Human factors engineering in projects

Report No. 454
August 2011

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1 Introduction

In simple terms, *human factors* are all those things that enhance or improve human performance in the workplace. As a discipline, human factors is concerned with understanding interactions between people and other elements of complex systems. Human factors applies scientific knowledge and principles as well as lessons learned from previous incidents and operational experience to optimise human wellbeing, overall system performance and reliability. The discipline contributes to the design and evaluation of organisations, tasks, jobs and equipment, environments, products and systems. It focuses on the inherent characteristics, needs, abilities and limitations of people and the development of sustainable and safe working cultures.

Human Factors Engineering (HFE) focuses on the application of human factors knowledge to the design and construction of socio-technical systems. The objective is to ensure systems are designed in a way that optimises the human contribution to production and minimises potential for design-induced risks to health, personal or process safety or environmental performance.

The major oil & gas operating companies recognise that Human Factors Engineering has an important contribution to make to ensure the quality, safety and fitness for purpose of equipment and facilities used in the oil & gas industry (appendix 1 provides examples of problems that can occur when HFE is overlooked in design).

This Recommended Practice (RP) adopts a practical, cost-effective and balanced approach to applying HFE on oil & gas projects. It recognises that many HFE issues can be controlled simply by ensuring compliance with existing technical standards. However, there are times where there is a gap between what can be specified in technical standards and the design features needed to support efficient, reliable and safe human performance.

This RP involves three elements for controlling HFE-related risk:

1. Compliance with relevant technical specifications
2. HFE specific design analysis and design validation
3. Organisation and competence to deliver appropriate standards of HFE quality control.

Compliance with this RP should normally satisfy requirements from national regulators for evidence that HFE has been adequately considered in design. The process allows projects to demonstrate that consideration has been given to reducing the HFE risks and the potential for human error to a level that can be shown to be As Low As Reasonably Practicable (ALARP) through engineering and design.

1.1 Scope

This RP is concerned with human factors issues that can reasonably be expected to be within the scope of CAPital EXpenditure (CAPEX) funded engineering projects, including the design and layout of platforms, process plants and associated piping, equipment and facilities; control rooms (including the Human Machine Interface (HMI) to Distributed Computer Systems (DCS) and other computer systems), as well as buildings (including administration, accommodation, warehouses and workshops).

Human factors issues predominantly under operational control – including manning, shift-work and supervisory arrangements, training, permitting and safety culture – are outside the scope of this RP.

> *Note: ASTM F1337-10 "Standard Practice for Human Systems Integration Program Requirements for Ships and Marine Systems, Equipment, and Facilities" provides guidance on processes and requirements that can be applied to integrate all human-related aspects of systems within a single "Human-Systems Integration" programme.*

1.1.1 Application

The process set out in this RP is intended for application to major projects (nominally defined as those with a capital value in excess of US$50 million), or those with the potential for major accident hazards – process safety, environmental incidents or major loss of life.

The process is scaleable to smaller projects and those that do not have major accident hazard potential. The emphasis is on project complexity rather than capital value. Assessment of project HFE complexity involves consideration of the degree of change or novelty being introduced, criticality (to process or personal safety, environmental control or production) as well as issues associated with the operational context such as geographical location, climatic conditions, and hazards inherent to the operation.

The principal differences are that for smaller and lower risk projects:

- The process can be applied with a lower level of HFE competence
- There would be no requirement to organise an HFE working group
- Smaller projects typically require less design analysis, or study; HFE requirements can usually be met by ensuring compliance with existing technical standards
- Projects without major accident potential do not usually need to identify and analyse safety critical tasks, or to demonstrate that risks of human reliability are ALARP.

This RP provides guidance on how HFE can be customised such that benefits can be realised for small or low complexity projects with levels of time and effort that are realistic in such projects.

1.2 Engineering contractors

Major capital projects in the oil & gas industry are only possible with support from third-party engineering contractors. At one extreme are global companies who – often in partnership or consortia – take on the role of principal engineering contractor, sometimes from Front End Engineering Design (FEED) through to Construction and Commissioning. At the other extreme are the very many consultancies and vendors providing specialist services or equipment across the industry.

An important aim of this RP is to help engineering contractors and suppliers deliver a higher standard of HFE support by providing consistency in terms of:

- Understanding of the scope of HFE and how it relates to other engineering disciplines
- The value that investment in HFE is expected to deliver
- The key activities and expected deliverables
- The competence – in terms of professional training and experience – expected of individuals assigned responsibility for managing, conducting or supporting HFE activities
- The type of organisational arrangements likely to be required within a project team.

1.3 Principles

This RP is based around the following principles:

- It recognises the relative lack of maturity of HFE as a professional discipline in the oil & gas sector. It therefore defines a number of levels of HFE competence balancing the need to allow maximum re-use of the existing skills and experience of the more traditional discipline engineers against the need for HFE professionals.
- It only recommends activities or controls that are not a normal part of oil & gas projects where experience has shown that there is a compelling need to introduce them in order to provide adequate quality control.
- The competence, activities, deliverables and level of verification required are customised to the assessed complexity, in HFE terms, of individual projects.
- Decisions on how to implement HFE on any project is left to the discretion of the project management, provided the project has been assessed for HFE risk by someone with the competence and experience to make an informed judgement.

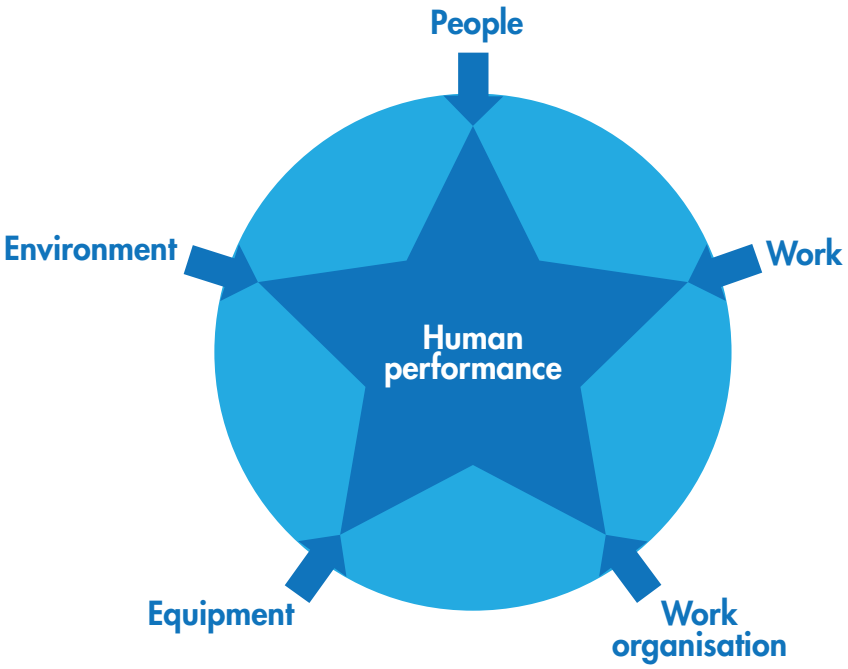
2 Human Factors Engineering

HFE is a "sociotechnical" approach to systems design. It recognises that any complex technological system that involves people is critically dependent on the organisational and social context in which it operates.

The term "ergonomics" is used by many organisations and can be considered synonymous with HFE. OGP, in common with many member companies, has adopted the term *Human Factors Engineering*. *Human Factors Engineering* is broader than the traditional scope of *Ergonomics*.

HFE is a multidisciplinary approach to engineering that focuses on the integration of the five elements illustrated on the Human Factors Engineering 'star' (Figure 1):

Figure 1: The scope of Human Factors Engineering



The five points of the star are:

- *People:* The characteristics, capabilities, expectations, limitations, experiences and needs of the people who will operate, maintain, support and use the facilities.
- *Work:* The nature of the work involved in operating, maintaining and supporting the facility.
- *Work Organisation:* How the people are organised, in terms of, for example, team structures, responsibilities, working hours and shift schedules
- *Equipment:* The equipment and technology used, including the way equipment is laid out, and the elements that people need to interact with, both physically and mentally.
- *Environment:* The work environment in which people are expected to work, including the climate, lighting, noise, vibration and exposure to other health hazards.

A focus on the integration between these five elements is the unique – and often critical – perspective that Human Factors Engineering brings to the development of socio-technical systems.

2.1 Aims and benefits of HFE

HFE is applied to the design of work systems, workplaces and products:

- To reduce risk to health, personal and process safety and the environment
- To eliminate, reduce the likelihood or mitigate the consequences of human error
- To improve human efficiency and productivity, thereby enhancing operational performance
- To improve user acceptance of new facilities.

Benefits of a proper integration of HFE in projects include:

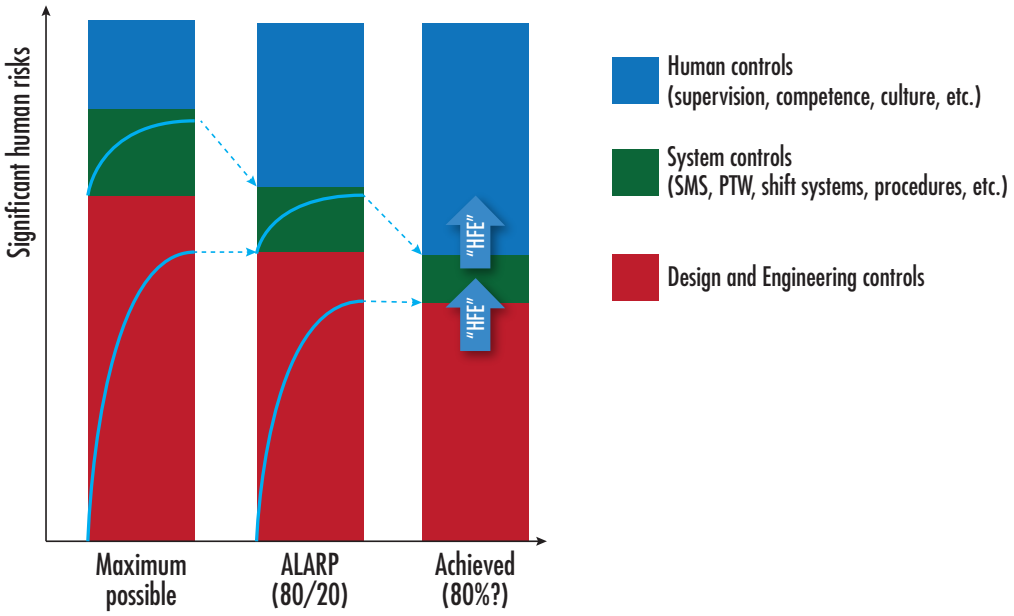
- Reduction in CAPEX by contributing to more efficient design and avoiding the need for expensive changes and/or re-work late in design.
- Reducing the need for re-work or change during or after construction.
- Reduction in life cycle costs of operating and maintaining facilities (OPEX).
- Improvements in HSE performance, and reduced operational HSE risk.
- Enhanced user commitment ('buy in') often resulting in faster approval cycles.

2.2 HFE and Behavioural-Based Safety (BBS)

Situations where human error contributes to major incidents are often a consequence of inappropriate organisational arrangements or breakdowns in operational working practices. Figure 2 illustrates the relationship between HFE and BBS.

To interpret figure 2, assume some total set of potentially significant human-related risks. The left hand axis of the figure indicates the proportion of this set that can be mitigated by design and engineering controls, system controls (*ie* safety management system, permit to work, procedures, *etc*) and human controls (*ie* competent people with good attitude to safety who are fit to work and are properly supervised, *etc* – BBS).

Figure 2: role of HFE in strengthening engineered defences against human-related risks



Assuming a reasonably complex facility:

- *Maximum possible:* even if everything theoretically possible is done, design and engineering controls cannot control all human-related risks. The effectiveness of design and engineering controls in mitigating risk of human failure will depend on many factors and is likely to change over time as facilities age. The gap is made up through a combination of system and human controls.
- *ALARP:* applying the criteria of doing what is "reasonably practical" – rather than what is theoretically possible (and assuming an 80/20 rule of diminishing returns) – the effectiveness of both engineering and system controls are reduced. As a consequence, the reliance on human controls – BBS – is increased.
- *Achieved:* in many cases, as investigation of major incidents repeatedly shows, the risk associated with human factors is not reduced to ALARP through engineering controls. The same argument can be applied to system controls (badly written, inaccessible or impractical procedures, lack of supervision or competence, *etc*). The consequence is that human controls (BBS) are again relied on to fill the increased gap.

Therefore, one way of viewing HFE is as a discipline concerned with ensuring that engineering and system controls against human unreliability are designed, implemented and maintained in a way that reduces the reliance on BBS. Other OGP RPs (see the list of references) address some of the system and human controls.

2.3 HFE and process safety

Projects with major accident hazard potential – including fire and explosion or toxic release with potential for major loss of life or significant environmental impact – must ensure that design features intended to support critical human tasks have been designed and implemented in such a way that the risk of human unreliability is reduced to a level that can be shown to be ALARP.

Critical human tasks are defined as those activities people are expected to perform as barriers against the occurrence of an incident, or to prevent escalation in the event an incident does occur. They include activities required to support or maintain physical and technological barriers.

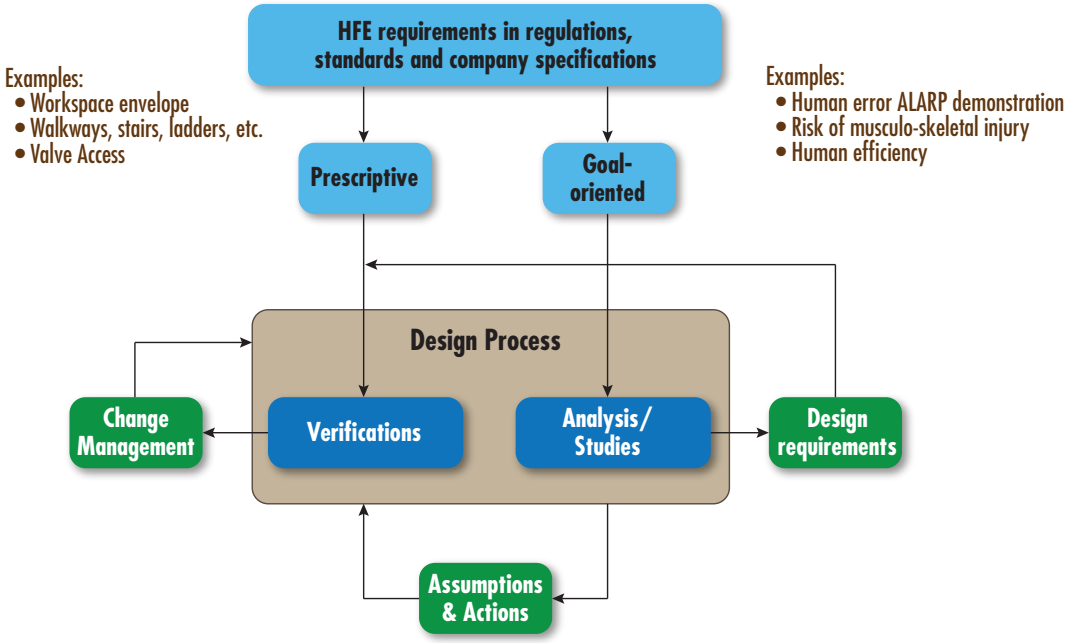
Appendix 2 provides examples of incidents where design features have directly contributed to loss of human reliability.

