Government of Western Australia
Department of Mines, Industry Regulation and Safety

WorkSafe
Western Australia

GUIDE

Human factors fundamentals for petroleum and major hazard facility operators

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Purpose of this guide

This guide highlights the importance of integrating human factors (HF) into safety management systems (SMS) to reduce the likelihood and outcome of major incidents. Many operators are already taking human factors into consideration, without making an explicit link to safety. To support operators on this journey, an overview of human factors topics, performance-shaping factors and managing human performance is provided.

It is not the purpose of this guide to make all operators experts in human factors. Rather, the aim is to enable all operators to consider human factors and recognise how multiple conditions throughout the operator's system can affect safety performance during day-to-day operations.

The guide sits alongside the human factors self-assessment guide and tool to assist operators to integrate human factors into their safety management systems.

As with the management of any safety matter in the workplace, seek expert advice when the limits of internal expertise have been reached.

Scope

The Department has produced these resources to assist petroleum and major hazard facility operators to integrate human factors into their safety management systems.

While both occupational and process safety are important, the information in this document and self-assessment tool focus on process safety rather than occupational safety. From this perspective, process safety covers the prevention and management of events that have the potential to release hazardous materials and energy, and affect the facility, people on site, surrounding environment and general public. Process safety is a framework based on good design principles, engineering, and operating and maintenance practices.[1]

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1 *International Association of Oil and Gas Producers, Process safety. Retrieved 27 July 2021.*

Contents

Introduction

Human factors is an established science with a focus on understanding interactions among humans and other elements of a system, and applies theory, principles, data and methods to design in order to optimise human wellbeing and overall system performance.[2]

Human factors is also referred to as 'human performance', 'human and organisational factors' and 'human factors and ergonomics'. There are slight variations in the definitions of these terms, so it is important to clarify what is meant by human factors in this document.

Human factors is a systems approach in which people are at the centre of the system. Human factors applied to process safety recognises the relationships and interactions between three types of components in the system which contribute to the likelihood and outcome of major incidents. These are:

- **organisation-related:** management systems and organisational structure, shift and roster systems, roles and responsibilities, incentive schemes, contracts, etc.
- **job-related:** design of the workplace, work environment and the job, and the demands the job makes on people's perceptual, cognitive and physical performance, including interpersonal interactions, etc.
- **individual-related:** skills, knowledge, attitudes, values, habits, personality, behaviours and other attributes individuals bring to the job.[3]

Human factors focuses on understanding how human performance is shaped by conditions within the system. That is, what tasks people are being asked to do and the characteristics of the task, who is doing the tasks and their competence, and the environment in which people are working and its attributes.

For a major incident to occur, multiple opportunities to prevent the incident would have failed. Therefore systems, equipment, workplaces and processes should be designed and used to support desired human performance. Integrating human factors into safety management systems is important for achieving error-tolerant systems. While the focus of this guide is on process safety and safety management systems, it is also important to acknowledge that other systems such as human resources, performance management and contracting models within the organisation also influence human performance.

Work-as-done and work-as-imagined

Many safety management systems are originally developed in a theoretical environment or for ideal situations that have implicit and explicit assumptions about the optimal performance of the system, equipment and human activities. This is often referred to as 'work-as-imagined' and is formally documented in training, procedures and equipment operating manuals. Differences in the designed performance or work-as-imagined and the realities of how work is actually done (known as 'work-as-done') are common.

Increasing alignment between work-as-imagined and work-as-done involves identifying, assessing and managing the conditions that positively or negatively shape human performance. Applying a human factors approach to understanding how work is actually performed will identify opportunities for better alignment and enhance human reliability.

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2 *International Ergonomics Association, What is Ergonomics? Retrieved on 28 July 2021.*

3 *Chartered Institute of Ergonomics and Human Factors, Learning from Adverse Events. Retrieved on 28 July 2021.*

Managing human performance

People performing normal work continually adapt and overcome unexpected situations, detect changes in risk, are flexible in managing and linking multiple tasks, can apply knowledge and judgement to identify patterns and understand impacts of actions, and can manage complex communications. Humans manage the normal variability of work.

Human performance plays a significant role in preventing initiation, mitigating the impact, preventing escalation and improving recovery efforts of major incidents or events. People apply their physical and mental capabilities (strength, flexibility, memory, attention, resourcefulness and problem solving) to keep the system functioning safely, effectively and efficiently. These capabilities are critical to safety and effective operational performance. However, human performance is also constrained by physiology, cognitive ability, memory, attention, and sensory and information processing limits. Systems, equipment, workplaces and processes should be designed and used to support desired human performance and accommodate the physical and mental constraints of humans.

Principles of human performance[4,5,6]

1. **Variation in human performance is normal and not causal.** Variation in human performance is normal and to be expected given the strengths and constraints that come with being human. Human performance should not be capable of leading to a major event or incident on its own.
2. **Blaming human performance fixes nothing.** Attributing the cause of a major incident to human performance is overly simplistic. More often than not, the performance is a symptom of wider systemic issues and even the best, most experienced, most competent people will make mistakes.
3. **Learning is vital.** Organisational learning, driven by leadership commitment and continuous improvement or a learning culture, is fundamental for preventing re-occurrence. Opportunities for learning should be sought from all types of incidents: actual loss or harm incidents, near misses and weak signals (i.e. small indications and signs that something is not correct or as it should be).
4. **Context drives behaviour.** Context is the meaning assigned to the situation. Context involves people's beliefs, perceptions, motivations and values which shape human behaviour. People perform in ways that make sense to them, they adapt to the demands of the situation, assess risks and make trade-offs with good intentions. Understanding the contextual factors which drive behaviour helps identify underlying weaknesses in the system and opportunities to improve the system.
5. **How leadership responds matters.** Visible leadership commitment and modelling desired behaviours and attitudes is pivotal as workers take their cues from their management and the immediate work environment. A 'just', no-blame culture encourages reporting and improvement.

4 Conklin, T. (2019), The Five Principles of Human Performance: A Contemporary Update of Human Performance for the New View of Safety. Independently published.

5 Daniellou, F., Simard, M. and Boissières, I. (2011), 'Human and organizational factors of safety: a state of the art', Cahiers de la Sécurité Industrielle (Foundation for an Industrial Safety Culture) No. 11(01), Toulouse, France. Available at foncsi.org/en.

6 Chartered Institute of Ergonomics and Human Factors, Learning from Adverse Events. Retrieved on 28 July 2021.

As people are the centre of the system, conditions within the system can influence or 'shape' their performance. These conditions are referred to as performance-shaping factors (PSFs). They can positively or negatively affect human performance. Performance-shaping factors can be latent or long-term conditions that eventually contribute to an incident, or active or short-term conditions that affect performance on the day of the incident. As with the system components, these factors can be categorised as organisation-related, job-related and individual-related:

- **organisation-related:** e.g. leadership commitment, organisational priorities, workplace culture, availability and adequacy of resources, level of supervision, change management, key performance indicators, communication systems.
- **job-related:** e.g. difficulty or complexity of tasks, time available, physical work environment, human-machine interface, availability and quality of procedures, team member behaviour, equipment being used.
- **individual-related:** e.g. personality, attitude and motivation, mental ability, individual health factors such as fatigue, drugs and alcohol, physical capability and mental health.

Performance-shaping factors are identifiable, assessable and manageable. Managing performance-shaping factors through enhancing organisational and job conditions supports human performance and reduces the risk of major incidents.

Human factors and safety management systems

The principles for integrating human factors into safety management systems are derived from international standards, best practice and in consultation with industry experts.[7] Adopting these principles will assist in achieving effective integration of human factors into safety management systems. These principles are:

- adopt a holistic and integrated approach
- place people at the centre of the system
- account for human variability
- ensure transparency of organisational processes and actions
- take account of social and organisational influences
- involve workers and respect and value their contribution
- encourage timely, relevant and transparent two-way communication between workers and leaders
- ensure fairness of treatment (i.e. a no-blame, just culture).

The benefits of integrating human factors into safety management systems

It is well recognised that the integration of human factors into safety management systems will result in benefits to operators. In regard to safety, the integration of human factors:

- facilitates continuous improvement to safety and the development of a learning culture
- increases understanding and ownership of safety processes
- establishes, maintains and improves safety culture
- promotes and develops proactive and predictive management of risk
- supports the allocation of appropriate resources to safety processes.

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7 *Civil Aviation Safety Authority. (2009). Integrating of human factors (HF) into safety management systems. Civil Aviation Advisory Publication CAAP SMS-2(0).*

Integrating human factors into safety management systems

Integrating human factors into a safety management system does not mean creating a new section in the existing documentation. Operators can demonstrate how human factors have been considered in existing sections of the safety management system documentation. The key areas of the safety management system to consider integrating human factors are:

- risk management of major incidents and hazards
- management of change
- design and procurement of systems, equipment, machinery and their subsequent usability
- job and task design
- selection and training of safety critical personnel and for safety critical tasks
- maintenance, inspection and testing of safety critical equipment and controls
- incident investigation.

