Human Factors in New Facility Design Tool

API Human Factors Task Force

Regulatory Analysis & Scientific Affairs Department

SECOND EDITION, OCTOBER 2005

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Purpose

This document describes a Human Factors Tool (or "Tool", as it will be described throughout the rest of this document) that may be used by operating plants as an aid to incorporate human factors principles in the design of equipment that will be operated and maintained by people.

Scope

This document focuses only on equipment design. Items such as human error, behavior-based safety, and operating procedure issues are not in the scope.

The Tool covers equipment that is common to both upstream producing and downstream manufacturing operations. Equipment associated with specific activities, such as drilling rigs is not specifically addressed. The human factors principles described in this document are intended for new equipment designs; however, many ideas provided in this Tool may be used to improve the operation of existing plants, where feasible.

Applicability

This Tool is applicable to equipment that is operated and maintained by people working in manufacturing plants. It is for use whenever one is trying to assess hazards associated with the equipment design process.

The human factors principles described here are intended to complement proper equipment designs, effective operating procedures and appropriate plant management systems to help eliminate unwanted incidents. This Tool is not a complete design standard for applying human factors in plant equipment designs. Companies are expected to use this Tool as a starting point in developing their own specific human factors design standards.

Structure of Tool

The Tool consists of three columns: Human Factor Issue, Example Situation, and Potential Solution. The topics addressed in each column are intended to be a representative sample of key issues and are by no means all-inclusive.

- The "Human Factors Issue" column addresses key human factors issues, or problems, related to various types of equipment.
- The "Example Situation" column provides examples of situations where the human factors issue in the first column may manifest itself. The purpose of this column is only to provide clarification of the specific human factors issue described in the first column and to aid the user in understanding that issue.
- The "Potential Solution" column provides ideas for actions that may be taken to address the human factors issue mentioned in the first column. Operating plants are encouraged to identify their own best solution(s) for their individual situations.

How to Use the Tool

The way this Tool will be applied in operating plants will depend on the specific project management systems used by each company. The expectation is that operating plants will use the Tool as the basis for creating their own human factors design standards for plant equipment and/or for incorporating the Tool contents into their existing design standards. Operating plants are encouraged to enhance their specific standards with

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additional site-specific and/or different human factors issues and/or potential solutions that are not presently included in the Tool.

The Tool is best applied during the early design phases of projects where early hazard identification and risk assessments are utilized in the overall risk management support of the project. Depending on a specific company's project management system, this could include the planning phase, the equipment design phase, and possibly through the construction and startup phases, since safety personnel are always trying to identify potential hazards during all stages of a project. Different parts of the Tool will be more applicable during one phase than another. Companies are encouraged to apply the different parts of the Tool to their specific project management systems. Following are some examples of how the Tool may be applied during the various phases of a project:

1. Planning / Design Considerations / Front End Loading Phase:

    In the initial phases of a project the human factors design standards and requirements for equipment are agreed upon and a plan is prepared on how the human factors considerations will be incorporated into the project equipment designs. During this phase the Tool may be used to help determine spacing requirements, especially around the larger equipment.

    For example, paragraph 14B (p. 40) of the Tool points out that for reactors containing toxic catalyst enough space should be provided to allow for proper catalyst removal. Similar spacing/accessing requirements are provided throughout the Tool as in paragraph 13E (p. 39) for machinery and 18E (p. 47) for exchanger valves. All these considerations need to be made in the early phases of the project to ensure that adequate plot plan spacing is provided.

2. Detailed Design Phase:

    Application of human factors principles is most prevalent during the detailed design phase of projects, usually during preliminary hazard identification and risk assessment studies.

    Essentially all equipment addressed in the Tool has at least one paragraph with requirements that need to be specified during the detailed design phase of the project. For example, Tool paragraph 9A (p. 31) may be used to appropriately locate the furnace pilot fuel valve and the igniter. Similarly, paragraph 17A (p. 44) addresses the human needs for accessing tank instrumentation. Paragraphs 1A (p. 5) on alarm management and 4A (p. 19) on emergency egress from substations are two more examples of how the Tool may be used to apply human factors in plant designs.

    During the model review phase of the project the design specifications made during the detailed design phase can be confirmed and/or altered/corrected.

    Technological advances are making it increasingly possible and financially acceptable to use 3-Dimensional (3-D) computer models in projects of all sizes. 3-D visualization of plant layouts during model reviews is making it easier to apply human factors principles during plant designs, particularly in the area of equipment access for both operations and maintenance. 3-D models may be used to confirm or correct the designs specified during the detailed design phase and may also be used to apply many of the human factors potential solutions provided in the Tool.

    For example, a 3-D model review may be the most appropriate way to determine whether a fire monitor has a clear line of sight to a fire-prone piece of equipment, as described in the Tool paragraph 5A (p. 23). Similarly, paragraph 9E (p. 31) may be more appropriately applied during the model review phase to identify access to specific equipment for both operations and maintenance personnel. Other examples

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where the Tool may be best applied during model reviews is paragraph 15A (p. 41), where access to safety showers is discussed; paragraph 4H (p. 20), where access to electrical equipment is mentioned; and paragraph 16F (p. 43), where the extension bars to ladder safety gauges on elevated platforms are discussed.

3. Construction/Startup Phase:

The Tool may also be utilized during the construction and/or startup phases of projects. At this stage, most of the human factors principles covered in the planning and design phases will be confirmed and evaluated against the completed design parameters, detailed equipment locations, and general operating/maintenance environment.

For example, as described in paragraph 5F (p. 24), on field alarms, the actual noise level surrounding a certain piece of equipment or unit during startup may make it necessary to increase the alarm sound level to ensure that personnel working nearby can hear it and evacuate the unit in an emergency. Similarly, paragraph 7C (p. 28) that addresses glare on field control panels and consoles may be applicable during the final project phases. Other examples include the application of Tool paragraph 10F (p. 33) on proper labeling of pipes and paragraph, and 4M (p. 22) on labeling and signage of electrical controls and displays. Other examples may be found in the Tool Section 11 (p. 34), on labeling / signage of process equipment, and in Section 20 (p. 49), on work environment.

Economic Discussion

A key component for the successful application of human factors principles in plant equipment designs depends on support and understanding from management on the need for, and benefits of, human factors application in plant equipment designs. The early application of human factors principles during a project design actually costs less than if human factors principles are not applied at all, or are applied after the equipment has been constructed and started-up.

One API member company recently estimated that the net cost of applying human factors to the design of an entire chemical plant unit was only 0.025 percent of the total project cost. This is considerably less than the project savings resulting from the absence of construction rework that is often necessary in many projects. In the particular chemical plant unit studied, most of the human factors principles were applied without any cost at all by arranging the equipment correctly as it was being built.

Another API member company performed a study in the mid-1990s and found that around 6-6.5 percent of the construction cost was saved in eliminating rework. This particular company implemented a process in the design phase to address human factors issues and then followed-up by working with the contractors for training, auditing, etc.

In cases where human factors principles are applied to an existing plant there is a cost associated with the retrofit. If human factors principles are applied early in a project, however, then the overall project cost is actually reduced because everything is done correctly the first time and there is no need for any rework.

In addition to reduced project cost, application of human factors can result in more efficient operations and reduced accidents. Understanding these cost/benefit issues is key to successful implementation of this Tool and application of human factors principles in general.

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Application of Tool in Existing Facilities

The Tool is primarily intended, and is more effective, for new facilities that are designed with human factors principles in mind; however, many of the issues identified in this Tool may also be used to improve the operation of existing plants where desired.

For example, Tool paragraph 2C (p. 9) on the presence of bleed and drain valves around pipeline blind locations, and paragraph 9D (p. 31) on provisions of motor operated valves (MOVs) for frequently decoked furnaces are two instances where the Tool can be useful during HAZOP reviews. Additional examples may be found in paragraph 10Ba (p. 33) on instrument isolation and paragraph 1D (p. 5) on determining alarm priority. In the case of valves, using the Tool promotes development of a qualitatively ranked list of all the valves that need attention from a human factors perspective. The list can be compiled with the help of operators who have been using the valves. A plan can thus be developed to replace or modify valves, as appropriate, using the guidelines provided in the Tool's "Potential Solution" column, or by taking other appropriate actions to resolve any specific issues that may not by addressed by the Tool.