2.4 Conceptual Model

Figure 3 summarises the conceptual basis of the process for applying HFE on projects.

HFE technical requirements exist in a number of sources, including regulations, international, national and industry standards, as well as company-specific standards and specifications.

Figure 3: conceptual model of HFE in design (amended from NORSOK S-002, 2004)



These requirements are generally of two types:

- *Prescriptive requirements:* specifying distances, sizes, space, weight, *etc* that engineers and designers can directly apply to technical drawings, use in calculations, *etc.* An example would be the specification for clearance for headroom above walkways which can be found in many standards.
- *Goal-oriented requirements:* specify the goal, or objective that is to be achieved but not the specific design parameters to be applied. Examples would be requirements to "reduce the potential for human error to ALARP" or to "provide human machine interface graphics that support span-of-control situation awareness"

  Note: many HFE Standards and specifications also include a third type of requirements – Process requirements – specifying the activities that are expected to be carried out in order to implement HFE on a project (such as task analysis). The actions defined in the HFE strategy (and the recommended HFE activities defined in this RP) are effectively process requirements).

For prescriptive requirements, once an appropriate technical baseline has been agreed, the HFE process during design and development, only needs to ensure that these requirements have been complied with. This is usually achieved via design reviews (reviews of plot plans, 3-D models, control rooms layouts, HMI graphic prototypes, *etc*). As there is very often a need to trade-off HFE requirements against other constraints, a change management process needs to be in place to control derogations from these requirements in the technical baseline.

In the case of goal-oriented requirements however analysis or study is required to turn the goals into specific technical requirements that can be implemented in design. The types of analysis required vary but typically include; task analysis, valve analysis, control room analysis,

etc (see Appendix 7). It will also include any specific studies required due to the particular complexity or risks faced by an individual project. The objective of design analysis is, so far as possible, to develop additional prescriptive requirements.

For projects of any significant complexity or novelty, or where critical human tasks are involved, both prescriptive- and goal-oriented HFE requirements will exist.

In the course of conducting HFE analyses and studies, many assumptions often need to be made and additional actions raised. Failure to properly assess critical assumptions is a common reason for failure to meet HFE expectations.

3 HFE in the project lifecycle

This section sets out recommended organisational arrangements and life-cycle activities for applying HFE on projects.

3.2 Roles and responsibilities

Table 1 defines the roles needed to support the implementation of HFE in projects. Competence and training requirements for each of these roles are defined in Appendix 6.

Supporting roles

In addition to the core roles defined in table 1, more complex projects may require support from an HFE specialist. This is usually an HFE professional, who may be internal to the company or a third party, meeting level 4 or 5 competence requirements (defined in Appendix 6).

The HFE specialist may have no formal project authority but may be a source of professional advice. However, a HFE specialist could perform the role of an HFE authorised person, if acceptable to the company sponsoring the project.

Table 1: recommended HFE roles and responsibilities on projects

Role	From	Description and competence
HFE technical authority	Sponsor company	An individual within the sponsoring company with authority to approve derogations from approved project standards. Should be an HFE Professional with HFE competence at Level 4 or 5 (see Appendix 6). *Note: Small/low complexity projects would not normally require an HFE Technical Authority. The role would be performed by an HFE Authorised Person.*
HFE authorised person (sponsor)	Sponsor company	A person within the sponsor company assigned responsibility to lead HFE activities on behalf of the company and approve deliverables for a project. Normally only required on major projects or those with significant major accident hazard potential. Should have HFE competence of at least Level 3 (see Appendix 6).
HFE authorised person (contractor)	Contractor	A person within the contractor organisation authorised and assigned responsibility to lead HFE activities and quality assure deliverables for a project. Should have HFE competence of at least Level 3 (see Appendix 6).
HFE co-ordinator	Contractor	The individual within the contractor organisation assigned responsibility for management and organisation of the project HFE activities, including coordination with the HFE technical authority, HFE authorised person and/or HFE specialist. Should have competence at least at Level 2 (see Appendix 6). The HFE Co-ordinator could be the HFE Authorised person.

3.3 HFE activities

HFE activities on capital projects can be organised into five stages, as illustrated on figure 4:

Stage 1: HFE Screening

Review the new project for potential HFE risks, issues and opportunities. Identify applicable standards and define the required scope of HFE activity. Develop a strategy and actions to ensure identified risks are adequately controlled.

Stage 2: HFE design analysis

Ensure the technical standards baseline contains adequate coverage of HFE issues and risks. Conduct HFE design analyses to capture and specify additional requirements necessary to support safe and effective performance of critical tasks. Support design within the scope of the Front End Engineering Design (FEED) study.

(FEED) study. Plan for HFE implementation during detailed design. Ensure measures taken to reduce risk of human error to ALARP by design are included in the initial design Safety Case.

Stage 3: HFE design validation

Complete HFE Design analysis, support development of detailed design and design validation. Ensure HFE design quality is not compromised during construction. Ensure the final design safety case reflects work done to reduce risk of human unreliability to ALARP.

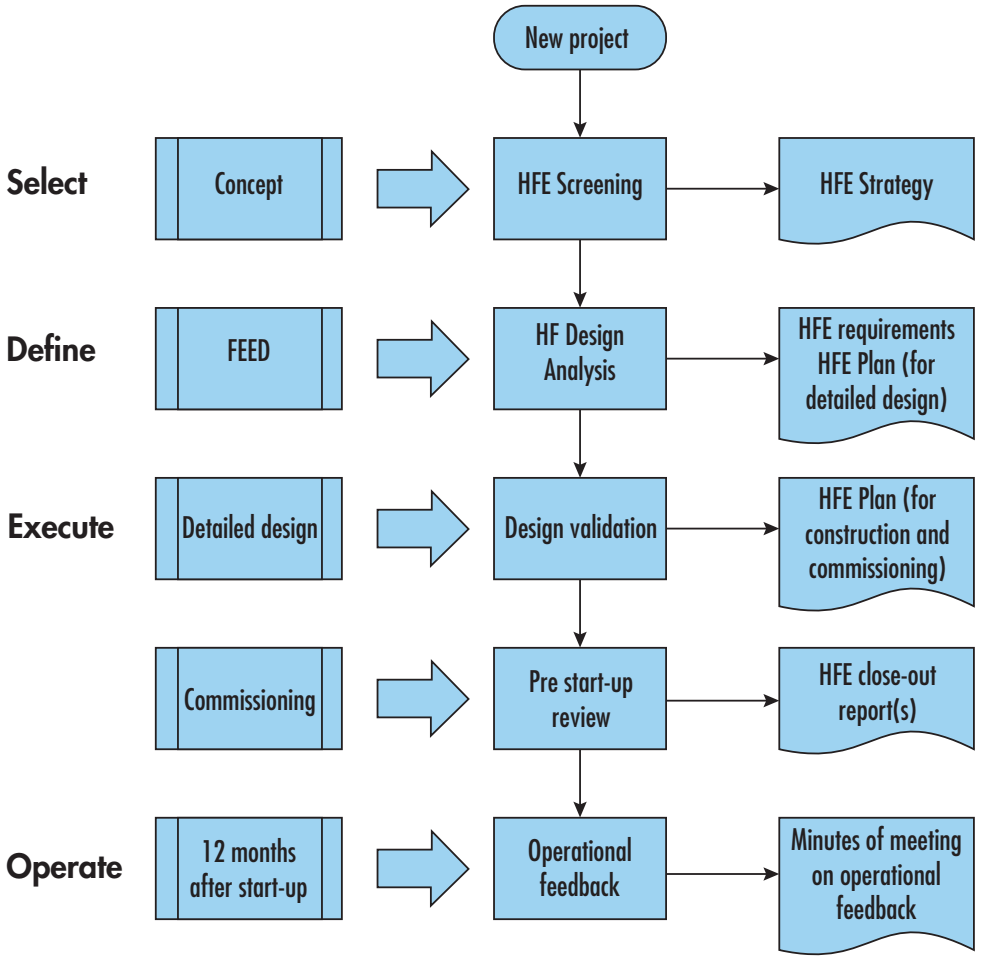
Stage 4: HFE support to start-up

Ensure the HFE programme has been implemented and all agreed actions have been completed. Support Pre-Start-Up Audit or commissioning inspections.

Stage 5: Operational feedback

Within one year of start-up review the success of HFE implementation and feed forward lessons learned.

Figure 4: overview of HFE in the project lifecycle



3.3.1 Stage 1: HFE screening

An HFE screening should be conducted early in the project life-cycle – preferably before initiation of a FEED study. The screening can be conducted in various ways, ranging from a desk-top review by an HFE specialist, to a structured workshop using recognised screening procedures.

The method used depends on the complexity of the project. Assessment of HFE complexity should be made by the project manager with input from operations and other key stakeholders taking account of considerations including:

- the degree of change or novelty being introduced, including the use of automation
- the criticality of the facilities to be developed (to process or personal safety, environmental control, or production)
- the operational context such as geographical location, climatic conditions, and hazards inherent to the operation.

The HFE screening should be facilitated by an individual with an HFE competence appropriate to the assessed level of complexity of the project: screening of major projects typically needs to be led by an HFE professional (with competence at Level 4 or 5 as defined in Appendix 6).

Appendix 3 provides an example of a tool that can be used to screen projects where the basic process units and equipment types are known.

The output of the HFE Screening will be either:

- A minuted record, included in the project file and approved by the Project Manager, that there is no value to be added by applying HFE to the project

  OR

- An HFE Strategy for the project.

HFE strategy

Where a project HFE strategy is required, it should:

- Summarise the key HFE risks, issues and opportunities identified in the screening.
- Identify the key actions and activities required in the current and subsequent phases of the project.
- Identify the HFE-specific standards or technical guidance to be included in the project technical baseline (the standards section lists a number of HFE technical standards commonly used by OGP members).
- For very large or particularly complex projects or projects with unusual operating conditions or unusual local regulations, the strategy should identify whether there is a need to customise existing standards
- Define the organisational arrangements necessary to ensure management of the risks.
- Identify competence requirements, including requirements for HFE awareness and other training required in the current and future project team,

The project HFE strategy for projects with major accident hazard potential shall include the following activities (described in Appendix 7):

- safety critical task inventory
- critical task analysis
- human error ALARP demonstration
- pre-commissioning human reliability review

For moderate and complex projects, and those with major accident hazard potential, the HFE strategy should be approved by the project HFE technical authority. For simple or low risk projects, the strategy can be approved by an HFE authorised person.

The HFE Strategy should be developed in two versions:

- The initial version should be produced by the sponsor company and included in the basis of design, project execution plan, project schedule, HSE plan or other relevant project document. This version should identify the key issues and risks, technical standards baseline, expected organisational arrangements, including competence and training, and the key activities to be performed during FEED.
- As soon as possible after a contract is placed with the engineering contractor, the strategy should be updated to a final version, taking account of the experience and capability within the contract organisation, the contractor's in-house standards & work processes and the project team structure. It should also take account of the geographical organisation of the project team and identify mechanisms to ensure a consistent approach to HFE if the team is distributed across multiple project offices.

HFE strategy and project complexity

For projects assessed as being low HFE complexity, the project HFE strategy will typically be based on ensuring compliance with existing technical standards and specifications and on

activities conducted by other disciplines (layout, piping, mechanical, C&I, *etc*). Specialist input can be of value in ensuring appropriate technical standards are specified and complied with.

Moderately complex projects might reach a sufficient level of HFE control through HFE design reviews or ensuring input from an HFE specialist to activities such as manual handling studies, HAZard and OPerability (HAZOP) studies or model reviews. Some simple HFE analyses – particularly valve categorisation, and vendor package screening (see Appendix 5) – often add value. Analysis to capture HFE requirements for control room and/or human machine interface design may be required.

Complex projects require a more detailed programme of HFE design analyses and validation. This usually includes some form of task analysis to capture design requirements to support novel, complex or critical tasks and operations. Because of the cross-disciplinary and cross-stakeholder nature of HFE, complex projects require a project HFE working group to co-ordinate and manage the HFE effort across stakeholders.

HFE working group

Complex projects should organise a Human Factors Engineering Working Group (HFEWG). The HFEWG provides a minuted forum – reporting to project management and with involvement from affected disciplines – to both oversee and manage the HFE work programme and to ensure effective integration and coordination of HFE with other project activities.

Organisational arrangements including attendance and reporting should be tailored to suit the logistics, contractual arrangements, needs and resources of the individual project.

Key elements of a successful HFEWG include:

- During FEED, the HFEWG should be chaired by a representative of the sponsoring company who is also part of the project management team. This may be the company HSE manager, engineering manager, project integrator or their delegate. If the FEED study is contracted to a 3rd party, then the organisation, management and secretarial support for the HFEWG should be included in the FEED contractors work scope.
- A strong HFE co-ordinator with a good understanding of the objectives of HFE and experience of capital projects, including working with contractors and vendors. For major projects, the HFE Co-ordinator should ideally have a background in operations, including significant time in a leadership role.
- The HFEWG should have permanent representation from company operations, maintenance and other disciplines depending on the scale and complexity of the project.
- During Execute/Detailed design phase, responsibility for organising and chairing the HFEWG should be included in the EPC contractors' work scope. The team may be expanded to include representation from the construction and commissioning teams as well as the construction contractor.
- The HFEWG should meet at a frequency appropriate to the pace of project activities and decision-making.
- HFEWG meetings should be minuted and the minutes distributed to relevant parties. Actions arising from should be tracked in the overall project actions register.
- The HFEWG should maintain and regularly review a register of issues and risks associated with the HFE programme, including important assumptions. Key risks should be integrated with the overall project risk register.

Appendix 4 contains typical terms of reference for an HFEWG for a major project. Appendix 5 contains an example of a generic role description for an HFE co-ordinator.

3.3.2 Stage 2: HFE design analysis (DEFINE)

Stage 2 involves five steps:

1. Review of standards
2. HFE design analysis
3. HFE validation
4. Implementation plan
5. HFE design close out

Review of standards

The standards specified for the project (regulatory, industry and company) shall be reviewed to ensure they support the HFE strategy. The review shall ensure the standards are appropriate for:

- The scope of work identified in the HFE strategy (workplace layout, valve accessibility, lighting, control room, HMI, *etc*).
- The anthropometric, biomechanical and cultural characteristics of the expected workforce.
- The legal context of the country or region where the asset is located. This includes determining whether there is any legal requirement to include human factors content within the safety case or other safety demonstration required by law in the target country.
- The interests of the project stakeholders (in the case of a joint venture project).
- Local business unit requirements and procedures

Conflicts between company and local regulatory requirements must be identified and resolved.

HFE design analysis (FEED)

Appendix 7 provides a summary of typical HFE design analysis activities. Activities often conducted during FEED include:

- Working Environment Health Risk Assessment (WEHRA)
- Valve Criticality Analysis (VCA)
- vendor oackage screening
- Task Requirements Analysis (TRA)
- HFE functional analysis for facilities, accommodation, buildings, *etc*.

For projects involving significant change or new design of control room and/or human machine interfaces to IT systems, HFE analysis during FEED phase can include:

- HMI requirements analysis
- control room requirements analysis
- control systems and alarm management

For projects involving major accident hazard potential, the HFE programme should include:

- safety critical task inventory
- critical task analysis (if required)
- human error ALARP demonstration.