Safety management system documentation should clearly demonstrate how human factors have been considered in the management of risk. The risk management process does not change. However, it should include and demonstrate consideration of various aspects of human performance in the areas of prevention, initiation, detection, control, escalation, mitigation and emergency response when identifying, assessing and controlling for major hazards and incidents.

The existence of a safety management system that does not consider human factors may not be sufficient to demonstrate the risks associated with major hazards and incidents have been reduced to low as reasonably practicable (ALARP) or so far as reasonably practicable (SFARP).

Managing the risk to ALARP/SFARP

Given that human performance alone should not be capable of leading to a major incident in any system, and remembering that the performance is usually a sign of wider systemic issues, an error tolerant system will have multiple controls (or defences) in place to prevent initiation of major incidents and reduce the outcome in the event a major incident occurs.

When determining risk controls, petroleum and major hazard facility operators should consider the relationship and interactions between the types of systemic factors within the system: organisational, job and individual. Applying risk controls will be less effective if these systemic factors are considered in isolation.

Controls should be targeted at the sources of risk within the system. This is done in the first instance through elimination controls followed by engineering, isolation and substitution controls. Common controls to support desired human performance focus on equipment design, workplace design, task and job design, and design of processes and procedures, supervision, and monitoring.

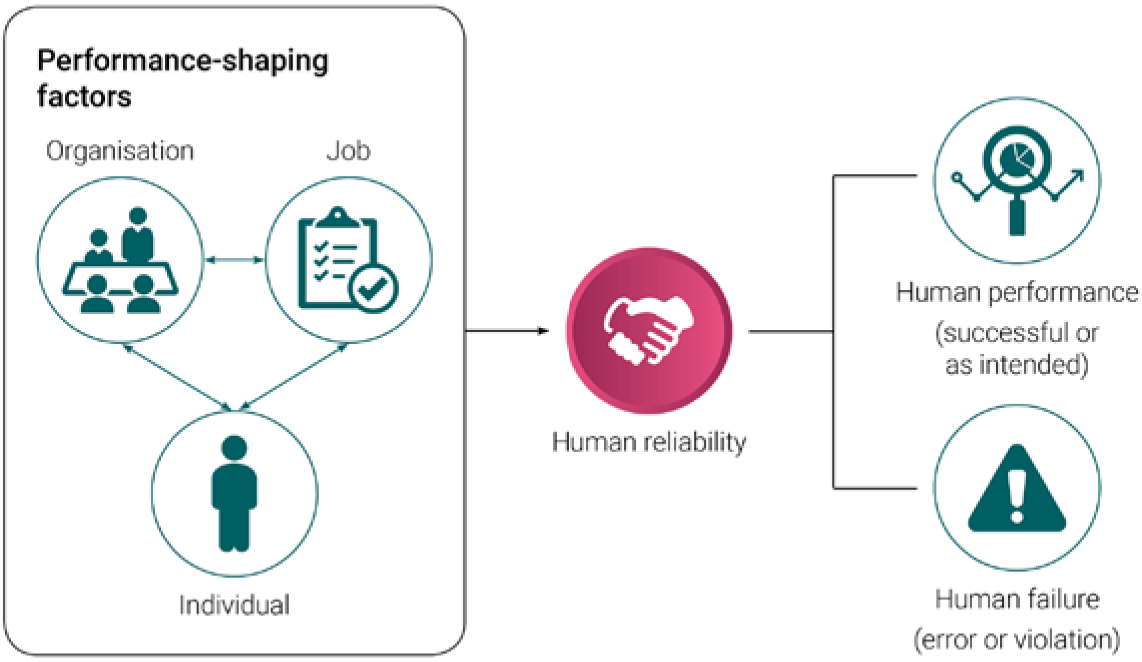
Human factors for the WA resources sector

The most prevalent human factors topics for the Western Australian resources sector were identified through a review of Departmental and other data sources, and industry consultation. The topics listed below are described in the following sections.

1 Managing human reliability

Human reliability refers to the likelihood of successful human performance within specified timeframes and environmental conditions. It is critical to overall system reliability and is one factor that contributes to, or prevents, unwanted events occurring.

Performance-shaping factors impact on human performance, contributing to how effectively and safely a worker is able to do their job. How well these factors are managed will influence human performance and the likelihood and outcome of human performance.



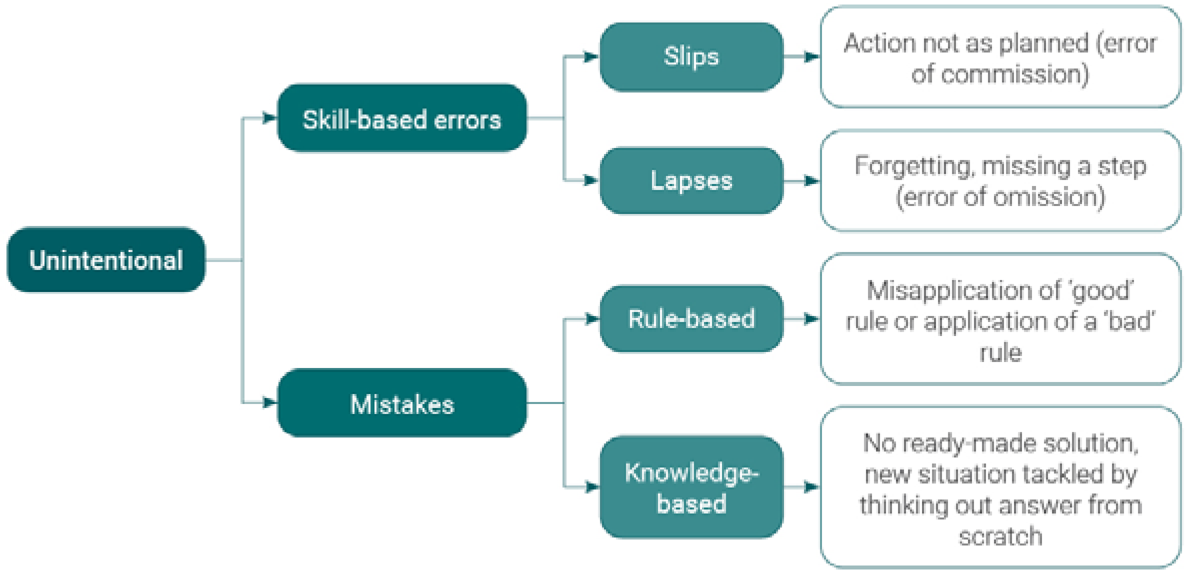
Performance-shaping factors and human reliability

Understanding human failure

Human failures refers to human errors, mistakes and violations. As human failure is often a symptom of wider systemic issues and not the cause of major incidents, identifying the type is important. This is because there are different systemic causes and contributing performance-shaping factors which require targeted controls.

Human failure can be identified, assessed and controlled to ALARP or SFARP by understanding the different causes and performance-shaping factors at the organisational, job and individual level.

Unintentional human failures



Skill-based errors (slips of actions and lapses of memory) are unintentional and tend to occur during highly familiar, routine tasks.

Skill-based errors generally occur when attention is diverted from a task, either by thoughts or external factors. Generally, when these errors occur, the worker has the right knowledge, skills and experience to do the task properly. This means that highly experienced workers may be more likely to encounter this type of error than those with less experience. This also means that retraining and disciplinary action are not appropriate responses to this type of error.

A *memory lapse* occurs after the formation of the plan and before execution, while the plan is stored in the brain. This type of error refers to instances of forgetting to do something, losing place in a sequence, or even forgetting the overall plan.

A *slip of action* occurs at the point of task execution, and includes actions performed on autopilot, skipping or reordering a step in a procedure, performing the right action on the wrong object, or performing the wrong action on the right object. Typical examples include:

- missing a step in an isolation sequence
- pressing the wrong button or pulling the wrong lever
- loosening a valve when intending to tighten it
- transposing digits when copying numbers (e.g. writing 0.31 instead of 0.13).

Slips and lapses can be minimised and mitigated through workplace design, effective fatigue management, use of checklists, independent checking of completed work, discouraging interruptions, reducing external distractions and active supervision.

Mistakes can be rule-based or knowledge-based.