The following scenarios are merely examples for illustration purposes only. (Each company should develop its own approach.) They are not to be considered exclusive or exhaustive in nature. API makes no warranties, express or implied for reliance on or any omissions from the information

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Human Factors Issue	Example Situation	Comment / Potential Solution
1. Alarm Management		
1A. Alarm limits do not provide early warning to the operator to enable a response before unit failure or shutdown.	1. A high-high alarm on a storage tank tripped the pump supplying product to the tank and sent the product to flare.	a. Design alarm system to: (1) Detect the process problem (2) Clearly indicate the severity of the problem to the operator (3) Guide the operator to diagnose the process condition (4) Allow sufficient time for the operator to correct the problem
1B. High priority alarms are ganged or grouped.	1. The operator assumed that the group alarm was referring to a problem fin fan, when in fact it was telling him that the uninterrupted power supply for the control system computer had malfunctioned. Several hours later, the control system failed and fires started.	a. Do NOT design the alarm system so it: (1) Annoys the operator with irrelevant process conditions (2) Repetitively tells the operator what he already knows (3) Confuses the operator with unclear information (4) Distracts the operator from urgent tasks (5) Misdirects the operator as to the process condition
1C. There is no formal process to define alarms and to maintain alarm design and configuration.	1. Definitions varied for the same alarms on different Distributed Control Systems (DCS) in the same plant.	a. Develop formal alarm philosophy process designed to establish: (1) Common definitions and purpose for the alarm system (2) Common design methodologies, such as how to establish alarm priorities (3) Design requirements
1D. There are many Priority 1 (High) alarms.	1. 30% of the unit alarms were classified as “Priority 1 high alarms”. As a result, the operator spent much of his time handling and clearing alarms.	a. Define the two major factors that determine alarm priority: (1) Consequence of failure to correct the process problem, and (2) Amount of time that the operator has to correct the problem b. Rule of thumb: (1) Priority 1 (high) alarms should account for 10 – 15% of the total number of alarms (2) Priority 2 (Medium) alarms should account for 70 – 80%, and (3) Priority 3 (Low) should account for 10-15%

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Human Factors Issue	Example Situation	Comment / Potential Solution
1E. There are many priority alarm levels and auditory alerting tones.	1. The operator was away from the console and missed an alarm because he thought it was from a neighboring console.	a. Number of alarm tones should be limited so the operator of a console recognizes that the tones come from his console. Moreover, directional speakers will restrict the spread of the sound to a small area. If the operator is away from the console, a light could advise him of the onset and priority of an incoming alarm. b. Limit the number of priority alarm levels to three (3) and the number of auditory alerting tones to three (3).
1F. Different criteria for alarm priorities exist in different process areas of same plant.	1. An experienced operator was filling in at another unit. He assumed that the alarm he received provided him with 30 minutes to correct the condition. Instead, on this unit, the alarm was high priority and the unit failed in 15-minutes before he could solve the problem.	a. Ensure that the criteria used for determining alarm priorities are consistent across the entire process plant. Adding the time and consequence information into the alarm message would have informed the operator of its urgency. Both experienced and novice operators could benefit from this.
1G. No hard wiring for High Priority alarms.	1. Due to a momentary computer failure, a Priority 1 alarm was missed on the DCS.	a. Ensure that the DCS and hard-wired alarms are appropriately integrated. b. Similar information on high priority alarms on a hard-wired panel would provide redundancy for the operator.
1H. No list of disabled or inhibited alarms.	1. The operator was unaware that a specific abnormal plant condition would not be annunciated.	a. Provide users with easy access to a list of alarms that are disabled and inhibited. b. An operator should be advised when one or more alarms are disabled. The operator then should be able to call up a single view and be able to see a list of all disabled or inhibited alarms.
1I. No systematic way of documenting alarm configuration changes.	1. An alarm setting was altered to change the behavior of the alarm system. But, when the temporary condition cleared, the operator did not reset the alarm.	a. Provide information on alarm configuration settings that deviate from design values. b. Operators should be advised that a deviation exists and be able to easily access the information and reset the alarm.

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Human Factors Issue	Example Situation	Comment / Potential Solution
1J. Alarms in computer cannot be listed according to priority.	1. The operator coming on shift did not see that a priority alarm had not cleared because the alarms were sorted by time of occurrence rather than priority.	a. Design the system so operators can organize active alarms by priority, time of occurrence, unit or subsystem b. One keystroke sorting would permit the operator to first examine Priority 1 (High) alarms, and then quickly reset to identify the other alarms on the same unit leading to quick diagnosis and resolution.
1K. Inadequate information provided on alarms.	1. Alarm message did not contain the control valve number, so, the operator sent the outside technician to the wrong location.	a. Design alarm messages to be clear, contain enough information for the operator to diagnose the problem, and be consistent across the plant. b. The alarm message should provide all of the information that the operator needs to determine what happened, when it happened, where it happened, and the best approach to solve the problem.
1L. High-priority alarms are not visible in a panel on the bottom or side of every DCS display.	1. During an upset, the operator had to replace the alarm screen with a plant screen. As a result, he did not have information on a high priority alarm and did not know that it had cleared.	a. Design a unique auditory display (tone) for high-priority alarms and ensure that the high-priority alarms are always visible to the operator.
1M. There is no clear indication that a certain alarm clears.	1. The operator was not advised that an alarm had cleared and was still working on a solution.	a. Design alarm system to alert operators when the process condition that initiated the alarm clears. b. Design alarm systems with a "ring-back" feature that alerts operator when alarms clear.
1N. A suppression system for low-priority alarms does not exist.	1. During an upset, the operator received many alarms that masked the real process condition and delayed response to it.	a. Use alarm suppression to minimize alarm floods during upset conditions. Operators should not be able to suppress critical (high-priority) alarms. b. Logic in the alarm management software should suppress alarms such as low pressure and low flow, when the equipment has shut down.

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Human Factors Issue	Example Situation	Comment / Potential Solution
1O. Low priority alarms cannot be temporarily disabled when a significantly large activity of alarms is taking place.	1. An operator temporarily disabled a lower priority alarm to concentrate on higher priority alarms. The operator forgot to manually reset the auditory display following the disabling of a lower priority alarm. Thus, the operator was not reminded again later.	a. Allow for temporary disabling of the auditory displays on low priority alarms for a fixed duration when there is a significant rate of alarm activity. b. It is important that any disabling or changes from design specifications be temporary or be set-up so each operator is continually reminded of the changes. Operators should not be expected to remember temporary changes that are made to the operating systems.
1P. Initial alarms are not captured when a series of alarms are received and acknowledged.	1. Owing to an alarm flood, the operator was unable to recall what the first alarm was that he received.	a. Capture first-in alarms during an upset for later examination. b. When operators are distracted by events, such as an alarm flood, they are unable to recall information in short-term memory. Capturing the information on the first-in alarms will help the operators diagnose the situation.
1Q. The Piping & Instrumentation Diagrams (P&IDs) do not show alarm information.	1. The Hazard & Operability (HAZOP) review process is not equipped with a technique that would permit alarm information to be captured during the review of the process and instrumentation drawings (P&IDs).	a. Integrate the alarm specification process with the HAZOP process. b. Alarm screening questions could capture important alarm information as the P&ID is reviewed, thus ensuring that it won't be forgotten when the HAZOP is over.

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Human Factors Issue	Example Situation	Comment / Potential Solution
2. Blinds and Blanks		
2A. Location for blind has not been specified, or the blind is not included on a blind list.	1. At unit battery limit 2. The blind is not rolled or inserted; incorrect isolation 3. The blind is removed.	a. Identify and label preferred blinding/isolation locations on drawings and actual piping. b. Specify which blinds are to be removed and which spectacle blinds are to be turned prior to, or during startup.
2B. Access to the blind is not defined or is difficult [too high, reach is excessive, obstructed, weight is 51 lb (>23 kg)[1]].	1. Blind is located under a vessel or beyond the reach of a platform. 2. Access to the blind is restricted by the facility or other equipment. 3. Blind is oriented horizontally, so lifting equipment is ineffective. 4. Blinds are associated with valves or lines that are themselves difficult to access. 5. Emission occurs at blinding location—H_2S/flammable hydrocarbons.	a. Develop specifications for lifting equipment and ensure access to blind by lifting equipment. b. Equip blinds heavier than 51 lb (23 kg)[1] with a lifting handle. c. Ensure blinds heavier than 102 lb (46 kg)[2] are oriented vertically and equipped for and accessible by a lifting device. d. Ensure lifting capability is built into equipment associated with blind (e.g. davit, hydraulic jack, beam for chain falls). e. Equip blind with handholds for more than one person. f. Ensure room to maneuver tools (e.g., sledge hammer) for horizontal blinds. g. Consider different material to reduce weight of blind. h. Identify and label preferred blinding/isolation locations on drawings and actual piping. i. Provide temporary/permanent platform with handrails/easy egress.
2C. The blind does not have associated bleed and drain valves or no clearly defined safe drain location.		a. Install display to indicate excess pressure or liquid levels. b. Ensure that pressure relief or drains are located downstream of blind and are identified on or near the blind flange.

[1] The NIOSH Load Constant (LC), which is used in the Recommended Weight Limit (RWL) equation is defined as fixed weight of 23 kg or 51 lb; generally considered the maximum load nearly all healthy workers should be able to lift under optimal conditions. The RWL is defined for a specific set of task conditions as the weight that nearly all healthy workers (i.e. 95%) could perform for up to 8 hours without an increased risk of lifting-related low back pain (LBP). [NIOSH Publication No. 94-110 (1994)]

[2] The NIOSH defines a Lifting Index (LI) as the ratio of the lifted weight / RWL (Recommended Weight Limit). This limit should not exceed 2.0 without engineering intervention. The maximum weight that can be lifted at an LI of 2.0 is 51 lb x 2 = 102 lb (46 kg).

