

MANUAL

HUMAN FACTORS ENGINEERING - DESIGN AND PROCUREMENT OF SKID-PACKAGED UNITS

DEP 30.00.60.18-Gen.

November 2006

DESIGN AND ENGINEERING PRACTICE



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The objective is to set the recommended standard for good design and engineering practice applied by Shell companies operating an oil refinery, gas handling installation, chemical plant, oil and gas production facility, or any other such facility, and thereby to achieve maximum technical and economic benefit from standardization.

The information set forth in these publications is provided to Shell companies for their consideration and decision to implement. This is of particular importance where DEPs may not cover every requirement or diversity of condition at each locality. The system of DEPs is expected to be sufficiently flexible to allow individual Operating Units to adapt the information set forth in DEPs to their own environment and requirements.

When Contractors or Manufacturers/Suppliers use DEPs they shall be solely responsible for the quality of work and the attainment of the required design and engineering standards. In particular, for those requirements not specifically covered, the Principal will expect them to follow those design and engineering practices which will achieve the same level of integrity as reflected in the DEPs. If in doubt, the Contractor or Manufacturer/Supplier shall, without detracting from his own responsibility, consult the Principal or its technical advisor.

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- 1) Operating Units having a Service Agreement with Shell GSI or other Shell Service Company. The use of DEPs by these Operating Units is subject in all respects to the terms and conditions of the relevant Service Agreement.
- 2) Other parties who are authorized to use DEPs subject to appropriate contractual arrangements (whether as part of a Service Agreement or otherwise).
- 3) Contractors/subcontractors and Manufacturers/Suppliers under a contract with users referred to under 1) or 2) which requires that tenders for projects, materials supplied or - generally - work performed on behalf of the said users comply with the relevant standards.

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All administrative queries should be directed to the DEP Administrator in Shell GSI.

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1. INTRODUCTION

1.1 SCOPE

This new DEP specifies requirements and gives recommendations for the Human Factors Engineering (HFE) aspects to be applied to skid-packaged units in order to achieve the required levels of operability and maintainability and to comply with Shell Minimum Health Management Standards.

This DEP should be read in conjunction with other HFE DEPs in the 30.00.60.xx series.

1.2 DISTRIBUTION, INTENDED USE AND REGULATORY CONSIDERATIONS

Unless otherwise authorised by Shell GSI, the distribution of this DEP is confined to Shell companies and, where necessary, to Contractors and Manufacturers/Suppliers nominated by them.

This DEP is intended for use in oil refineries, chemical plants, gas plants, exploration and production facilities and supply/distribution installations.

When DEPs are applied, a Management of Change (MOC) process should be implemented; this is of particular importance when existing facilities are to be modified.

If national and/or local regulations exist in which some of the requirements may be more stringent than in this DEP, the Contractor shall determine by careful scrutiny which of the requirements are the more stringent and which combination of requirements will be acceptable with regard to the safety, environmental, economic and legal aspects. In all cases the Contractor shall inform the Principal of any deviation from the requirements of this DEP which is considered to be necessary in order to comply with national and/or local regulations. The Principal may then negotiate with the Authorities concerned, the objective being to obtain agreement to follow this DEP as closely as possible.

1.3 DEFINITIONS

1.3.1 General definitions

The **Contractor** is the party that carries out all or part of the design, engineering, procurement, construction, commissioning or management of a project or operation of a facility. The Principal may undertake all or part of the duties of the Contractor.

The **Vendor** is the party that manufactures or supplies equipment and services to perform the duties specified by the Contractor.

The **Principal** is the party that initiates the project and ultimately pays for its design and construction. The Principal will generally specify the technical requirements. The Principal may also include an agent or consultant, authorised to act for, and on behalf of the Principal.

The word **shall** indicates a requirement.

The word **should** indicates a recommendation.

1.3.2 Specific definitions

skid-packaged unit equipment designed and supplied as a largely self-contained physical unit, and mounted on a portable skid. Skid-packaged units are designed, built and tested at the Vendor's premises and delivered for integration into the overall plant.

operability and maintainability ease and efficiency of performance of operational and maintenance activities during all phases of the project and during the life of the facility, with all HSE risks kept as low as reasonably practicable.

1.3.3 Abbreviations

FAT	Factory Acceptance Test
FEEEM [®]	Front End Ergonomics Evaluation Matrix design analysis
HFE	Human Factors Engineering (often used synonymously with "Ergonomics Engineering")
SAT	Site Acceptance Test
EMIS [®]	Ergonomics Management and Information System

1.4 CROSS-REFERENCES

Where cross-references to other parts of this DEP are made, the referenced section number is shown in brackets. Other documents referenced by this DEP are listed in (4).

1.5 CONFLICTING REQUIREMENTS

Compliance with the ergonomic requirements shall not relieve the Vendor of the obligation to follow sound engineering practice throughout.

In case of conflicting requirements with any other specification or standard issued on the project, the Vendor shall notify the Contractor for resolution.

1.6 COMMENTS ON THIS DEP

Comments on this DEP may be sent to the DEP Administrator at standards@shell.com. Shell staff may also post comments on this DEP on the Surface Global Network (SGN) under the Standards folder.