HFE validation

Ensuring that HFE requirements have been satisfied in detailed design, layout and construction is central to achieving the HFE objectives. HFE validation activities conducted during FEED may include:

- Formal and informal design reviews focusing on specific HFE requirements and issues arising from the HFE design analysis. These can include checking for compliance with specified technical standards.
- Supporting the review or inspection of equipment and packages to be procured from vendors.
- Providing HFE support to drawing and 3D model reviews.
- Supporting reviews of conceptual layouts, including plot plans, buildings, workplaces, control rooms and operator consoles
- Ensuring HFE requirements are included in relevant specifications, including ITTs and bid packages.

A formal process should be adopted and followed to record, request and approve HFE deviations during design validation.

HFE plan

If required, an HFE Plan (HFEP) shall be produced, specifying the HFE activities to be conducted during the *execute* phase and the roles, responsibilities and lines of reporting, including those of the EPC contractor and vendors that need to be in place.

The HFEP should define whether the HFEWG will continue to meet and whether additional HFE design analysis and/or HFE validation activities need to be conducted during the *execute* phase.

The HFEP should be included in the ITT package or project schedule for the *execute* phase.

HFE close-out of DEFINE

An HFE close-out meeting shall be held at the end of FEED. The objectives of the meeting are:

- to ensure all HFE Actions raised either have been completed or closed, or are included in the HFE Plan for the *execute* phase
- to review key HFE issues and risks and ensure plans are in place to mitigate them
- to ensure the proposed implementation of the HFEWG in the *execute* phase captures lessons to improve the efficiency and impact of the working group.

3.3.3 Stage 3: HFE validation ('execute')

Stage 3 involves three steps:

1. HFE design analysis (complete)
2. HFE design validation
3. HFE plan for construction

HFE design analysis ('complete')

The aim should be to complete the majority of the HFE design analysis during the FEED process. However, for complex projects the analysis may have to continue into the detailed design stage.

Additional HFE design analysis may need to be performed in the *execute* phase to ensure critical tasks are adequately supported in design. This is most likely to involve further analysis of critical operations or maintenance tasks not covered in sufficient detail in FEED.

Further HFE design analysis may be needed if either the control room or HMI to the process control system are complex or novel.

HFE design validation

For projects assessed as moderate and high complexity, HFE should be represented at relevant design and 3D model reviews during the *execute* phase. The aim is to ensure compliance with workplace design and specified standards. It should also ensure requirements identified through HFE design analysis have been met.

For projects with major accident hazard potential, critical human tasks should be reviewed to ensure the design has incorporated features identified as being necessary to reduce risk of human error to ALARP.

HFE plan for construction

An HFE plan for construction should be developed.

The purpose of the HFE construction plan is to guide the construction contractor with respect to installing equipment not usually shown in 3D CAD models. This concerns mainly 'field run' installed equipment (small bore piping, instrument cabling, secondary cable trays. *etc*). The aim is to ensure that the HFE design intent is assured throughout the construction phase and is not compromised by the location of fieldrun items.

It may be necessary to insert relevant requirements into the installation contractors' work scope, and to monitor and verify that these have been met. This can be achieved by:

- Ensuring adequate HFE competence within the construction contractor.
- Onsite HFE awareness sessions. These should be attended by all relevant disciplines (*eg* inspectors, structural, electrical, instrumentation).
- Execution of HFE/operations & maintenance worksite inspections during construction and commissioning.
- Implementing a procedure which advises the contractor how to deal with construction site changes with potential risk to HFE design intent.

A formal process should be adopted to record, request and approve HFE deviations during construction and commissioning.

3.3.4 Stage 4: support to start-up

There are two steps involved in this stage:

1. HFE support for pre start-up audits
2. HFE close-out review

HFE support for pre start-up audits

For projects where high risks associated with HFE are identified, an HFE authorised person should be included in pre start-up audits and inspections.

HFE close-out review

An HFE close-out review(s) should be held in the presence of all relevant stakeholders covering two main items:

1. *Confirmation that there are no outstanding HFE issues which need to be resolved prior to start-up:*
   - *Actions:* have all actions raised in the HFEWG, or elsewhere in the HFE programme been completed or closed?
   - *Results:* did the results of the pre start-up audit and other pre-commissioning inspections indicate that HFE standards and requirements had been complied during design and construction?
   - *Remaining risks:* are there significant risks to health, personal or process safety that have not been reduced to an acceptable level and that may require additional organisational controls? Are there issues associated with operations or maintenance of the facility that have not achieved the expected standard?
   - *Safety Case:* does the design safety case include demonstration of the efforts taken to reduce risk of human error to ALARP through engineering and design?
2. *Identification of lessons learned to improve the application of HFE in future projects*
   - *Initiation:* was HFE initiated at an appropriate time to have effective input to defining the project standards and technical baseline?
   - *Competence:* did the project have access to adequate resource in terms of HFE competent people, and were steps taken to ensure awareness among discipline engineers and contractors, including construction contractors?
   - *Implementation:* did the project effectively implement the agreed HFE strategy for FEED and the HFE plan? If an HFEWG was organised, did it operate effectively? Were technical HFE deviations/variances approved by the appropriate HFE technical authority?
   - *Value:* has implementation of HFE on the project added sufficient value to justify the costs and resources applied?
   - *Process understanding:* are there any issues arising or anything to learn from the project experience that should be fed back to the sponsoring company to improve the HFE process or standards?

The HFE close-out review should be approved by the project HFE technical authority or authorised person (company).

3.3.5 Stage 5: operational feedback

No more than one year after start-up, a meeting should be organised to review:

- the level of operability and maintainability achieved
- HFE issues identified over the operational period, changes made and proposed modifications for HFE
- incidents, near misses and other operational difficulties considered to have an HFE aspect
- lessons to be fed back to the sponsoring company and contractor
- identification of HFE value and, if possible, in comparison with similar projects at a similar stage of operation.

3.4 Resourcing

Table 2 illustrates the level of HFE resourcing (in terms of full time equivalent people) that may be required to implement HFE during FEED and detailed design stages of projects. The table is based on recent experience from a range of projects conducted by a number of OGP members.

3.5 Decision gates

Most operating companies include formal 'decision gates' within their project lifecycles. These are fixed points where senior management review progress and decide whether to commit further capital to the project.

The key HFE input to decision gates should be:

1. At the end of the SELECT phase, *ie* before entering the FEED study, where there should be an HFE strategy.
2. During pre-start-up phase when the HFE close-out review confirms that there are no significant outstanding HFE issues which need to be resolved prior to start-up.

Both of these controls should be approved by the project HFE technical authority or HFE authorised person (see Table 3).

3.6 Deliverables and quality assurance

The deliverables resulting from implementation of HFE on projects, as well as the level of quality control required, depends on the scale and complexity of the project. Deliverables and quality assurance requirements should be identified in the HFE strategy developed during FEED.

Table 3 summarises the deliverables that can be normally be expected, and indicates which of the identified HFE project roles (see Table 1) should be responsible for assuring their quality.

These deliverables, as well as records of quality assurance, can be incorporated into contracts to track and monitor HFE progress.

Table 2: Examples from recent OGP member projects of Full-Time Equivalent (FTE) HFE effort

Project description	Technical authority	HFE authorised person (sponsor)	HFE authorised person (contractor)	HFE co-ordinator	HFE specialist
"Elephant" project, USD multi-billion CAPEX. Significant technical novelty and complexity, extreme environmental conditions, significant major accident potential, extreme toxicity in field. Modular construction requiring transportation to asset site.	0.2		1	0.2	1
Major offshore project with significant space and weight constraints. Significant drive to minimise manual intervention for operations or maintenance.	0.2		1	0.2	1
Major expansion of existing onshore facility with history of significant problems of poor access for operations and maintenance. Severe winter conditions.	0.1	0.5	1	0.2	
As above. National regulator requires explicit Human Factors ALARP demonstration in design safety case.	0.1	0.5	0.5	0.2	0.5
Addition of new field to existing FPSO. Field characteristics similar to existing field. FPSO has spare capacity – original design allowed for future expansion. New facilities largely copies of existing, with additional instrumentation, F&G and DCS.	0.1		0.25	0.1	0.2
Modification of depleted gas field for CCS, including multi-phase transportation overland, compression and injection. CCS facilities to be added to existing offshore production platform. High reliance on control room operator for monitoring well behaviour.	0.05		0.2		0.1
New-built, spread-moored FPSO (including hull, living quarters and topsides), and subsea production, water injection and gas injection systems, and a moored offloading buoy.	0.2		1		1
New-built onshore gas processing facilities including a three train LNG plant, condensate handling facilities, carbon dioxide injection facilities and associated utilities.	0.1	0.2	1	0.5	1
New-built LNG Project, the onshore facility comprises multiple LNG trains, a Domestic Gas Plant associated with each LNG train, together with associated utilities and a marine terminal for export of LNG. Condensate handling, storage and export are also included in the scope of the project.	0.1	0.2	1	0.5	1
A new-built dry tree floating drilling and production facility (Extended Tension Leg Platform), with topside oil & gas processing facilities including inlet separation; gas dehydration; flash gas, booster and export gas compression; oil treatment and export pumping; produced water treatment; and utility systems.	0.2		0.5		0.75

Table 3: Summary of recommended HFE Deliverables (See Table 1 for definition of QA roles)

Stage	Deliverables	Used in Gate Review?	Quality sssurance			Notes
			Simple	Moderate	Complex	
SELECT	HFE strategy (company)	Yes	Authorised person (company)	Technical authority		
DEFINE/FEED	HFE strategy (contractor)	No	Authorised person (company)	Technical authority		
	HF WG minutes	No	HFE co-ordinator			
	HFE design analysis summary report	No	Authorised person (contractor)	Authorised person (company)		Results incorporated directly into project specifications, etc, where possible. Single report summarising HFE analyses.
	HFE design analysis reports	No	Authorised person (contractor)	Authorised person (company)		If stand-alone HFE analysis reports are required.
	HFE plan	No	Authorised person (contractor)	Authorised person (company)		
EXECUTE/Detailed design	HF WG minutes	No	HFE co-ordinator			
	HFE design analysis summary report	No	Authorised person (contractor)	Authorised person (company)		As for FEED
	HFE design analysis reports	No	Authorised person (contractor)	Authorised person (company)		As for FEED
	HFE plan for construction	No	Authorised person (contractor)	Authorised Person (Company)		
	HFE close-Out report	Yes	Authorised person (company)	Technical authority		
OPERATE	Operational feedback report	No	No formal QA required			

3.6 Management of change

Changes introduced late in the design process need to be assessed to ensure that they do not violate important HFE design intent or introduce significant new HFE issues. The mechanism for managing change should be via the HFEWG and the HFE technical authority or authorised person, as appropriate.

Acronyms

Acronym	Meaning
ALARP	As Low As Reasonably Practicable
AOCB	Any Other Competent Business
BA	Breathing Air
BBS	Behavioural-Based Safety
BoD	Basis of Design
BU	Business Unit
C&I	Control & Instrumentation
CAD	Computer-Aided Design
CAPEX	CAPital EXpenditure
CCS	Carbon Capture and Storage
CCTV	Close Circuit TeleVision
CPU	Central Processing Unit
CRT	Cathode Ray Tube
CTA	Critical Task Analysis
DCS	Distributed Computer System
EPC	Engineering and Procurement Contractor
FEED	Front End Engineering and Design
FPSO	Floating Production Storage and Offloading Vessel
FTE	Full-Time Equivalent
HAZOP	HAZard and OPerability
HFE	Human Factors Engineering
HFEP	HFE Plan
HFEWG	HFE Working Group

Acronym	Meaning
HMI	Human Machine Interface or Interaction (depends on context)
HSE	Health, Safety, Security, Environment
IT	Information Technology
ITT	Invitation to Tender
LNG	Liquefied Natural Gas
O&G	Oil & Gas
OGP	The International Association of Oil & Gas Producers
OPEX	OPerational EXpenditure
PPE	Personal Protective Equipment
P&ID	Process & Instrumentation Diagram
PFS	Process Flow Scheme
PSV	Pressure Safety Valve
PVC	PolyVinyl Chloride
QA	Quality Assurance
RP	Recommended Practice
SADIE	Safety Alert Database and Information Exchange
SMS	Safety Management System
TRA	Task Requirements Analysis
USD	United States Dollars
VCA	Valve Criticality Analysis
WEHRA	Work Environment Health Risk Assessment

References & standards

International standards

- *Human-centred design processes for interactive systems*, ISO 13407
- *Ergonomics principles in the design of work systems*, ISO 6385
- *Ergonomic Design of Control Centres*, ISO 11064

National standards

- NORSOK
- S-002 Working Environment
- S-005 Working Environment Analysis and Documentation
- *Safety of machinery —Ergonomic design principles – Part 1 Terminology and general principles*, BS EN614-1:2006
- *Safety of machinery —Ergonomic design principles – Part 2: Interactions between the design of machinery and work tasks*, BS EN 614-2:2000

Industry standards

- *Guidance notes on the application of ergonomics to marine systems*, ABS Publication 86
- *Standard practice for human engineering design for marine systems, equipment and facilities*, ASTM F1166
- *Standard Practice for Human Systems Integration Program Requirements for Ships and Marine Systems, Equipment, and Facilities*, ASTM F1337-10
- *Recommended Practice for Development of a Safety and Environmental Management Program for Offshore Operations and Facilities*, API RP 75
- *US Department of Energy – Human Factors/Ergonomics Handbook for design for ease of maintenance Parts 1, 2 & 3*, DOEHDBK11402001

OGP/IPIECA publications

Managing fatigue in the workplace – a guide for oil & gas industry supervisors and occupational health practitioners, OGP Report № 392

Managing workplace stress – a guide for oil & gas industry managers and supervisors, OGP Report № 378

A guide to selecting appropriate tools to improve HSE culture, OGP Report № 435

Lifting & hoisting safety recommended practice, OGP Report № 376

A Roadmap to Health Risk Assessment in the oil & gas industry, Parts I and II, OGP Report № 384

A Guide to Health Impact Assessments in the opil & gas Industry, OGP Report № 380

Other publications

- Hollnagel, E. (1998) *Cognitive Reliabilty and Error Analysis Method*, Elsevier
- Reason, J.T. (1990) *Human Error*, Cambridge University Press
- Reason, J.T. (1997) *Managing the risks of Organisational Accidents*, Ashgate.
- Woods, D., *et al* (2010) *Behind Human Error*. 2nd Edition, Ashgate

Appendix 1 — Examples of issues arising from lack of HFE design control

Dangerous railings

Description

This sharp edge is extremely dangerous to everyone using this access way with potential for serious injury. This walkway is an escape route, so people could be moving fast without paying attention to hazards such as this.

Note also that the lower railing juts out further than the hand rail.

Valve access

Description

The operator has to stand on piping in order to operate most of the valves in this image. This is dangerous because the operator can slip and fall. Proper and safe access must be provided to operate valves and valves must only be operated from the normal standing surface of permanent access platform surface. Temporary access such as scaffolding may also be provided under certain circumstances typically determined by a valve criticality analysis.