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Human Factors Issue	Example Situation	Comment / Potential Solution
2D. The blind is an unfamiliar design not used before in the plant (e.g., proprietary blind).	1. Hammer blind.	a. Write procedures on the operation of the blind. b. Train operators in the operation of the blind before startup. c. Develop and install warning signs near blind to alert operator to novel design.
2E. The blind is used in an extreme service [toxic exposure, pressure >50 barg (>725 psig), temp. >200°C (>390°F)].	1. Blind is associated with valves that are used frequently or in an emergency.	a. Blind is accessible from grade or from a platform. b. Warning signs are developed and installed near blind to alert operator to hazardous service. c. Vents and drains are installed and routed to safe location. d. Procedures are written on the installation and removal of blinds and operators are trained.

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Human Factors Issue	Example Situation	Comment / Potential Solution
3. Control House Ergonomics		
3A. The control room is not large enough to support the people, equipment and tasks.	1. There is no space for the people attending the morning meetings. As a result, people lean or sit on the console creating the potential for control errors. 2. The printer, the FAX and communication equipment took up all available workstation space provided for the operator. 3. Addition of new PC equipment crowds operator workspace and no floor space is available to add additional workstations.	a. Conduct a conceptual design of the control room, using task and functional analysis techniques, that considers the following: (1) Number of consoles (units) in the same room (2) Number of personnel, including console operators, for both normal and abnormal operations (3) Number, type and sizes of equipment that will be installed based on the tasks performed (4) Storage needs (5) Work surface needs for normal and abnormal operations (6) Traffic patterns as well as exits and entrances (7) Adjacent areas b. Estimate the type, amount and sizes of the equipment that will be installed in the control room using task analyses. c. Prior to laying out the equipment drawing, the footprint and access points of each piece of equipment should be determined. d. Provide sufficient work surface area for log preparation, notebook use, and PC use close to the operator position. e. The 'rule-of-thumb' in all workstation designs is to go up – not out. PCs, printers, FAX machines etc. should be mounted on shelves above or below the work surface, thus leaving the work surface clear for operator use.
3B. Control room illumination is inadequate.	1. Control room operators complain about the lack of illumination on the work surfaces at the ends of the consoles.	a. Often the overhead lights are turned down because of glare produced on the screens. As a result, there is not enough illumination for paper and pencil tasks. Task lights should be installed for the areas that require paper and pencil work. These may be ceiling mounted (recessed pot lights) or desk mounted. b. Indirect lighting would reduce the screen glare and permit the level of ambient illumination to be increased so paper and pencil tasks do not suffer.

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Human Factors Issue	Example Situation	Comment / Potential Solution
3C. Glare from the control room lighting is excessive.	1. The location of the ceiling luminaires is a glare source on the DCS displays (Figure 7). 2. An image of the ceiling-mounted luminaire was reflected in the DCS monitor causing distraction and masking the information on the screen.	a. Avoid precisely locating luminaires and ventilation outlets in the ceiling until after the control room layout has been finalized and sitting positions are known. b. The incorrect location of the luminaires can be identified early in the project if a "Reflected Ceiling Plan" is developed and reviewed prior to locating the lighting fixtures. A reflected ceiling plan locates the equipment and lighting fixtures on the same plan view. c. Install uniform and diffused lighting to reduce CRT glare and flicker. As a general rule, design the lighting system to achieve the following results: (1) Illumination levels should be adjustable from 50 to 250 Lux at the console work surface (2) A color rendering index (CRI) >/= 80 (3) Indirect (up-) lighting (4) High-frequency, electronic ballasts to avoid flicker (5) Ceiling-mounted pot lights directed to surfaces where reading tasks are performed d. Up- or indirect lighting should be installed in control rooms to reduce screen reflections. An example of a retrofit indirect light source is shown in Figure 8. e. Parabolic lenses work only if the screen is located outside the effective cut-off range of the luminaire. f. DCS screens should be placed perpendicular to the floor and not be angled upward toward the ceiling.
3D. Visual access to the major control room displays are inadequate.	1. Operator's vision of a wall display that tracked the critical condition of a unit was blocked by the top of the console (Figure 9).	a. Consider visual clearance over equipment when operators need to see each other or to see equipment on the other side of the console. b. All wall-mounted or panel-mounted displays should be located so the shortest control room operator can see them over the console. c. The console height should be determined by the eye height of the 5th percentile operator.

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Human Factors Issue	Example Situation	Comment / Potential Solution
3E. The console operators are unable to relocate or re-orient equipment to reduce visual problems.	1. The operator is unable to eliminate the reflection of an overhead glare source on the DCS monitor.	a. Design consoles so as to allow operators to adjust computer monitor and keyboard positions. b. The operator could reduce the glare in the following ways: c. Rotating the monitor downward d. Inserting a glare shield on the top the monitor (recommended as a last resort) e. Inserting a glare screen (recommended as a last resort) f. Turning off the single glare source g. Changing the source to an indirect luminaire
3F. The control room equipment is not laid out to support the visual access of the operator.	1. Operator vision to a set of instruments was blocked by a large pack of cables from the ceiling plenum to the console.	a. Avoid placing obstructions, such as pillars or cable packs, in such a way that they can affect vision and communications. b. Raised floors should be used to run wire and cabling to the control console from the computer area.
3G. The control room feels dark and lifeless.	1. Much of the equipment is in shadow.	a. The amount of light that falls on a work surface depends not only on how much illumination is produced, but whether it is reflected or absorbed by the surfaces it falls on. If the high walls and ceiling are painted in highly reflective colors (e.g. white), more light will be reflected into the room.
3H. Noise is excessive in the control room space.	1. In a multi-console control space, the noise from the radios in one console disturbs those in an adjacent console. 2. Operators in a round control room complain about the level of noise from other areas of the control room. 3. Noise from the radio speakers in the adjacent control console interferes with communication and annoys the operators.	a. Identify potential sources of noise both internally and externally and reduce them so ambient noise level is 50 dbA or less. b. Noise in the room can be reduced by: (1) Installing noise absorbing ceiling tiles (2) High plenums (space above the tile) (3) Reducing ceiling fixtures that reflect noise (4) Installing noise absorbing material on walls between 45 cm (18 in.) and 183 cm (72 in.) high (5) Orienting consoles so noise is directed away (Figure 10). (6) Using directional microphones

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Human Factors Issue	Example Situation	Comment / Potential Solution
		c. Make the control room square or rectangular with the sides as near the same length as possible. Avoid long narrow rooms. Square or rectangular control rooms reduce noise reflections more than circular rooms. d. Directional speakers have been developed that will restrict the spread of noise throughout the space. e. Design the noise environment to meet the principles outlined in the "Work Environment" section of this Tool. f. Consider that any communication that is between others is a noise source to those not involved and design accordingly.
3I. The working environment is uncomfortable and affects operator performance.	1. Operators complain that the cold air vent from the Heating Ventilating and Air-conditioning (HVAC) system is located directly over their positions and sends cold air on their heads.	a. Design the thermal environment to meet the principles outlined in the "Work Environment" section of this Tool. b. The poor positioning of the cold air vents could be avoided if they are installed after the sitting positions are known. c. A reflected ceiling plan should be used prior to locating the cold air vents.
3J. Too many people are in the control room space.	1. Not enough room is available in the control room for morning meetings.	a. If the culture of the plant is to have the shift change meetings include the control room operator, enough room must be provided in the control room to accommodate the people that must be at the meeting. b. Specify task areas within the control room including: (1) Process control consoles and operator (2) Communication console (telephone, public address, radios) (3) Permit handling (4) Administrative (e.g., shift log preparation) (5) Analysis and diagnostic that could include several persons discussing problems over a process display (6) Site emergency command and communication center (7) Training area that could consist of process display, workspace for studying (8) Engineering area (9) Printer/fax area

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Human Factors Issue	Example Situation	Comment / Potential Solution
3K. The wrong people are being permitted to enter the control room (CR) space.	1. The doorway to the control room is located so visitors naturally walk through control room A to get to control room B. 2. Each morning the control room is filled with contractors waiting for work permits.	a. Design work area to form a natural barrier to prevent uninvited visitors from entering the console area. b. People do not want to intrude on the space of others. If the entrance door is relocated a few meters either side of its current position, visitors may not walk through control room A. c. Access to the control room should be limited to shift personnel, engineers and maintenance people who have business there. Contractors should not be allowed access to the control room and could easily be blocked by a door and asked to line up to a permit counter.
3L. Communications within the control area is insufficient.	1. The console for the finishing area of the polypropylene plant was not located next to the console that ran the reactor. Consequently, communication between the two operators was difficult and was an annoyance to the operator on the console between them.	a. Consoles should be arranged in a control room based on their affinity to each other. Tools are available to determine affinity values. An affinity analysis would identify the potential conflicts to communication and alert the design team to the changes required. b. When two or more unit consoles are in the same room, provide direct visual and voice communication between console operators that have strong functional ties.
3M. Unnecessary traffic is excessive in the control space.	1. The office of the applications engineer is located between control rooms A and B. But, the only access to the application engineer's office is from each control room. 2. Because the control room is in a central location, it is shorter to walk through it than around it.	a. Locate office of the supervisor and applications engineer so their visitors will not have to enter the control room to access their offices. b. Install an access door to the applications engineer's office from the perimeter hallway, so people can access it without entering through the control room. c. Design traffic patterns in the control house so control room is not used as a shortcut or for outside access. d. Locate control room entrance and exit doors so the path between them does not cross the control room in either direction.
3N. Exits and entranceways are not designed to handle the largest piece of equipment that is likely to come into the control space.	1. A large, one-piece DCS counter is too long to make a turn in the access hallway.	a. Design doors, passageways and elevators to accommodate the largest pieces of equipment in the control room. b. It is important for designers to consider all aspects of access especially dynamic fit.