2. BACKGROUND INFORMATION

2.1 GENERAL

A significant proportion of equipment is procured in the form of skid-packaged units. Examples of typical skid-packaged units include:

Large:

- Generators, Compressors
- Turbines
- Motor Controlled / Switchgear buildings (MCCs)

Medium:

- Chemical Injection units
- Fire water pumps
- Sand-wash units

Small:

- Utility air compressor units
- Hydraulic power units (HPUs)
- Wire-line units
- Vent snuffing units

Experience from many areas shows significant variation in the application of standards in the design and procurement of skid-packaged units. Although over-application of standards can lead to increased costs and/or reduced performance, failure to apply standards can be much more expensive in terms of total life-cycle costs.

2.2 APPLICATION OF HFE

HFE is the process of integrating human capabilities, limitations, requirements and expectations into the design of products, workplaces and work systems (plant and facilities) to ensure effective, efficient, safe and healthy functioning of human beings, thereby improving operational and maintenance task performance. Benefits of effective HFE in design can be both tangible (such as improved utilisation and performance of assets and resources and reduced overheads) and non-tangible (reduced risk, improved working conditions, improved workforce motivation, etc.).

2.3 KEY PRINCIPLES OF HFE DESIGN ANALYSIS PROCESS FOR SKID-PACKAGED UNITS

The HFE design analysis is based on the following principles:

- The process can be applied quickly and efficiently. It must however be led by an individual with appropriate HFE Competence (as defined in DEP 30.00.60.10-Gen.). It also requires input from Operations and Maintenance representatives.
- The process is integrated with the overall Shell HFE Process as defined in the Yellow Guide 'Human Factors Engineering in Projects' and in DEP 30.00.60.10-Gen. The overall process ensures compliance with Shell Minimum Health Management Standards.

- HFE effort must be focused on areas where there are significant opportunities to add value by either reducing HSE risk or improving asset performance. The process therefore concentrates on skid-packaged units that are considered critical to the asset in terms of HSE or Production, **and** that require significant levels of human interaction for operation or maintenance.
- For procurements assessed as critical and with significant human interaction, HFE quality controls, commensurate with the risks and opportunities identified, should be applied to the design and development process.
- Skid procurements that are entirely off-the-shelf are handled differently from projects where the procurement includes design activity.

2.4 AIMS AND BENEFITS

The quality of design of skid-packaged units in the area of HFE (including what was traditionally known as “Ergonomics”) can often be greatly improved. Poor HFE design in skid-packaged units has been found to impact business performance in a number of ways:

- Avoidable accidents and lost-time injuries;
- Inefficiency in operations and maintenance, such as maintenance activities being more complex, and requiring longer shut-downs than necessary;
- Potential for human error arising from poor layout of controls and displays, as well as difficulty in accessing and operating valves.

DEP 30.00.60.12-Gen. provides a tool for assessing whether any proposed changes to skid designs arising from HFE analysis can be justified in terms of the benefits sought.

2.5 TIMING OF PROCESS

The HFE process should be initiated during Front End Engineering, as soon as it is reasonably clear which work systems are likely to be procured as skid-packaged units.

The requirement to apply this process should be identified as part of the HFE Input Analysis (required by DEP 30.00.60.10-Gen. and in compliance with Shell Minimum Health Management Standards).

3. HFE DESIGN ANALYSIS OF SKID-PACKAGED UNITS

3.1 PROCESS DESCRIPTION

Figure 1 summarises the steps involved in implementing this DEP.

