety culture and morale in general.

In a review of research on organisational and behavioural factors associated with US mine safety[17] numerous management factors were found to distinguish high-accident rate mines from low-accident rate mines. High-accident rate mines tended to be characterised by management's poor scheduling and planning, and more conflict/misunderstanding over directions and assignments, whereas low-accident rate mines were characterised by the abundance of training and the importance of keeping good safety records.

One of the critical safety aspects of any job is how well the worker is supervised. The adverse consequences of fallible decisions made by the organisation could be alleviated if line management or supervisors were competent. However, if line-management is limited by resources, put under undue time pressure, has inappropriate perceptions of the hazards, is ignorant of the hazards or has motivational difficulties, it is unlikely that they will identify these problems. In this case, line-management deficiencies could result in a management failure (such as deficient training) revealing itself as a human error (such as carrying out a task incorrectly). Had the management failure been rectified, the task may have been carried out correctly[5].

Initial research into crew factors was investigated in the aviation industry as early as the 1970's when John Lauber, the American aviation psychologist, termed the interaction between crew members as 'cockpit resource management'. Specific human factors training programmes derived from this research are now known as 'crew resource management' (CRM) and are being used in other domains, such as merchant navy ships, hospital operating theatres, nuclear plants and the offshore oil industry[18]. The USA National Transportation Safety Board indicated that 73% of accidents were the result of flight crew failures rather than technical problems[19]. In the 1970s investigations by NASA (in the form of accident analyses, pilot interviews and simulator observations), indicated that there was a need for further focus on pilots' communication and team work as well as leadership, command and decision making. Crew factors found to affect safety performance include the attitudes of the team toward communication and co-ordination, command responsibility and recognition of stressor effects. Members of high performing (or low error) crews were found to have a clear understanding not only of their own roles and responsibilities but also those of other team members. Research has shown that assertiveness is often lacking in junior crew members, where they are reluctant to point out poor decisions or errors made by the captain. In contrast high performing crews are found to have a climate of openness and trust where the leaders are receptive to alternative views and team members are not afraid to express themselves[18]. The aviation industry has made strenuous attempts to improve crew performance by utilising specific human factors training for awareness in the function of CRM[20].

The importance of crew factors to safety in the offshore oil industry was highlighted in the post-mortem analysis of the Piper Alpha disaster[13]. There was a serious communication failure, where the day crew on the Piper Alpha had failed to pass on information to the night shift about the removal of a pressure safety valve which was replaced by a blind flange without proper tagging. This would normally mean that pump A would be out of service, however the night shift tried to start it which may have been the initial leak. This indicates that there was a serious flaw in the shift handover system.

Group factors seem to play an important part in the safety of high hazard industries, where communication between different members of the organisation plays a major part. Other factors which contribute include management's leadership abilities, supervisor's resources and relationships between individuals[5]. In the following section, factors affecting safety which relate to the individual are investigated.

3.1.3 Individual factors

Previous research into individual factors has mainly focused on the man-machine interface (or ergonomics). This section, however, focuses on the factors which affect a person's performance, broadening the definition to include external influences, such as stress, motivation and health risks.

Lee[16] indicated that organisations which devote more of their resources to safety training generally have better accident records. Training in skills is also of relevance to safety, and should include skills requiring the use of potentially hazardous tools and equipment.

In a review of human factors in the mining industry, job ambiguity was found to affect safety, where miners in high-accident mines tended to be given unclear instructions in comparison with those working in low accident rate mines[17]. Workers at high accident rate mines were more likely to report that they were overworked than those workers at low accident rate mines. Worker autonomy was found to improve mine safety, where crews who were given entire responsibility for making the day-to-day decisions of the production of coal were thought to have been responsible for the improvements in mine safety. In addition, miners working at high accident rate mines often reported that they were troubled by some of their co-workers' behaviour.

The post-mortem analysis of the Piper Alpha disaster indicated that the management of personnel failed[13]. This included problems with the hiring, screening, training and promotion of personnel. There were insufficient qualified and trained personnel and temporary promotions of the maintenance, operators and production personnel allowed inexperienced workers to run Piper Alpha in a period of high activity.

In summary, the individual factors which were found to affect safety include the level of training and experience, the clarity of the job instructions, being overworked and not given enough responsibilities. A compilation of the common human factors causes of accidents found in high reliability industries could assist accident reporting forms by defining the necessary human factors codes. In addition to using research findings to compile an accident reporting form, examining the human factors accident causation codes used by high reliability industries would also be of interest. Accident reporting forms from aviation, marine and nuclear industries were examined in the following section, followed by more detailed discussion of forms from offshore.