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Human Factors Issue	Example Situation	Comment / Potential Solution
3O. The equipment is not designed to accommodate the wide range of operator body sizes that work in the control room.	1. Small operators had difficulty reaching the touch screen display. 2. Operator was unable to access shelf-mounted materials when the workstation was in the standing mode.	a. Design consoles to meet ergonomic standards for the extremes of the user population. These standards are given in Reference 28. b. Consider the use of sit/stand DCS consoles to impede the onset of fatigue and boredom (Figure 11). c. Reach envelopes are provided in several ergonomic reference books (Reference 28). However, they are likely designed for the North American / European population. The extremes of the user population must be considered in every design. d. All of the materials that support the workstation (e.g. storage and shelving) should move up and down with the workstation when it is designed as a sit/stand workstation.
3P. Control room seating is inadequate.	1. Seating in the control space was old and shabby and the height adjusters on many of the chairs were broken.	a. Provide good quality seating that fits the extremes of the user population. b. The control room operators' chairs are pieces of furniture that are used excessively. They are used 24-hours a day by a wide range of body sizes and must accommodate each operator. Chairs should meet the specifications of the Bureau of Institutional Furniture Manufacturers Association (BIFMA).
3Q. Control room storage space is inadequate.	1. Storage space is overcrowded and items hard to find. 2. Critical operating procedures are not close by when needed during an emergency.	a. Provide sufficient shelf and storage space to store operations and maintenance documents and ensure that those documents required in an emergency are quickly available. b. Required documents should be identified prior to assigning shelf and storage space. Non-core storage should be assigned elsewhere. c. Storage space for critical documents must be assigned to the control room layout early in the project.

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Human Factors Issue	Example Situation	Comment / Potential Solution
3R. Equipment layout does not allow easy access for maintenance.	1. Insufficient clearance is provided behind the equipment console to swing open the panel covers and pull out the equipment racks.	a. Design and locate equipment and instrumentation for ease of maintenance and cleaning while avoiding interference with process operations. b. The equipment access must match the space available. Both must be considered together for a new design or retrofit and the specifications for each written accordingly.
3S. The control room is difficult to keep clean.	1. Oil tracked in from the plant has permanently stained chair coverings and countertops.	a. Use building and construction materials that need minimal cleaning. b. Building materials that need to be especially well-chosen include: (1) Coverings for tiles on raised floors (2) Seat coverings (3) Console and writing surfaces
3T. Operator support areas are not located close enough to the control space.	1. An operator who was in the toilet missed the onset of a critical alarm.	a. Locate operator support areas such as kitchens, toilets, rest areas as close as possible to the control room. b. Operators should notify a stand-in for absences. c. Equipment should be designed to alert the operator to incoming alarms in areas outside of the control space, such as toilets and lunchrooms.
	2. Lack of outside access to permit counter requires contractors to walk into the control space and disturb the console activities.	a. Locate permit counters near 'public' entrances to the control room. b. Access to permit counters should be directly inside the 'public' entrance. At no time should contractors be in the console area. In addition, the permit counter area should be provided with seating for those waiting for permits. A toilet and telephone should be available near the outside doors.
3U. Control room windows are not properly located or designed.	1. Operators complained of the glare from bright sunlight in the afternoon through a window.	a. Avoid installing outside windows in control rooms unless operator must monitor a specific piece of equipment. b. Windows should be installed facing north. If this is not possible, each window should be provided with glare treatments such as vertical blinds and reflective coatings.

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Human Factors Issue	Example Situation	Comment / Potential Solution
3V. The control room does not contain sufficient equipment for the tasks that are conducted.	1. The applications engineer must test new versions of software online with the control system operating. To do so, he has to displace the control room operator from his console.	a. Provide additional DCS consoles for technical and maintenance staff. If the AE is provided with his or her own console, testing could be achieved without displacing the control room operator.
3W. Operators are continually being distracted by unwanted and unnecessary demands.	1. Operators are frequently disturbed from their duties by managers who want them to display the operations performance overview screen.	a. Provide overview displays for: (1) Supervisors remote from control room (2) Operators when several need to share the same information b. The overview display could be as simple as a projection of the input from one of the DCS screens (controlled by that screen's keypad). c. Consider also the use of high-resolution, flat-panel, plasma displays.
3X. The location of major visual displays are inadequate.	1. The control room operator is responsible for monitoring an unmanned loading rack with a closed-circuit television monitor. He did not observe a truck driver at a loading rack who was not wearing correct PPE. The monitor was mounted above and behind the operator making it difficult to monitor the rack. (Figure 12).	a. When operators are seated at the console, locate critical displays: (1) Within a visual angle of +/- 30 degrees to the operators forward line of site (2) At a reading distance that is 200 X character height
3Y. The location and orientation of controls and displays are inadequate.	1. Owing to the width of the keypad and the depth of the counter, a short operator has to stand to reach the touch screen display.	a. Locate critical controls (including touch screen displays) within the functional arm reach of the 5th percentile operator. b. All equipment should be designed to meet the physical limitations of the extremes of the user population.

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Human Factors Issue	Example Situation	Comment / Potential Solution
4. Electrical Substations and Field Housing for Instruments		
4A. Substations and instrument field housings do not have emergency egress systems.	1. A short in a high voltage switch causes an explosion that starts a fire and cuts all lighting. Workers attempting to exit the building have no guidance, and are confused by a maze-like path.	a. Ensure that personnel can exit substations quickly and safely in an emergency (e.g., wayfinding signage, emergency lighting, panic hardware on external doors). b. Cannot always assume that qualified workers are familiar with the layout of the substation building. Moreover, smoke and fire may make the exit path difficult to maneuver. Hence the reason for good floor-path wayfinding and emergency lighting or lighted signage.
4B. Heavy switchgear is mounted too high or too low for the local population.	1. Lack of handholds on the bottom of the face of the switchgear makes it difficult to pull out by short operators when it is mounted in the upper rack.	a. Ensure that heavy switchgear can be accessed by the extremes of the user population when it is mounted in the upper and lower racks. b. Specifications for switchgear must ensure that it can be pulled from the upper and lower racks by the extremes of the user population.
4C. Access to electrical equipment is compromised for minor additional projects because of space considerations.	1. Recent additions required new equipment to be installed in an existing building. So, the spacing standards had to be exempted causing the equipment to be located so close together that access space was compromised.	a. Mount switch racks and terminal boxes so they can be easily accessed for operations and maintenance. b. Spacing standards are necessary for both the initial capital project and for local and maintenance projects. Taking exception to spacing standards may mean rethinking the design of the equipment that is installed to find another way of accessing it.
4D. Personnel may contact high voltage cabinets with tools that may be used in or near the cabinets.	1. Cabinet was designed to resist personnel contact via clothing and/or skin, but not to prevent a tool used by a person from breaching the space provided.	a. Design high-voltage cabinets so the risk of operator contact with exposed connections is minimized. b. Anticipate the tools that would be used for maintenance and the procedure used. Design the equipment to prevent them from contacting live connections. c. Design non-conductive tools. d. Require a last-minute risk assessment to be performed by the workers to identify the possibility that the tools could inadvertently breach the protection.

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Human Factors Issue	Example Situation	Comment / Potential Solution
4E. Pulling of electrical / instrumentation equipment drawers blocks the aisles.	1. Aisle width did not consider the situation in which switchgear would be pulled out for maintenance, thereby blocking the aisle.	a. Set enough clear space around fully extended draw-out equipment or open cabinet doors. b. 3D-CAD files, where available, should automatically specify an envelope around equipment that moves, such as pullout gear and cabinet doors that swing open.
4F. Lifting equipment for heavy electrical items has not been provided.	1. Batteries in a substation weigh 60 lb (27 kg) each and they are stored in a rack consisting of three tiers of batteries. Lifting equipment can only access batteries in the upper tier, not the lower ones.	a. Provide lifting equipment for items weighing more than 51 lb (23 Kg)[Note3] and ensure that the lifting equipment can access all heavy items. b. Each piece of equipment in the facility that weighs more than 51 lb (23 Kg) must be identified before detailed engineering begins so access can be designed in.
4G. Heavy electrical equipment cannot be rigged for lifting.	1. A worker suffered a back injury while lifting a piece of equipment that he could not prepare for lifting with a hoist.	a. Install lifting lugs on all equipment intended to be lifted with hoists. b. Ensure that lifting lugs are added to the purchase specifications.
4H. Electrical equipment is located on the outside of tall building high above grade and cannot be easily accessed for service.	1. In order to service an air-conditioning unit on a raised building, the maintenance department hired a company to scaffold up to the air conditioner.	a. Ensure the equipment on the outside of raised buildings that requires frequent access for operations and maintenance can be reached from grade or from a platform and does not require scaffolding. b. Scaffolding may be more expensive than the equipment being accessed. During design, lowering the attachment points on buildings should be considered. c. If lowering the equipment is not an option so it can be accessed from grade, then permanent platforms should be considered.