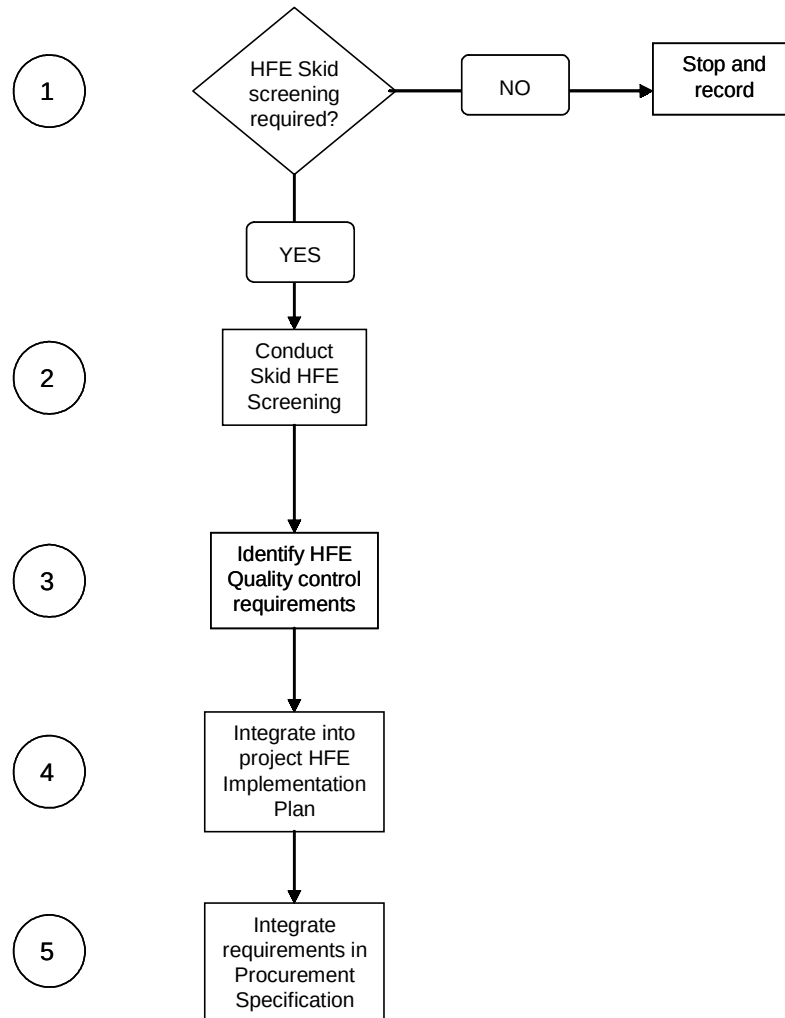


Figure 1 Flow scheme of activities for HFE skid analysis

3.2 KEY STEPS OF FIGURE 1

1. Is an HFE Skid Screening required?

The project manager, supported by the project HFE Coordinator, is responsible for deciding whether the scope of the project justifies a more detailed HFE screening of likely skid units. This can be efficiently carried out as part of the project HFE Input Analysis (required by DEP 30.00.60.10-Gen. and in compliance with Shell Minimum Health Management Standards).

2. Arrange and conduct an HFE screening for skid-packaged units

The screening should be carried out as early as realistically feasible, as soon as the likely scope of skid units involved in the project has been identified. The screening shall be conducted in advance of the project's 10 % cost estimate.

The screening requires HFE Competence at the Skilled level (see DEP 30.00.60.10-Gen.). Appendix A provides a tool for carrying out the screening.

As a minimum, the following stakeholders shall be involved:

- Operations and Maintenance representatives;
- Discipline engineer responsible for each skid-packaged unit;
- Other disciplines, depending on the nature, and particularly the newness of design, of the packages to be assessed;
- Construction engineer, if appropriate.

The output of the screening is a categorisation (1 – HFE Critical, or 2 – HFE Non-Critical) of each skid unit expected to be procured.

3. Decide what level of HFE Quality Control to apply

HFE Quality Control activities shall be defined for each unit identified as Category 1 – HFE Critical. Appendix B provides guidance on identifying the level of design control to be applied to each type of procurement.

For units identified as Category 2 – Non HFE Critical, no special HFE quality control requirements are required, although the design should comply with basic HFE 'good practice', including relevant industry and international standards. The following standards provide general specifications of 'good practice' in HFE/ Ergonomic design:

- Human Factors / Ergonomics Handbook for the design for ease of maintenance. US Department of Energy DOE-HDBK-1140-2001 Feb 2001, Parts 1,2,3.
- Guidance notes for the application of ergonomics to marine systems, American Bureau of Shipping.

Units categorised as being HFE critical shall comply with the HFE Principles in Appendix C. So far as possible, they should also comply with the specific HFE requirements in Appendix D.

This step will depend on the type of skid procurements involved. For the purposes of controlling HFE design quality, skid units fall into three types:

- Entirely 'off-the-shelf'; i.e. units that have already been designed. (Such units are often operational at other facilities and installations).
- Hybrid; i.e. an otherwise off-the-shelf item modified to meet specific project requirements.
- Largely new design, where the Vendor's scope of supply includes responsibility for design of the unit. Typically, the design work involves integrating a number of smaller off-the-shelf components into a single skid-packaged unit.

4. Integrate agreed HFE activity into the project HFE Implementation Plan

If the overall HFE Input Analysis identifies the need for further HFE activity, DEP 30.00.60.10-Gen. requires that an HFE Implementation Plan be prepared as a means of planning, estimating and managing this effort.

If HFE activities are necessary to control the HFE design quality of skid units, the project's overall HFE Implementation Plan shall include a section on skid-packaged units, including a plan of action, and the required competencies, resources and deliverables.

5. Integrate HFE requirements into Procurement.

Where Step 3 has identified the need for HFE Quality Control or for compliance with specific HFE requirements, this shall be reflected in the procurement process.

Step 5 involves ensuring that appropriate content is included in Procurement Specifications, and that Vendors are required to explain how they will meet the HFE requirements, including demonstrating their competence and access to resources.

Step 5 includes ensuring that reasonable and sufficient budget is allowed for HFE activities. The HFE Cost-Justification tool (DEP 30.00.60.12-Gen.) can be applied to determine whether the additional costs of HFE effort are justified by the overall life-cycle benefits.

3.3 SUMMARY OF RESPONSIBILITIES

STEPS	RESPONSIBILITIES						
	Project Manager	HFE Coordinator*	HFE specialist	Lead Skid Engineers	Operations/ Maintenance	Other PT Members (inc. HSE and Tech Safety)	Procurement
Decide whether an HFE Skid Screening is required	APP	EXE	CHK	CON	CON	CON	
Conduct HFE Skid Screening	APP	CON	EXE	CON	CON	CON	
Identify HFE Quality control requirements	APP	CON	EXE	CHK			
Integrate into HFE Implementation Plan	APP	EXE	CHK	CHK	CHK		
Integrate HFE requirements into Procurement	APP	CON	CHK	CHK			EXE
* The HFE Coordinator shall have the required K level competence to organise the HFE analysis process. If in doubt, the Coordinator should be supported by an HFE Specialist (Skilled level).							

Key:

EXE = Execute

CON = Contribute

CHK = Check, verify results;

APP = Approve;

SUP = Support

4. REFERENCES

In this DEP, reference is made to the following publications:

- NOTES:
1. Unless specifically designated by date, the latest edition of each publication shall be used, together with any amendments/supplements/revisions thereto.
 2. The DEPs and most referenced external standards are available to Shell staff on the SWW (Shell Wide Web) at <http://sww05.europe.shell.com/standards>.

