1 Introduction

The purpose of this document is to support project engineers and designers to integrate human factors into projects.

This document is intentionally not comprehensive and can only define minimum requirements. Designers should be able to demonstrate that they have selected the best solution that optimised human performance and minimises risks to As Low As Reasonably Practicable (ALARP). The demonstration should include reference to standards, guidance and good practices. To achieve this designers should be able to demonstrate that Inherent Safety has been an objective in the design by:

- Specifying non-hazardous processes wherever possible and minimising hazards where elimination is not reasonably practicable;
- Ensuring all aspects of the system are as simple as reasonably practicable;
- Selecting and designing equipment to be reliable and fail safe;
- Creating a design that is based on reasonable assumptions of staffing arrangements during construction, commissioning and operations phases.

Additionally, designers should be able to demonstrate that residual risks can be managed effectively by applying the hierarchy of risk controls that balances use of engineered systems, administrative controls, mitigation and emergency response.

1.1 Objectives

The focus for human factors in projects should be the interaction between the human and the work system. The overall objective is to design systems, jobs and organisations that match human capabilities and limitations.

Avoiding or reducing risks during projects is considered to be reasonably practicable, and the earlier this is addressed the more effective the outcome is likely to be. This includes designing-out human performance problems and increasing the likelihood that human failures that do occur will be detected and mitigated effectively.

1.2 Implementation strategy

It should be the designers' responsibility to ensure that human factors requirements are fully understood and to demonstrate that an optimum solution has been achieved. In doing this the following strategy should be applied:

- The design process should be 'user led' so that end user requirements' (e.g., process operators, maintenance technicians, tanker drivers) are properly understood, documented, and integrated into the design.
- Potential human factors risks should be identified and evaluated. They should be eliminated through design wherever possible, whilst ensuring transfer of risk is avoided (i.e. replacing one risk with another).
- Residual human factors risks should be identified, and methods of control should be demonstrated as achieving risks to ALARP;

- The required level of human factors competence applied during the project should be determined according to the level of risk, complexity and novelty.

1.3 Achieving risk that is ALARP

The designers should be able to demonstrate that their design achieves a level of human factors risk that cannot reasonably be reduced further because the remaining options are unfeasible, impractical or ineffective. This should be achieved by applying the hierarchy of risk controls in a sound and sensible way, based on a thorough understanding of how the system will be used (e.g. operated and maintained). Assessments should recognise uncertainty due to novelty of design where applicable.

2 Physical design for people

Physical arrangements of the plant should be designed for the normal range of the intended population with the smallest person being the female 5% percentile and the largest the male 95% percentile. Manual activities requiring human strength (e.g. operating valves, lifting objects) should be possible by the female 5% percentile without risk of physical harm.

As a guide for UK projects the range of human height to be accommodated in the design should be minimum 1,500mm and maximum 1,900mm.

Use of Personal Protective Equipment (PPE) should be factored into the size ranges (i.e. additional height created by safety helmets or girth created by breathing apparatus).

Suggested minimum requirements for physical design are suggested below. An exercise should be carried out early in a project to review and modify the specification.

2.1 Walkway width

Designers should be able to demonstrate that access and egress routes including doors and manways are large enough for people, tools and equipment that may need to pass.

Minimum width:

- Normal walkway – 900mm
- Major / emergency walkway (including stretcher use) – 1200mm

2.2 Head clearance

Minimum head clearance

- Over walkways or stairs – 2100mm

Be careful of items crossing above stairs because the impact on head clearance may not be immediately apparent during design.

2.3 Work space / platform dimensions

Designers should be able to demonstrate that the layout of the plant provides work areas that are large enough for tasks (e.g. operations and maintenance) to be performed. If routine or urgent work will have to be performed at elevated heights, suitably sized platforms should be provided.

Minimum size of work space at ground level or permanent platform:

- Length x width – 900mm x 900mm .

This is for a single person working alone with basic hand tools. Larger sizes should be provided if more than one person needs to be present to perform a task, and to accommodate tools and equipment laydown where appropriate.