[3] The NIOSH Load Constant (LC), which is used in the Recommended Weight Limit (RWL) equation is defined as fixed weight of 23 kg or 51 lb; generally considered the maximum load nearly all healthy workers should be able to lift under optimal conditions. The RWL is defined for a specific set of task conditions as the weight that nearly all healthy workers (i.e. 95%) could perform for up to 8 hours without an increased risk of lifting-related low back pain (LBP). [NIOSH Publication No. 94-110 (1994)]

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Human Factors Issue	Example Situation	Comment / Potential Solution
4I. Substation building requires frequent maintenance access from under it.	1. A building was raised only 2 ft (60 cm) making it difficult to clear local wildlife before work began and also making it necessary for maintainers to crawl under the building and lie on their backs while working.	a. Provide sufficient overhead clearance beneath substation buildings that require maintenance access.
4J. Carts necessary for substation internal maintenance work are too wide to fit through the substation doors.	1. Carts were not designed to the dimensions of the switch gear. As a result, they were too wide for the door. Moreover, their small wheels could not negotiate the threshold between the building and the platform.	a. Design building doors: (1) Wide enough to accommodate the largest pieces of equipment (2) To ensure that access is unobstructed between building and outside staging platform b. A system approach must be used in the design of substation buildings that considers: (1) The installed equipment (2) The maintenance and operations tasks that will be conducted with the equipment (3) The facilities and equipment necessary to assist with the tasks c. The system must be analyzed before detailed design.
4K. No platform is provided for large equipment that will need to be pulled out of substation for maintenance.	1. The platform was not large enough for the switchgear. Consequently, the cable on the outside crane pulled the switchgear out of the building at an angle. When the gear sprung free, it swung into the crane.	a. Design outside platforms large enough to comfortably stage the largest equipment for loading and offloading. b. The platform size should be considered during the review of the maintenance and operations tasks.
4L. Switches and controls extend outside flat instrument panels without protection.	1. A worker inadvertently activated a circuit by bumping a pushbutton as he walked by it.	a. Ensure that all switches and controls are accessible by and visible to the user population and protect all switches and controls from accidental operation. b. People walking by will contact pushbuttons on flat panels. It is essential to design for random contacts and ensure that the button is only activated on purpose.

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Human Factors Issue	Example Situation	Comment / Potential Solution
4M. Labeling and signage of electrical controls and displays is inadequate.	1. Switch was inadvertently closed by a contractor who thought the green light on the panel meant that the equipment was operating.	a. Label and sign all controls and displays to ensure that their functions are understood. b. Confusion between process and electrical color-coding can lead to catastrophic errors. Ensure that all controls and displays in substations are redundantly coded with color, labels and signs.
4N. Substation is inadequately identified from the outside.	1. Contract maintenance worker enters the building by accident.	a. Attach “DANGER – High Voltage – Do Not Enter” signs on all exterior doors. b. Signs serve several purposes. They are a reminder for experienced personnel, a training aid for inexperienced personnel and a WARNING for uninformed personnel.
4O. Lighting inside substation is inadequate.	1. The specified level of ambient illumination was provided by fluorescent downlighting from the ceiling. The shadow thrown inside the switching cabinet made it difficult for the operator to make out the individual terminals and increased the risk of error.	a. Ensure that levels of ambient illumination meet plant guidelines and that additional illumination (task lighting) is provided for those areas in which critical maintenance or operations are conducted. b. Ceiling-mounted ambient illumination does not always provide enough light to perform all jobs. Each maintenance and operations task should be reviewed prior to detailed design to ensure that the unique lighting requirements are identified.

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Human Factors Issue	Example Situation	Comment / Potential Solution
5. Emergency Equipment		
5A. Operator of the "fire monitor" does not have a clear line of sight to the target.	1. Potential fire area is blocked by a structure.	a. Raise monitor using a platform. b. Develop a portable system that is available for "blind" areas.
5B. Operator's access to fire monitor or hydrant is obstructed.	1. Operator is unable to access hydrant or monitor.	a. Ensure alternate method of accessing hydrant and monitors based on fire scenarios.
5C. Operator is unable to initiate deluge as he or she is leaving the area.	1. Local deluge activation box is not located in an escape route.	a. Ensure that emergency exit routes are identified and that the deluge activation box is located on the route and clearly labeled so operator doesn't have to search for it. b. Ensure box is well signed so operator will not have to search for it. c. Consider duplicate or separate deluge activation boxes for inaccessible or multiple egress locations. d. Ensure that the operator receives feedback that the deluge system is operating. e. Ensure that the operation of the system is communicated to the emergency control station. f. Consider "automatic" activation of deluge.
5D. Operator is unable to initiate deluge from the battery limit station (BLS).	1. Main deluge panels are not located at unit periphery (B/L).	a. Ensure that the deluge panel for the unit that is serviced by the BLS is at that station. b. Ensure that the operator receives feedback that the deluge system is operating. c. Ensure that the operation of the system is communicated to the emergency control station. d. Consider "automatic" activation of deluge.

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Human Factors Issue	Example Situation	Comment / Potential Solution
5E. Operator in the unit/field does not see/hear flashing lights/alarms on automated emergency systems during emergency response.	1. Personnel unaware of toxic gas release in area. 2. Person inside an enclosed, loud compressor area and is unable to hear the alarm.	a. Ensure indication is visible / audible at entry points to area of concern. b. Include initial PPE and gas testing plan in emergency response plan. c. Ensure that a visual alarm indication is installed in the proper location in all work areas where the audible alarm may be masked by noise. d. Ensure that highly important emergency systems have special identification (e.g., reactor depressurizing, heater fuel isolation).
5F. Voice communication systems are chosen for reliable operations for the settings in which they will be used.	1. System failure.	a. Ensure that there are back-up and/or alternative communication systems.
5G. Personnel evacuation is required.	1. Numerous decisions are required.	a. Ensure that procedures contain only specific response actions with no more than three actions per step. b. Use commonly known graphics to efficiently and effectively describe a step. c. Ensure windsocks are visible and easily understood.
5H. Adequate and suitable space is provided for emergency equipment and supplies provided so that they are readily accessible.	1. Lack of maneuverability and critical resources.	a. Provide for permanent staging of emergency equipment and supplies. b. Consider sufficient, passable emergency vehicle turning and staging areas.

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Human Factors Issue	Example Situation	Comment / Potential Solution
6. Field Analyzer Buildings		
6A. Layout of the equipment in analyzer buildings is inadequate.	1. A large technician is unable to access a transmitter mounted behind a field gas chromatograph.	a. Provide adequate space (clearance) between equipment in field analyzer buildings for maintenance and operations access. b. Minimum access dimensions must be developed that accommodate the 95th percentile user. The specified dimensions should not be expected to accommodate those operators that are larger through the mid-section than the 95th percentile.
6B. Access and clearance around analyzer buildings is inadequate.	1. A technician bumped his head on a drain valve located on a line that was installed after the building was completed.	a. Provide adequate head clearance to overhead lines or equipment (Figure 13). b. Clearance specifications (typically 81 in., 205 cm) should be reviewed during the planning of all retrofit equipment.
6C. Test points and other interfaces have not been standardized.	1. A new test probe recently purchased by the plant is unable to access a test point on a field instrument.	a. Ensure that test points are located and oriented so they have sufficient clearance for connecting test equipment. b. Test and evaluation equipment improves even though the design of the plant remains the same. The question that needs to be answered when test equipment is upgraded is whether the new equipment will physically fit the old plant. If not, other manufacturers need to be considered or a retrofit of the existing plant needs to be factored into the cost of the equipment.
6D. Access to equipment is inadequate.	1. A wall-mounted instrument cabinet cannot be unlocked and opened by a 5th percentile operator (Figure 14).	a. Locate controls, latches, and displays so they can be operated and read by the extremes of the user population. b. Before cabinets are mounted, the designer or engineer must consider the means of access. In Figure 14, the cabinet latches are located on top of the cabinet and the operator cannot reach high enough to operate them.

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Human Factors Issue	Example Situation	Comment / Potential Solution
	2. A storage tank that is mounted next to the building, but below the test point blocks access to an instrument test point.	a. Do not block maintenance or operations access to equipment with other equipment either internally or externally around the building perimeter. b. When designing for access, the width of equipment must be considered as a potential obstruction to the equipment above it. The designer must consider the angle of approach to the test point as a result of the obstruction and whether a 5th percentile person can reach it.
6E. Connections to different test sources have not been uniquely designed or adequately coded.	1. When routing the input line from a sample stream to a gas chromatograph, the line was connected to the wrong gas chromatograph.	a. Test the design and layouts of all interconnect panels for clarity and understanding by the user population. b. The interconnections should be clear and well labeled. A mimic design that presents a graphic illustration of the process connections has shown to reduce the potential for error better than other less pictorial solutions.
6F. The design of the regulators and manifolds for gas bottles is inadequate.	1. A technician blocked the regulator line in preparation for the removal and repair of the regulator. When the block valve was closed, gas was shut off to the instruments and the process went into alarm. 2. In order to change a gas bottle, the technician has to remove three others from in front of it, and then reinstall them with the new bottle (Figure 15).	a. Design gas bottle regulator systems to: (1) Provide unobstructed access to gas bottles (2) Ensure that the failure of a regulator or the change-out of bottles does not disable the entire gas system b. In a multiple regulator system, each regulator should be able to be bypassed and isolated for removal without disabling the system. c. Gas bottles are heavy and awkward. They should be immediately accessible without moving others. They should also be located so the path from the bottle storage to the exchange area (e.g. truck) is unobstructed and does not require the technician to negotiate stairs or doorway thresholds.