SHELL STANDARDS

Human factors engineering in projects	DEP 30.00.60.10-Gen.
Human factors engineering – investment justification model	DEP 30.00.60.12-Gen.
Human factors engineering - valve analysis	DEP 30.00.60.13-Gen.
Front end ergonomic evaluation matrix - FEEEM [®] Design analysis	EMIS.PMQ.02
Human factors engineering audit of engineering contractors	EMIS.PMQ.09

AMERICAN STANDARDS

Human factors/ergonomics handbook for the design for ease of maintenance	DOE-HDBK-1140-2001
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Issued by:
U.S. Department of Energy
AREA HFAC,
1000 Independence Avenue, SW
Washington, D.C. 20585,
USA

Guidance notes for the application of ergonomics to marine systems	ABS 86
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Issued by:
American Bureau of Shipping,
ABS Publications,
16855 Northchase Dr,
Houston, TX 77060,
USA

INTERNATIONAL STANDARDS

Ergonomic requirements for the design of displays and control actuators - Part 1: Human interactions with displays and control actuators	ISO 9355-1
--	------------

Environmental management systems – Requirements with guidance for use	ISO 14001
---	-----------

Issued by:
International Organisation for Standardisation
Case Postale 56
Geneva 20 Switzerland CH-1211

Copies can also be obtained from national standards organizations.

APPENDIX A GUIDANCE ON SKID CATEGORISATION

Step 2 of the HFE Design Analysis for skid-packaged units involves categorising skid units as either:

- Category 1 – HFE Critical. Units that EITHER are critical in terms of Health, Safety, Environmental protection or Production OR entail complex, very frequent or novel operational and/or maintenance activity.
- Category 2 – HFE Non-Critical. Units not critical in terms of HSE or Production, AND entailing simple, infrequent and familiar operational and maintenance activity.

The following steps can be used to carry out the categorisation. These steps should be applied for every skid-packaged unit expected to be procured. Table A.3 can be used to record the results for each unit.

Step A1 Assess Criticality of the skid unit

Use Table A.1 to assess the potential criticality of the unit in terms of health, safety, environment and production.

The rating of unit criticality is based on the highest rating on any of the four categories. For example:

1. If the unit is assessed on Table A.1 as “Yes” for Safety, but “No” for all other categories, the overall rating is “Yes” – the unit is considered critical in at least one of the categories.
2. If the Unit is assessed on Table A.1 as “Probably” for Environment, and “Possibly” for the other categories, the overall rating is “Probably” – the unit should be treated as “Probably” being critical.

Step A2 Assess Task Complexity

Use Table A.2 to estimate the complexity of operational and maintenance tasks likely to be performed with the unit.

This task shall be performed with input from Operations and Maintenance.

It should draw on previous experience and lessons learned from units considered similar either in terms of the functions/ processes performed, or in the experience of the likely Vendor.

If either Operations or Maintenance tasks are assessed as “Complex”, overall task complexity is considered to be “Complex” (in Step A3).

If both Operations and Maintenance are assessed as “Simple”, overall task complexity is considered to be “Simple” (in Step A3).

For any other combinations, task complexity is considered “Moderate”.

Step A3 Identify level of HFE Design Control Policy

With the results of the assessments in Steps A1 and A2, use this matrix to categorise the skid in terms of HFE Criticality.

If unit criticality and task complexity do not clearly fall into a category, use Step A4 (as shown on the following matrix).

Unit Criticality (from Table A.1)	Yes	Cat 1	Cat 1	Cat 1
	Probably	? Apply Step 4	? Apply Step 4	Cat 1
	Possibly	Cat 2	? Apply Step 4	? Apply Step 4
	No	Cat 2	Cat 2	Cat 2
		Simple	Moderate	Complex
Task Complexity (from Table A.2)				

Step A4 Assess Task Frequency and Novelty

(Reminder: Step A4 is only performed if it has not been possible to categorise a skid unit in terms of criticality and task complexity alone).

This step shall be answered with input from Operations and Maintenance representatives.

Consider the assessment of the complexity of operational and maintenance tasks (from Step A2) and answer the following question:

- *Are any of these tasks likely to be performed frequently: i.e. (nominally) more often than about once every 3 months?*

If the answer to this question, for EITHER Operations or Maintenance, is "Yes", then the unit is Category 1 – HFE Critical.

If the answers are both "No", answer the following question:

- *Are any of the tasks considered particularly time consuming, novel, or significantly different from tasks that the personnel at the facility or installation are currently familiar with?*

If the answer to this question, for either Operations or Maintenance, is "Yes", then the unit is Category 1 – HFE Critical. If the answer for BOTH roles is "No", then the unit is Category 2 – HFE Non-Critical.

Table A.1 Assessment of unit criticality

Category	Consideration	No	Possibly	Probably	Yes
Health	Could the unit be considered to have a Critical impact on Health? Will Procedures, PPE, or other measures be needed to prevent operators or maintainers being exposed to serious health hazards associated with working with the unit?				
Safety	Could the unit be considered to be safety critical? Are there reasonably foreseeable circumstances where failure of this equipment, or human error, could lead to fire, explosion, spillage of toxic or highly corrosive materials, or impairment of the ability to respond to emergency situations?				
Environment	Could the unit be considered to be environmentally critical? Are there reasonably foreseeable circumstances where failure of this equipment or human error could lead to spillage or release of hydrocarbons or other materials controlled under ISO 14001 requirements?				
Availability/ Production	Could the unit be considered to be critical to production? Are there reasonably foreseeable circumstances, where loss of availability of the equipment for even a short time, would lead to reduction or loss of production? NOTE: It is assumed here that the likelihood of loss of availability could be reduced by a better Human Machine Interface design.				