Obstructed walkway

Description

These three pipes run directly over a walkway. The operator has to stand on top of the pipes in order to cross them. The pipes are often slippery, and the area is poorly lit at night. There is significant potential for serious injury, as well as damage to the piping.

A difficult oil trap

Description

The design of this oil trap makes the operator's job unnecessarily difficult and raises a number of health and safety issues.

Operators are expected to routinely visually inspect the state of the trap. The area around the oil trap is poorly lit. At night, operators have a very difficult time seeing the trap contents. They climb down so they can get close and use torches to try to see. The working area around the trap does not have railings, creating the risk of an operator falling into the trap.

There is also a real threat of environmental release if operators fail to detect an increase in oil level.

Poorly planned access routes

Description

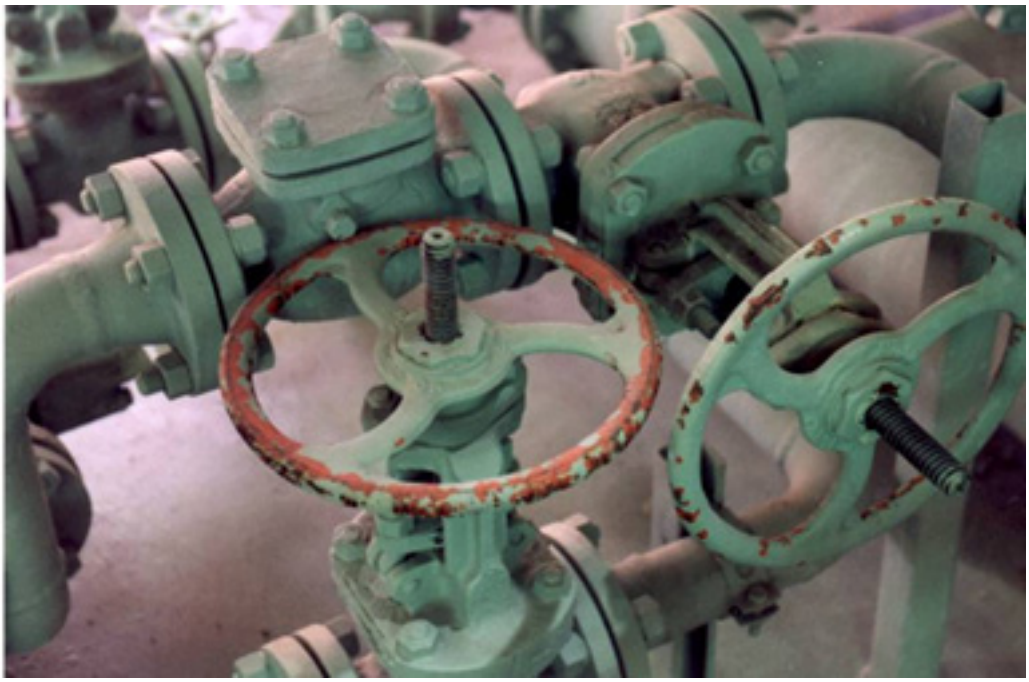
Operators are expected to routinely take samples at this tank farm. To access one of the sample points, they drive to the site and use the steps provided to cross the red and green pipes (right hand side of the picture). They are then expected to walk towards the camera, over a bridge, and then back to the sample point. This is some distance.

In practice, in order to avoid the long walk, operators routinely slide down the concrete banking and climb over the piping to access the sample point. This is a dangerous practice as the decline is very steep, slippery when wet and the area is badly lit.

Spacing congestion

Description

Design arranged to minimize shipping dimensions leading to spacing congestion and poor accessibility.



Accessibility

Description

Difficult accessibility to safety critical and frequently used equipment. Encourages potentially dangerous behaviour (standing on possibly slippery pipes, at height) and increases potential for human error.

Failure to design for local workforce

Description

Global standardised design, based on US civilian anthropometrics. Not suitable for size of local (Japanese) work force.

Reach to controls

Description

This picture shows pipes routed in front of the control panel. The operator has to reach between the pipes to access the controls located on this control panel and this may easily result in human error due to the limited visibility of the controls and associated labels.

HFE standards typically provide design requirements for easy and safe access to controls and displays mounted on flat, vertical surfaces for standing operators. A minimum clear operating space depth of 30 inches (762mm) in front of control panels containing controls and displays is normally required. The HFE required height range above the normal standing surface of controls (*eg* pushbuttons) is from 30 inches to a maximum of 76 inches (762mm to 1930mm). The HFE required height range above the normal standing surface for displays (*eg* gauges) is from 41 inches to 70 inches (1041mm to 1778mm).

It is important to ensure during drawing reviews and three-dimensional (3D) model reviews that there is a minimum of 30 inches (762mm) of clear and unobstructed access in front of all control panels and all door openings. It is also the ideal opportunity to ensure that all controls and displays are located within the HFE height range above the normal standing surface. By complying with the HFE design requirements for control and display location will ensure safe and easy access and minimise human error.

Safety gate problems

Description

Swing gates do not work on small access platforms. A self-closing drop bar should have been used on this small access platform. The operator can barely get on or off this access platform because the safety swing gate radius is blocking safe access.

Obstructed maintenance access

Description

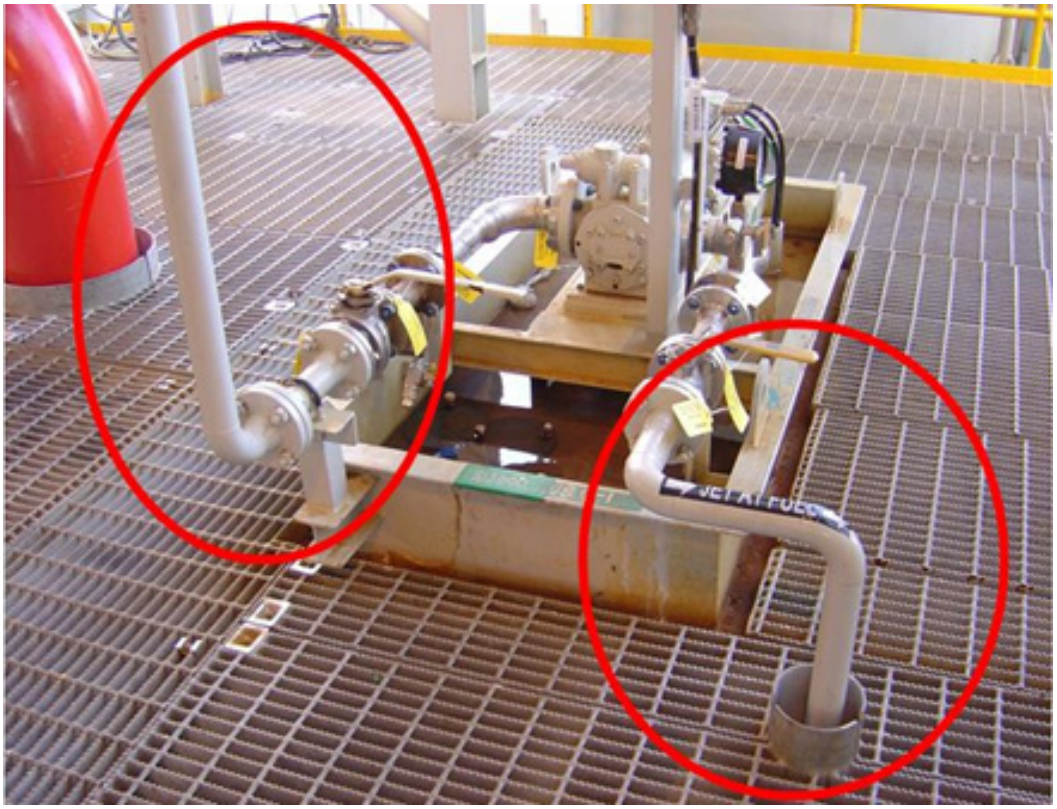
This motor is located in a position where a structural member is blocking maintenance and the removal and replacement of the motor. Equipment vendors should be made aware of the importance of making sure that all equipment must be clear of any obstructions for easy and safe maintenance.

Pump skid design

Description

The vertically routed pipe should have been designed to be located within the skid boundary limits. The skid isolation valve should have been orientated in the vertical orientation (after the horizontal pipe support) and then the connecting pipe would have been within the skid boundary.

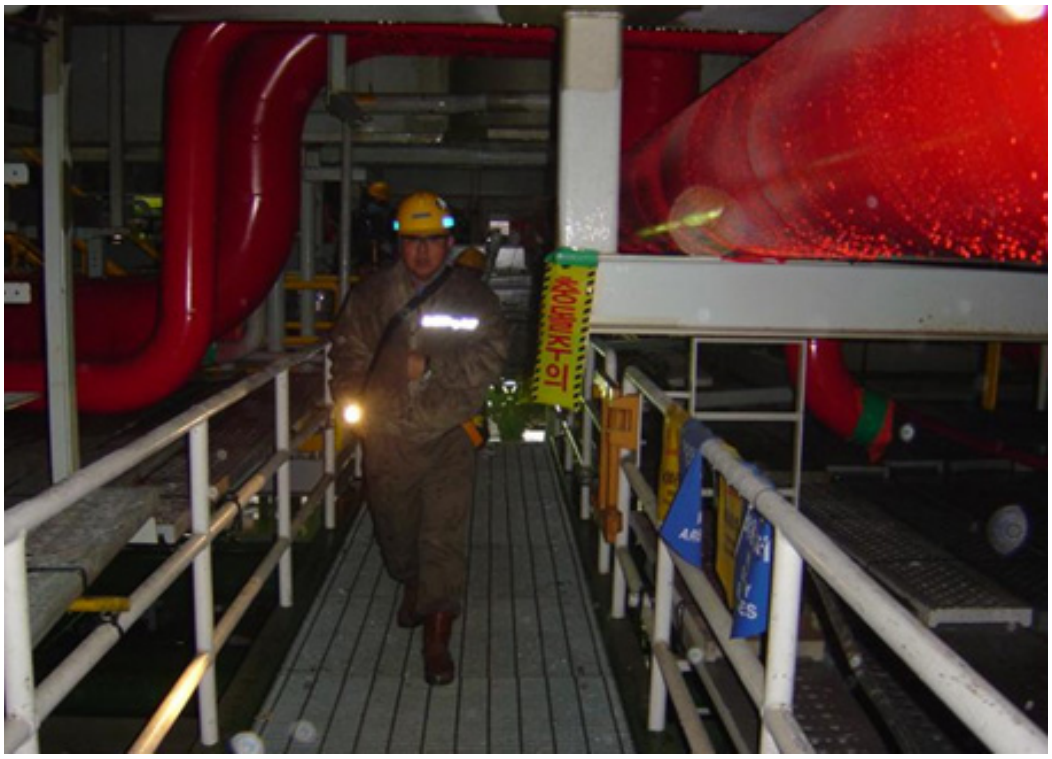
The pipe on the right hand side of the picture is a potential tripping hazard and should have been elbowed down within the skid limit, through the pipe sleeve. This would allow a clean, clear and non-obstructed walkway around the skid.



Egress route obstruction

Description

This pipe support is located right in the Emergency Egress Route path. During 3-D model reviews it should be ensured that egress route "exclusion volumes" are reserved and then it should be ensured that nothing protrudes into these "exclusion volumes" as the design progresses.



Control room design

Description

The first image below shows a control room where typical office desks were provided for the operator workstations resulting in inadequate desktop space for the displays and equipment and inadequate work space. Printers and CPUs were located under the worksurface resulting in inadequate legroom.

The bottom image shows the same control room after the desks were replaced with ergonomic operator consoles and the CRTs were replaced with flat panel displays. The CPUs were placed inside the consoles and adequate legroom is now provided. Printers were relocated in the back of the room.

Human/machine interface design

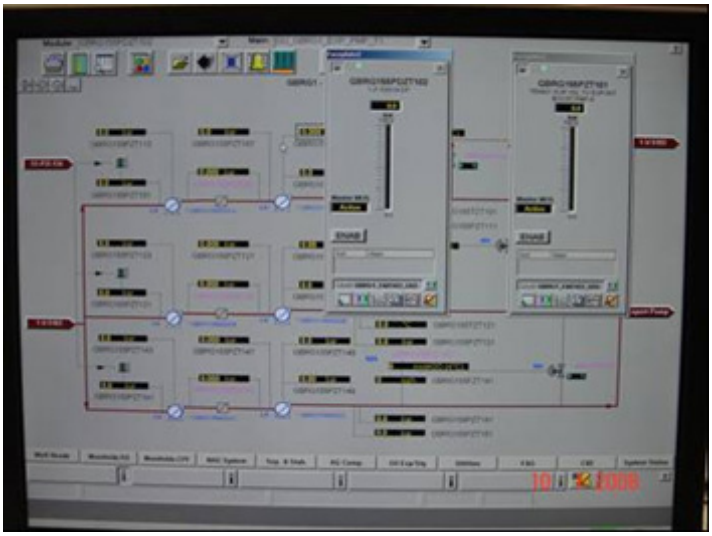
Description

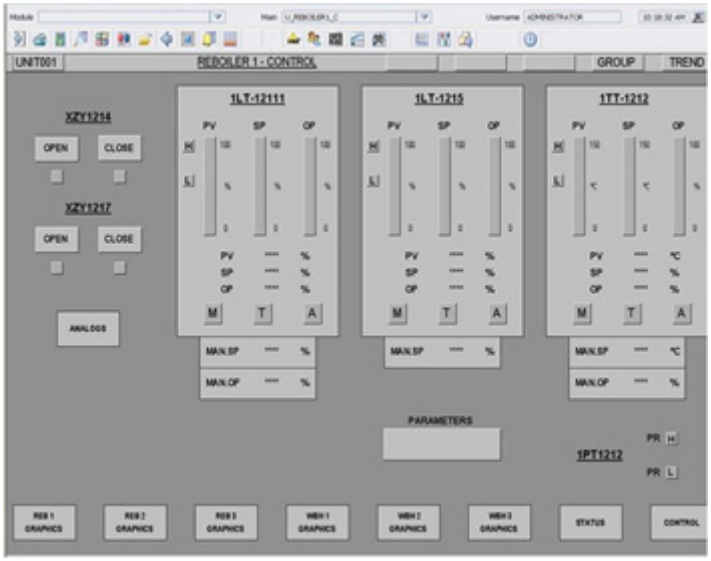
Human interaction with information displayed on graphical displays has repeatedly been identified as an issue in major process incidents. Examples include Three Mile Island, Milford Haven, Texas City and Deepwater Horizon.

The two examples illustrate different approaches to the design of Human Machine Interface graphics for process control systems.

These examples were developed by the same DCS vendor, for the same energy company, at the same time, using the same HMI Toolkit and the same version of the DCS software package.

A DCS vendors' HMI Toolkit itself provides no control over the potential for human error in HMI interaction. Without effective HFE design control, the same HMI Toolkit can be used to develop an HMI that has high potential for human error and loss of situation awareness, as easily as one where the risk of human error is ALARP.





Appendix 2 — Examples of design-induced human unreliability

This appendix contains examples of major incidents that illustrate how loss of human reliability ("human error") can occur as a consequence, whether direct or indirect, of failure to properly account for human performance during engineering design. That is, where human error is "design-induced".