3.2 Categorisation of human factors in other industries

This section describes the accident reporting forms used by other high reliability industries such as the nuclear, marine and aviation industries. A classification scheme which gives an overall picture of the causes of accidents was developed by Miller *et al.*[9]. This includes human factors causes of accidents based on different theories from various psychological domains used for analysing accidents in German nuclear power plants. This research was carried out by a multi-disciplinary team of human factors specialists composing of psychologists and engineers. A comprehensive list of factors affecting safety including types of human errors ('failure types') was compiled and an in-depth view of the factors which contribute to accidents is presented. The scheme is comprised of 8 categories.

1. *General aspects*; time, state of system, operational phases, locus, affected parts, characteristics of the component and actors.
2. *Organisational aspects*; co-operation between organisations, safety culture.
3. *Personal aspects*; characteristics of acting person and on group characteristics.
4. *Job factors*; content and characteristics of task, level of task, procedures for task, information about task, tools and safety devices.
5. *Aspects of the failure*; the trigger, the failure type, violations of rules and procedures.
6. *Aspects of causes*; conditioning factors, communication, erroneous decision making and level of information processing.
7. *Aspects of feedback*; feedback characteristics, error consequence, error discovery.
8. *External impacts*; lightning, flood.

Human factors accident causation codes used by two British nuclear companies follow the International Safety Rating System (ISRS)[21] which covers the following areas: (1) Personal Factors; inadequate capability, lack of knowledge, lack of skill, stress, improper motivation and (2) Job Factors; inadequate leadership/supervision, inadequate engineering, inadequate purchasing, inadequate maintenance, inadequate tools/equipment, inadequate work standards, wear and tear, abuse or misuse. These categories were often used by companies in the offshore oil industry (see Section 4).

The US Office of Marine Safety, Security and Environmental Protection and the Office of Navigation Safety and Waterway Services recently developed a strategy to prevent casualties resulting from human error[22]. They categorised accident causes into 5 groups: *management* (e.g. faulty standards and inadequate communications); *operator status* (e.g. inattention, carelessness, fatigue); *working environment* (e.g. poor equipment design); *knowledge* (e.g. inadequate general technical knowledge) and *decision making* (e.g. poor judgement, inadequate information). They found that the majority of accidents were caused by fatigue, problems with crew co-ordination and inadequate technical knowledge. The research group believed that the reason for the persistence of marine casualties was because of the lack of root cause investigations, lack of identifying and analysing high risk operations and lack of identifying, developing and implementing measures to prevent human errors.

The human factors categories developed by the UK Marine Accident Investigation Bureau (MAIB) contains six sections; (1) external bodies liaison, (2) company and organisation, (3) crew factors, (4) equipment, (5) working environment and (6) individual. Items of relevance to the offshore oil industry in the *company and organisation* section include communication, pressures, inadequate resources, training, skills, knowledge. The *crew factors* section include; communication (between any member or group of the crew), management and supervision inadequate, allocation of responsibility inappropriate or individual takes inappropriate responsibility, procedures inadequate, manning insufficient/inappropriate, training deficient and discipline of crew. *Individual factors* include; communication of the individual (language; not passing on information), competence, training, knowledge and skill/experience, health, domestic issues (stress arising from events at home), fatigue/vigilance, perceptual abilities/disabilities, failure to use all the information available/poor decision making and risk perception/risk taking behaviour inappropriate. The factors used by MAIB display a comprehensive list of the human factors categories.

The British Airway's Human Factors Reporting programme 'BASIS' divides accident causation into 5 categories; (1) crew actions, (2) personal, (3) organisational, (4) informational and (5) environmental. The majority of the items listed under these factors are of relevance to the offshore oil industry and are listed. *Crew actions factors* included; crew communication, briefing, assertiveness, decision process, group climate, planning, procedure, role conformity, workload management as well as some human errors: action slip, memory lapse, mis-recognition, mistake and misunderstanding. *Personal factors*; included knowledge, morale, personal, environmental and operational stress, tiredness, boredom, environmental awareness, distraction and recent practice. *Organisational factors* included; commercial pressure, company communication, group violation, maintenance, recency problems, technical support and training. *Informational factors* included; electronic checklists, manuals and Standard Operating Procedures (SOP's). *Environmental factors* included; communication systems, unclear information, ergonomics, language, weather conditions and operational problems.