Demonstrating that work areas are acceptable should be based on a comprehensive task list for the plant / equipment.

2.4 Vertical access

Preferred options for people to traverse vertical height changes are a sloped ramp or stairs. Ladders can be provided for infrequent access (weekly) and as secondary escape:

- Stairs:
    - Height of stair tread – 160 to 220mm;
    - Minimum depth of stair tread – 200mm;
    - Maximum number of stairs between landings – 20;
    - Minimum dimension of stair landings – 1600mm;
- Slopes:
    - Maximum slope for ramp pedestrian traffic - 15°;
    - Maximum slope for materials handling - 7°.
- Ladders:
    - Space between ladder rungs – 230 to 300mm;
    - Maximum length of ladder between landings – 7000mm;
    - Minimum space behind ladder rungs – 200mm;

Ladders should be arranged so that the person steps sideways at the top when getting on / off (i.e. side-step not step-over).

Working from ladders or stairs should be avoided and only considered for very simple tasks requiring minimal force. Any situations where working from ladders is being considered should be documented with a full justification by the designers and receive approval from the relevant parties.

2.5 Hand rails

Minimum height for handrails:

- Around platforms, and along walkways and stairs – 1100mm.

2.6 Displays and controls (including manual valves)

Wherever possible, all operable and maintainable items shall be located to provide easy access for someone working from ground level or a permanent platform. However, it is recognised that this may not always be possible and/or desirable. Accessibility should be based on the following principles:

- Items requiring frequent (monthly) or urgent use shall be provided with permanent access that will allow the person to maintain optimum posture and reach (may be defined as Category 1 items);
- Items accessed less frequently (6 monthly) shall be provided with access that will allow the person to maintain acceptable posture and reach. This may

include use of a mobile platform, which will be provided by the project (may be defined as Category 2 items);
- Items accessed very rarely (less than every 2 years) may not be provided with access and temporary access (e.g. scaffold) would be used (may be defined as Category 3). A clear justification shall be recorded and planning systems shall be in place to ensure the provision of access is ensured before a task is expected to commence.

Preferred heights (for Category 1):

- Maximum height – 1300mm;
- Minimum height – 450mm;
- Minimum clearance in front – 700mm;
- Maximum forward reach (i.e. over an obstruction) – 400mm.

Acceptable heights for Category 2):

- Maximum height – 1800mm;
- Minimum height – 300mm;
- Minimum clearance in front – 700mm;
- Maximum forward reach (i.e. over an obstruction) – 600mm.

Temporary access (e.g. scaffold, scissor lift) can be used for less frequently used items (annual), as long as urgent access is not required. A purpose built mobile platform may be provided for more frequently used items if permanent access cannot reasonably be provided to achieve the maximum height specified above.

Process requirements have to be taken into account when deciding if access is possible from ground level, and in some instances may dictate access that is not consistent with the guidance above. Where this occurs a specific justification shall be made identifying risk mitigation that ensures risks are ALARP.

It should be recognised that manually operated valves are a potential source of human factors risk both to the individual from manual handling and the process due to time taken to operate. Actuators or motors should be considered for valves that are large, may require a large 'cracking' force or sustained effort to operate, are operated very frequently or may have to be operated in an emergency (see below).

2.7 Actuated valves

Actuated valves reduce operational requirements but can create significant maintenance issues due to the size of actuators (including structural support due to increased weight). If the requirement for actuators is identified late in the project, after plant and pipework layout has been fixed, it can be impossible to provide safe access for preventative and corrective maintenance.

A Valve Criticality Analysis (or similar) should be carried out to determine functional importance of each valve (safety, production), operational scenarios for use (especially emergencies), failure modes and consequences. This process is likely to identify requirements for actuating valves beyond the purely human factors issues identified above. Also, it will indicate maintenance frequency. This analysis should be carried out early in the project, particularly for larger valves, to ensure sufficient space allocation; and reviewed as the project progresses.