Human error is complex. Most safety professionals are aware of the models of human error developed through the work of James Reason and others (*eg* Reason et al, 1990, 1997). The most widely used model organises human errors into intentional and unintentional ones, recognises latent and active errors, and illustrates the importance of understanding error types, shaping factors, *etc*.

While this Reason-based model is widely used, and relatively easy to understand and apply, many psychologists and cognitive engineers (including human factors professionals with a background in cognitive psychology) recognise that it does not provide a satisfactory understanding of the psychological – and especially the contextual and situational – nature of "human error", especially where the human performance involved is highly cognitive in nature or involves team interaction. Alternatives to the Reason-based approach to human error can be found in the works of researchers such as David Woods, Kim Vicente, Eric Hollnagel, and Jens Rasmussen (for examples of these approaches, see Hollnagel, 1998, or Woods et al, 2010).

In the oil & gas industry there are very few situations where human error alone can result in a major loss of process safety or environmental control. There usually need to be failures in a number of other barriers and controls – often organisational – in order for a human error (at least at the level of operations or maintenance activities) to have serious consequences.

Incident: vinyl chloride monomer explosion

Date: April 2004

What happened?

An operator drained a full, heated, and pressurized PVC reactor. Investigators believe that an operator opened the bottom valve on an operating reactor, releasing its highly flammable contents.

The safeguards to prevent bypassing the interlock were insufficient for the high risk associated with this activity. Two similar incidents at FPC USA PVC manufacturing facilities highlight problems with safeguards designed to prevent inadvertent discharge of an operating reactor.

Consequences

Five dead. Three injured. Community evacuated.

Root causes

- Current and previous owners did not adequately address the potential for human error.
- Over-reliance on a written procedure to control a hazard with potentially catastrophic consequences.

Human performance

- Operator interacted with the wrong reactor. Meant to work on a reactor that was not in service, involved in cleaning process. Actually acted on a reactor that was in mid-process.
- Operator did not realise that the reactor was in operation.
- Operator tried to open bottom valves to drain reactor. Safety-interlock operated, as designed, to prevent valve opening. Operator used emergency air to override safety inter-lock, leading to release.
- Operator did not request permission to by-pass interlock.

Design issues

- Recognise the potential for the operator to go to the wrong reactor (24 identical reactors in groups of 4).
- Ensure the identity and status of the reactor is perceptually very clear to anyone in the vicinity of the reactor.
- Automatic detection in case of by-passing interlocks.

Recommendations made by investigators

- Companies need to evaluate factors that alone do not create high-risk situations, but combined, make human error more likely.
- Implement policies and procedures to ensure that chemical processes are designed to minimize the likelihood and consequences of human error that could result in a catastrophic release.

Other factors involved

- Current and previous owners did not learn from similar incidents or implement recommendations identified in earlier hazard analysis activities.
- Operators working on the lower level had no means to communicate with operators on the upper level who had ready access to reactor status information (operators did not normally carry radios)
- New owners reduced manning, removing role of Area Group Leader making it more difficult for operator to easily access Supervisor in case of doubt.
- Various failures in Emergency Response.
- Reactor cleaning procedure was never subject to hazard analysis.
- Uncontrolled access to valve interlock bypass. Bypass could be used without detection.

Further information

Chemical Safety Board REPORT NO. 2004-10-I-IL. Report and safety video available at www.csb.gov

Safety Video available from www.csb.gov

Incident: major fire in Resid Hydrotreater unit (RHU)

Date: July 2005

What happened?

Maintenance contractor accidentally switched an 8-inch diameter carbon steel elbow with an alloy steel elbow during a scheduled heat exchanger overhaul. The alloy steel elbow was resistant to high temperature hydrogen attack (HTHA) but the carbon steel elbow was not.

The carbon steel elbow ruptured after operating for only 3 months. The escaping hydrogen gas from the ruptured elbow quickly ignited.

Consequences

1 minor injury. $30Million property damage

Root causes

Construction costs may have been saved by making three elbows on each heat exchanger assembly dimensionally identical. Doing so requires fewer pipe assembly fabrication drawings and weld joints in each assembly.

Human performance

Because the elbows are dimensionally identical, the piping contractor had to ensure that the low alloy steel elbows 2 and 3 were installed in the correct locations when the RHU was built. Contractor was not aware of the different materials and switched elbows after maintenance.

Design issues

- Had the elbow design dimensions been different, elbow 1 would not have been interchangeable with elbows 2 or 3.
- Piping systems can be designed such that incompatible components cannot be interchanged.
- Recognise the safety critical nature of the task of verifying the correct elbow.

Recommendations made by investigators

Human factors based design: designers should consider the entire process system life cycle, including planned maintenance, to avoid piping configurations that allow critical alloy piping components to be interchanged with non-compatible piping components.

Other factors involved

- Maintenance contractor was unaware of the material differences in the elbows. Company did not require the contractor to implement any special precautions to prevent inadvertently switching the elbows or any post-reassembly testing to confirm the alloy elbows were reinstalled in the correct locations.
- Material verification procedure did not require critical piping component testing during equipment maintenance, even though the incompatible components could be inadvertently switched.
- Company did not alert the maintenance contractor that two of the three elbows were alloy steel piping components and must not be interchanged with the carbon steel elbow

Further information

US Chemical Safety and Hazards Investigation Board Safety Bulletin No. 2005-04-B, October 12, 2006. Positive Material Verification: Prevent Errors During Alloy Steel Systems Maintenance. Available from www.csb.gov

Incident: propane release from drain valve

Date: 2009

What happened?

As part of a Cat Cracking Unit (CCU) turnaround, a vessel that normally separated liquid propane/propylene (C3) from a liquid solvent was steam purged to allow entry for inspection. This required opening all drain valves on the level bridle assembly connected to this vessel. After the turnaround, operators prepared the unit for startup, which included "walking the line" and ensuring all valves were in the correct position.

However a drain valve and port on the level bridle assembly remained opened (the gate valve was open and the plug was missing).

During the first pressurization test, nitrogen escaped from this valve body. An operator installed a plug into the screwed opening at the bottom of the level bridle. In the days that followed, the level bridle assembly passed through an additional PSR, and the system was pressured to 90 psig (6.2 barg) with Fuel Gas.

Ten days later, C3 feed was introduced and the system reached its normal operating pressure of 260 psig (17.9 barg). Twenty hours later, the plug was expelled from the level bridle assembly drain valve body and the leak occurred.

Consequences

Release of 13-16,000 kg (30-35,000 lbs) propane and propylene (C3). A vapour cloud developed, but did not ignite. There were no injuries.

High potential incident which could have resulted in multiple fatalities and significant asset damage.

Root Causes

1. The drain valve was opened and remained open
2. The plug was partially engaged in the threads, and
3. The plug was expelled 20 hours after operating pressure was reached

Human performance

1. The operators could not see the drain valve and did not check its' status during pre-start-up review. It was assumed to be in its' normal position. It was inaccessible, not visible, and had been covered by insulation.
2. The operator struggled to install the plug and did not fit it securely into the drain. The drain was awkward to access with no direct sight line.

Design issues

During design of new equipment, do not under estimate the importance of drain valve and plug visibility

Investigation insights

When valves are difficult to see (under insulation, scaffolding or other obstructions), valves may potentially be left open and plugs missed.

Indirect indicators that the drain plug was sufficiently seated may not be as reliable as visually aligning the plug to the port and observing the plug entering the port through multiple rotations (*ie* more direct indicators).

Appendix 3 — Example of an HFE screening tool

This Appendix provides an example of a tool (the "HFE Equipment Screening Tool") developed by one of the major oil companies for conducting an HFE screening. The tool involves a structured and facilitated review of the characteristics, as well as operational experience with the individual process units and equipments involved in the project.

The tool is suitable for projects where the major units and equipment items are known, or can be anticipated, but detailed requirements have not yet been specified and contracts have not been placed with equipment vendors.

The tool is usually applied to projects which are at a very early stage of development, where engineering solutions are defined at a high level and specific process units or equipments have not yet been identified. Minor/simple projects can be screened using simpler tools.

The choice of how to conduct an HFE screening for a specific project is a skilled judgement requiring HFE competence at least at level 3 (as defined in Appendix 6).

HFE Equipment Screening Tool

Overview

The HFE Equipment Screening Tool quickly identifies whether there are any significant issues or opportunities associated with the facilities being developed that would benefit from further HFE activity. The screening provides the basis for preparation of a HFE strategy.

The tool is usually applied within a workshop format attended by an experienced facilitator, representatives of operations and maintenance, relevant discipline engineers and other specialists as appropriate. During the workshop, the results should be projected on a screen such that all team members can see what is being recorded.

Facilitator

For complex projects, use of the HFE Equipment Screening Tool should be facilitated by the project technical authority, authorised person or HFE specialist. For less complex projects, the HFE co-ordinator may be able to facilitate use of the tool.

The facilitator has a critical role in ensuring important assumptions and expectations about human performance with the new facility are made explicit and are challenged. This includes challenging assumptions about the role of people – particularly how the human role might change compared with previous systems – and how users and other stakeholders might be affected, or how they might react or behave with the new facility.

Operations and maintenance input

The tool depends critically on interaction between the facilitator, discipline engineers and operations and maintenance representatives. The screening cannot be completed without the presence of operations and maintenance representatives. For projects involving significant development or change of instrumentation, panel operators should be involved.

Applying the tool

During the screening session, the team first decides the level at which to apply the tool. The level chosen might be:

- An overall process area or processing unit (such as a processing train, sub-sea well-heads, buildings, tank farms or area of a refinery).
- Individual equipment items (such as compressor packages, gas dehydration units, flow-lines and manifolds, control room, DCS system, *etc*).
- Operations (such as turnarounds on individual units, unit start-ups, oil movements, ship loading, *etc*).

Once the screening level has been agreed and a list of relevant units or items compiled, the team systematically reviews each item against the following six screening factors:

1. The complexity of the manual activities involved in operating, maintaining and supporting the item.
2. Whether the item is critical for operations or hazard control, or is involved in hazardous service
3. The frequency with which people need to interact with the item (other than routine operator rounds).
4. The novelty of the item: whether it will require the workforce to gain new knowledge, or skills, or will it introduce new procedures, work practices or organisational structures.
5. The status of design at the time of the screening.
6. Known issues with similar equipment, or areas of particular concern to operations or maintenance.

These factors are detailed on tables 3.1 to 3.6 together with possible ratings and guide words. For each factor, the team should agree a rating based on consideration of the guide words shown in the tables.

The facilitator (or minute taker) should take careful notes to ensure issues contributing to the rating are properly recorded.

Once an item has been screened against the six factors, the team, guided by the Facilitator, decides whether any further HFE quality control activity should be applied to the unit or item.

On completion of the screening, the Facilitator should use the results as the basis for preparing the HFE Strategy for the project.

Table 3.1 – task complexity

How complex are the manual activities involved in operating, maintaining and supporting the item?

Ratings	Meaning
Simple	There are only a few manual tasks and they are inherently simple discrete actions with minimal mental demands (such as pressing Start/Stop buttons, reading gauges, etc).
Moderate	Neither Simple, nor complex
Complex	• There are a reasonable number of tasks to be performed (>10), AND/OR • Tasks can be difficult, complex, time consuming or require very high levels of human reliability
Unknown	No information available

Guide words	Definition
Operations	Is the item likely to impose a substantial amount of work on operations personnel – plant, field or panel?
Maintenance	Is the item likely to impose a substantial amount of work on maintenance or technical personnel?
Physically demanding	Is the work likely to be physically demanding (climbing, pulling, lifting, etc)?
Mentally demanding	Does the work require high levels of concentration and vigilance, or does it make a lot of demands on thinking, reasoning, calculating or decision-making? Is a human expected to monitor or take account of trends over time, or to detect relationships between a number of items or parameters?
Labour intensive	Does the task require several individuals to complete or repetitive actions of the same few individuals?
Time Consuming	Does the task take a lot of time to complete?
Other	

Table 3.2 – unit criticality

Is the unit critical for operations or hazard control, or is it involved in hazardous service?

Ratings	Meaning
Yes	No doubt. The item is critical or very hazardous.
Probably	More than a 50/50 chance that if the unit did not perform as designed, either production would be affected or people would be exposed to hazards.
Possibly	There is less than a 50/50 chance, but not negligible.
No	Would not affect production and would not expose anybody to hazards.

Guide words	Definition
Start-up/shut-down	Is this item integral for safe & efficient start up or shutdown?
Production	Is the equipment essential for production/unit reliability/on stream factor?
Product quality	Is the equipment essential to ensuring product meets quality specifications?
Process safety	If the item did not perform as designed, could it represent a major risk to process safety, or does it provide a control against loss of integrity? (explosion, fire, release of hazardous materials, etc.)
Personnel safety	…could it introduce a major risk to personnel safety? (e.g. loss of protection).
Health	…could it introduce a major risk to health? (e.g. exposure to chemicals, radiation, noise, fumes).
Environment	…could there be a major breach of environmental controls (e.g. spillage of hydrocarbons or chemicals)?
HSE control	Does the equipment keep a medium or high risk to people, asset, and environment under control?
Sour service	Yes: H_2S in the process stream is >10% Possibly: H_2S in the process stream >1%
Benzene	Yes: More than >10% benzene? Possibly: More than 1%
Above auto-ignition temp	Does the item routinely contain hydrocarbons above their auto-ignition temperature?
High pressure service	Is the equipment normally operated under high pressure?
High temperature service	Is the external temperature of the equipment high?
Other	Other ways in which the unit is considered critical (be specific).

Table 3.3 – task frequency

How frequently are people likely to need to interact with the item (other than routine operator rounds)?

Ratings	Meaning
Frequent	Significant work on the item more than once every 3 months
Occasional	…more than once per year
Rare	…less than once per year.
Unknown	No information available

Guide words	Definition
Start-up/shut-down	How frequently might the item need to be manually started up or shut-down?
Trips	What is the expected frequency that the item might trip?
Routine Ops	The frequency of routine operations?
Routine maintenance	The frequency of routine maintenance activities (including change-out of major components).
Breakdown	The frequency that the unit might be expected to breakdown.
Inspections	The frequency of major inspections (other than visual checks)
Cleaning	The frequency of cleaning
Transportation	Frequency of moving the item or its' components.
Re-supply	Frequency of re-supplying the item or its' components.
Other	

Table 3.4 – novelty

Will the item require the workforce to gain new knowledge, or skills, or will it introduce new procedures, work practices or organisational structures.

Ratings	Meaning
Same	More or less identical to existing units at the asset.
Variant	A variant of items that are well known to the local workforce.
Similar	A new type of unit, though generally consistent with existing competencies and experience.
New	A new unit. Little or no relevant experience at the asset.
Unknown	

Guide words	Definition
Asset	New to the asset, but not new to the Business Unit (BU). Experience available at other assets.
Business	New to the business unit, but not new to the company. Experience available in other BUs.
Company	New to the company. Experience available in the industry.
Industry	Not previously used (or not used in the same way) anywhere in the industry.
Capacity	Significant change in capacity from existing units.
Feed	Will be used with a different feedstock.
Process	Not previously used for the intended process.
Competencies	Will introduce requirement for new competencies at the asset.
Procedures	Will require new procedures that are significantly different in content, or major changes to existing procedures.
Organisation	Will require significant changes to the organizational structure (team-working, supervision, shift-work or overtime arrangements, etc).
Use of contractors	Reliance on contractors/vendors to carry out new functions.
Other	

Table 3.5 – design scope

To what extent is there scope to influence control over HFE aspects of the design, procurement or layout of the item?