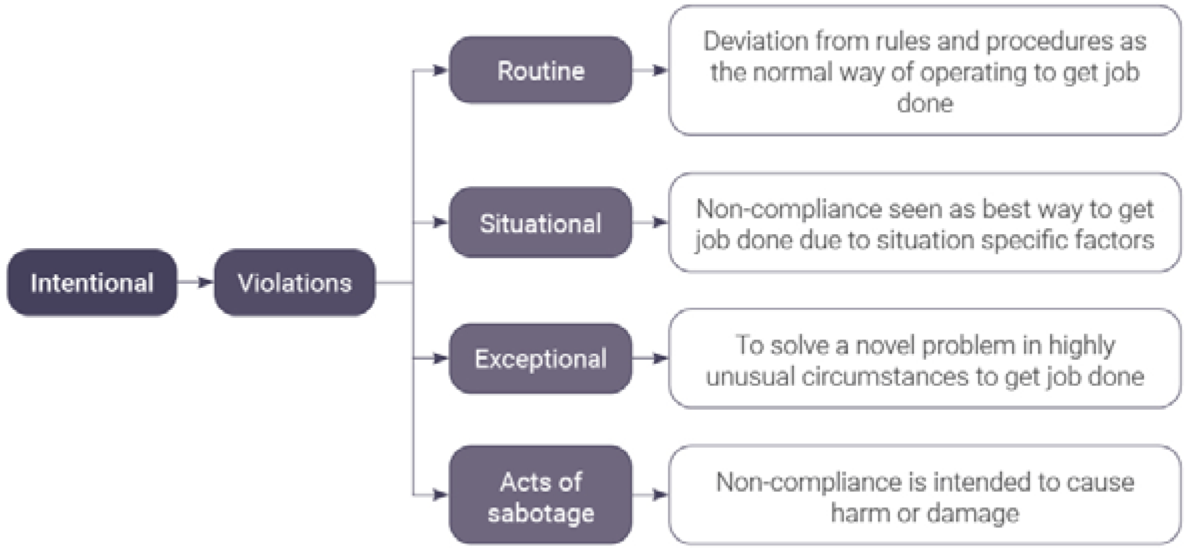
Knowledge-based mistakes result from 'trial and error'. In these cases, insufficient knowledge about how to perform a task results in the development of a solution that is incorrectly expected to work. Rule-based mistakes refer to situations where the use or disregard of a particular rule or set of rules results in an undesired (i.e. unintentional) outcome.

Some rules that are appropriate for use in one situation will be inappropriate in another. Incorrect application of a good rule occurs when a rule has worked well on previous occasions, so it is applied to a similar situation with the incorrect expectation that it will work. Sometimes rules are inappropriate or incorrect, and adherence leads to negative outcomes. Bad rules may be created based on incorrect knowledge (i.e. knowledge-based mistakes), or a good rule may become bad following changes that are not managed appropriately.

Workers with less knowledge and experience may be more likely to experience mistakes. Mistakes are not committed 'on purpose'; as such, disciplinary action is an inappropriate response to these types of error.

> Mistakes can be minimised and mitigated through robust competency assurance processes, good quality training, proactive supervision and a team climate in which co-workers are comfortable observing and challenging each other.

Intentional human failures



Violations are classified as human error when the intentional action does not achieve the desired outcome, or results in unanticipated adverse consequences. These violations tend to be well-intentioned, targeting desired outcomes such as task completion and simplification.

> Where a violation does achieve the desired outcome, and does not cause any other undesired outcomes, this is NOT human error. These types of violations may include violation of a bad rule, such as a procedure that, if followed correctly, would trip the plant. In such cases, a review of the rules and procedures is advisable.
>
> This is indicative of human adaptability due to weaknesses in the system.

There are four main types of violations: routine, situational, exceptional and acts of sabotage.

- A *routine violation* is one which is commonplace and committed by most members of the workplace. For example, in a particular office building it is against the rules for personnel to use the fire escape stairwell to move between floors, but it is common practice for workers to do so anyway.
- A *situational violation* occurs, as its name suggests, in response to situational factors, including excessive time pressure, workplace design, and inadequate or inappropriate equipment. When confronted with an unexpected or inappropriate situation, personnel may believe that the normal rule is no longer safe, or that it will not achieve the desired outcome, and so they decide to violate that rule. Situational violations generally occur as a once-off, unless the situation triggering the violation is not corrected, in which case the violation may become routine over time.
- An *exceptional violation* is a fairly rare occurrence and happens in abnormal and emergency situations. This type of violation transpires when something is going wrong and personnel believe that the rules no longer apply, or that applying a rule will not correct the problem. Personnel choose to violate the rule believing that they will achieve the desired outcome.
- *Acts of sabotage* are violations designed to cause damage. Acts of sabotage occur when the planned action (violation) has achieved the desired outcome (damage). This type of behaviour does not constitute human error and, following investigation, should be managed through appropriate disciplinary measures.

Preventing violations requires an understanding of how motivation drives behaviour. Planned behaviour (intentional action) is driven by a worker's attitude towards that behaviour. Further, individual decision-making is primarily influenced by the consequences the worker expects to receive as a result of their behaviour, which can influence their attitude towards that behaviour.

> Violations can be minimised and prevented through education about risks and consequences, training in 'why' not just 'how', the use of decentralised decision-making structures, dedicated site-based roles for procedure modification approval, allowing sufficient time for risk management activities, the use of lead indicators as targets, and active workforce involvement in the development of rules and procedures that will affect them.

Managing human reliability for safety-critical tasks

Managing human reliability refers to preventing the likelihood of an error occurring in the first place. In order to manage human reliability, it is essential to identify:

- tasks that are safety-critical for different operating conditions (i.e. normal operations, abnormal operating conditions, maintenance, start-up and shut-downs, and emergency situations)
- performance-shaping factors and potential human errors
- controls to reduce the risk from identified errors and performance shaping factors and mitigate the consequences to ALARP or SFARP.

Safety-critical tasks refer to those activities where people are expected to perform as barriers against the occurrence of a major incident/fatality or to prevent escalation in the event an incident does occur. They include activities required to support or maintain physical and technological barriers.[8]

It may be helpful to document this risk management process as a bow-tie diagram.

Management should be aware of the ways that errors can occur – especially in safety-critical tasks and recognise the measures necessary to prevent them, ensure early detection when an error is made and mitigate the consequences, should something go wrong.

Human performance in incident investigation

Some incident analyses cite human error as the cause of the incident, and then go further to identify that the human error was due to a lack of training. A typical remedial action is to retrain the person involved in the incident. However, in terms of human factors, it is not sufficient to note 'limited' or 'lack of training' as a root cause. The analysis should find out why the person involved lacked training, what led to an untrained person being involved in the task and what system within the organisation failed. That is, identifying the performance-shaping factors that contributed to the incident and therefore inform effective recommendations for improvement.

Human factors recognises that human performance alone should not be capable of leading to a major incident in any system. For a major incident to occur, multiple opportunities to prevent the incident would have failed.

The following questions may assist in identifying corrective actions that reduce the risk from human factors to ALARP/SFARP:

- What types of human error occurred?
- What system components contributed to the human performance and can these components be designed out?
- Can the performance-shaping factors be changed to be more positive; e.g. developing a positive health and safety culture?
- Can the human performance element be eliminated; e.g. by automation?
- Can human performance be assured by using interlocks or other engineered means?
- Can the consequences of the error be prevented; e.g. by additional barriers in the system?

The key to effective investigations is to ensure that the approach used discovers the underlying reasons why an incident occurred, not just the error made by the last person involved. Effective incident investigation is promoted by a 'no blame', 'just' or 'learning' culture – a culture that encourages incident reporting and examines performance-shaping factors within the broader system that led to the incident occurring, to make improvements to the system to reduce the likelihood of reoccurence.

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8 *International Association of Oil & Gas Producers (2011). Report 454: Human factors engineering in projects. London: OGP Publications.*

2 Usable procedures

Procedures are generally designed to increase human reliability by providing a consistent and safe means of performing a task and act as job aids to assist with reducing skill-based error from slips and memory lapses. Procedures include work instructions, permits to work and safe work method statements. These procedures recognise an agreed safe way of performing a task, and may include:

- step-by-step instructions
- safety-critical tasks and information
- diagrams
- checklists
- photographs
- original equipment manufacturer (OEM) instructions.

Procedures form part of an effective safety management system. Provision of clear, concise and accurate procedures is an important measure that needs to be taken to prevent and mitigate unwanted outcomes. If procedures are difficult to use, it can increase the likelihood of incidents.

Properties of usable procedures

Not only do usable procedures contain and emphasise safety-critical information, they are:

- clear and concise
- easy to obtain when needed
- fit for purpose; e.g. a laminated pocket guide, a large manual, electronic copies on an intranet, a folder on a desktop, checklist, flow chart
- accurate and up-to-date
- signed and dated, showing who authorised them and when they need to be reviewed again
- checked regularly to ensure procedures continue to properly reflect the job they are being used for and therefore remain a valid control. Be prepared to make changes if required.

Guidance on the development and use of procedures

It is important to have an effective system for producing procedures and to ensure that the content is relevant to the context in which it will be used. Procedures should:

- be written based on a task analysis and risk assessment of the task to be done. The workers who carry out those tasks should be involved in the analysis and writing process.
- include controls, wherever possible. The simplest example of this is a procedure that identifies the personal protective equipment (PPE) to be worn while doing a specific job.
- be clear about what happens next. If an instruction is given, the procedure should make it clear what the effect will be; e.g. 'When pump AB12 starts, pressure on gauge CD34 will begin to rise.'
- be realistic. It should be feasible to carry out the actions in the procedure given the availability of workers and their competence, the equipment and amount of time.
- be easy to navigate, giving a short description of the whole job, a clear contents page and index, sections with headings, flowcharts, etc. Consider developing a standard for designing procedures.
- be complete and contain the right amount of information, including pictures and diagrams.
- consider the literacy and numeracy capability of the workers using the procedures.