Accident databases developed to combine accident information, whether it be from within the installation, within the company[23] or across different companies[24,25] also highlighted the impact of management and organisational factors. One such database was established by the Commission of the European Communities in 1984 for collecting information on world-wide major industrial accidents, called 'Major Accident Reporting System' (MARS). From 1984 to 1994 the most common immediate causes of accidents were found to be component failures and pipework failures, and the second most common were operator errors. The underlying causes of accidents were detailed as follows.

1. *Managerial/organisational omissions*, which included insufficient procedures, relating to design inadequacies, insufficient operator training and lack of a safety culture.
2. *Design inadequacy*, which included analysis of the inadequacy of the process, codes/practises provided for limited protection only.
3. *Short cuts*[25].

This section has described the human factors accident causation codes used by companies in the nuclear, aviation and marine industries. The majority of items in these human factors coding systems are of relevance to the offshore oil industry, in particular the crew factors used by British Airways and the Marine Accident Investigation Bureau. In the following section, the accident reporting procedures and human factors coding systems used in the UK sector are described in detail.

4 HUMAN FACTORS IN THE OFFSHORE OIL INDUSTRY

As part of a larger project which is investigating the human and organisational factors affecting offshore safety[26], a study was designed to identify the human factors categories used to ascertain the underlying causes of accidents in the offshore oil industry. The aim of this study is to compile a comprehensive human factor coding system which could be used for accident reporting, safety training and generally raising awareness of the human factor causes of accidents. As part of this exercise, a sample of 25 British sector offshore oil and contracting companies' accident reporting forms and manuals were acquired from company safety managers. The accident reporting and investigation procedures of the 25 companies were analysed and described briefly in the following section. In addition, the human factors codes used by the companies were combined and were summarised in Section 4.3. Finally, recommendations for improving the human factors codes in the accident reporting forms were put forward.

4.1 Accident reporting procedure in the offshore oil industry

In an ideal world, all incidents and accidents that occur would be thoroughly investigated to determine all root causes of the accidents. In the most part, incidents and accidents in the offshore oil industry are investigated to some extent. There is much variation between companies with regard to the procedures they use to carry out an incident or accident investigation, though they usually follow a similar pattern. For minor accidents, the investigators are the supervisors and safety officers and they usually have some training, though there is not always the time and resources for in-depth training with regard to, for example, human factor causes of accidents. Where required, an investigation team is appointed to carry out a more detailed investigation in to the occurrence. For a serious incident, teams will fly to the installation from the onshore office as well as government accident inspectors. Initially, the person involved in or observing an accident or incident reports it to their supervisor as soon as possible. The first line supervisor or foreman obtains written statements from the injured persons and witnesses and organises photographs, sketches, drawings of the scene, obtains relevant documents, procedures and relevant permits to work. The supervisor will also carry out a preliminary investigation into the facts and circumstances surrounding the event to establish causes and will recommend actions to prevent recurrence. In addition, the supervisor completes the Accident/Incident Report Form, Company Standard Form and submits it to the Safety Officer and Senior Site Supervisor for approval.

The Senior Site Supervisor then discusses the event with the supervisor/foreman and any additional recommendations are added at this point. The Senior Site Supervisor then appoints personnel responsible for executing the recommendations and sets target dates for its completion. The Accident/Incident Report Form is then submitted to the Project Manager/Department Head and the circumstances of the event are brought to the notice of employees and other interested parties with a view to increase safety awareness. The Project Manager/Department Head will discuss the accident/incident with the relevant Supervisor and the Safety Advisor and endorse or reject the recommendations. After a Lost Time Accident the Project Manager/ Department Head meets with the injured person to discuss the circumstances surrounding the accident to identify the accident causes and highlight areas where the individual may have contributed to the accident. The endorsed Accident/Incident Report Form is submitted to the Corporate Safety Department. The Safety Advisor enters details of the report onto computer database and makes a report at monthly intervals to senior management on accident frequencies and trends. Final copies of the accident report would be given to the onshore Safety Department, the immediate supervisor, the OIM, the legislative authority (depending on severity) and where there is an injury, a copy is kept in the Medical Centre.

4.2 Accident reporting forms

An accident reporting form will tend to contain most of the following basic items [27].