Table A.2 Estimation of task complexity

Role	Task Descriptions	Complexity
Operations	Operators probably need to perform only a few tasks with the unit.	Simple
	AND The tasks involved are inherently simple, mainly discrete actions with minimal cognitive demand (pressing buttons, reading instruments or checking valves, etc.).	Complex
	EITHER: Operators probably need to routinely carry out a reasonably large number of tasks (nominally more than 10) with the unit. OR Although there are only a few operational tasks, experience suggests the tasks could be difficult, complex or time consuming or require very high reliability.	
	Neither of the above	Moderate
Maintenance	Maintenance staff probably needs to perform only a few tasks with the unit.	Simple
	AND The tasks involved are inherently simple, mainly discrete actions - such as pressing buttons, reading instruments or checking valves, etc.	Complex
	EITHER: Maintenance staff probably needs to routinely carry out a reasonably large number of tasks (nominally more than 10) with the unit. OR Although there are only a few maintenance tasks, experience suggests the tasks could be difficult, complex or time consuming, or require very high reliability.	
	Neither of the above	Moderate

Table A.3 Summary sheet for skid unit HFE criticality screening

[illegible]

APPENDIX B GUIDANCE ON HFE QUALITY CONTROL REQUIREMENTS

B.1 GENERAL

This Appendix provides guidance on assuring the HFE design quality of skid-packaged units identified as being Category 1 - HFE Critical (Step A2 of the HFE design analysis for skid-packaged units).

These design assurance activities shall be performed either by the Principal (project team), or by the Contractor, or as part of the skid package Vendor's scope of supply.

The required level of HFE quality control depends on the type of skid-packaged unit involved. Three identifiably different types are identified in Step 3 of the process (off-the-shelf, new design and hybrid).

Skid-packaged units that are entirely off-the-shelf are handled differently than those which are custom-designed.

B.2 OFF-THE-SHELF SKID PACKAGES

B.2.1 Usage

This section applies to off-the-shelf skid-packaged units categorised as Category 1 - HFE Critical.

B.2.2 Process

Procurement of off-the-shelf skids should follow the steps shown in Figure B.1.

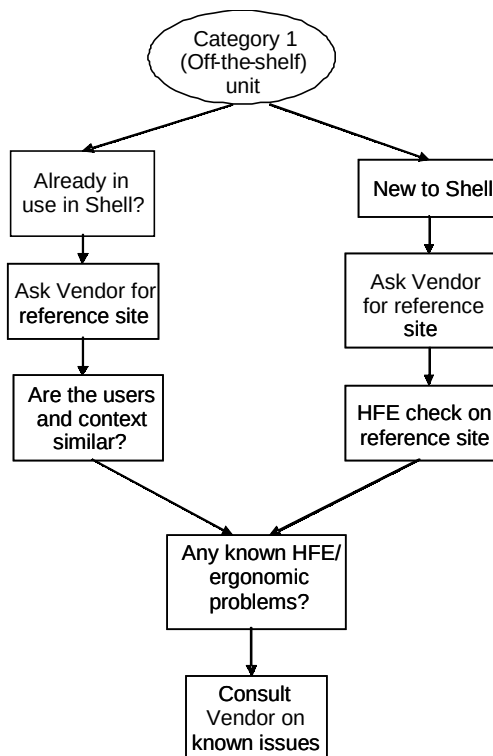


Figure B.1 Summary of process for Category 1 – HFE critical off-the-shelf skid units

Steps in Figure B.1 are as follows:

- Step B1 Vendors will know if the skid-packaged unit they are offering is of a type already in use within Shell. If it is, determine whether the proposed usage is significantly different from previous Shell applications in terms of the characteristics of the user population, the work organisation, or the working environment. In particular:
- Significant differences in body sizes (for example, a unit designed for US or North European users may not be suitable for users in Asia).
 - Significant differences in language and culture (for example, technicians in Asia not being able to read English well; switches are flipped down to turn machines on, while they are flipped up in the US).
 - Significant differences in work environment (e.g. a unit suitable for an onshore tropical environment may not be suitable for use in arctic or offshore conditions).
- Step B2 Ask the Vendor to supply a reference site within Shell. Find out if previous Shell applications have experienced serious operability, maintainability or other HFE issues associated with the units. Just because equipment is in operation within Shell does not mean that it is well designed from an HFE perspective: experience has shown that corrective action is taken if equipment fails or malfunctions, but it is rarely reported that equipment is difficult to operate or maintain due to poor HFE design.
- Step B3 If the skid-packaged unit has not previously been used within Shell, the Vendor should be asked for information on the user population and work environment at other installations. If possible, the Vendor should be asked to supply details of a reference site, and feedback should be requested on the usability and ergonomics of the units.

Any serious HFE issues identified in Steps B1, B2 or B3 should be reviewed and discussed with the Vendor with a view to minimising the potential impact on HSE performance and productivity.

B.3 HYBRID AND NEW DESIGN SKIDS

B.3.1 Usage

The requirements in this section apply to skid-packaged units categorised as Category 1 - HFE Critical featuring either an entirely new design, or significant modification to an existing design.