Ratings	Meaning
A lot	Item will not be "off-the-shelf" and has not yet been procured. Vendor's scope of supply includes design activity. There is still a lot of scope to influence both item design and positioning on the plant.
A little	There is some opportunity to influence the design of the item itself, but it will be limited.
Plant layout only	No opportunity to influence the design of the item itself. Can still influence location, orientation and local space on the plant.
None	Item has allready been bought or will be entirely off-the-shelf'. Vendor scope of supply does not include any new design. Location allready frozen.

Guide words	Definition
Integral	The design, location & positioning of components integral to the item. Includes the location and space around valves, flanges, sample points, etc, as well as the design and location of instruments, labels, and signs. (If there is no opportunity, further screening may be of limited value).
Plant layout	The positioning and orientation of the item on the plant, the space around it, and provision of access (including for escape), walkways, lay-down areas, etc.
Control panels	Local instrument panels.
HMI	Human Machine interface to DCS or other IT systems, including graphics.
Instrumentation	Design of instrumentation, including alarm set-points, to assist panel operators detect abnormalities and diagnose faults from the control room.
CCTV	Provision of CCTV monitoring of the item, of leakages, or of the safety of people working in the area of the item.
Lighting	Local lighting arrangements.
Noise and vibration	Noise and/or vibration control measures.

Table 3.6 – known problems

Is there a history of problems associated with the design or layout of the item? Concern is with issues that can affect operations, health and safety, process safety or environmental integrity.

Ratings	Meaning
Major	There are known to have been significant issues with similar items in the past
Minor	There have been some issues where the design has not been as good as it might have, though they are not considered major problems.
None	Not aware of any previous issues with similar equipment or operations.

Guide words	Definition
Escape routes/ congested space	Inadequate escape routes or space for escape, including escape wearing arctic clothing and/ or BA. Space for stretchers, or ease of access for emergency teams carrying emergency response equipment.
Equipment access	Access ways and space to bring in equipment needed to start-up, inspect, or maintain the item.
Awkward or static posture	People are forced to adopt awkward or uncomfortable postures, involving twisting or bending of the spine, hips or neck, or excessive reaching with the hands and arms. Especially where there is a need to apply force while twisted or extended, or to maintain a static awkward posture for extended periods.
Excessive force/weight	People required to apply unreasonably high levels of force (especially when combined with awkward postures) or to carry heavy weights (especially above torso height, or at a distance from the body).
Repetitive motions	People being required to perform the same physical movements repetitively over extended periods (e.g. regularly having to repeat the same movements of the fingers, hands, arms, legs or head/neck every few minutes over periods in excess of an hour).
Material handling	Difficulties manually handling materials. Due to weight, size or shape, lack of space to adopt safe posture, poor grip, PPE, or poor communication/ cooperation between people working together.
Poor lighting	Inadequately lit workspaces. Lighting not repaired. Lighting too bright. Insufficient light to read, perform visual inspections or to see manual activities.
Weather	Exposure to extreme heat, cold, wind, dust, etc.
Comms/ noise/radios	Issues around difficulties of communication. As well as high noise levels, could include lack of direct line of sight, radio 'black-spots, cross-language issues, delayed information, errors (e.g. in permits), etc.
Procedures - confusing, conflicting	Procedures that are badly written, contradictory, illegible, not clear, unnecessarily complex or otherwise difficult to follow. Documented procedures (including their HMI implementation, e.g. in DCS screens or alarm set points) that do not reflect current operational practice or experience.
Mistakes/ human errors	A history of human error, including mistakes, failure to complete tasks correctly, or procedure violations. Situations where human error has led to incidents including breach of safety or environmental control or production upsets. Includes error by 'front-line' workforce, as well as support or admin staff, contractors, or during commissioning, construction or turnarounds.
Other	Any other history of known problems affecting the ability to work efficiently and safely.

Appendix 4 — Example HFE working group terms of reference

This appendix includes an example of the Terms of Reference for a HFEWG for a complex project.

1 Purposes and scope

- The HFEWG provides the formal project forum for discussion and resolution of issues associated with the HFE work programme. It shall maintain oversight and ensure progress on technical issues associated with implementation of HFE design requirements.
- The HFEWG shall oversee implementation of the project HFE Strategy and provide a forum to resolve cross-disciplinary issues and facilitate integration of HFE across the project.

2 Core attendees roles and responsibilities

Additional personnel may be invited to attend specific meetings to help address any specific issues that have been identified by the HFEWG.

Role	Responsibility	Name and contact details
Project HFE chair	Chair the HFEWG meetings and highlight critical issues with other members of the project management team to ensure necessary support for follow up.	
HFE coordinator	Coordination of HFE activities and delivery of the HFE work scope.	
HFE technical authority	Quality assurance and quality control of the HFE CTR deliverables.	
Operations and maintenance	Provide operational experience	
Discipline engineers	Facilitate integration of HFE with relevant engineering disciplines.	
Other specialists	Integrate with HFE	

3 Meeting duration and frequency (example)

Two hour meeting on a 2 weekly basis for the first 3 meetings. Subsequent meetings as required, but expected to be held on at least a monthly basis.

Where possible, HFEWG meetings should be scheduled shortly before the monthly HSE meeting. This will enable the HFEWG Chair to highlight relevant HFE issues at the HSE meeting.

4 Standing agenda (example)

1. Minutes of previous HFEWG
2. Actions Arising
3. Progress against HFE Work Plan
4. Progress against Deliverables
   a. Deliverables developed since last meeting
   b. Deliverables expected before next meeting
5. HFE Interfaces with other disciplines
6. Review of key HFE Risks
7. AOCB

5 Minutes of Meeting (MoM) Distribution List

List of roles who should receive copies of the HFEWG meeting minutes.

Appendix 5 — Example terms of reference for HFE co-ordinator

Role

The role of the HFE Co-ordinator is to act as a manager and focal point for Human Factors Engineering (HFE) on a project.

Initiation

The role of the HFE Co-ordinator should be initiated following the project HFE Screening, where it is identified that an organised programme of HFE activity is required. The role should therefore normally be initiated early in FEED, once the project HFE Strategy has been approved.

Responsibilities

- Liaise with the project HFE Technical Authority.
- Ensure individuals on the project who have responsibility for conducting or supporting HFE activities, have the appropriate level of HFE competence.
- Ensure contractors comply with the HFE requirements defined both in their work programme, and within the project technical specifications.
- Ensure effective communication and liaison between the HFE project team and other activities in the project HSE and engineering programme.
- Manage the resolution of conflicts between HFE and other technical and commercial requirements.
- Maintain a register of HFE risks and track until completion.

Accountabilities

- Organise and report on activities of the project HFE Working Group.
- Act as deputy chair of the HFEWG.
- Manage delivery of the project HFE Implementation Plan for the Execute/Detailed design phase.
- Ensure project HFE deliverables are subject to appropriate technical review and other QA requirements.

Reporting (example)

The HFE Co-ordinator should report to the Operations Manager and HSE Manager for the business unit sponsoring the project.

Interfaces

- Directly with HFE Technical Authority for technical support as required.
- Operations Support.
- HSSE function.
- Hazard Analysis Leader.
- With other project engineering disciplines and specialists via the project HFE team.

Competence requirements

- At leastlevel 2 competence in HFE.
- Will preferably have a background in operations, with at least 15 years experience, including significant time in a leadership role.
- Must have experience on capital projects, and understand project processes.

Appendix 6 — HFE competence requirements

Table 6.1 (overleaf) summarises five recommended competence levels for HFE.

The table also identifies the roles that an individual at each level of competence is able to fill on projects, and the level of training and experience needed to achieve each competence level.

Table 6.1: HFE competence definitions

Level	Project roles	Competencies	Project specific activities	Minimum training requirements	Experience	Verification
1	Project Manager: Engineering Manager Discipline Engineers Operations Representative HSE, Safety Delegates Members of HFE Working Group.	Knowledge of the scope and relevance of HFE. • Aware of the existence of key industry standards • Able to recognise how and where HFE is relevant to their job	Member of HFEWG Apply HFE principles to areas of responsibilty	Completed HFE Awareness training (1-2 hours)	Training only	Record of attendance at HFE Awareness training
2	HFE Coordinator	Level 1 plus "can do" the following: • Understand and use HFE terminology correctly. • Understand what makes projects complex in terms of HFE. • Conduct HFE screening for low complexity projects • Understand the role and organisation of an HFEWG. • Lead simple HFE design analyses. • Aware of scope and content of relevant standards and legislation.	• Chair HFE Working Group. • Conduct HFE Screening and prepare HFE Strategy for Simple projects. • Facilitate simple HFE Analyses (e.g. Valves Criticality Analysis). • Act as technical point of contact with HFE Technical Authority/authorised Person.	16 hours classroom training AND Acted as HFE Coordinator on at least one project with supervision by an individual of Level 4 or 5 HFE competence.	Understand project context, constraints and daily working from personal experience. Minimum 2 years experience in projects.	Confirmation by individual of Level 4 or 5 HFE competence.
3	HFE Coordinator HFE Authorised Person	Level 2 PLUS 'can do' the following: • Consistently carry out HFE activities to the required standard: • Perform satisfactorily the majority of HFE activities • Translate HFE guidelines and standards into practical actions • Solve common HFE technical and/or operational problems • Able to advise others on technical aspects of HFE.	• Facilitate HFE Screening for complex projects • Facilitate HFE Design Analysis • Represent HFE in Reviews and technical meetings.	Either: 1. Equivalent to Certified Ergonomics Associate (CEA) of the USA Board of Certification in Professional Ergonomics. OR 2. At least 3 years experience as HFE Co-ordinator or leading HFE on projects including application of HFE Standards.	3 years relevant industry experience. At least 10 years oil & gas industry experience (e.g. operations, Engineering, HSE).	Assessed by level 4 or 5 practitioners as having sufficient technical knowledge and being capable of producing quality HFE deliverables.
4	HFE Technical Authority (Company) HFE Specialist	As level 3 PLUS: • Solve significant, complex, non-routine HFE problems • Adapt HFE practices from other markets or countries • Generate substantial improvements to local HFE practices and procedures. Assess and authorise HFE competence levels 2 and 3	As level 3 PLUS: Act as project HFE Technical Authority	Satisfies professional certification requirements of recognised professional bodies: • CREE (Europe) • CPE/CHFP (USA) • CCCPE (Canada) • Register of Professional Certified Ergonomists (Australia) • BCNZE (New Zealand) • JE Certification Program for Professional Ergonomists (Japan)	At least 10 years relevant professional experience, including at least 5 years oil & gas industry experience.	Assessed competent by a Level 5 HFE practitioner.
5	HFE Technical Authority (Company) HFE Specialist	As level 4 but significantly more oil & gas HFE experience. Owner/approver for Company HFE standards. Assess and authorise HFE competence levels	Company HFE Technical Authority.	As Skilled	20 years relevant professional experience including at least 7 in oil & gas industry.	

Appendix 7 — Typical HFE design analysis activities

This appendix summarises ten activities used to support HFE design analysis on capital projects. These activities are similar – though in general simpler – to methods widely used in other industries. They are in general use by OGP members and found to be cost effective and efficient in supporting implementation of HFE in capital projects within the oil & gas industry. In some cases they have been customised to support specific OGP member needs or standards.

The activities summarised in this appendix are (in no particular order).

1. Working Environment Health Risk Assessment. (WEHRA)
2. Valve Criticality Analysis (VCA)
3. Vendor package screening
4. Task Requirements Analysis (TRA)
5. Human Machine Interface (HRI) requirements analysis
6. Control room requirements analysis
7. Control system and alarm management analysis
8. Safety critical task inventory
9. Critical task analysis
10. Human error ALARP demonstration.

These techniques have been consistently demonstrated to be efficient and cost-effective in adding value, particularly when applied during front end engineering design. In addition to the established analysis activities, this appendix includes advice on how HFE can be integrated into HAZOP activities. No similar guidance currently exists.

To be effective, all of these activities are critically dependent on:

- being led by individuals who are competent and experienced in applying them; and
- input from key stakeholders, in particular operations and maintenance representatives.

The techniques described are not definitive or comprehensive of the tools that may be used to support HFE activity on oil & gas projects. Other tools can be and should be used if they are better suited to the specific objective or the project team's experience.

In all cases, the tools used, as well as the competence of the individual proposed to facilitate the application of the tool, should be approved by the project HFE technical authority.

7.1 Working Environment Health Risk Assessment (WEHRA)

Objective:

To identify and asses the Working Environment Health Risks in all activities and to ensure they are proactively managed to reduce the risk.

Application:

Can be used in operations, new projects, modification projects and to assess risks in mergers, "farm-ins" and acquisitions.

Key requirements

- Map and create an activity chart where types of activity, area of work, duration and frequency of the work tasks are described.
- For development projects, activities and work tasks should be predicted.
- Determine the frequency of, and duration of, the tasks to assist in the assessment of the health and environment exposure level.
- The identified activities and tasks should be assessed against the potential working environment hazards listed below (key HFE in project elements are listed in bold). The type of site/plant/working environment defines which factors should be assessed.
  - Ergonomics
  - Arrangement/layout
  - Human factors
  - Chemical substances and preparations
  - Noise
  - Vibration. Whole body and hand-arm
  - Biological agents
  - Lighting (sight)
  - Indoor climate
  - Outdoors operations/climate
  - Radiation
  - Psychological and organisational conditions (from GPS/PRI)
  - Shift work and travel
  - Visual display units
  - Any other relevant work environment hazards

Application

- A risk score for each work task and health hazard is assigned based upon knowledge of work tasks, health hazards and tolerable limit values available from regulations and guidance.
- Resulting risks are summarised in a table with work task and health hazards as axes.
- In development projects, risks are assessed without any controls in place. By inserting technical, and organisational controls as measures or actions to reduce the risks and then reassessing with those controls in place a new residual risk matrix is developed. The risks assessed should be the estimated risks in the completed and operational plant.
- A prioritised list of mitigating measures (actions) can be developed and responsibility allocated for actions. These should be prioritised to according to the assessed risk score.
- The choice of method for mitigation should follow this ranking:
    1. Elimination/removal of the hazard/change of design.
    2. Substitution of the hazard.
    3. Implement technical mitigating measures.
    4. Implement organisational mitigating measures.
    5. Use of personal protective equipment.
- When mitigating measures have been implemented and verified, a new assessment can be performed to demonstrate control of risk and illustrate risk reduction.
- In some cases it may be necessary by virtue of the risk assessments and scores to follow up with further in depth studies using expert tools, site visits and/or measurements. These should also be presented as actions.
- The output and the action plan should be reviewed for quality by the project manager, HSE manager, HFE technical authority and HFE specialists. An independent review of the work by a suitably qualified person should be undertaken.

Product/output

- A comprehensive understanding of the Working Environment risks.
- An agreed and prioritised plan with timelines and accountabilities for implementing mitigating measures.
- A visible and communicable reduction in the Working Environment risk through the application of appropriate mitigation measures.

Additional Guidance

- NORSOK S-002 Working Environment.
- OGP HRA guidance.