Monitoring and review of procedures

There is potential for the effectiveness of any system to degrade over time, including procedures. To prevent this and maintain system efficacy, regular monitoring, review, audit and corrective action are required. Plans and commitments for monitoring and review should be made early in the development of the petroleum operator's safety case or major hazard facility's safety report.

Auditing can check procedures are being adhered to and whether workers have made any deliberate adjustments to procedures or whether they have inadvertently deviated from them. Identifying the reason for the intended or unintended adjustments or deviations is necessary to maintain procedural relevance and to determine whether the changes are justifiable and need to be formalised, or whether the changes compromise safety.

3 Training and competence

Training is a key component of ensuring competency and consistency are achieved and maintained. Training updates existing knowledge and skills, and provides workers with new knowledge and skills. Competence is the combination of skills, experience and knowledge required to undertake the responsibilities of a role and consistently perform activities to a recognised standard on a regular basis. However, in order to become competent, workers need to apply and practice what they have learnt. Training and competence, collectively, can reduce errors caused by lack of knowledge and teach behaviours that will support desired human performance preventing initiation, mitigating the impact, preventing escalation and improving recovery efforts of major incidents and accidents.

Workers should be competent in their day-to-day tasks and also in health and safety matters such as recognising hazards and risks at work. Having competent staff is critical to running a safe operation. This includes being able to supervise contractor work to a level that can assure quality and safety.

The provision of information, instruction, training and supervision is an essential component of any risk management strategy for ensuring the competency of workers.

It is important to remember that training and competency is not a universal safeguard, as even the most experienced and competent workers will make mistakes. Mistakes are normal.

Training management systems

A training management system provides a framework for an organisation to define, develop, establish and maintain all training requirements across the organisation. A robust training management system is fundamental to the safety of not only those conducting tasks, but also other workers and people who may be affected by their work.

Aspects that need to be considered to achieve an effective training and competency system include:

- selection of workers: develop a clear understanding of the skills and experience required to fulfil the vacant role.
- job requirements: functional job analysis can be a useful tool for determining all the requirements of a job, including competency-related matters, as well as functional capacity. It can assist in identifying any gaps in new recruits' skillsets which the petroleum or major hazard facility operator will then need to be willing to address.
- training needs: conduct a training needs analysis to determine the training and competency requirements for workers, roles, teams, departments, etc. It is beneficial to develop individual training plans for all workers, identifying their specific training needs at different stages of their work lifecycle.
- skills consolidation: on completion of training, a skills consolidation period should apply. This is so the learner can gain experience and reinforce the skills learned prior to being assessed or undertaking the task.
- assessment: some training may require a formal assessment to validate competence against an agreed standard. This may include tests, assignments, on-the-job observations or follow-up observations. By developing consistent standards to measure against, petroleum and major hazard facility operators can ensure training achieves its objectives.

- monitoring and review: within the training management system, there should be provision for ongoing and regular review of worker competence, including refresher training. The Department recommends an audit is conducted on the training management system regularly to ensure petroluem and major hazard facility operators are meeting their system requirements as well as legislative requirements.
- records management: as part of a safe system of work, it is essential that training and assessment records are maintained and easy to access. In particular, supervisors need to be able to access workers' training and assessment records to confirm a worker is competent before assigning tasks, and workers should be able to access their own training records so that they know what they are deemed competent in.

Details of training management systems should be outlined in the petroleum operator's safety case and the major hazard facility's safety report, and operationalised within the operator's safety management system. It should be clear that an effective training management system has been developed for the operation or facility.

4 Staffing and workload (including supervision)

Ensuring appropriate staffing and workload is critical for effective process safety performance and maintaining a safe workplace for workers. Ensuring appropriate staffing is not just a matter of having enough staff, but also ensuring that they have suitable knowledge, skill and experience to operate safely.

It is important to consider the physical, cognitive and emotional workload required for tasks when determining what is expected from workers, and to make sure these expectations are reasonable given human capabilities and limitations.

High workload and inadequate staffing can cause fatigue and adversely affect decision making. They are known contributory factors of many process safety incidents. One way to effectively manage workload is to ensure appropriate staffing.

Workload

The workload of a task can either be physical, cognitive or emotional or a combination of all three.

Physical workload refers to the physical effort required to carry out a task. Some tasks have a high physical workload such as lifting, carrying, pushing, pulling, or other sustained effort, or a large number of physical tasks that have to be done in a given timeframe. Working in a cramped or restricted environment can also add to physical workload as can climbing ladders and working at heights.

Tasks with high physical workload can affect a worker's ability to carry out the work safely and effectively if not adequately managed.

Cognitive workload refers to the mental or cognitive effort required to carry out a task. It varies across tasks, with some demanding more of our cognitive resources than others. Situations that include any of the following require a high mental workload:

- diagnosing a problem and developing an effective solution, especially when the problem is complex or there are multiple problems to solve
- processing multiple sources of information and making difficult decisions
- applying fine judgement
- remembering or recalling lots of facts or pieces of information
- applying sustained attention or vigilance
- maintaining a high level of situational awareness of both the current state of the situation and the correct response if the situation changes.

Alarm management, including alarm prioritisation, is a cognitive demand and has particular relevance to control room operators. Applying established industry standards for alarm management can simultaneously address cognitive overload and lower operational risk.

Emotional workload refers to work that is high in emotional demands. This includes work that is emotionally disturbing, requires high emotional involvement from workers or requires workers to regularly hide their emotions. Examples of work that is high in emotional demands include:

- emergency response
- customer service
- managing community and worker complaints
- interacting with third parties, such as dissatisfied landowners.

Combined physical, cognitive and emotional workload

Tasks with combined high physical, cognitive and emotional workload become more demanding if:

- they are performed under time pressure or have to be sustained over a long period of time
- workers are required to multi-task
- workers are not yet fully competent in the tasks (e.g. they have not been able to practice the skills acquired)
- they are conducted in unusual or emergency situations
- information available is unclear or ambiguous, provided late, or requires some form of conversion or processing
- the result of the activities are critical to safety, environmental protection or financial success
- the worker is fatigued or distracted
- workers are not fit for work (mentally or physically) and are therefore unable to perform effectively in their roles.

Conducting risk assessments or task observations can assist organisations to identify and enhance the job conditions, design of work, and organisational factors to support desired human performance and manage the risk.

Staffing

Staffing, meaning both the number of people and skillsets required, should be matched to the volume of work.

To ensure appropriate staffing, petroleum and major hazard facility operators should maintain sufficient staff numbers and skills mix to carry out all required tasks. This means:

- when reducing the number of personnel, consider how all functions are to be carried out effectively by remaining workers without overloading them
- maintaining sufficient staffing for emergency situations which may require more personnel than under normal conditions, and confirm that personnel have the skills to carry out their emergency role
- considering contingencies in the event of illness, emergency work and times of peak workloads
- providing training to increase the number of workers who are competent to carry out safety-critical tasks.

Staffing also includes ensuring that the span of control of supervisors is appropriate for the tasks being undertaken.

Staffing levels may be inadequate if there are:

- increases in rates of safety incidents
- safety-critical tasks not being completed or completed later than they should be
- maintenance backlogs
- increases in overtime being required to meet operational targets
- increased complaints and absences due to stress, fatigue or other ill-health
- increases in staff turnover, absenteeism and presenteeism
- emerging breakdowns in communication.

Supervision

Supervision is a fundamental safety function applicable within all levels of an organisation. It complements the provision of information, instruction and training, and influences how well organisations achieve their safety and health objectives and performance standards.

Supervisors play a vital role in shaping the safety culture of an organisation. Supervisors can have a significant impact on a range of performance-influencing factors such as compliance with procedures, training and competence, safety-critical communication and staffing levels and workload.[9]

The role of a supervisor includes:

- controlling, influencing and leading a team, including conflict management, discipline and building teamwork
- planning, scheduling and allocating work and managing staffing and workload
- monitoring performance and compliance, including health and safety performance and compliance
- managing contractors
- ensuring workforce involvement.

Supervisors not only need to manage the day-to-day routine operations, they also need to manage abnormal and emergency situations.

Crucially, failures in supervision have been identified as a contributing factor in many major incidents, such as the Esso Longford gas plant explosion in Victoria in 1998 where it was found that, along with deficiencies in the supervision of day-to-day operations, both supervisors and workers did not have the necessary knowledge to deal with the events that occurred following a pump shutdown.[10]

Effective supervisors should have the required skills, knowledge and experience to carry out their role and responsibilities, and a thorough understanding of local hazards and control measures, as well as emergency and recovery procedures and processes. To do this effectively, it is vital that they are adequately resourced and supported by senior management.

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9 Health and Safety Executive (HSE) UK, Human factors: Supervision. Retrieved 22 June 2021.