B.3.2 Prior to contract

Prior to placing a procurement contract for the unit the Contractor should carry out the following activities:

- Ensure potential Vendors have appropriate competence in HFE (EMIS.PMQ.09 provides a method for assessing competence).
- Ensure relevant material is included in the Invitation to Tender to achieve compliance with this DEP.
- Prepare a summary of important characteristics of the target user population (see Appendix C) and anticipated work environment.
- Ensure realistic space is available for the intended skid-packaged unit and clearly specify from which sides of the skid-packaged units there will be access at the installed site.

B.3.3 Vendor tenders

As part of their tender response, Vendors should:

- Identify which HFE or Ergonomic standard they intend to comply with. Should a Vendor propose his own in-house standard, this shall be approved by an HFE Specialist.
- Provide an HFE Implementation Plan covering, as a minimum, the items covered below (under Post-Contract).
- Confirm his intention and ability to comply with Appendix C of this DEP.
- Identify the design tools proposed to assist designers, engineers, and operator and maintainer representatives to review the layout. As a minimum, composition layout drawings shall be proposed showing all elements, which occupy physical space, in order to enable adequate detailed reviews of Operations and Maintenance aspects. Depending on the complexity of the work, the use of 3-CAD-system or plastic design model may be required.
- Provide a summary of ways in which Human Factors and Ergonomics considerations have been implemented in the proposed solution or design changes.
- Provide details of areas of the design where opportunities to improve the HFE quality of the design have been considered, but have not been proposed or implemented due to other constraints (including cost).
- Provide details of areas where changes to existing components required to satisfy the requirements of this DEP will influence cost and/or delivery.

B.3.4 Post-contract

Once a contract has been awarded, and, before detail design is 30 % complete, the Vendor shall:

- Ensure he or she assigns responsibility for management of HFE design quality to individuals having at least a Knowledge level of competence (as defined in DEP 30.00.60.10-Gen), with access to individuals with Skilled levels of competence, as may be required by the scope and complexity of the HFE design activity.
- Identify and assess the key functions and high-level tasks involved in operating and maintaining each unit, using either the Front End Ergonomics Evaluation Matrix (FEEEM[®], see EMIS EMIS.PMQ.02) or an equivalent focused Task Analysis approach.
- Ensure that important requirements identified through the Task Analysis as necessary to support safe and efficient human performance are documented and used in generating and evaluating design options.
- Hold one or more HFE Design reviews (depending on the complexity of the human interaction)

Before detail design is 60 % complete, the Vendor shall:

- Hold a further design review demonstrating that HFE actions and changes identified at the 30 % review have been adequately resolved.

Once the equipment has been built, but before installation on-site, the Vendor shall:

- Hold an Operability and Maintainability walk-through as part of FAT, to demonstrate that the key tasks identified via the FEEEM[®] or equivalent Task Analysis are adequately supported in the solution.

Once the equipment has been installed on-site, the Vendor shall:

- Hold an Operability and Maintainability walk-through as part of the SAT, to ensure that installation and field run equipment has not violated the HFE design intent.

APPENDIX C HFE DESIGN SPECIFICATIONS

This Appendix provides guidance and technical specifications on design issues that are known to have caused difficulties in operating or maintaining skids on Shell assets.

C.1 PRINCIPLES

C.1.1 Human characteristics

Vendors should be given guidance on relevant characteristics of the population expected to operate and/or maintain the units. This is particularly important where items are procured for use in countries other than the country where the unit is designed.

The guidance needed will vary between projects and between types of skid-packaged units. The following information should always be taken into account:

- Details of the range of body sizes of the target workforce, whether both male and female operators are to be accommodated, and the range of body sizes to be allowed for in the design (such as 5th to 95th percentile stature). This may be derived from standard national anthropometric data. Commercial software packages are available providing relevant dimensions.
- The extent to which the technology or process supported by the skid-packaged unit is likely to be familiar to the target workforce, and areas that are significantly new or different from previous local experience.
- Type of clothing, including personal protective equipment expected to be worn by those working with the skid units.

C.1.2 Working posture

The skid unit should be designed so that no operator or maintainer has to adopt working postures that are awkward or uncomfortable, or require working with the hands at or above shoulder height or below knee height in order to perform routine tasks.

Where awkward or uncomfortable postures are unavoidable due to other design constraints, this is only acceptable for tasks that are performed infrequently and are of low priority.

Operators shall never be required to sustain working postures for extended periods that involve twisting or bending of the spine, or excessive extension or rotation of the neck or limbs.

C.1.3 Layout

Layout of skid-packaged units shall be such that operational and maintenance activities can be carried out in a way which makes efficient use of manpower, minimises the likelihood of human error, avoids placing operators or maintainers in situations that might damage their health or safety, and gives adequate warnings of dangers with adequate means of escape.

A design should never require operators or maintainers to perform work where they cannot see what they are doing, whether due to obstructions from equipment items or due to poor lighting.

A list of priorities, preferably identified by the Vendor using FEEEM ® design analysis or a similar task analysis method, should be prepared for each unit. This should indicate the frequency of required operator attendance or maintenance of machines or machine parts.

If HFE considerations have to be weighed up against other design aspects, frequently operated/maintained components shall be given high priority.

Components should be arranged so that those requiring human intervention are not obstructed (e.g. cabinet in front of a filter, cables in front of a valve, etc.). Wherever possible, components should not have to be dismantled to gain access for maintenance.

Items requiring regular visual inspection (e.g. reading of gauges and visual inspection for leaks or signs of corrosion) should be located so that they are clearly visible and accessible (at eye level) from adjacent walkways.