7.2 Valve criticality analysis

Objective

Prioritise valves according to their criticality and frequency of operation ensuring that when compromises have to be made, adequate consideration is taken of the importance of each valve with respect to ease of access and visibility for operation or maintenance.

Key requirements

Determine an agreed ranking methodology. Typical practice is to rank on the following basis.

Category 1: Valves that have a high criticality or a high frequency of operation (at least once in a 6 month period). Includes valves essential to normal (including start-up and shut-down) or emergency operations where rapid and unencumbered access is essential. These valves should be positioned to ensure that they are visible and easily accessible either from grade or from a permanent platform. They should also satisfy good practice in valve ergonomics.

Category 2: Valves that are not critical for normal operation or emergency operations but are used during routine operations. These valves should be located with permanent access at deck level, or access via stairs. However with suitable justification alternative means of access could be considered.

Category 3: Valves usually only rarely operated and are not used in critical situations. If necessary ease of access to priority three valves can be compromised to meet competing project demands such as the cost or the practicality of providing permanent access.

Application

- Valve Priorities should be marked up on PFSs or P&IDs.
- Visibility access should be checked during 3-D model reviews.
- Access and visibility of Category 1 valves should be checked during pre-commissioning reviews.

Product/output

- Technical specification of valve access requirements and ergonomic requirements.
- A reduction in injury and potential for human error resulting from appropriate valve accessibility and maintenance standards.

Additional guidance

- ASTM F1166-07, Chapter 12.

7.3 Vendor package screening

Objective

To identify those vendor packages where, based on the criticality and frequency of manual interaction, special attention needs to be paid to HFE aspects of the design and layout of the unit.

> *Note: the term "vendor packages" – or "skid packages" – refers to equipment that is manufactured at a vendors premises mounted on a frame (or "skid") and then transported to the required location. Because of the need to design vendor packages such that they can be readily transported, they are frequently very compressed, creating problems of accessibility or ease of operation or maintenance over their working lives.*

Key requirements

- Prepare a comprehensive list of all vendor packages.
- Screen the vendor packages into :
  - Category 1: Vendor packages that are considered critical to maintain operations, safety or environmental integrity, or which require frequent manual intervention.
  - Category 2: Vendor packages where human intervention is infrequent and not critical.
- For Category 1, packages hold discussions with potential vendors, and jointly develop HFE quality controls for inclusion in the procurement specification.
- Category 2 packages would typically rely on existing technical design standards and would not require additional HFE-specific quality control.
- For vendor packages that are procured 'off-the-shelf' there can be little scope for re-design for individual projects. Often however, vendors are prepared to consider design improvements where there is a clear benefit in operability or maintainability of their product.

Product/output

- Specific HFE actions to improve the operability and maintainability of vendor packages.

Additional guidance

- There is no industry guidance on vendor package screening. Some OGP companies have their own internal guidelines to HFE design of vendor packages.

7.4 Task requirements analysis

Objective

To provide an early analytical focus on operational and maintenance tasks identified as being either particularly important to the safe and efficient operation of oil & gas facilities, are particularly difficult, time consuming to perform, or have the potential to impose significant health hazards. The analysis identifies design requirements that need to be satisfied in order to optimise human performance on the identified tasks. Where possible it transforms goal-oriented HFE requirements into prescriptive requirements (see section 2.4).

TRA should only be conducted on units/equipment/operations identified as being critical and where the results are expected to be of significant value to the design or operations. The level of detail to which the analysis should be taken should be driven by the potential to reduce risk or add value to the design.

> *Note: TRA is a limited version of the more widely adopted Task Analysis techniques widely used throughout many industries. For many applications – such as assessing human error potential, operator workload, or supporting design of training or procedures, more detailed forms of Task Analysis should be used. For example, Section 7.9 describes Task Analysis for safety critical tasks.*

Key requirements

Design requirements identified through the use of TRA generally fall into two categories:

- New technical requirements necessary to support effective human performance that are not already specified in existing standards or specifications, or
- Existing requirements which are specified in existing standards, but which are emphasised for particular critical tasks.

Scope of design requirements identified through TRA can include:

- Requirements for the design and layout of the physical workspace.
- Facilities to aid manual handling and manoeuvring of heavy or awkward items.
- Environmental considerations, including provision of adequate task lighting.
- Requirements for the need to work in or minimise the need for, PPE, or the provision of special tools or other identified resources (such as scaffolding).

Product/output

Results from TRA's are captured in standardised templates. The principal output is a specification of design requirements as well as tracked actions to be taken forward into relevant project specifications – including ITT's and bid packages – and design validation activities.

The quality of the output is to a very large extent dependent on the skill, experience and judgement of the facilitator in focusing the analysis team's attention and probing issues that require further clarification.

Additional guidance

- Kirwan, B., and Ainsworth, L.K. "A Guide to Task Analysis" 1992, Taylor & Francis

7.5 Human Machine Interface (HMI) requirement analysis

Objective

The term 'HMI requirements analysis' refers to a range of techniques to ensure 'usability' requirements for the design and validation of human-computer interfaces are adequately specified. In oil & gas projects it is most often used in supporting development of the HMI to Distributed Control Systems (DCS), though it can equally be used for any non-trivial human-computer interface.

Efficient human-machine communication is a precondition for safe and efficient operations. The purpose of performing a HMI requirement analysis is to ensure that requirements for the design, layout and navigation of an HMI are clear and unambiguous and delivered in a such a way that it is clearly understood.

Analysis of the human-machine interface is carried out with reference to industry best practice, ergonomic standards and functional requirements to ensure the optimum user interface, minimise risk for health disorders or injury, and to ensure the risk of human error is reduced to a level that is ALARP.

Key requirements

An HMI requirements analysis should not try to define the design solution. It should specify those requirements necessary to ensure a high level of usability for the specific processes or operations to be supported, and aim to provide vendors with the maximum scope to utilise their existing HMI toolkits to design and deliver highly useable solutions.

For example an analysis might specify:

- Who the primary users of the system will be and the viewing requirements of the various user groups.
- How colour is to be used in the HMI.
- The relative priorities of visual salience (i.e. the extent to which it captures visual attention) to be applied to different types of displayed information.
- The visual coding techniques to be used for each visual salience level (luminance, shape, text size, background colour, etc).
- Critical tasks that are required to be performed from a single screen or workplace.
- How the HMI is to be validated and the types of usability demonstrations to be conducted during system testing.

Product/output

A comprehensive list of requirements necessary to ensure a high level of usability for the specific process or operation.

Additional guidance

- ASM® Consortium Guidelines for Effective Operator Displays.

7.6 Control room HFE requirements analysis

Objective

To conduct a requirement analysis in situations where information and communication technology is to be applied in a control room environment, either in a new or re-engineered situation to improve virtual collaboration and decision making processes. It can also be applied where the current method of allocating functions and tasks is challenged.

Applications

- Human factor design analysis is conducted in connection with the construction or modification of control rooms, cabins for drilling and crane operations, monitoring centres, interaction rooms and operation rooms.
- HFE control room analysis is conducted when transferring or reallocating functions between offshore and land, and in connection with the use of operation rooms, interaction rooms and integrated operations.

Key requirements

Before the analysis is conducted, the objective, scope and delivery must be clarified and a clarification meeting held with representatives from the customer/management and the individuals carrying out the analysis.

The analysis will typically include a number of distinct enquiries necessary to constrain the acceptable design solution for a control room and will typically include:

- A 'vision statement' succinctly summarising what the asset operators expect of the new or changed control room, how they intend to use it and, in the case of modifications to existing control rooms, how the legacy and new design will work together.
- A functional analysis, documenting the functions to be supported from the control room, or from adjacent areas. As well as identifying functions necessary to support the process, the analysis might for example identify the need to support functions such as shift handover, permitting, emergency response, personnel monitoring, helicopter or marine management.
- A functional analysis should include definition of the equipment and any other facilities needed to support each function. For example, a requirement for a shared large screen display to support team situation awareness and shift team meetings.
- Identification of the manning and roles to be supported in the control room. This should include primary roles (those who need dedicated space and facilities within the control room such as panel operators), as well as secondary roles (who may need to physically access the control room occasionally, but do not require dedicated space or facilities).
- Task analysis of key operator roles and critical tasks to be performed from the control room.
- Adjacency analysis for both roles and equipment. Adjacency analysis identifies the expected relationships in terms of the expected frequency of direct physical contact between different roles, and the frequency with which each role is expected to need access to different equipment or dedicated areas with the control room or surrounding areas.

Product/output

A comprehensive analysis and record of control room HFE requirements that can be given to the architects or end users, as an input to the generation of design concepts for the layout of the control room.

Additional guidance

Guidance on performing control room HFE requirements analysis is available in a number of documents, including:

- ISO 11064, Ergonomic Design of Control Centres.
- US Department of Energy, 'Human factors Guidance for Control Room and Digital Human Computer Interface Design and Modification' Report 1008112, November 2004.

7.7 HFE alarm analysis

Objective

To determine criteria for an alarm system such that the operator can clearly identify a need to act and select an effective course of action especially in emergency conditions. A secondary objective is to provide clear guidance on the event logging design.

Key requirements

To accomplish the above objectives an alarm analysis should define the functions required to:

- Alert the operator about the existence of an alarm condition.
- Clearly inform the operator about the priority and nature of the alarm.
- Repeat the operator response to the alarm.
- Restrict the number of alarms to those which are essential.
- Provide assistance in analysing events.
- Provide a detailed chronological event log.

The following operator tasks and actions shall be supported by the alarm system and the analysis needs to clearly define the functionality required:

- The monitoring and control of the plant.
- The ability to respond to situations before the safety system initiates automatic actions.
- An ability to respond to dangerous situations if the automatic safety systems do not function as intended.
- An analysis of alarms.
- An ability to acknowledge alarms.
- An ability to perform corrective actions with the most important performed first.
- A timely alerting of plant personnel.
- Verification that all actions have been completed.

Product/output

A comprehensive analysis and record of alarm requirements that can be given to the DCS and other vendors, as an input to the generation of alarm design and functionality.

Additional guidance

- Better alarm handling, Chemical Information Sheet 6 (2000) HSE Books (HSE Books website www.hsebooks.co.uk)
- Alarm systems, a guide to design, management and procurement, Engineering Equipment & Materials Users Association Publication No 191 (1999) ISBN 0 8593 1076 0.
- The management of alarm systems Bransby, M. L. and Jenkinson, J., HSE Contract Research Report 166 HSE Books (1998) ISBN 0 7176 1515 4.
- The explosion and fires at the Texaco Refinery, Milford Haven, 24 July 1994: A report of the investigation by the Health and Safety Executive into the explosion and fires on the Pembroke Cracking Company Plant at the Texaco Refinery, Milford Haven, HSE Books (1997) ISBN 0 7176 1413 1.

7.8 Process safety critical task inventory

Objective

To provide a summary of all of the human tasks and activities identified as being involved in avoiding process safety incidents at the facility. To ensure that these tasks and activities have the highest level of scrutiny when providing additional barriers to human error.

Application

- To provide an inventory of human tasks that, if performed incorrectly, could either directly initiate a hazardous scenario or would breach one of the planned defences against loss of containment.
- To provide an inventory of Human tasks that are required to be performed in order to assure the performance of automated safety systems (such as maintenance of gas detectors, or visual corrosion inspections).
- To provide an inventory of Human tasks which are explicitly identified as a barrier against escalation of a loss path. An example would be for a panel operator to detect and correctly respond to a process alarm.

Key requirements

- Tasks to be included in the inventory should be captured throughout the FEED and detailed design phases. They can be identified from a number of sources, including HAZ-OP's and other hazard analysis activities or risk assessments, as well as from HFE design analysis, especially task requirement analysis.
- Inventories should typically have a low threshold for tasks to be considered process safety critical- i.e. if a human task appears to be possibly process safety critical it should be nominated for potential inclusion. However, the inventory should have a relatively high threshold for tasks confirmed as being process safety critical.

Product/output

A comprehensive prioritised inventory of human related process safety critical tasks to which the efficacy of additional barriers to error can be assessed.

Additional guidance

- The UK HSE research report 033 'Evaluation report on OTO 1999-092 – Human Factors Assessment of Safety Critical Tasks, defines a screening procedure that has been successfully applied to identify the tasks that meet the definition of being Process Safety Critical.
- API Task Force March 2004, 'Tool for incorporating human factors during PHA reviews of plant designs.

7.9 Critical task analysis

Objective

Critical Task Analysis is a variant of more general task analysis which focuses on analysing tasks identified to be critical (i.e. those included in a safety critical task inventory – see section 7.8) in sufficient detail to perform a human error ALARP demonstration – see section 7.10).

Key requirements

- There are a variety of well established techniques used in safety critical industries for assessing the reliability of human tasks. The most appropriate method depends on the nature of the task (principally whether it is a predominantly manual or cognitive task, and whether it is an individual or multi-person activity) and the operating context (e.g. operations performed in especially hazardous environments, or while wearing extensive PPE can require special treatment).
- The precise method to be used is at the discretion of the project team. However, the project HFE technical authority or HFE authorised person should approve the technique.
- Conducting a critical task Analysis is a skilled activity. It must be led by an individual approved by the project HFE Technical authority as having the necessary competence.
- Operational knowledge of tasks is an essential requirement for a successful CTA. The analysis must involve experienced operators and/or maintenance personnel, (according to the nature of the task).

Product/output

An analysis of critical tasks broken down into sufficient detail to provide a human error ALARP assessment

Additional guidance

1. The UK Health and Safety Executive has published a method (a) for assessing safety critical tasks that has subsequently been validated in an independent study (b).
   a. HSE UK Research Report OTO1999–092 – 'Human Factors Assessment of Safety Critical Tasks' Brazier, Richardson and Embrey, 2000. Available at: www.hse.gov.uk/research/otopdf/1999/oto99092.pdf.
   a. HSE UK Research Report 033 'Evaluation report on OTO 1999-092 – Human Factors Assessment of Safety Critical Tasks' DNV 2002.
2. Guidance on Human Factors Safety Critical Task Analysis, Energy Institute, London. March 2011

7.10 Human error ALARP demonstration

Objective

To conduct a formalised assessment of human tasks identified in the process safety critical task inventory (see 7.8) and provide a record of the supporting documentation for ALARP judgements. Where additional work is required to further reduce the risk, or be able to support the ALARP judgement an action plan for the work is developed and included in the project's HSE programme.

Key requirements

Tasks identified in the critical tasks inventory are subject to assessment to:

- Confirm the assessment of the critical nature of each tasks, and
- Assess the extent to which design or engineering decisions have reduced the risk to a level that can be shown to As Low As Reasonably Practical.

For most tasks this review comprises two elements:

- A review of each task to ensure the related risks are adequately understood and to review other controls (barriers, escalation factors or controls) associated with it.
- A review of the impact of the current state of design on performance of the task. This should include assessment of the state of compliance with relevant technical standards. It should also include a review and assessment of the task in the context of the current representation of the 3-D plant layout model, HMI prototypes, or alarm philosophy.

Product/output

The output of the review is a record of the ALARP judgement for those tasks included in the critical task inventory, and an action plan to ensure any work needed to further reduce the risk, or be able to support the ALARP judgement, is included in the HSE programme.