1. Type of incident: injury, disease, property damage, material loss, process disruption, poisonous or flammable substance leaks, fire or explosion, dangerous occurrences, environmental harm, near-misses, hazards.
2. Personal details of people involved, including supervisor at the time
3. Date, time and location of occurrence
4. Work being carried out, experience of person involved
5. Equipment being used, including safety equipment and devices
6. Equipment failures
7. Protective clothing being worn
8. Other people working in the area
9. Permits being issued, procedures being used
10. Contributory factors, e.g. environmental conditions, any hazards present
11. Immediate and underlying causes

4.3 Categorisation of human factors in the offshore oil industry

A sample of 25 UK offshore oil companies' accident reporting forms were analysed and the immediate and underlying causes of accidents were compiled into lists. 'Immediate Causes' were either technical or human (Table 1), and

Table 1. Immediate causes in Offshore Accident Reporting Forms

Immediate causes-human
Operating without authority
Failure to warn/secure
Improper speed
Made safety device inoperable
Used defective equipment
Used equipment improperly
Did not use proper equipment
Serviced equipment in operation
Adjusted equipment in operation
Horseplay
Under the influence of drugs/alcohol
Improper lifting/loading
Failure to wear PPE
Lack of attention/forgetfulness
Working on unsafe or live equipment

Table 2. Personal factors in Offshore Accident Reporting Forms

Capability	Knowledge and skill	Stress	Improper motivation
Physical capability	Lack of experience	Fatigue	Peer pressure
Mental capability	Inadequate orientation	Stress	Aggression
Lack of competence	Inadequate training	Monotony	Inattention
Concentration demands	Lack of education	Health hazards	Lack of anticipation
Perception demands	Lack of job instruction	Frustration	Horseplay
Judgement demands	Inadequate practice		Recklessness
Inability to comprehend	Misunderstood directions		Inappropriate attempt to save time
Poor judgement	Lack of hand on instruction		Insufficient thought and care
Memory failure	Lack of awareness		Attitude

'Underlying Causes' were listed under: 'Personal Factors' and 'Job Factors' (see Tables 2–3). Descriptions of these categories are given later.

4.3.1 Immediate causes

Immediate causes could be categorised as either technical failure or human and were usually listed in no particular order. The technical failures were recorded generally as equipment or safety device failures, lack of personal protective equipment, environmental conditions and hazards present. The human failures were violations of procedures, working at improper speed, failure in communication, horseplay and under the influence of drugs or alcohol and are listed in Table 1.

4.3.2 Underlying causes

1. Personal factors

Under the heading of Personal Factors, there were four main categories; (1) capability (2) knowledge and skill, (3) stress and (4) improper motivation (see Table 2). Of the 25 accident reporting forms, 64% followed the basic ISRS coding system[21] (i.e. capability, knowledge, stress and improper motivation), 20% either had no items or very few of these items and 16% had extra items (between 6 and 10 items).

2. Capability

The majority of accident reporting forms contained a category detailing the mental and physical capability of the person. This included the extreme concentration, perceptual and judgement demands as well as memory loss.

3. Knowledge and skill

The majority of accident reporting forms had the basic 'lack of knowledge' or 'lack of skill' items. Other accident reporting forms contained extra items such as 'lack of experience', 'lack of education', 'lack of job instruction' and ' inadequate training'.

4. Stress

Under this heading there was usually only the one item: 'stress'. However, some accident reporting forms described the stress in more detail: 'fatigue', 'monotony', 'frustration' and 'health hazards'.

5. Improper motivation

This category usually contained only the title item, although a few accident reporting forms contained more detail such as: 'inappropriate peer pressure', 'horseplay', 'inappropriate attempt to save time' 'attitude' and 'insufficient thought and care'.

6. Job factors

Under the main heading of 'Job Factors', 60% of the accident reporting forms followed the basic ISRS coding system[21], where 'inadequate leadership and supervision' 'inadequate engineering', 'inadequate purchasing', 'inadequate maintenance', 'inadequate tools and equipment', 'inadequate work standards' 'wear and tear' and 'abuse or misuse' were used. Twenty-four percent of the accident reporting forms contained extra items under each heading and 16% of the reporting forms had either no items or very few. There was a large degree of variance between companies with regard to the number of items in

Table 3. Job factors in Offshore Accident Reporting Forms

Organisation	Management	Supervision	Task
Company policy	Inadequate planning	Inspection	Poor or no job description
Inadequate safety plan	Management practices	Work planning	Confusing directions
Working hour policies	Communication	Unclear responsibilities	Conflicting goals
Competence standards	Management job knowledge	Instruction, training	Equipment selection
Inadequate staffing and resources	Qualifications and experience criteria	Improper production incentives	Inadequate matching of individual to job task
Inadequate procedures	Bad management example	Supervisory job knowledge	Work planning
Safety system		Inadequate discipline	Time problem
Adequacies of systems		Supervisory example	Failure in communication

each category and the items were often listed in an unclear manner. In order to divide items into meaningful categories, items were listed under the following four categories: organisational, management and supervision issues (see Table 3).