10 DM Dawson and BJ Brooks, Report of the Longford Royal Commission (Parliament of Victoria, June 1999).

5 Managing change

Changes can introduce new hazards or increase risk for existing hazards. Effective management of all changes to a facility or pipeline including operational, organisational and procedural changes should be in place. In a process safety context, changes can be:

- temporary and emergency
- changes in design
- changes in operating conditions
- organisational change
- introduction or new or changed systems.

Petroleum and major hazard facility operators should have a competent and detailed management of change system outlined in their safety case and safety report, respectively. The management of change procedure should be used for introducing new or modifying existing hardware such as plant, tools, materials and machines. Management of change procedures should also address making changes to the organisation and the way people work.

Management of change processes should include:

- clear objectives and leadership responsibilities
- a structured procedure
- consulting with members of the workforce that will be impacted by the change
- a risk assessment of the change itself and the change process
- reviewing training and competency requirements
- reviewing and monitoring the change to ensure effective safety performance and no new hazards or risks have been introduced.

The established management of change system should ensure that changes will be analysed, evaluated and communicated to all members of the workforce before implementation.

The Department's Management of change guide provides detailed information on managing change for petroleum and major hazard facility operators.

Permit-to-work systems

Permit-to-work systems are one of the most critical safety procedures in industry and are an important part of the management of change. Permit-to-work systems provide a safe framework for work to take place by ensuring hazards are identified and controlled. Permit-to-work also provide opportunities to identify and prevent human failures (e.g. inadvertent isolation of the wrong plant and non-compliance with safety-critical control measures. Failings in permit-to-work systems have been identified as contributory factors in a range of major incidents (e.g. Texas City, Piper Alpha). Permits-to-work are required for different types of activities in normal operations, construction, maintenance (such as break containment), confined space entry and hot works.

Performance-shaping factors can impact the performance of permit-to-work systems:

- Organisational-related performance-shaping factors such as work scheduling and the provision of sufficient, competent personnel to issue and supervise permits.
- Job-related performance-shaping factors such as the design of the permit issuer's job and whether they are required to check the conditions of the permit are being complied with at the start and end of the job.

6 Safety-critical communication

Spoken and written communication can be critical for maintaining safety. Safety-critical communication focuses on helping workers negotiate hazards in the workplace, increase reliability and perform their jobs safely, thereby contributing to the effective safety performance of operations and plant. Examples of safety-critical communication include two-way radio communication between the control room, field operators and maintenance personnel, shift handovers and emergency response.

Conditions in the workplace that support effective safety-critical communication include:

- communication equipment being readily available, usable and reliable
- defined minimum standards for effective safety-critical communication (e.g. who needs to communicate and what information needs to be communicated)
- known transmission blackspots are addressed.

Effective communication is vital for the performance of safety-critical tasks. Poor communication, especially at shift handover, was identified as a key contributor to a number of major accidents, including incidents at Piper Alpha, Grangemouth, Texas City and Buncefield.

Shift handover communication

For an effective start of shift or shift handover that reduces the likelihood of an incident arising during the shift, consider:

- providing procedures describing key information that needs to be exchanged, the method for doing so and order of priority, given due consideration to higher risk handovers, such as:
  - during shutdowns, unusual operating conditions, maintenance and emergency breakdowns
  - during work which involves complex permits and/or isolations
  - when workers have had extended absences from the worksite
  - when there are inexperienced workers on the job
  - when there is handover between experienced and inexperienced workers
- where possible, providing both a written handover and in-person handover to allow for crews to openly discuss issues to reduce the possibility of misunderstandings and have a written reference to refer to, if needed
- allowing sufficient time for handovers to remove time pressure and other distractions, checking that the content of handover communication is relevant, so as not to obscure the information with irrelevant detail
- regular auditing of the quality and effectiveness of the handover process, including consulting with the workforce on their experience of shift handover communication.

7 Designing for people

Designing for people is a design process that focuses on the needs and characteristics of the users or operators.

Good design takes into account how the worker is expected to interact with the workplace set up, the work equipment and how the work equipment fits into the system as a whole. Facilities, hardware, systems, equipment, tools, materials, layout and configurations are adapted to human skills, limitations and anatomy.

The design process requires an analysis of the work tasks that workers have to carry out and the effect of any constraints that the design and its influence on the environment (e.g. noise, vibration) is likely to have on the operator's health, safety and wellbeing. These constraints can contribute to variability in human performance.

The design of control rooms, alarm systems, plant and equipment has a huge impact on human performance; that is, the likelihood of workers performing their tasks as planned. Designing tasks, equipment, processes and the work environment to suit the user can enhance human performance, reduce accidents and incidents, and improve consistency in achieving outcomes.

The earlier that the intended user is considered in the design process, the better the results are likely to be.

Consultation

In the context of designing for people, effective consultation involves implementing a participative ergonomics approach. Participative ergonomics refers to the process of involving workers in improving their workplace to reduce the risk of major incidents and increase productivity. With firsthand experience of performing the work on a regular basis workers are best placed to be involved in the risk management process relating to their work.

Designing safe, effective and productive work systems

In regard to process safety, designing safe, effective and productive work systems for workers involves considering:

- the work environment
- human-machine interface
- alarm management.

Work environment

Designing work environments to optimise performance involves applying good work design principles to manage environmental conditions such as lighting, thermal comfort, noise, vibration and atmospheric contaminants. It is important to examine the work environment as part of designing good work as these factors can positively and negatively impact on human performance; that is, the likelihood of workers performing their tasks as planned.

Environmental conditions are those external factors in the environment that affect worker comfort and performance at work. These factors can cause work-related stress and, combined with psychosocial hazards, can heighten overall work-related stress and affect human performance through impairing decision-making and the ability to carry out tasks as planned.

Types of environmental stressors include:

- noise
- thermal comfort
- lighting
- vibration
- air quality
- available workspace.

A **mentally healthy workplace** is one where workers and management collaborate to protect and promote the health, safety and wellbeing of all. Maintaining a mentally healthy workplace involves continually addressing health, safety and wellbeing concerns in, and due to, the work environment. A mentally healthy workplace enhances human performance and workers' abilities to carry out their tasks safely and effectively.

Strategies to assist in designing a mentally healthy workplace include:

- identifying and managing psychosocial hazards within the workplace, including those associated with job design, fatigue management, reporting, etc
- educating the workforce on psychosocial hazards so they can be prevented, reported and managed
- adopting a culture of respect when it comes to interpersonal communication: bullying, sexual harassment and aggression are not acceptable
- conducting functional job assessments on each position to ensure each position has tolerable work demands and appropriate support
- providing multiple channels for reporting within the workforce.

Human-machine interface (HMI)

Human-machine interface refers to the interactions between the human, the machine and the environment, and is an important consideration in designing for people.

The overall principle for designing good human-machine systems is that the machine and its associated elements (i.e. displays, controls, instructions, etc.) are suitable for the operator and the given task. In order to realise this principle, the machine system should consider human characteristics, with respect to physical, psychological and social aspects. These include:

- suitability for the task – machinery should support the operator when performing repetitive tasks. The operator should be supported in such a way that the operation does not overload or underload their mental abilities
- self-descriptiveness – underlying process and the functioning of the machinery should be easily understandable for the operator
- controllability – operator should have control over the machine and its components
- conformity with user expectations – machinery should be, as far as possible, compatible with the operator's expectations based on previous work experience and training
- error tolerance – machinery should be error tolerant and provide the operator with the means for handling errors so that an error does not lead to a hazardous situation
- suitability for individualisation – machinery should allow operators an appropriate degree of autonomy with regard to decisions on priorities and procedures
- suitability for learning – machinery should allow the development of existing abilities and the attainment of new skills
- flexibility – machinery should be flexible enough to be adapted to the variation of the skills within the operator population and, if necessary, to special needs.

Alarm management

Alarm management refers to applying human factors and ergonomic design principles to the design of alarm systems and management of alarms, including alarm floods to ensure maximum usability and effectiveness.

The design of the interaction between the operator and the machine should consider the following questions:

- Are alarm systems designed to ensure maximum usability?
- Is information needed to perform the task readily available to the operator? This information should be presented in such a way that the operator can readily understand and act on it. For example, providing a quick overview of the whole work system as well as detailed information on key parts and components.
- Are displays and signals designed in a manner compatible with the characteristics of human perception and the task to be performed?
- Where an interactive system is used, are icons, symbols and commands consistent in appearance and function?
- Are visual deficiencies accounted for? Colour should not be the only sort of coding. Shape, position, symbols and text should also be used.
- Where it is not possible to rely on auditory signals, are signals other than acoustic ones (e.g. visual, tactile) considered?
- Do controls and displays clearly correspond with their functional output?

8 Fitness for work

The concept of fitness for work is broad and relates to the capacity of a worker to do their role or specific job activities safely and productively. This is separate to competency. Fitness for work can be impacted by:

- fatigue
- medical fitness (i.e. physical health and functional capacity)
- mental health and wellbeing
- alcohol and other drug use.

Fitness for work impacts on many of the abilities relied on to support desired human performance in preventing initiation, mitigating the impact, preventing escalation and improving recovery effects of major incidents and accidents. It impairs worker:

- ability to process information
- decision-making and judgement
- concentration and memory
- risk perception
- reactions to changes in a situation
- physical coordination
- communication.