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Human Factors Issue	Example Situation	Comment / Potential Solution
7. Field Display Panels		
7A. Use of the panel requires a procedure with more than seven steps.	1. Compressor startup from a local control panel that requires more than seven steps.	a. Ensure panel is designed with controls and displays in the same sequence as the sequential steps. Order is from left to right, top to bottom. b. Ensure that procedure is the correct procedure, and it is sequential, logical, and available at the local location. c. Provide checklists locally (e.g., posted near the equipment) to remind the operators of activity sequence. d. Use consistent color-coding on panels at all locations to be used to prevent confusion (i.e., Red = Off/Closed, Green = On/Open).
7B. Consistent design and layout provided for multiple panels that operate similar equipment on the unit.	1. Emergency Block Valve (EBV) panels on the same unit are not designed the same way.	a. Ensure panels are consistently designed plant-wide b. Ensure local equipment control panels are located for visual access from the expected location of the operator to the necessary information on the panel. c. Ensure adequate lighting, glare avoidance and maintenance access. d. Use the same color-coded controls and displays on local equipment control panels and auxiliary panels in control rooms. e. Use ergonomic design of control consoles to help reduce the likelihood of musculoskeletal disorders. There should be at least 42 in. (1070 mm) clearance behind the chair to allow operator adequate access. f. Group together Controls and associated displays necessary to support an operator activity, or sequence of activities. g. Locate controls and displays on local equipment control panels and auxiliary panels in control rooms as per Figure 1. Avoid "mirror image" control panels. h. Locate Safety critical controls and displays separately from those used normally for process control.

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Human Factors Issue	Example Situation	Comment / Potential Solution
		i. Separate controls at least as indicated below to avoid accidental activation[4]: a. Push buttons by 1 in. (25 mm) b. Toggle switches by 2 in. (50 mm) c. Controls operated with the whole hand by 5 in. (125 mm). j. Space adjacent keyboards on control consoles should be spaced at least 30 in. (760 mm) center-to-center.
7C. Panels are used under all light conditions [lighting sufficient and glare eliminated].	1. Boiler start up panel is not well lit. 2. Panel instruments are unreadable due to the glare from direct sunlight.	a. Ensure illumination of control panels and consoles is free of reflected glare when viewed from anywhere within the following range of viewing positions: (1) Between the 5th percentile of female eye height (e.g., 56.3 in, 1430 mm for North American female population) and the 95th percentile of male eye height (e.g. 5 ft-10 in., 1770 mm for North American male population) elevation above floor. (2) Between 1 and 4 ft (300 and 1200 mm) horizontal distance from panel or console. b. Ensure panel controls and displays are self-illuminating.
7D. Panels are used under emergency conditions [clarity of layout sufficient].	1. ESD panel.	a. Design panel so the operator can obtain information quickly. Example formats include: (1) Geographical (mimic) associated with location in plant (2) Functional (mimic) where displays and controls are laid out in a process flow b. Indicate “safe state” sequence on the board c. Use of consistent color-coding on panels at all locations to be used to prevent confusion (i.e., Red = Off/Closed, Green = On/Open)
7E. Panels are used during normal surveillance [located in surveillance path].	1. Furnace panels. 2. Pump operation panels.	a. Locate: (1) Displays and local panels so that they are visible from the surveillance path and visibility is not obstructed by other equipment. (2) Align displays during field installation to be visible from the surveillance path.

[4] From MIL STD 1472 "Human Engineering Requirements for Military Systems, equipment and practices" Amendment 2 published in April 1984

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Human Factors Issue	Example Situation	Comment / Potential Solution
8. Filters		
8A. Filter must be frequently cleaned, cleared, drained, switched.	1. Operator is unable to easily access filter for cleaning.	a. Ensure that filter access is included in the design. b. Ensure that platform is designed to allow the filter components to be staged properly before and after installation.
8B. Product being filtered is hazardous and/or operator must wear Personnel Protective Equipment (PPE).	1. Operator's vision is blocked by the PPE. 2. Operator is unable to manipulate filter elements, tools or hardware in PPE.	a. Design the job of servicing filters to ensure that the PPE does not interfere with the task. b. Conduct Task Analysis on filter servicing activity to ensure that the operator can work safely and efficiently. Strainers, filters, cleaning and flushing connections should be accessible from grade or platform with sufficient clearance and lifting devices to facilitate removing the strainer or filter media, using rodding out devices, and connecting hoses for flushing. Utility stations should be located within a single hose length of the connections in process equipment and piping used for cleaning and flushing. c. Mockup the filter and conduct task scenario before detailed design. d. Ensure that the specifications include provisions for the concerns above if filter is being purchased. e. Application of "inherent safety"—examine and backflush rather than dismantle/clean.
8C. Weight of filter or filter element cover exceeds 51 lb (23 kg). (see Note 1 under "Blinds")	1. Operator services only the filter and should not be manually handling the equipment. 2. Insufficient clearance has been provided for lifting equipment.	a. Conduct Task Analysis to identify the components that will require handling by the operator. b. Use available biomechanical analysis tools to determine the maximum lift for the postures assumed. c. Weigh components and compare with above analysis. d. Ensure that lifting equipment can access those components that are identified as too heavy for the operator. e. List potential hazards (e.g., pyrophoric iron, etc.).

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Human Factors Issue	Example Situation	Comment / Potential Solution
8D. [Height of top of filter above grade or floor of platform] + [length of filter element] exceeds shoulder height of the 5th percentile of the female user population (e.g., 48.8 in. or 1240 mm for the North American female population).	1. Operator is unable to remove filter element from the filter.	a. Ensure filter dimensions satisfy the extremes of the user population. b. Consider lifting equipment if (a) cannot be satisfied.
8E. Filter internal pressure to be verified locally at filter.	1. Operator or maintenance person not able to verify that pressure is off of filter housing before opening to atmosphere.	a. Install local gauge and vent to atmosphere, which can be rodded. b. Install local interlock with housing apparatus and atmospheric vent.

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Human Factors Issue	Example Situation	Comment / Potential Solution
9. Furnaces and Fired Heaters		
9A. Furnace is manually lighted off.	1. Gas pilot valve, flame window and igniter are located too far apart for operator to operate together. 2. Access to valve, igniter and flame window is poor.	a. Locate valve and igniter to a position near the flame window. b. Locate the pilot gas valve and the igniter switch so as to allow the operator lighting the pilot to see the pilot flame through an observation port during the light-off procedure.
9B. Furnace is automatically lighted off from a remote location and no local panel is provided.	1. No indication of valve position and burner operation is provided to the operator.	a. Install display to show position of valves and burner operation.
9C. Interior of the firebox requires frequent visual monitoring.	1. Firebox view window is located above grade and is not utilized by operator.	a. Improve flame detection hardware. b. Review surveillance path to ensure that operator visits firebox window. c. Ease access to above grade position (e.g. stairs instead of ladders).
9D. Furnace must be frequently decoked, switched, visited.	1. Decoking valves are large multi-turn and located very close to the furnace.	a. Conduct energy expenditure analysis on decoking task to find areas producing excess fatigue. b. Install MOVs, or c. Modify valve actuator for use with a hand power tool to turn valve. d. Rotate valve-turning task between operators to ensure that one operator is not excessively fatigued by task. e. Take into consideration the anthropometrical characteristics of the plant operating personnel.
9E. Access to other supporting equipment required while unit is online.	1. Safe access and egress required for maintenance personnel (e.g., access platforms, furnace draft fans and soot blowers, furnace stack sampling systems and analyzers, etc.).	a. Include heat barrier / insulation for personnel protection. b. Ensure that equipment is located with proper access areas.

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Human Factors Issue	Example Situation	Comment / Potential Solution
9F. Sufficient fired heater testing ports required to allow for verification that heater box is purged.	1. Heater box is purged to render it safe to light. Access to the testing ports is not adequate.	a. Ensure presence of required heater testing ports, so that combustion chamber explosivity can be tested at multiple points for large heaters.
9G. Furnace refractory is potentially toxic (arsenic) and must be handled by personnel in PPE.	1. Limited room for storage and handling. 2. Atmosphere may be contaminated.	a. Design enough room into the facility to permit staging refractory in preparation for removal or installation depending on the task necessary. b. Provide lifting equipment if refractory is staged above grade. c. Install air ventilation and filtration systems. d. Ensure the design and the required use of PPE are compatible.