All components requiring regular maintenance and/or operation should be easily accessible from adjacent walkways.

As far as practical, operation and maintenance should be possible from outside the skid/unit.

Layout shall take adequate account of the final positioning and orientation of the skid, taking account of issues such as access and clearance, line-of-sight requirements, communications, and potential sources of glare.

C.1.4 Work environment

The design of skid units, and the work entailed in operating and maintaining them, shall take into account and be appropriate for the anticipated work environment. Factors to be considered include the following:

- Local weather conditions (extremes of heat or cold, wind, monsoon rain, etc.). Rain may make walkway surfaces slippery, and possibly obscure gauges and window displays. Regular heavy snow may mean that significant manual effort is needed to keep walkways and access points clear.
- Local lighting at the expected site of the unit (both natural and artificial lighting).
- Noise, whether produced by the skid itself or emanating from machinery nearby.

C.2 DRAWINGS

The general arrangement and layout drawings for skid-packaged units, including local control panel layout drawings, should be sufficiently detailed to allow a check for compliance with HFE principles and specifications. Drawings should include the proposed routing of cable trays and instrument impulse tubing or piping. Instead of drawings a 3-D computer model is preferred.

APPENDIX D SPECIFIC HFE REQUIREMENTS

D.1 BASE FRAMES FOR MACHINERY

Base plates that are designed with walkway areas which are higher than 350 mm above grade, shall be equipped with a guard railing surrounding the walkway area. Guardrails of the tubular type are preferred. If frequent access is required and if the top of the machine base frame is higher than 450 mm, stairway access to the base frame should be considered.

Corners of base frames located adjacent to walkways and which may present a tripping hazard shall be guarded by a railing to safely divert operators around these corners.

Drain pans under base frames shall be covered with open grating of suitable strength. The pans shall be completely self-draining with no liquid retention. Grating shall be removable in sufficient areas to allow cleaning, inspection and painting of these drain pans.

Base frames for equipment drivers greater than 15 kW shall have jacking screws to facilitate motor alignment in both horizontal directions.

Machinery cover bolting on major equipment items shall be accessible for removal and tightening without personnel having to climb on surrounding equipment. Couplings and their guards shall be accessible from both sides. The provision of sufficient access between machinery components by use of spacer couplings should be considered.

Noise enclosures shall be easily removable and divided into manageable sizes with permanent lifting lugs on sections with a mass greater than 20 kg (20 kg is the maximum for 1 person to lift. 40 kg is the maximum for 2 persons to lift. Above 40 kg some form of assisted lifting device is required). Frequently observed gauges and frequently checked controls shall be positioned outside noise enclosures. This requirement governs whether the noise enclosure is close fitting or of the 'walk in' type.

D.2 OPERATION AND MAINTENANCE SPACES

The free space around and above machinery or machinery parts shall depend on the dimensions of tools, tool handling, and the need for temporary laying down of parts during maintenance. In general the free space should not be less than 900 mm wide and 2100 mm high.

Adequate space for efficient and rapid access and egress shall be provided to all areas for operations and maintenance personnel.

D.3 STATIC AND ROTATING EQUIPMENT

Manholes, handholes, coupling guards, covers, junction boxes etc. shall never be obscured by stairs, ladders, railings, piping, conduit, etc.

Machinery guards over rotating parts of the unit shall be at least strong enough to support a heavy man standing on them. The shape and orientation of the guards shall discourage the use of the guard as a platform. It shall not be possible to remove the guard without correct tools; quick fasteners or similar shall not be used.

Machinery requiring frequent observation or maintenance should be set at table height so that it does not require operators to adopt a bent posture (700 mm to centreline for pumps etc. is suggested as a guide).

Pumps/compressors/turbines shall be located at the outside of the skid. A hoisting method shall be available, with free hoisting space provided.

Driving gear (belts, chains) and cogwheel units should be located at the outside of the skid. The design shall ensure ease of dismantling and sufficient workspace to allow ease of access for routine adjustments of belts/chains etc.

Where balanced torquing is required as part of maintenance activities, the design shall minimise the likelihood of operator error.

D.4 ELECTRICAL COMPONENTS

Junction boxes shall be sited so that terminal strips are between 1000 mm and 1500 mm above the flooring. Cable shall enter these boxes from the underside. Junction box covers shall not be obstructed or obstructing and shall be easily accessible.

Horizontal runs of cable trays and conduits shall be installed so as not to obstruct access or visibility of machinery requiring inspection or interaction during operations or maintenance.

Equipment installation height shall take into account motor cable installation and the space required by the minimum bending radius of the cable. Motor connection boxes shall, wherever possible, have removable gland plates to assist cable connection.

Cables shall be routed so that accessibility during machine maintenance is not restricted. Removal of cable during maintenance is not allowed.

Electric motors shall preferably be located at the outside of the skid.

D.5 INSTRUMENTATION

All instruments and valves required for controlled start-up or emergency shut down of the unit shall be mounted at the same side of the unit and be easily accessible/visible from adjacent walkways.

Frequently monitored instruments shall be mounted at eye level and shall be readable sequentially from a single observation point on a walkway adjacent to the unit.

Electrical or mechanical (capillary tubing) connections to instruments shall be of ample length or coiled sufficiently to allow easy dismounting and mounting. Excess coils of capillary tubing shall be tied back neatly so that they do not become entangled in maintenance tools during maintenance.

Instruments shall be mounted at a height that allows access for routine maintenance and calibration without requiring awkward or uncomfortable working postures.