7. Organisational

Two items which were identified in most of the accident reporting forms were: 'inadequate company policy' and 'inadequate planning/organisation'. A few reporting forms included the category of 'systems inadequacies' which included items such as 'inadequate maintenance system' and 'control system'. In addition, the category of 'inadequate procedures' was used which included 'inadequate audit procedures' and 'poor or no work permit procedure'.

8. Management

Items which were used most often in relation to management included 'lack of management job knowledge', 'bad management example/practices', 'inadequate staffing/resources', 'poor or no job description' and 'not providing adequate reference material'. Of the 25 accident reporting forms, 52% mentioned 'failure in communication'.

9. Supervision

The majority of accident reporting forms only gave the options of 'inadequate supervision', 'inadequate work planning' 'inadequate inspection/monitoring' and 'inadequate instruction/training'. Reporting forms with extra details gave options as to whether or not reporting relationships were unclear or conflicting, whether or not the assignment of responsibility was unclear or conflicting and whether or not there was adequate reinforcement of proper/improper performance. In addition, some reporting forms questioned the supervisory example, the level of supervisory job knowledge, the clarity of directions and instructions and the suitability of the person to the job.

The underlying causes of accidents currently used in the UK offshore oil industry were outlined in the previous section, where the majority of accident reporting forms (60%) follow the ISRS coding system[21] which divides human factors codes into: 'Personal' and 'Job' factors. In the most part, the accident reporting forms lacked a detailed structure and were inconsistent across companies. Few accident reporting forms were detailed (20%) and others lacked even the basic categories (20%). In the following section, ways to improve these categories were suggested.

4.4 Improvement of accident causation categories

The two sections of accident reporting forms which could be improved upon are the immediate human causes of accidents and the underlying causes of accidents. These will be discussed in the following section.

4.4.1 Immediate causes

As described earlier, the immediate causes of an accident can either be technical or human in origin. The immediate human causes of accidents can be defined in terms of the type of activity which is being performed (i.e. skill, rule or knowledge based). As described in Section 2.1, the errors which relate to these categories include 'action' and 'checking' (skill-based slips and lapses), 'retrieval' and 'transmission' errors (rule-based mistakes), and 'diagnostic' and 'decision' errors (knowledge-based mistakes). By analysing the immediate causes of the accident in terms of the type of activity and its related human error, this may give an intimation as to the underlying causes (see Fig. 1). For example, the disruption of a job which is skill based may be caused by personal stress. These human error categories were suggested for the accident reporting form, as they are fairly easily understood and can give further detail as to the nature of the incident.

4.4.2 Underlying causes

The definition of human factors which was given at the beginning of this article, defines the three main categories as: *organisational factors* which include company policies, company standards, systems and procedures. *Group Factors* include: management weaknesses, supervision and crew factors. *Individual factors*: which include knowledge, perceptions, stress, motivation and human errors. These categories were used by other industries, such as the marine and aviation industries, where the focus was redirected from the

Table 4. Organisational factors

1. Company policies
Safety plan
Company communication
Commercial pressure
Company safety culture
Staffing/resources
Working hours policies and practise
2. Company standards
Development/maintenance of standards
Communication of standards
Qualifications and experience criteria
Group violation
Training standards
Competence standards
Providing inadequate reference material
3. Systems and procedures
Maintenance system
Warning/safety systems
Control systems
Planning/organisation
Audit procedures
Operating procedures
Work permit procedure

individual factors to organisational and group factors. For the offshore oil industry to improve their accident reporting methods, following this lead could be an important move.