2.8 Maintenance access

Dismantling and remaking flanged joints using hand or powered tools, and other similar tasks requires space for the people and tools to be used. More than one person may be involved and / or access may be required on two or more sides of the joint, particularly for larger items.

Minimum clearance between the item being accessed and adjacent items (e.g. pipework, structures):

- Edge of flange to obstruction when using hand tools – 150mm;
- Edge of flange to obstruction for large pipework where person may need to stand between flange and obstruction – 500mm;
- Front or edge of flange from floor – 300mm.

Allowance should be made for insulation / lagging, ice build-up (low temperature systems) and clearance for bolt removal (i.e. length of bolt).

2.9 Manway sizes

Manways should be large enough for the intended primary user. Actual sizes should take into account use of Personal Protective Equipment (PPE), Breathing Apparatus (BA), and emergency cases (e.g. use of stretcher or harness for evacuation).

Manway dimensions:

- Circular manway, minimum internal diameter – 610mm;
- Circular manway, preferred minimum internal diameter – 815mm;
- Square manway, minimum internal dimension – 610mm.

2.10 Manual handling

Manual handling includes lifting, pushing and pulling.

Maximum weights for objects to be lifted by people:

- Single person – 25kg;
- Two people – 40kg.

Weight is only one consideration and the above figures are a guideline only and not considered as a blanket criteria. All manual handling should be evaluated, taking into account frequency of lifting by the person, posture used when lifting (affected by working space, obstructions etc.) and grip on object (provide handles or similar whenever possible). Mechanical handling devices should be available for all items heavier than above and should be considered as an alternative for all manual handling as long as it is practical and realistic.

Forces for pushing and pulling objects

- Maximum force when starting or stopping a push / pull action – 150 N;
- Maximum force to keep a load in motion – 70 N.

2.11 Manual valve operation

Opening and closing of manual valves, and number of turns should be within reasonable human capabilities:

- Maximum cracking force (to start moving): 800 N
- Maximum sustained force (to continue moving to open / closed) – 200 N.

If this is not possible the valve should be actuated / motorised. Use of levers (e.g. valve key) or portable actuators should only be considered after confirming the valve construction is sufficient to withstand the additional forces that may be applied.

2.12 Hot / cold surfaces

Protect people from hot and cold surfaces by insulation or barriers that prevent contact.

Surface temperatures that people can come into contact with:

- Hottest surface temperature – 60°C;
- Coldest surface temperature – -10°C.

3 Supporting reliable human performance

There are many aspects of design that cannot be specified with objective measures. It is important that designers understand their responsibility is to develop optimum solutions (not just follow standards).

3.1 Layout guidelines

Consistency and logic should be the aims when laying out plant and equipment:

- Orientate similar items the same way (avoid mirror images);
- Arrange items in a logical order, following local conventions (e.g. left to right);
- Make operation of controls intuitive;
- Ensure visibility of displays from a safe location;
- Provide easy access without having to move or disconnect items (e.g. piping or cabling);
- Protect fragile items.

3.2 Labels and signage

Signs, labels, tags, markings etc. should be provided to support human reliability in operations and maintenance. Content of labels:

- Use the local language(s);
- Use pictograms where possible (make sure they are used consistently and understood by users);
- Only use abbreviations that are commonly understood;
- Use units of measurement consistently;
- Use San Serif font.

Text size and spacing:

- Viewing distance less than 1 metre – 5mm;
- Viewing distance less than 3 metres – 15mm;
- Viewing distance more than 3 metres – 30mm;
- Space between characters - 40% of character;
- Space between words - width of one character;
- Space between lines - ½ character height.

Every valve, instrument and operable item should have a defined tag number that is displayed on the item. All plant and equipment (e.g. tanks, vessels, pumps etc.) and critical valves and instruments should have signs or labels showing tag number and description.

Pipework should be labelled at regular intervals (visible from strategic locations around the site) showing the material handled and direction of flow.

Safety and warning signs should comply with local standards for colour etc.