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Human Factors Issue	Example Situation	Comment / Potential Solution
10. Instrumentation Systems		
10A. Instrument must be accessed frequently for calibration, clearing, rodding.	1. Rodding instrumentation ports on the sides of vessels are blocked by the structure. 2. DCS instruments are not accessible from grade or platform.	a. Ensure: (1) DCS instruments are accessible from grade platform or ladder. The maximum horizontal reach from a platform or ladder should not exceed forward shoulder grip reach of the 5th percentile of females (e.g. 20 in. (510 mm for the North American female population). The maximum overhead grip reach from grade or a platform should not exceed the functional overhead reach of the 5th percentile of females (e.g. 6 ft or 1800 mm for the North American female population). (2) Conduct Task Analysis if task is intended to be completed by one person (e.g., ensure nitrogen valves and displays are close to rodding location).
10B. Instrument is located in an area that is potentially hazardous to the operator, because of heat, elevation, and exposure to process.	1. Instruments on the sides of hot vessels. 2. Instruments in hazardous service.	a. Ensure instruments can be isolated with block valves. b. Install insulation in the area and ensure design of instrument takes into account insulation thickness. c. Provide reasonable space for egress in event of leak (e.g. gland oil).
10C. Clearing, rodding requires extra space.		a. Ensure access for the rods (which may be quite long) is not blocked by other structures.
10D. Instrument itself is inherently dangerous (e.g., radioactive).	1. Access to rod-out ports is obstructed by the structure or other equipment.	a. Ensure instrument shielding is adequate. b. Install local monitoring devices to warn operator in the event of failure of containment. c. Provide hoist or cart for manual handling instead of carrying by personnel.
10E. Controls are designed to match the expected control action (e.g., buttons, switches, levers, etc.).	1. Toggle switch is set to provide immediate or near immediate feedback (e.g., light or similar).	a. Ensure that controls are designed consistently and match the expectations of operating personnel.
10F. Pilot/purge lines to critical instrumentation are properly and clearly labeled.	1. Critical purge line to a safety shutdown valve is closed.	a. Ensure that purge and pilot lines to critical instrumentation are clearly labeled and the required positions/flows are indicated.

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Human Factors Issue	Example Situation	Comment / Potential Solution
11. Labeling / Signage of Process Equipment		
11A. Equipment is not labeled as to its function.	1. New lines are installed but are not labeled.	a. Identify the equipment, components, vessels and piping in the facility that require labeling and signage. b. A revision must be made to the management of change process to ensure that labeling is added to the list of items that require attention whenever new facilities or equipment are installed in the plant.
11B. Equipment is labeled with unfamiliar signs.	1. Warning signs are designed in the USA to US standards, but are being used in a plant in Singapore that is regulated by a different signage standard with different formats for Warning and Caution signage.	a. Ensure that the labels and signs meet regulatory requirements. b. Project process must include the need to review all regulations in the jurisdiction in which the plant will be operated to ensure that the local regulations are taken into account in the design of the project. c. Symbology used in one culture may not be understood by those in another culture. Project personnel must ensure that the workers in the plant will understand the symbology used on labels and signs.
11C. Labels and signs in the field are not consistent with those in the P&IDs.	1. Label on level controller reads differently from the designation on the P&ID. 2. Sign references procedure "xyz" and was not changed when procedure was renamed.	a. Ensure that information contained in labels and signs is consistent with the information contained in procedures and P&IDs. b. Work by different groups responsible for specifying the labeling, writing procedures and preparing P&IDs needs to be coordinated. c. One person or group may be entrusted with the responsibility to ensure that systems with common issues are designed consistently.
11D. Labels fade or become easily damaged.	1. Plastic labels are in service on a unit that routinely emits hydrocarbon vapors. The labels deteriorate quickly in the environment.	a. Ensure that the label materials and means of attachment are compatible with the components and the environments in which they are used. b. Process engineers need to review labeling materials to ensure that they can withstand the rigors of the environment in which they are installed.

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Human Factors Issue	Example Situation	Comment / Potential Solution
11E. It is not clear which piece of equipment is described by a certain label.	1. Labels for overhead valves are placed on the wall and not on the valves.	a. Place and orient labels and signs to maximize legibility. b. Develop a checklist for labeling and signage that includes a walkthrough of the facility to ensure that all labels and signs meet the design and orientation principles.
11F. Labels are not replaced / corrected when old equipment is reused in a different service.	1. A label on a replacement control valve was not replaced with one that matches the P&ID for the service that the valve is in. 2. Label is missing a tag number that can be referenced back to the P&ID.	a. Ensure that a process is established to replace lost or damaged labels and to acquire new labels when they are required. b. Pre start-up checklist should include a series of questions that ensure the labels and signs have the same information as the procedures and the P&IDs.
11G. Labels for all services and equipment have the same format and style.	1. Sign is designed as a procedure but does not meet the formatting requirements of a procedure (point form, active verbs, left justified).	a. Develop formatting standards for labels and signs that are based on the most up-to-date research on information processing. b. A formatting standard would ensure that the information on the label refers to the P&ID. c. Signs used as procedures must follow the same style guides that are used for procedures. The procedure style guides must be inserted into the formatting guidelines for labels and signs.
11H. Labels on older equipment are not replaced when they get damaged, become unreadable, fall off, etc.	1. Labels purchased from an outside vendor needed to be replaced, but the vendor is out of business.	a. Develop a means of administering labels that are purchased from outside vendors. b. Ask original vendors, as part of the contract, to develop a label specification guide that contains the information necessary for the plant to be able to prepare a labeling specification that another vendor could provide.

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Human Factors Issue	Example Situation	Comment / Potential Solution
12. Loading/ Unloading Facilities		
12A. The product being loaded / unloaded is in a hazard class where defined exposure criteria must be observed.	1. Operator is in PPE and cannot operate the controls, valves or see the displays properly.	a. Conduct a Task Analysis to identify those activities where the operator might make operating or reading errors. b. Mockup the operation to test PPE. c. Correct any deficiencies that come out of the empirical (observation) study before beginning detailed design.
12B. Weight of facilities (arm/hose/platforms etc.) to be manipulated manually exceeds 51 lb (23 kg) (see Note 1, under “Blinds”).	1. Operator weight manipulation limits exceeded.	a. Conduct a Task Analysis to determine whether the equipment that the operator will have to manipulate exceeds the lifting limits. b. Determine the maximum acceptable weights of the equipment, given operator postures, and using accepted biomechanical tools. c. Compare what is and what should be and either change task or provide lifting assistance to the operator.
12C. Top-loading/unloading is required.	1. Operator is unable to see product level in the tank.	a. Provide proper lighting for night operations. b. Provide the operator with a high level alarm. c. Ensure that the operator is able to access the controls that stop and start product easily from on top of the vehicle, or ensure that an emergency stop control is available at the top of the vehicle.
	2. Fumes escaping from the tank overcome operator.	a. Conduct operation remotely. b. Provide operator with appropriate PPE and analyze task to ensure that he/she can perform the task without error in PPE. c. Ensure direct, unobstructed access to safety showers. The shower and eyewash should be in an accessible location, which requires not more than 10 seconds to reach, and a travel distance of not more than 100 ft (30 m) from the source(s) of exposure and in an area that is free of the contaminant.

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Human Factors Issue	Example Situation	Comment / Potential Solution
	3. Operator is unable to properly line up the vehicle with the loading facilities.	a. Ensure communication between the operator and the vehicle operator is optimized (may include radio or signals). b. Ensure that system designed to spot vehicles is tested for practicability and usability (errors and overshoots are minimized). c. Mark the correct locations with paint.
	4. Operator is at risk of falling from the vehicle.	a. Provide proper guarding around the top of the vehicle. b. Provide proper staging space on the platform.
12D. Loading/unloading requires continuous operator attendance.	1. Unit operator needed elsewhere in the unit but is tied up unloading. 2. Safety and security monitoring system is less than adequate.	a. Consider whether space for operator to stand should be included in the unit design. b. Provide cross training of other unit operators to cover loading/unloading activities. c. Consider each of the operator’s jobs for design and location of cameras and monitors.
12E. Loading / unloading performed with contract personnel.	1. Contractor vs. employee training / understanding of issues.	a. Design equipment with shutdowns / kill stations. b. Post critical procedures / steps. c. Post facility rules. d. Ensure Labeling.
12F. Loading/unloading is a 24-hour activity.	1. Lighting is less than adequate for night operations.	a. Install portable task lights (top and bottom loading) that can be positioned where needed.

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Human Factors Issue	Example Situation	Comment / Potential Solution
13. Pumps and Compressors		
13A. Must be blown to a closed system before maintenance and product/process is hazardous.	1. Pump is in hazardous service.	a. Design equipment drains to ensure connections can be made to a closed blowdown or drain system; consider double valves. b. Ensure connection to closed blowdown or drain system is located near equipment and is easily accessible (e.g., without climbing over lines). c. Ensure unobstructed access to safety showers and eyewash stations. The shower and eyewash should be in an accessible location, which requires not more than 10 seconds to reach, and a travel distance of not more than 100 ft (30 m) from the source(s) of exposure and should be in an area that is free of the contaminant. d. Ensure equipment is located at grade.
13B. Local controls and displays are associated with start-up, shutdown or surveillance.	1. Displays are not oriented to face the associated controls, so operator cannot see them during start-up. 2. Displays are not oriented for easy monitoring during operator rounds.	a. Ensure the layout of auxiliary equipment, valves, controls and displays for parallel units (e.g., spared pump is identical in relation to the equipment controlled). b. Avoid mirror-image layouts. c. Field-check installation should be field checked. d. Ensure local displays are oriented to the surveillance path so operator can easily see out-of-limit conditions without leaving his/her rounds route (see Figure 2 for recommended layout of equipment and piping at pumps).