Petroleum and major hazard facility operators should assess if workers are able to safely complete their specific work-related activities. This means taking into consideration the person's functional capacity, potential impact of any medical conditions they may have and the nature of the work and working environment.

Fatigue

Fatigue can be caused by many factors, both in and out of the workplace. It is a significant performance-shaping factor that needs to be managed properly. Fatigue can lead to errors, major incidents and accidents, ill-health and injury. It has been identified as a root cause of some major accidents; for example, Texas City and Exxon Valdez.

Risk factors for fatigue may be interrelated and can be cumulative. Petroleum and major hazard facility operators and workers all have a role to play in making sure any risks associated with fatigue are minimised.

Fatigue risk management needs to address:

- working hours – e.g. average weekly hours, shift length and rotation
- work demands – e.g. repetitive work, work with high physical, mental and emotional demands
- extended exposure to environmental conditions – e.g. noise, extreme temperature, vibration
- lifestyle factors – e.g. amount and quality of sleep, recent illness or injury.

In consultation with workers, petroleum and major hazard facility operators must develop control measures to address the risk of fatigue arising from the work and work environment. This should include adequate supervision and competency in managing worker fatigue, procedures for fatigue risk management and provision of information and training about fatigue to workers.

Medical fitness

Operators need to be aware of the physical requirements associated with each of the tasks that workers are required to perform. Understanding the physical requirements of each job allows operators to identify and manage risks associated with the role.

Examples of methods to determine the physical requirements of each job include:

- developing job descriptions for each position, including details of specific functional requirements of physical tasks
- analysing functional requirements of all physical tasks required of workers on site and managing associated hazards in accordance with the hierarchy of control
- conducting functional capacity assessments of individuals prior to employment and at regular intervals to monitor for change
- promoting early reporting of all physical injuries that occur on site and off site so that the workplace can make necessary modifications to job design or environment in order to prevent exacerbation of injuries.

Mental health and wellbeing

In the same way that physical injury or ill-health can impact on somebody's ability to function at work and perform their job safely, compromised mental health can do the same. Approaching the management of mental health at work can be done following similar procedures to those used to manage physical health with provisions for prevention, intervention and recovery.

When it comes to decisions about the management of mental health at work, it is important to consult with the relevant worker and mental health professionals.

Alcohol and other drugs

Being under the influence of alcohol or other drugs can impair a worker's ability to do their job safely, thereby increasing the probability of human error and process safety incidents and occupational injuries.

Key considerations to address the issue of alcohol and drugs in the workplace are:

- developing a policy that clearly details the organisation's expectations about alcohol and drugs in the workplace
- establishing a process to support workers whose alcohol or drug use impinges on workplace policies and procedures
- implementing screening and testing – pre-employment, routine checks, and in specific circumstances to monitor a problem
- developing a process for identifying and addressing drug or alcohol use that contravenes workplace policies and procedures
- educating workers on the effects of alcohol and drugs on safety in the workplace.

Some medications can affect or impair worker performance and safety. It is important to encourage workers to discuss any medications they may be taking with their supervisor in case alternative work arrangements need to be made.

9 Health and safety culture

An organisation's health and safety culture is a subset of the overall organisational or company culture. Organisational culture forms the context in which people judge the appropriateness of their behaviour and influences performance and behaviour at work. It is a reflection of the values, attitudes, perceptions, competencies and behaviours of the people working there. It reflects the organisation's commitment to, and prioritisation of, health and safety, as well as the effectiveness of the organisation's safety management system.

Key elements of a positive health and safety culture are:

- visible leadership commitment and role modelling
- a safety management system and practices for effectively controlling major accident events, incidents and hazards
- a positive attitude towards risk management and compliance with the control processes
- the capacity to learn from accidents, near misses and safety performance indicators for continual improvement.

A positive health and safety culture can be cultivated through the development of a culture that fairly allocates accountability for accidents, incidents and near misses to the workplace's systems, rather than the individual workers involved. Visible leadership commitment and modelling desired behaviours and attitudes is pivotal as workers take their cues from their management and the immediate work environment.

This improves safety performance through encouraging reporting, reflecting on previous incidents and accidents, and incorporating identified solutions into work systems to decrease subsequent accident and incident rates, and risks of serious and/or catastrophic failures.

An organisation's health and safety culture is driven by effective health and safety leadership, health and safety supervision and contractor management.

Leadership drives culture

Everyone contributes to the culture of their workplace, not only by what they say, but also by what they do. Effective leadership and a positive safety culture set the tone for workplace relationships and drive the allocation of resources to support effective implementation of preventative actions and controls.

Key messages that promote a commitment to safety need to be supported by appropriate action, by leaders and managers, to ensure the behaviours underpinned by these messages are valued and become part of the prevailing culture.

Leadership practices which drive safety culture include:

- highly developed hazard and risk awareness
- provision of adequate resources
- clearly defined responsibilities and delegated authority
- accountability for key performance leading indicators for safety
- visible adherence to, promotion and reinforcement of safety critical processes and procedures.

Training and education may be required for leadership, as well as those with management and supervisory responsibilities, to achieve the desired competencies to effectively drive a culture that prioritises safety.

10 Maintenance, inspection and testing

Human performance during maintenance, inspection and testing activities continue to be identified as significant causal factors in major incidents (e.g. Buncefield, Piper Alpha). Petroleum and major hazard facility operators should pay particular attention to enhancing conditions within the system to support desired human performance in maintenance, inspection and testing activities.

As maintenance, inspection and testing requires human labour, its quality – and thus the safety of the plant and pipelines – depends upon the performance of the people who carry out the work. Ensuring the quality of maintenance, inspection and testing activities involves a system which supports human performance.

Human factors in maintenance, inspection and testing activities

When performing maintenance, inspection and testing activities even experienced, highly trained workers can make errors (e.g. returning equipment or systems to service in an unsafe state). Errors are normal, often identifiable and can be managed.

Common maintenance, inspection and testing failures due to human performance include incorrect reassembly, wrong specification of replacement items, omission of a task step, recommissioning errors, safety features left disconnected, instrument set-points incorrectly set and leaving tools inside plant. In most situations, performance-shaping factors contribute to maintenance, inspection and testing errors.

Latent conditions can be introduced through maintenance activities (e.g. a fault into the plant which malfunctions at a later date). These type of conditions can be reduced by performing adequate inspection and testing, and includes independent verification. Independent verification of isolation of plant, equipment and hazardous chemical and energy sources is a safety-critical control and should be included as part of safety-critical tasks, including safety-critical maintenance activities. The bypassing or absence of independent verification is a common contributing factor observed by petroleum safety and major hazard inspectors when reviewing incident reports from petroleum operators and major hazard facility operators.

The incident on the Piper Alpha oil platform in 1988 is a well known example of a catastrophic incident following a maintenance error within the petroleum industry. There are many examples of disasters in other industries where maintenance errors are a causal factor.

To help avoid such incidents, it is essential that organisations establish a maintenance system of work which considers performance-shaping factors to support desired human performance during maintenance, inspection and testing activities.

Considerations to support human performance

Planning

- Provision of adequate resourcing (people, tools, parts, etc.) to make tasks achievable.
- Planning and scheduling maintenance activities to ensure tasks can be performed safely.
- Clear task-specific and role-specific competency requirements.
- Clear task, role and work group supervision requirements.
- Provision of role clarity for all workers involved in maintenance activities.
- Identification of environmental factors that may impede workers or maintenance operations (e.g. temperature extremes, lighting, atmospheric contaminants or oxygen levels).
- Defined contingency plans; for example, if a job looks like it might run overtime or if emerging problems arise along the way.
- Structured change management (how to deal with changes that arise during maintenance activities, changes to maintenance schedules or changes as a result of plant modifications).

Process

- Clear means to identify plant that is to be isolated/maintained.
- Set methods for how equipment will be maintained to specified requirements.
- Defined processes to identify and assess error potential in safety-critical maintenance tasks.
- Independent / second party verification checks at defined hold points in processes/procedures/work instructions to ensure critical actions have been undertaken correctly.
- Provision of clear accept/reject criteria with respect to plant condition prior to being put back into service, or allowed to continue in service.
- Integrated quality assurance into the process to minimise the risk of unrevealed errors.

Communication and consultation

- Provision of all necessary information, including written instructions, permits, diagrams and other paperwork, as well as ensuring labels are clear and up-to-date.
- Provision of reliable and transparent means and opportunities for information to be communicated; particularly so that maintenance crews (and others who might be affected by maintenance) know what and where work has been done. This is especially important at shift handover.
- Involvement of all relevant maintenance personnel in plant and equipment design, job design, task analysis, writing procedures, etc.