Additional guidance

The UK Health and Safety Executive has relevant guidance available on their web-site:

http://www.hse.gov.uk/humanfactors/topics/humanfail.htm

7.11 HFE in HAZOP

Objective

Hazard and Operability Studies (HAZOP) are very widely used across the global oil & gas industry as means of ensuring hazards are recognised and adequate controls are in place during the project engineering cycle.

In some cases, particularly for smaller and less complex projects, it may be possible to use the HAZOP process as the means of assessing whether a formal HFE programme will add value to the project, and the type of controls that need to be in place.

Currently, no industry-wide guidance or standard exists on how to effectively integrate HFE into HAZOP. Current practice depends largely on the skills and experience of the HAZOP chairperson, and the skills, awareness and experience of individuals who attend HAZOP meetings.

Additional guidance

Appendix 8, which is based on an OGP funded study of current industry practices as well as research publications, provides guidance that may be used where a project wishes to more formally integrate HFE into existing a HAZOP meeting.

Appendix 8 — HFE in HAZOP

8.1 Introduction and background

This appendix provides advice for improving consideration of Human Factors in the HAZOP process. This includes consideration of issues where human performance could:

- be a direct cause of deviations in a process (i.e. failure modes):
- form part of the mechanisms of failure:
- be relied on as part of safeguards against failure.

The aim of this appendix is to support a more systematic, practical and effective approach to including the consideration of human-related issues within the HAZOP process than is currently available.

8.1.1 Fundamentals of the HAZOP process

The procedure described here is based on a number of observations about the role and implementation of HAZOP in capital projects in the oil & gas industries. These include:

- Globally, HAZOP is very widely adopted as one of the key processes aimed at identifying potential causes of major incidents in petrochemical processes, and ensuring risks are adequately controlled through engineering controls.
- HAZOPs take the form of highly structured reviews of a process, focused on keeping the hazards "inside the pipe". The focus is mainly on the process and mechanical sub-systems, although reference is frequently made to operational tasks and organisational controls (procedures, etc).
- There are differences in how HAZOP is implemented across the industry. These include differences in the controls surrounding the quality of the HAZOP process itself, assurance that identified actions are implemented, and management of change following completion of the HAZOP process.
- HAZOP typically has a number of characteristic features, including:
  - It is performed by a team in a workshop environment (i.e. face-to-face)
  - It is led by an external chairperson, usually accredited as a HAZOP chairman by an approved industry body.
  - It is usually performed at least 2 levels of detail; a 'coarse HAZOP', performed early in Front End Engineering, and a 'Detailed HAZOP' performed during detailed design.
  - It is based around a systematic review of project documents representing the state of the process design (such as P&IDs and PEFs).
  - It proceeds as a systematic review of each point in the process flow at which there is potential for release or loss of control (referred to as 'nodes').
  - At each node, key process parameters are reviewed against a series of parameter-specific 'guide words' to help identify reasonably foreseeable causes of process deviations (e.g. the process parameter 'Pressure' might be reviewed against the Guide words 'Too High', 'Too Low', etc).
  - The HAZOP team is not usually concerned whether human error as such may be the cause of an unsafe condition, or how to prevent the error. They would simply consider a situation where, for example, a valve has been opened spuriously or not closed completely, etc.

8.1.2 Limitations of current practice

In some organisations - though not all - current HAZOP practice is limited in the extent to which it can be relied on to systematically consider the potential for Human Factors as causes or controls against process incidents. Reasons for this usually include:

- lack of adequate consideration during the HAZOP session of the context in which operators and maintainers work. (Important elements of context include; workplace stressors, communications issues, difficulties inherent in task performance arising from equipment design or layout, competing priorities, operator workload or even lack of awareness of the state of the plant and process at the time),
- unrealistic assumptions about human performance, ("an operator will be aware..."), allied to lack of awareness of previous incidents where human performance has been unreliable in a similar context.

8.1.3 Premises

The guidance described below is based on the following premises:

- Most members of a HAZOP team are aware of the potential for Human Factors to lead to process incidents. Training leading to accreditation of HAZOP chairpersons usually includes coverage of human sources of failure. However, few HAZOP team members have detailed training or awareness of the scope, range or complexity of human and organisational factors that can lead to major process incidents, or have had the opportunity to study research or investigations into loss of human reliability in the past.
- HAZOPs teams rarely include Human Factors professionals
- Consideration of potential sources of failure associated with nodes frequently discuss human-related causes. Similarly, human performance is frequently assumed as part of the defences against failure of a node (or recovery in case of node failure).
- HF-related terms are often included within guide words (Appendix 9 provides some examples). However, they are rarely applied systematically or with any real degree of technical rigour. While there may be exceptions, generally HAZOPs are led and attended by engineering professionals who do not have detailed understanding of the mechanisms by which human and organisational factors contribute to major incidents.

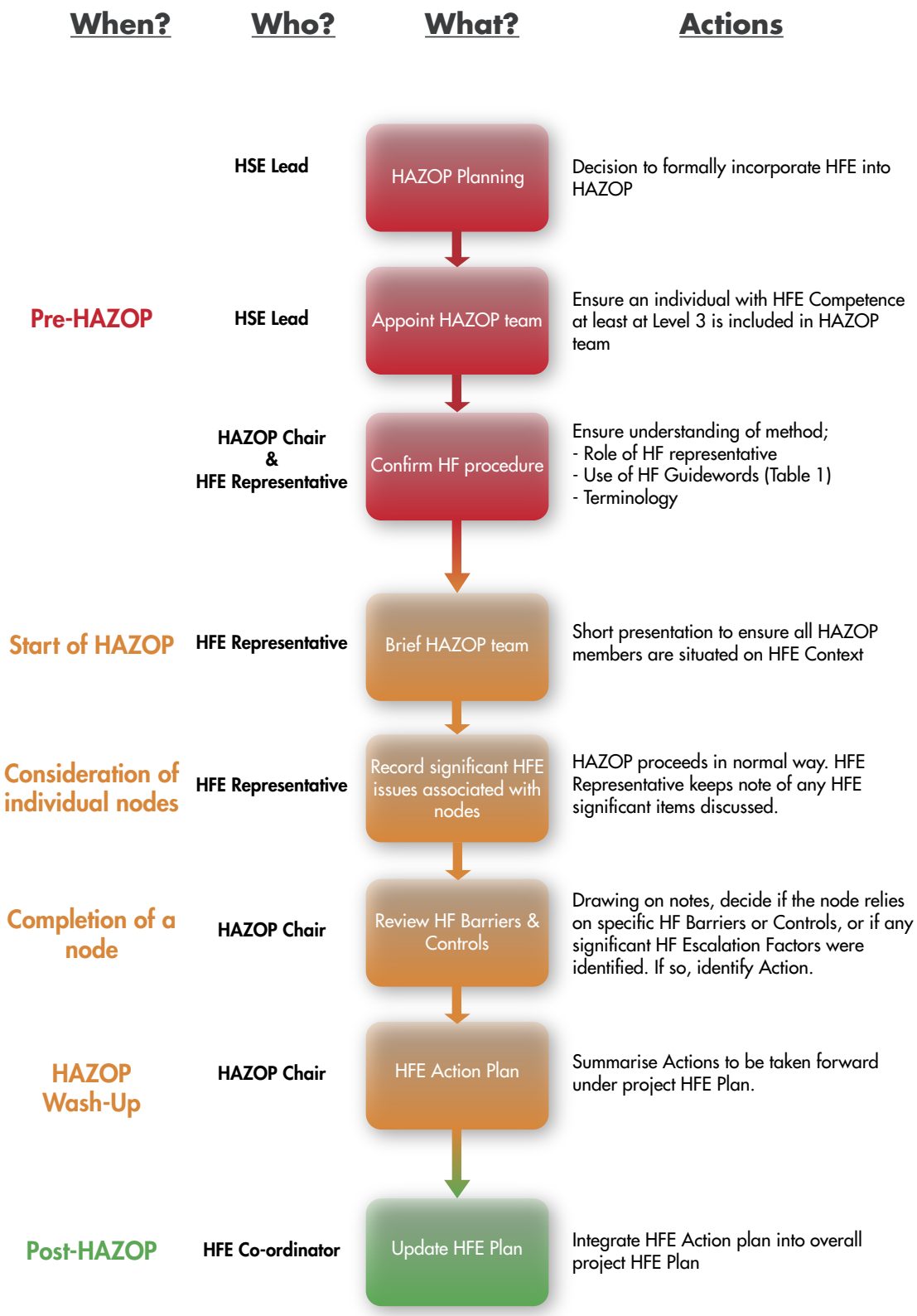
8.2 Recommended procedure for incorporating HF into HAZOP

This guidance is based on three key principles:

1. Extracting maximum value from existing HAZOP practices. (I.e. minimum change to practices already in widespread use).
2. Ensuring appropriate HFE competence within the HAZOP team.
3. Raising awareness among the HAZOP team of factors likely to impact on human performance and reliability at the asset, as well as the ability of the project to provide engineering solutions to identified risks. The aim is to try to prevent the HAZOP team from making unreasonable assumptions about the types of human behaviour and performance that can be expected.

Figure 8.1 summarises the guidance. The key steps are summarised in the following sub-sections.

Figure 8.1: Summary of process for incorporating Human Factors into HAZOP



8.2.1 Preparation for the HAZOP

As part of preparation, the individual responsible for performance of the HAZOP (for example the project HSE Manager), should perform 3 actions:

1. Determine whether there is a need to formally incorporate Human Factors considerations into the HAZOP. For example, this would be the case where:
   - The project does not have any other structured HF (or HFE) process.
   - The project is required to control potentially significant process or environmental risks.
   - Incorporation of HF into HAZOP is recommended in the project HFE Strategy.
2. If HFE is to be formally included in the HAZOP, appoint a competent person onto the HAZOP team as HF representative (see 'During the HAZOP' for recommendations on the role of the HF representative).
3. The HAZOP Chair and HF representative should meet prior to the HAZOP to clarify the procedure to be followed, ensure the HF Guide words to be used are clear and understood (Table 8.1), and resolve any issues of terminology.

8.2.2 During the HAZOP

1. Following the Introductions and scene-setting by the HAZOP chair, the HF representative should deliver a short briefing to the HAZOP team. The briefing should consider the items summarised in Appendix 10 to this Appendix.
2. The HAZOP should then proceed in the normal way under the leadership and using the Guide words selected by the Chair.
3. During discussion of Guide words associated with each node, the HFE representative should:
   - Contribute to the discussion as any other HAZOP member, focusing on issues relating to expectations about human performance as barriers, as controls to maintain barriers or in responding to incidents.
   - Make notes recording relevant items arising in the general discussion that relate to the team's expectations or assumptions about human performance.
   - As appropriate, bring to the HAZOP teams' attention known instances of human error relating to items under discussion.
   - As necessary, challenge assumptions made by the team about the standards of human performance or behaviour that can reasonably be expected at the asset.
4. Following completion of the discussion of the standard Guide words for each node, the Chair should invite the HF representative to summarise any significant human-issues identified. These should be focused on the HF-specific Guide words, shown on Table 1.

Table 8.1 – human factors guidewords

Guidewords	Meaning	Examples
Operational Barriers	Are there any specific human activities or behaviours expected of normal operations associated with the node that are directly relied on as a Barrier preventing an event or incident occurring, or to mitigate the consequences?	• Assuming the panel operator will always appreciate the significance of an alarm (e.g. fail to realise a known nuisance alarm is actually real in this instance). • Detecting signs of corrosion during visual inspection • Assuming that the operator will act on the correct unit or equipment (e.g. where an asset has multiple trains or similar units).
Maintenance Barriers	Is the HAZOP team aware of any instances where human performance or behaviour during maintenance has led to failure to properly maintain a safety critical barrier?	• Incorrect isolations. • Fitting of incorrect gasket on a manifold. • Replacing valves in wrong orientation following turnaround. • Fitting incorrectly threaded. • Taking oil sample from filter under pressure.
Escalation factors	Are there any credible factors specifically associated with the node that could increase the likelihood of human unreliability in operating or maintaining an identified safety barrier, or in responding to an event at the node?	• Particularly difficult tasks, especially involving complex cognition, reasoning or reliance on memory. • Lack of space causing poor accessibility • Difficult viewing conditions (sight lines, legibility, lighting, etc) • Associated safety hazards (hot surfaces, falls from height, radiation sources, etc) • PPE, breathing air or winter clothing • Particularly difficult or unpleasant working conditions.

8.2.3 After the HAZOP

Two typical deliverables from a HAZOP are the HAZOP Worksheets and the HAZOP Chairman's report. Both should contain a record / audit trail on key HF issues and assumptions.

Actions identified in response to HF issues will be of one of two types:

- Actions to be addressed within the main project HFE programme. (For example, these might be where the HAZOP recognised the critical importance of ensuring good access to a manual valve, clear and well positioned signage identifying the valve, and good visibility of the valve position indicator).
- Actions to be addressed by other disciplines. (For example, ensuring that the procurement specification for the manual valves includes a requirement for clear visual feedback of the valve position).

The HFE representative would be made the action party for actions to be integrated into the project HFE programme. Other actions would be assigned to the relevant disciplines.

The HAZOP Chairman's report

The HAZOP Chairman's report should include a section on HF, summarising how it was covered, (competence, awareness, guide words used), commenting on the quality and scope of human issues considered, issues and actions to be carried forward, and any key assumptions made about human capabilities, or organisational arrangements at the asset (roles, shift structures, manning, contractor responsibilities, etc).

Appendix 9 — Example of HF issues associated with traditional HAZOP guide words

Primary keywords (Parameters)	Modifier (guide words)	Comments	Example HF issues
Flow	No/None	Discussions of causes of No Flow in defined lines.	Operator closes valve in error or leaves valve closed after maintenance.
	Less/Low	Discussions of causes of Reduced Flow in defined lines, extreme consequences and safeguards are often identical to No Flow.	Operator calibrates a control valve (FCV) wrongly such that less flow goes through than required.
	More/High	Discussions of causes of Increased Flow in defined lines, more than would normally be expected.	As above but calibrated to allow more flow than required.
	Reverse	Discussions of causes of Reverse Flow in defined lines.	Possible manual valve misalignment breaching pressure interface and thus allowing reverse flow. Valve fitted in wrong orientation, or replaced in wrong orientation following maintenance.
	Misdirected	Discussions of causes of Flow being Misdirected into other lines, often already discussed under Reverse Flow but with additional causes such as PSVs and Drains passing.	Drain or vent valve most fully isolated after maintenance allowing some passing.

Appendix 10 — HAZOP team HF briefing

Table B1 summarises a range of issues that the HF Representative should consider when preparing the HF briefing recommended to be delivered at the start of a HAZOP meeting. The briefing should usually last no more than 30 minutes.

In preparing the briefing, the HF representative should consult with representatives from Operations and Maintenance.

Incident databases (such as SADIE) should be consulted to identify examples of incidents involving equipment or facilities with similarities with the nature of the project and where human factors were known to be significant.

For each item, a simple way to summarise the overall Human and Organisational context for the HAZOP team is to indicate the extent to which, from the available information, it seems fair to assumed that risks associated with each of the item are under reasonably control, using the following rating scale:

Table 10–1

+2	+1	0	-1	-2
There are strong grounds for being confident that risks associated with the item are well controlled at the asset.		Neutral. No objective reasons for being confident, or concerned.		There are strong grounds for concern that control of risk associated with the factor at the asset cannot be relied on.

For further information and publications,
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