1. Organisational factors

The main problem with the 'job' factors section of the accident reporting forms was that it lacked structure and detail. Investigation of accident reporting forms from various high reliability industries (e.g. aviation, marine, nuclear and offshore oil) have led to the following structure being used to describe the organisational factors: (1) company policies, (2) company standards and (3) systems and procedures (see Table 4). *Company policies* include the effectiveness of their safety plan, how well the company communicates with its employees and the public, the commercial pressure which the company puts on its employees, the company safety culture, the staffing and resource levels and their policies on working hours. The item 'failure in communication' is ambiguous unless described with regard to the two parties involved in the communication. Thus, it is necessary to have this item listed under each of the main headings.

2. Company standards

These include the competence of the employees, the standards of work which are expected, the training standards, the development and maintenance of standards and how well standards are communicated to the workforce. These were included as they are important to the overall safety standards. Ineffective standards may be more difficult to distinguish as causing a particular accident, however, by having a list of possible causes, the task could be assisted. The sub-heading *Systems and Procedures* describes those systems and procedures which if faulty could endanger the safety of the installation.

3. Group factors

This section was practically ignored in accident reporting forms in the UK sector of the North Sea. The sub-headings under Group Factors include (1) management, (2) supervision and (3) crew factors (see Table 5). Communication is the only item which is listed under each of the sub-headings and it has a slightly different role to play in each one. Offshore management needs the skills to communicate with onshore management as well as the workforce. Supervisors need to be able to communicate effectively with their crew members as well as their superiors. Crew members need to be able to communicate among themselves as well as up the line, particularly to their superiors. If the culture of an organisation encourages communication not only between members of a work group but also between personnel from different levels of the hierarchy, there is less chance of misunderstandings and errors occurring.

Table 5. Group factors

1. Management
Communication
Management/leadership
Management job knowledge
Manning insufficient/inappropriate
Training deficient
Bad management example
Management practices
Discipline of crew
Allocation of responsibilities
Decision process
2. Supervision
Communication
Inspection
Work planning
Supervisory job knowledge
Supervisory example
Instruction, training
Confusing directions
Conflicting goals
Unclear responsibilities
Job description
Briefing
Inadequate discipline
3. Crew
Communication
Group climate
Assertiveness
Planning
Procedure
Time problem
Workload management

4. Management

Management has a significant role to play in setting the proper standards of work practice and safety and leadership and communication skills are important for the development of a positive safety culture in the organisation. It is important that management's job knowledge is sufficient and appropriate as the workforce may otherwise have difficulty respecting and trusting their leaders. Often managers talk about 'getting things done' and forget to mention safety, which can leave the impression that safety is less important than production. The 'pressure for production' may not be verbally explicit, however, often what is not said is as important as what you say. In addition, bad or wrong decisions are the first line of safety defence which can be broken and thus management's 'decision-making' must also be in question during the investigation of an incident or accident.

5. Supervision

Supervisors have a particularly difficult role to play in terms of safety[28] where they are the 'middle-men' between management and the workers. Supervisors can receive conflicting signals from above (such as the 'production versus safety' conflict) and are expected to pass on both messages to the workforce. For example 'work safely, but make sure you get the job done on time'. An example of this is highlighted in the Chernobyl disaster, where operating staff were given contradictory instructions by their supervisors when they were asked to carry out tests as quickly as possible as well as to follow normal operating procedures[2]. The supervisor's role also includes 'inspection' of the worksite and 'planning' the work, which requires supervisors to have sufficient knowledge of the job, and to be a good example. Supervisors are also expected to give their crew clear job descriptions, responsibilities, instructions, training, directions and goals. Finally, a good supervisor will be able to brief the workers before their job begins and have the skills to discipline those in need of it.

6. Crew factors

Crew factors are those elements which affect safety when it is dependent on relationships between members of a crew or between crew members and their superiors. An important factor is the 'group climate' or how well the members get along with each other. This will also affect how assertive the crew members are within the group. For example, 'new starts' may lack the confidence to tell those members who are more experienced that they are doing the job wrong or have missed something. Crew members need to work together in order to plan a job, which would include planning the procedures which allow them to complete the job on time, and being able to manage the workload.

7. Individual factors

The category *individual factors*, which is often termed 'Personal Factors', contains three sub-headings: (1) competence, (2) stress and (3) motivation (see Table 6). These describe how the individual involved in the incident contributed to the cause of the accident. Under the sub-heading *competence*, the individual's level of training, knowledge, skill, experience and recent practice in the relevant job is called into question, as is their ability to communicate information on to others and their English language skills. This section also covers their decision-making skills, any perceptual difficulties which may have arisen such as extreme concentration demands, risk perceptions, risk taking behaviours and any distractions which may have been present.