Materials used to make signs, labels and tags, and all printing should be resistant to the local environment and plant conditions. Methods of attachment should be compatible with the materials (i.e. avoid dissimilar metals and corrosive adhesives, and ensure moisture cannot be trapped).

Colour can be used to reinforce messages but should not be relied on. As a minimum, colour coded signs should have text and/or pictograms to confirm meaning.

3.3 Panel and console design

Controls and indicators should be labelled clearly and consistently. It should be obvious which label relates to which item and the label should be visible when being used (i.e. not obstructed by the person's hand).

Local gauges and controls should be designed for consistency across the site. The aspects of design covered include:

- Orientation of switch (up or down) for on and off;
- Rotation direction (clockwise or anti-clockwise) for increase and decrease;
- Colour convention (red and greed) for on and off;
- Units of measurement;
- Decimal places for digital readouts.

3.4 Lighting

Designers should be able to demonstrate that the lighting design will provide the levels of illuminance required for safe personal movement around site and for tasks that may be performed routinely or urgently. Temporary lighting should only be considered for non-routine tasks.

The type of lighting used should ensure that rendering of critical colours and legibility of displays is not compromised. For areas where people will be located routinely (e.g. control rooms) the selection of lamp type including colour should take account of wellbeing.

Minimum lighting levels at the point where people will be working:

- Site roads – 5 Lux;
- General process areas – 50 Lux;
- Break rooms – 100 Lux;
- Rotating equipment, sample points, local panels – 200 Lux;
- Reception areas, corridors, washrooms in offices – 200 Lux;
- Offices – 300 Lux (ideally adjustable plus task lighting);
- Workshops – 700 Lux;

- Process control rooms – adjustable at each console desk 200 – 1,000 Lux plus task lighting.

3.5 Noise

Designers should be able to demonstrate that the noise levels will be safe, not interfere with communication and enhance wellbeing.

Maximum noise levels:

- Offices and other quiet areas – 45 dB;
- Background in work areas – 65 dB;
- Plant areas – 75 dB;

Noise levels of 80 dB and above (background or as the result of high noise events) should be identified as hearing protection areas. The effect on communication should be considered.

3.6 Use of Automation

Designers should be able to demonstrate that suitable "allocation of function" has been used to implement automation in the design to achieve overall risks that are ALARP and to support reliable operation. This will be achieved by balancing technical safety advantages with potential negative effects on human factors including situational awareness and competence management.

3.7 Human machine interfaces (HMI)

A separate specification should be developed if new HMI are being introduced. It may be part of a Control Room specification (see below), although HMI can be introduced in many different places. Designers should be able to demonstrate that HMI follow consistent designs and have been optimised for operations in all modes of operation. Appropriate standards, guidance and good practice should be applied (e.g. EEMUA 201).

An HMI specification should cover the following:

- Use of colour for static and dynamic elements;
- Use of symbols;
- Page structure and navigation;
- Page footers and headers;
- Types of data displays (numerical, graphical and trends);
- Alarm display;
- Subjective requirements (logical layout, not cluttered).

3.8 Control room design

A separate specification should be developed if new control room is being introduced or an existing one is being modified significantly. Designers should be able to demonstrate that control rooms have been optimised for operations in all modes of operation. Appropriate standards, guidance and good practice should be applied (e.g. EEMUA 201).

3.9 Alarm management

A separate specification should be developed if new alarms are being introduced or existing ones are being modified significantly. Designers should be able to demonstrate alarm management principles applied in the design are consistent with human factors principles and will support safe and reliable operation. Alarms should only be configured where a timely action is required by a process operator to reduce reliance on engineered controls. Appropriate standards, guidance and good practice should be applied (e.g. EEMUA 191).

Highly Managed Alarms (HMA) should be avoided through design where reasonably practicable. If any are required, the designers should ensure that they can be used effectively to manage risks to ALARP.

M: 07984 284642 www.abrisk.co.uk E: andy.brazier@gmail.com