D.6 LOCAL CONTROL PANELS

Indicators and controls in local panels shall be oriented to ensure consistency in reading and operation, and shall be consistent with local conventions (e.g. all indicators pointers indicating in same direction when in normal operation; all switches pointing the same way for 'Open' or 'Closed'). Graduations shall be static and pointers moveable.

The arrangement and physical location of displays, control switches and push buttons depends on the importance of these instruments. This is based on a 3 level classification:

Class 1 instruments (very important OR frequently used – e.g. more than once per month)

Class 2 instruments (less important AND infrequently used – e.g. less than once per 6 months)

Class 3 instruments (occasionally used, or used as a back-up or for reference only)

In the case of Class 3 instruments, Vendors should clarify why they are required and any conditions in which they could become important.

Displays and arrangements of push buttons, indicators and switches on instrument panels shall mimic the physical orientation and layout of the components on the skid-packaged unit in order to present the operator with a logical sequence of operation relative to the layout and the process. ISO 9355-1 specifies ergonomic principles such as grouping, functional allocation, etc. that will help reduce operator error and the risk of injury.

The front of the panel shall be divided into the following zones (dimensions as measured from the operating floor).

Height above walkway	Control switches and push buttons, including individually mounted push buttons, switches and indicators.	Display windows
1800 mm	Class 2, 3	Class 2, 3
1600 mm (eye level) ¹		Class 1
1400 mm (shoulder height) ²	Class 1	
1200 mm		
1000 mm (elbow height) ³		
500 mm to 1000 mm		
0 mm to 500 mm	No displays or controls	

- NOTE:
1. Eye level of 5th percentile Asian males is 1470 mm.
 2. Shoulder height of 5th percentile Asian males is 1300 mm.
 3. Elbow height of 5th percentile Asian males is 950 mm.

The anthropometric criteria of the target user population should be defined as part of the project specification document.

Displays with LEDs shall be protected against direct illumination by sunlight as they then become poorly readable and difficult to interpret.

D.7 PIPING ARRANGEMENTS

Pipe flanges that require frequent disconnection shall be installed at a height between 600 mm and 1400 mm (e.g. 1300 mm for Asian population) above standing level. Only if this is not feasible should a permanent or moveable platform be considered to allow easy access.

Pipe spools with a mass of more than 40 kg (maximum lifting weight for 2 persons) that require frequent removal (e.g. more than once per year) for maintenance shall be equipped with hoisting lugs. Alternatively, straps/slides may be used if this can be done safely. Flange bolting of these pipes shall be accessible with good visibility of flange face conditions. Pipe spools shall be installed without stress and the necessity for flange jacking screws. These pipes shall be capable of complete draining by gravity and be suitably sectioned in length to allow easy removal without interfering with other pipelines.

Auxiliary piping that needs to be run in close proximity to the major equipment (lube oil, cooling water, nitrogen lines) shall be routed at as low an elevation as possible to maximize accessibility for maintenance.

Piping runs for flow measurement instruments, where height, straight lengths and instrument orientation are of critical importance, shall be positioned so as to allow access for maintenance and calibration without compromising the operational installation requirement. The minimum height of horizontal piping for non in-line flow measurement instruments may exceed 600 mm if the transmitters are positioned below the taps.

D.8 VALVES

The Vendor shall complete the Identification Valve Analysis procedure defined in DEP 30.00.60.13-Gen. Valve accessibility and operation shall be designed in accordance with the resulting classification of valves on the skid unit (i.e. category 1, 2 or 3).

The fitting of protruding (horizontal) spindles of valves, e.g. in walkways, shall be avoided.

Operation of low mounted valves shall not be hindered by protruding machine parts.

Valve positions, spindle lengths and orientation shall be shown in the arrangement drawings.

D.9 LUBRICATION, SEAL SYSTEMS AND GREASING SYSTEMS

Lubrication and seal buffer systems shall not obstruct any space identified as being required for operational, maintenance or other activities.

Grease nipples for manually operated grease guns shall be easily accessible and situated so that they can be used without having to adopt an awkward or uncomfortable working posture.

Oil drains, if not permanently piped, shall be suitable for hose attachment for gravity draining into a small container.

Oil sumps with a volume of 25 litres or more shall be equipped with either a facility for vacuum removal of oil or a fixed pump out system, integral with an auxiliary oil pump and pipelines to a storage/disposal tank.

Seal buffer liquid vessels for mechanical sealing shall be easily accessible for refilling, draining and maintenance. When frequent refilling is required then the installation of a special platform shall be considered.

D.10 HOISTING FACILITIES

Lifting of any component with a mass of more than 40 kg (maximum lifting weight for 2 persons) shall be possible by pedestal crane, mobile crane, forklift truck, beam clamp & hoist etc. Where this is not practical or possible, permanent hoisting facilities shall be provided.

The arrangement of equipment on a base frame shall, when specified, allow the use of hoisting equipment such as (small) mobile cranes. Vendors shall advise where hoisting access is recommended.

Machines containing heavy parts requiring special guides or trolleys etc. for precision fitting (turbine rotors, impeller rotors, motor rotors) shall have ample access and viewing space to safely remove and install those parts with precision control.

D.11 INSTRUCTIONS ON MACHINERY

Nameplates, equipment labels and instructions on machinery shall be positioned and have letters of adequate size and suitable font so as to be legible for personnel in the standing position (eye level) under the poorest lighting conditions expected. Safety notices shall be durable, non-removable and prominent.