The origins of *stress* are difficult to determine precisely, however, a list describing the possible causes is given. The various forms of stress include: personal stress originating from the home, the stress of the environmental conditions and the operational stress from high workload or complicated procedures. Boredom and frustration with the job may also be contributing factors, as could fatigue from long working hours or changing from day shift to night shift, morale and ill health (see Flin[29] for discussion on stress offshore). The *motivation* of an individual to carry out a task can affect they way they complete it. If an individual feels the pressure to get the job done (e.g. pressure for production or peer pressure), they may inappropriately try and save time by cutting corners. If an individual is not motivated, or does not have a positive attitude they may put insufficient thought and care into the job.

Table 6. Individual factors

1. Competence level
Competence
Training
Recent practice
Knowledge, skill, experience
Decision-making
Perceptual disabilities
Lack of anticipation
Judgements
Risk perception/risk-taking behaviour
Distraction
Communication
2. Stress
Personal stress/problems
Environmental stress
Operational stress
Boredom
Frustration
Fatigue
Morale
Health
3. Motivation
Inappropriate attempt to save time
Peer pressure
Attitude
Insufficient thought and care/inattention
Horseplay/recklessness
Aggression

5 REDUCING ACCIDENTS USING HUMAN FACTORS DATA

Various accident researchers have identified ways to improve accident reporting systems in order to prevent accident and incidents occurring in the future. The necessary steps to prevent the occurrence of future accidents described from a traditional engineering point of view, would be to (1) make immediate technical recommendations, (2) investigate ways of avoiding hazards, and (3) investigate ways of improving the management system[13]. From a psychologists' point of view, Reason[5] describes the causes of accidents in terms of active and latent failures, which points the finger at the decision makers, line management, individuals and system defences.

Others believe that by creating a human factors database on incidents and accidents more accidents and incidents could be prevented[6,23,30]. This would include identifying latent errors, events that trigger accidents, human errors and error inducing conditions present before and after the event. In addition to an accident database, task inventories could be performed to describe work groups' objectives and operating procedures, the hazards and the potential of the work group to cause an accident and the possible outcomes of any incident. In addition, the operator's performance could be regularly reassessed, by studying operator's habits during routine activity. Brazier and Black[27] state that it is important the safety programme is open for all employees to participate in and must be perceived as quite separate from any element of blame. Further, it should be emphasised that change may not happen rapidly. The following section describes the advantages and disadvantages of accident reporting, auditing of unsafe acts and latent failures in order to prevent accidents from occurring in the future.

5.1 Reporting accidents and incidents

Accidents which are reported usually represent those at the tip of the iceberg (e.g. fatalities, serious accidents and LTI's). Each accident has unique characteristics and if the goal is to remove the chance of other dissimilar accidents from occurring in the future, feedback from this 'retrospective' reporting system is of limited use. However, this method encourages the awareness of types of accidents that can occur.

In order to increase the offshore accident information base six companies combined their accident data into a database called 'Synergi'[24]. In 1992, three Norwegian oil companies (Norsk Hydro, Saga Petroleum and Statoil) together with 3 offshore contractors (Aker, Braathens Helikopter and Smedvig) developed the first version of the system and data is presently collected by the Rogaland Research Institute in Stavanger, where the companies send their accident reports via electronic mail. There is an increasing emphasis on the underlying causes of accidents which include the human factors. Each company receives an updated version of the database on a quarterly basis and the system was extended to be used in English as well.

The operating company Shell's answer to Synergy is GUARD[23] (Group Unified Accident Reporting Database), which uses feedback from accidents that have occurred, and includes the use of immediate and underlying causes and areas of weakness. Accident information is entered into a computer and details on the corrective actions are included. The main emphasis of this system is on the identification of basic accident causes which include personal, organisational and job factors and definitions of the causes of accidents are provided with the system. This system can provide an accurate historical base of accident information and which could serve as a data-bank for safety studies and can help promote consistent safety recording and reporting and increase the reporting of non-injury related accidents and unsafe acts throughout Shell world-wide.

5.2 Auditing unsafe acts and latent failures

Another method of feedback is the auditing of unsafe acts, by sampling the frequency and nature of unsafe acts. Analysis of unsafe acts can enable managers to assess weak spots and failures before an accident occurs. Examining the types of unsafe acts which are prevalent can indicate which underlying problems are leading to some unsafe acts being performed more than others. However, this is a resource intensive method of accident prevention and clear boundaries as to what defines an unsafe act are more difficult to determine.