Appendix 1 Key concepts

As low as reasonably practicable (ALARP): when providing evidence that the risks are reduced to a level that is ALARP, a fundamental requirement is to demonstrate that the hazard identification and risk assessments carried out have been systematic and detailed as this provides the foundation on which to base the control measure selection. Risks are required to be periodically reviewed to ensure that they still meet the ALARP criteria, and to ascertain whether further or new controls need to be introduced to take into account changes over time. This may include new knowledge about the risk, the availability of new methods and technologies for reducing or eliminating risks, or when reliability of controls is less than initially thought.

Different operating conditions:

- *normal operation:* most operations functioning correctly with no or minor issues
- *abnormal/irregular operation:* significant issues encountered during operations, including emergency response and upset conditions
- *start-ups and shutdowns*: how the operation is managed during start-ups and shutdowns
- *care and maintenance:* the restricted operations during care and maintenance
- *remote control:* the areas of the facility where operations can be managed through remote control.

Environmental conditions: the work environment can impact on a person's health and performance in a number of different ways, including effects that damage health (e.g. heat stress; hypothermia/hyperthermia; noise-induced hearing loss; inhalation of hazardous dusts, chemicals, mists and fumes; hazardous manual tasks; whole body and hand-arm vibration) and effects that reduce the individual's ability to perform a task (e.g. poor lighting, distraction, noise and vibration).

Good work design principles: the most effective design process begins at the earliest opportunity during the conceptual and planning phases. At this early stage, there is the greatest chance of finding ways to design out hazards, incorporate effective risk control measures and design-in efficiencies. Effective design of good work considers the:

- *work:* how work is performed, including the physical, mental and emotional demands of the tasks and activities, the task duration, frequency, and complexity, and the context and systems of work
- *physical working environment:* the plant, equipment, materials and substances used, and the vehicles, buildings, structures that are workplaces
- *workers:* physical, emotional and mental capacities and needs.

Human factors: human factors is an established science based on social science, psychology and engineering. It includes tools, principles and methodologies that aim to understand the human condition and better design work to improve reliability, safety and performance. Human factors is a systems approach with people at the centre of the system.

Human performance: human performance is the human contribution to system performance and refers to how people perform their work.

Mentally healthy workplace: a mentally healthy workplace is one where workers and management collaborate to protect and promote the health, safety and wellbeing of all. Maintaining a mentally healthy workplace involves continually addressing health, safety and wellbeing concerns in, and due to, the work environment. This includes the:

- organisation and design of work
- workplace culture
- physical environment
- facilities provided.

Performance-shaping factors: performance-shaping factors (PSFs) are conditions that 'shape' human performance and contribute to the likelihood of human error occurring. They can have a positive or negative effect on performance. These factors can be categorised as organisation-related, job-related and individual-related. Performance-shaping factors can be latent or long-term conditions that eventually contribute to an incident, or active or short-term conditions that affect performance on the day of the incident.

Personnel: this include all members of the workforce such as permanent and temporary staff, and contractors.

Psychosocial hazards: these are related to the psychological and social conditions of the workplace, rather than just the physical conditions, and can be harmful to the health of workers and compromise their wellbeing. These include stress, fatigue, bullying, violence, aggression, harassment and burnout. Exposure to psychosocial hazards can impact on a person's ability to perform their work safely.

Safety-critical tasks: those activities where people are expected to perform as barriers against the occurrence of a major incident/fatality or to prevent escalation in the event an incident does occur. They include activities required to support or maintain physical and technological barriers.[11]

So far as reasonably practicable (SFARP): the risk assessment must demonstrate that the operator has reduced the risks associated with identified major incidents to meet the acceptance criteria and to a level that is SFARP. This should include a detailed description of the necessary prevention, detection, control and mitigation measures implemented. Operators should include details of their definition of serious harm and risk acceptance criteria. Summaries of the risk assessment studies should also demonstrate that the various major incidents and cumulative risks meet the acceptance criteria and reduced SFARP. This demonstration should include a technical argument as to why, having achieved the risk acceptance criteria, it is not reasonably practicable to implement further control and mitigation measures.

11 *International Association of Oil & Gas Producers (2011). Report 454: Human factors engineering in projects. London: OGP Publications.*

Appendix 2 Case study

Toxic gas release at a processing plant

(Generic toxic gas– examples include hydrogen sulphide, titanium tetrachloride, mercaptan (gas odorant), chlorine, ammonia, sulphur dioxide, carbon monoxide)

The aim of this case study is to show how human factors can contribute to a sequence of events that will lead to an incident.

The processing plant in this case study has a well-established safety management system which contains all the correct structural components. The plant has not, however, considered the role of human performance in preventing initiation, mitigating the impact, preventing escalation and improving recovery efforts of a major incident or event.

Incident description

A toxic gas is stored under pressure at low temperature within a large pressure vessel at a processing plant. The low temperature is used to maintain the substance as a liquid with a low vapour pressure. The site has good engineering controls during normal operations, including multiple sensors to detect leakage, an enclosure around the vessel and a scrubber system.

During the annual shutdown, a scrubber stack gas alarm went off. On investigation, it was identified that the vent valve on top of the pressure vessel was faulty and had a minor leak. A decision was made to proactively address this leak through a change out of the valve during the shutdown.

The plant superintendent prepared a job hazard analysis (JHA) and amended a standard isolation list to change out the faulty valve. The night shift supervisor reviewed the JHA and pre-wrote a permit for the replacement of the valve. They handed over the JHA, isolation list and permit to an incoming day shift supervisor.

The pressure vessel was vented overnight through the scrubber system, reducing the pressure to approximately 50 kPa, with the valve left in the open position at shift handover. The JHA required the pressure to be reduced to atmospheric levels, to limit the loss of the gas during the work. The liquid was not drained from the vessel. This was considered in the JHA and deemed appropriate. It is noted in the JHA that the liquid will slowly warm up and vaporise, releasing more toxic gas, so there is some urgency to completing the task.

Two workers donned self-contained breathing apparatus (SCBA) and commenced removal of the vent valve. The intention was to quickly replace the valve to minimise the release of the gas. To perform the task, the work crew chocked the door to the enclosure open to provide light and ease of access. The scrubber system had been taken off-line for other work associated with the shutdown. The work crew were not aware of this, and it was not considered in the JHA.

When the valve was removed, several hundred litres of toxic gas was released from the vessel.

With the doors open and the scrubber off-line, the gas drifted out of the enclosure and into the adjacent work areas. The gas detectors alarmed, both in and outside of the enclosure, and in the control room. The control room operator noted the alarms and advised the supervisor. The emergency response plan was not activated.

Other workers in the adjacent areas were exposed to the toxic gas and moved away from their work areas to the fence perimeter. These workers had emergency respirators; however, they were not used. One worker used their canister face mask provided for spray painting, believing this would also work for toxic gas.

Several workers were affected by the gas and became ill, requiring oxygen treatment on site. One worker was taken to hospital.

The gas cloud drifted across the site boundary into the neighbouring facilities. These facilities activated their emergency response plan and mustered the site. Several workers on these sites were also impacted by the toxic vapour.

The loss of containment was stopped when the replacement valve was bolted into position. The doors were closed, containing the highly toxic atmosphere to the building where the scrubber system could draw this away for safe treatment. The work crew removed their SCBA and decontaminated.

The control room operator noticed that the gas concentration within the enclosure was not noticeably decreasing. The supervisor donned SCBA and entered the enclosure with another worker. The worker cycled the scrubber suction valve while the supervisor checked for issues.