The auditing of latent failures can be undertaken without an incident ever occurring. Auditing at this level has been demonstrated on North Sea gas platforms[6] and in a desert drilling operation by Hudson and colleagues in a project called TRIPOD[30]. This was developed to highlight the latent factors in the causation of accidents. Underlying latent failures are central to the idea of how accidents happen and are referred to as General Failure Types, which include hardware, design, maintenance, procedures, error enforcing conditions, housekeeping, incompatible goals, organisation, communication, training and defences. These General Failure Types often lead to specific unsafe acts and triggering events. In order to assess the state of an organisation or activity in terms of its underlying latent problems, an instrument was developed, called a Failure State Profile, to measure the extent of the underlying problems on the basis of a sample of General Failure Types. Specialist personnel on the desert rig (e.g. tool-pusher, drill supervisor) rated their rig on each of the General Failure Types. From these data, a checklist was developed which was sent out to six rigs. The results indicated that training appeared to be the main problem and defences and hardware appeared to be the least important of the General Failure Types. There were differences between the beliefs of drilling supervisors and tool pushers with regard to the problematic General Failure Types, where the tool pushers tended to believe that after training, incompatible goals and error enforcing conditions were the main problems whereas the drilling supervisors thought that after training, organisation and operating procedures were the main problems. Rig staff (tool pushers and drill supervisors) thought that communication on the rig was good, whereas office staff thought it was poor. One of the problems with the TRIPOD method is that only a limited number of possible latent failures have been described. There may be other latent errors which remain undiscovered if this method is followed rigidly. The TRIPOD approach, however, encourages an understanding of safety on a specific installation as well as a basic understanding of how accidents occur.

6 CONCLUSION

This article has provided a brief introduction to some of the human factors issues surrounding safety and accidents in the offshore oil industry. Investigation into the human factors accident causation codes used by high reliability industries, such as, marine, aviation, nuclear and offshore oil, indicate that similar themes are covered in each. The immediate causes of accidents detailed in the offshore accident reporting forms tended to be labelled as technical faults, though some human errors (such as communication) were labelled. This article attempted to include 'human error' categories to further describe accidents in terms of their immediate cause. The main categories used to describe the underlying causes of accidents in the offshore reporting forms were 'job' and 'personal' factors. The marine and aviation industries, investigated in this study, additionally used 'organisational' and 'crew' factors.

There was a large degree of variance between the 25 UK offshore accident reporting forms with regard to the number of items in each category, their clarity and structure. Suggestions have been given of ways to categorise accidents in terms of their immediate causes and have incorporated the work previously carried out in this area of research[5,7,8]. The three main categories used to describe the underlying human factors causes of accidents are 'organisational', 'group' and 'individual' factors, as these were labelled as the factors which make up 'human factors' by contemporary human factors researchers[3].

As a starting point, accident reporting can give a wealth of information if it is carried out with the care and commitment needed to provide a comprehensive analysis. However, training in human factors accident causation is necessary for effective collection of data. By gathering statistics on the most common human factors causes of accidents, such information could be fed back to management, the supervisors and the workforce with the view to make personnel aware of the possible causes of accidents. The human factors categories could be used to train crews in working together as a group and making them aware of the crew factors which could disturb or aid their working relationships. In addition, these factors could be used to train supervisors and management on how to improve their supervisory or management skills with regard to the human factors.

One of the major problems which oil companies are faced with today when using accident trends to prevent further accidents from occurring is that there are too few accidents for statistical analysis. Companies which have large worldwide populations are able to create accident database with which they can analyse and obtain meaningful human factors accident trends. Other companies have integrated their accident databases to form large accident databases, such as Synergi[24]. However, it seems that as yet there has been no attempt to combine accident databases from various industries. By joining forces with other process industries, such as chemical or nuclear, there could be great benefit in learning from each other and from the large accident database which would result. One of the major obstacles with this is that there is no consistent accident reporting form used across companies let alone across different industries. Thus, the first step is for companies and industries to agree upon a common accident reporting form.

This first phase of research has provided a description of the human factors causes which are used in the UK offshore oil industry today. The theoretical question which was described in this article refers to the relationship between human errors and their underlying human causes. This area needs further indepth research to develop an understanding of these relationships. At present research is being undertaken to investigate how consistently personnel complete accident reporting forms with respect to the human factors, how valid these data are and how the collected human factors data from the accident reports can be utilised.

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