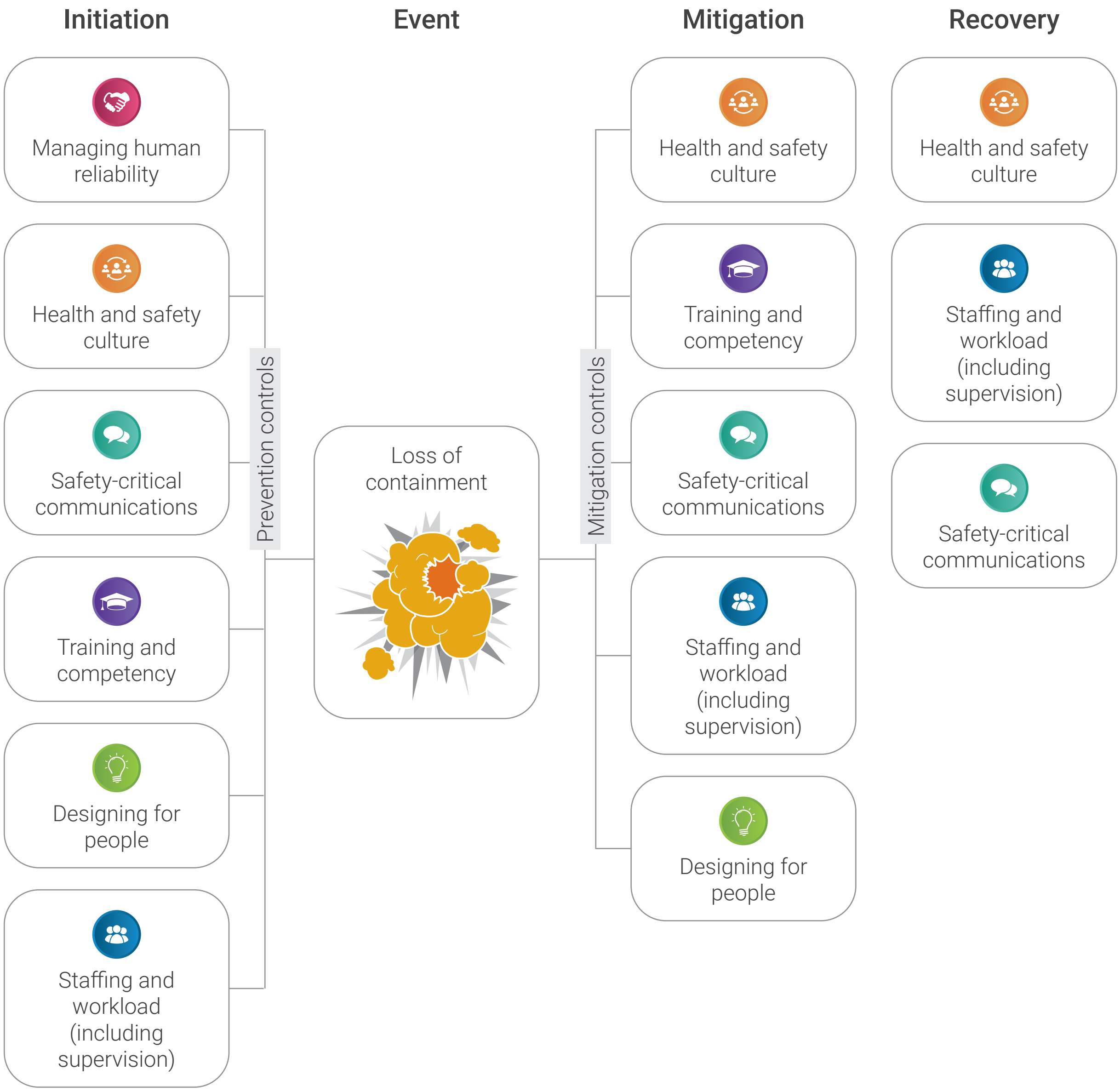
Three hours after the initial release, the emergency response plan was implemented, a command-and-control structure established and the site mustered. Personnel were informed that no entry to the enclosure would be permitted without authorisation of the plant manager.

By the end of the day shift, the storage detectors returned to a zero reading. This was confirmed by portable gas detectors.

The worker taken to hospital was discharged with no ongoing issues.

Findings

Upon investigation, the following human factors, including performance shaping factors, were identified.



Miscalculations and assumptions

The planned task did not receive an appropriate review to determine that it would be safe to undertake the work on a tank containing toxic gas. It was treated as a routine rather than an unusual task.

Management, supervisors and workers were of the view that this type of work had been previously undertaken safely and there was an expectation that a small amount of gas could be released during the replacement of the valve. No review of other ways of undertaking the work was undertaken.

This involved both a knowledge-based mistake and a rule-based mistake. It was not recognised at any level that this was potentially a safety-critical task, particularly given the operating conditions, including that the scrubber system had been taken offline for other work associated with the shutdown.

There was an assumption that, based on previous experience, this was a low risk undertaking and, consequently, there was no risk assessment of the actual task at hand.

Performance-shaping factors: training and competence, supervision, and health and safety culture.

Work was permitted while some residual pressure (50 kPa) remained in the tank despite the JHA calling for the tank to be at atmospheric pressure. There was a knowledge gap and the combination of tank pressure and gas volume was not understood by those preparing or assessing the JHA.

This was a routine violation endorsed by supervisors, involving a deviation from procedures as the normal way of operating to get the job done, along with a knowledge-based mistake about the nature of the hazard.

Performance-shaping factors: training and competence, supervision, and health and safety culture.

JHA and permit-to-work

The site JHA procedure incorporates a systematic team approach to the identification of hazards and determination of a safe work method.

The JHA was prepared in isolation by the plant superintendent and reviewed by two separate shift supervisors, but was not systematically reviewed by team members. One team member undertaking the work was unaware that a JHA had been compiled for the job. The JHA was not signed by any party.

Job roles within the task were poorly defined. Persons undertaking the work were not clear in who was undertaking which tasks. The standby person was actively involved in the work. Task steps were not adequately broken down and there was no verification of controls included as separate steps throughout the JHA.

The permit-to-work and JHA did not identify the scrubber was offline due to other shutdown activities. The permit-to-work was allowed to be worked under without being appropriately authorised by the permit issuer. Permit-to-work procedures are vital to ensuring that hazards are properly identified and controlled. Missing steps out and bypassing independent verification are known contributing factors to process safety incidents.

This involved routine violations where supervisory staff deviated from procedures at a number of key points, including verification, authorisation, communication and consultation. Routine violations are indicators of a poor health and safety culture.

As the tasks steps were not sufficiently detailed, some critical steps were missed and there was confusion about who was supposed to be undertaking which tasks including consideration of the impact of simultaneous maintenance activities. Safety-critical controls and equipment were offline (e.g. scrubber) and were not considered in the JHA and permit-to-work. The standby person was incorrectly involved in the task and no other person took on the role which created a gap in recognising when the emergency response needed to be triggered.

Performance-shaping factors: supervision, safety-critical communications, designing for people, and health and safety culture.

Work environment

Chocking the door to the enclosure open to allow for light allowed the gas cloud to escape the containment room. The inadequate design of lighting led to a work-around. Lighting should be appropriate for the tasks being performed.

The work environment was not designed for optimal human performance which led to a work-around to increase lighting for the tasks being performed. This work-around created an opportunity for the gas cloud to escape the containment room.

Performance-shaping factors: designing for people.

Emergency response and recovery

There were failures in recognising and responding to the seriousness of the event. Communication during the emergency response and recovery phase was poor with no structured team briefings or co-ordinated plan.

The plant superintendent witnessed the gas cloud escape the building. They did not raise the alarm or use the radio to notify others.

Site muster alarms and the emergency response plan (ERP) were not activated during the early stages of the event. Workers did not don respiratory protective equipment.

The plant manager was made aware of the event around 40 minutes after the release when one of the ill workers was brought into the administration building on the way to the first aid room.

No communication was made to neighbouring facilities. Instead, the facilities contacted the plant manager seeking an explanation.

Control of the emergency response and recovery phases was not coordinated and a command and control structure was not established until three hours after the event.

Personnel present onsite were accounted for informally when one of the supervisors walked around the perimeter of the premises, rather than systematically reconciled.

The lack of defined roles resulted in a lack of clarity around who was responsible for triggering the ERP creating a significant delay in initiating the ERP. Furthermore, the failure to recognise the seriousness of the event and respond appropriately occurred at every level. This is an indicator of a poor health and safety culture, lack of situational awareness and lack of competence at the supervisory level.

Workers did not have an appropriate level of risk awareness and did not recognise the seriousness of the event which led to the failure to use respiratory protective equipment. Supervisory staff should be competent in a range of operating conditions, including recognising and responding to an emergency situation. The failure to recognise and respond to the seriousness of the event indicates low hazard risk awareness and situational awareness.

Performance-shaping factors: Safety-critical communication, designing for people, training and competence, staffing and workload (supervision), health and safety culture.

Management of the recovery process to return the storage enclosure to a gas-free state was poorly coordinated, and this resulted in poor communication and poor control of the initial recovery activities, and ultimately a breach of confined space procedure by individuals making decisions in isolation.

The recovery was poorly managed largely due to the accumulation of errors and the breakdown in safety-critical communication resulting in, and from, the failure to trigger the ERP.

Performance-shaping factors: safety-critical communication, health and safety culture, staffing and workload (supervision).

Corrective actions

Contributing HF / PSF	Recommended corrective actions
Managing human reliability	• Conduct a safety critical task analysis to identify tasks vulnerable to human performance and implement controls to reduce the risk to ALARP/SFARP • Conduct independent verification of isolations • Conduct job observations and feedback • Implement interlocks
Health and safety culture	• Demonstrate visible safety leadership • Develop a positive team climate in which team members are comfortable observing and challenging each other • Incorporate job observation and feedback • Conduct internal compliance audits
Design for people	• Provide clear task instructions, including roles and responsibilities • Actively involve workers in designing procedures and rules • Provide appropriate lighting for the tasks being performed
Staffing and workload (including supervision)	• Ensure job hazard analysis are undertaken as prescribed through active supervision and compliance audits • Review supervision resources to ensure an appropriate level of supervision is provided for the tasks being undertaken • Conduct a review of staffing to ensure the number of staff, and skills and experience levels are adequate for maintaining the safe operation of the plant under different operating conditions
Training and competency	• Re-complete training in risk awareness and risk assessments • Provide refresher information to ensure those undertaking the JHA have the required knowledge to assess the risk • Re-complete emergency response training and competency assurance
Safety-critical communications	• Establish communication processes to ensure all affected areas are aware of maintenance operations and simultaneous activities • Establish clear communication processes and delegated lines of authority for emergency situations • Conduct regular internal compliance audits of the permit-to-work system

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