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Human Factors Issue	Example Situation	Comment / Potential Solution
13C. High noise levels are expected.	1. Manufacturers data indicates that noise levels in excess of 80 dBA[5] are to be expected.	a. Consider remote operation. b. Mandate ear protection and post signing. c. Ensure noise mitigation design and installation procedures are pursued. d. Ensure equipment is housed in a noise-insulated enclosure. e. Install visible emergency alarms for operators since auditory displays will not be able to be heard. f. Conduct periodic noise monitoring, especially during high noise periods, e.g. startup, to ensure proper NRR equipment is used.
13D. Auxiliary systems or package units are used.	1. Specialized design for which only a limited number of vendors make equipment that meets performance specifications (e.g., large diaphragm pump).	a. Specify peripheral equipment (e.g., local control panels) that can be modified for site use.
13E. Machinery needs to be removed and carried away.	1. Removal of machinery to shop for repair is difficult. Lifting equipment is blocked by other facilities and equipment.	a. Ensure layout of machinery allows sufficient clearance and access to enable removal with mobile hoisting equipment. Alternatively, provide fixed overhead lifting facilities.

[5] dBA = Decibel. "A" is the filter that most represents the human ear. Reference Attwood, D.A. (1996) "The Office Relocation Sourcebook" John Wiley and Sons, New York, Page 75

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Human Factors Issue	Example Situation	Comment / Potential Solution
14. Reactors/Dryers		
14A. Reactor must be entered for cleaning, repair, and catalyst filling.	1. Manway is not located for convenient entry. 2. Introduction of air or water (humidity) is a dangerous reactant with catalyst.	a. Provide temporary internal ladder and temporary or permanent ladder to manways for access and escape. b. Ensure manways are large enough to not only accommodate a healthy individual, but are also large enough to permit the evacuation of those who might be unconscious. c. Ensure nitrogen (or equivalent) purge is required during catalyst unloading and loading operations. d. Post caution signs for entry into vessel below a loaded, or packed section, or stacked reactors.
14B. Reactor catalyst is toxic, reactive, or pyrophoric and must be handled by personnel in PPE.	1. Limited room for storage and handling. 2. Atmosphere may be contaminated.	a. Ensure enough room is designed into the facility to permit staging catalyst in preparation for removal or installation, depending on the task necessary. b. Provide lifting equipment if catalyst is staged above grade. c. Install air ventilation and filtration systems. d. Ensure design for operation is compatible with the PPE that is being used.
14C. Multiple reactors which must be switched frequently.	1. Confusion over status and potential for error. 2. Switching operation is awkward and may require operators to access different levels frequently and could be time consuming.	a. Ensure that the operator knows the status of reactors through the use of displays that clearly show the state of the process (e.g., mimic diagrams). b. Complete all reactor-related work on the same level and in the same general area.

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Human Factors Issue	Example Situation	Comment / Potential Solution
15. Sample Points		
15A. The product being sampled is in a hazard class where defined exposure criteria must be observed.	1. Caustic sample point. 2. Sampling valve and sample outlet are not located close together.	a. Ensure operator has unobstructed access to safety showers and eyewash stations. The shower and eyewash should be in an accessible location, which requires not more than 10 seconds to reach, and a travel distance of not more than 100 ft (30 m) from the source(s) of exposure and should be in an area that is free of the contaminant.
15B. The sample point is located above grade.	1. Hazardous sample must be carried down stairs or a ladder.	a. Ensure sample is accessible from a platform. b. Provide two means of escape if substance is harmful.
15C. The sample system is (is not) using a closed purge system.	1. Sample bomb in closed purge system. 2. Open system for caustic samples.	a. If closed purge, ensure the sample loop is long enough to allow operator to access the sample point without obstruction. b. If not closed purge, then operator must have unobstructed access to sampling station.
15D. Design of operator access to the sample point has not considered the wearing of PPE.	1. Hazardous sample without a closed purge system.	a. Unobstructed access to sample point is assured if operator is wearing PPE. b. Ensure sample point at grade. c. Consider modifying to a closed loop sample system to eliminate need for PPE. d. Minimize (or eliminate) sampling of hazardous streams.

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Human Factors Issue	Example Situation	Comment / Potential Solution
16. Structural: Ladders, Stairs, Guards, Handrails		
16A. Ladders are used to access frequently monitored equipment.	1. Ladders are used to access a platform that contains a field display panel that is monitored during surveillance rounds twice per shift. 2. A caged ladder is used to access a battery limit valve platform.	a. Make ladders the default equipment for moving from one level to another. Use stairs, not ladders: (1) As the primary method of escape (2) Where personnel are required to carry large tools or pieces of equipment, including SCBA, up or down the structure (3) Where equipment must be accessed during emergencies (4) Where equipment is frequently accessed (5) For access to critical valves b. Critical tasks, including surveillance rounds should be identified before detailed engineering commences, so designers will know the access requirements. c. Critical valves should be identified before detailed engineering commences, so designers will know the access requirements.
16B. Structural components used for personnel access, like stairs and ladders, do not conform to the local facility standards.	1. The stairs and ladders were designed by an Italian Engineering firm to European standards for use in a Japanese chemical plant.	a. Design stairs and ladders in accordance with accepted local standards (e.g., OSHA in the USA). b. The project execution process should require that all equipment be designed according to local regulations.
16C. Inadequate, or no platforms provided for frequently accessed equipment (e.g., filters, sample points).	1. Cartridge filters cannot be easily removed and replaced from the platform provided.	a. Use platforms and walkways to access the following equipment when they cannot be accessed from grade: • Emergency block valves • Sample points • Vertical cartridge filters • Instrumentation and controls that are operated, adjusted, serviced or monitored during plant operations • Control valves • Service and inspection openings • Loading racks

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Human Factors Issue	Example Situation	Comment / Potential Solution
		b. Platform height should be adjusted so that the sum of the height from the platform to the lip of the filter plus the length of the cartridge is no greater than the shoulder height of the 5th percentile worker measured from the platform.
16D. Controls on a loading platform are too small for workers wearing PPE and errors are often made.	1. The access to the local display panel failed to consider that personnel would be in rubber suits, gloves and boots because of the product being transferred. As a result the controls could not be manipulated with the gloves worn and the gloves could not be removed to set the controls.	a. Ensure that operations and maintenance personnel are provided with the means for proper access to facilities and equipment when they are wearing proper clothing and personal protective equipment and when they are using the proper tools. b. If the task had been analyzed prior to specifying the local panel, the controls would have been designed larger and spaced further apart, so they could have been operated with rubber gloves.
16E. Stairs are not well designed for the user population.	1. The stairs were designed according to USA guidelines, but were installed in a plant in Singapore. Chinese and Malaysian workers, who make up 90% of the working population, find it tiring to climb stairs that are spaced too far apart for their body characteristics.	a. Ensure that clearances above and between equipment and the detailed design of stairs and ladders conform to the user population. See Figure 5 for an example of stairs design. b. Provide handrails for all stairs.
16F. Ladders located near edge of small elevated platforms do not have safety gauge extensions to the platform handrail.	1. Technician descending onto platform loses balance upon reaching the platform and falls backward over the platform handrail.	a. Provide extension bars from the ladder safety gauge to the top of the platform handrail, as shown in Figure 6. Consider all elevated platforms where the top of the ladder is greater than 20 ft (6.1 m) above grade and the ladder centerline is within 2 ft (0.6 m) from the platform side rail, or 4 ft (1.2 m) from the handrail opposite the ladder.

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Human Factors Issue	Example Situation	Comment / Potential Solution
17. Tanks		
17A. Instruments, valves, gauging (stilling) wells, sampling hatches, or other equipment that operators need access to are located at the top of fixed roof tank.	1. Manual gauging or sampling of tank.	a. Provide circumferential stairway and handrail from grade to the top of the tank. b. Install guard railings along the edge of the roof, extending at least 15 ft (4.5 m) beyond the platform in each direction. c. Install a guard railing, 30 in. high by 4 ft long (750 mm x 1200 mm) at the outside edge of each inspection hatch. (OSHA & ANSI have requirements for 42 in. guardrails on platforms.)
17B. Floating roofs of tanks and other equipment located at the top of the tank need to be inspected.	1. Foam chambers. 2. Various pieces of equipment on the floating roof.	a. Provide a top platform with a guardrail from the top of the stairway to the gauge well and the floating roof ladder. b. Install guard railings on wind girders specified to be used as walkways completely around the tank when multiple foam outlet stations are present. c. Provide slip resistant rungs on stairs to the top of the floating roofs to ensure no personnel slippage as the angle of the stairs keeps changing with the floating roof movement. d. Provide proper lighting on stairways and on equipment at top of the tank.
17C. Above ground pipes located inside a tank dike hinder operator's access to the entire dike area.	1. Foam laterals.	a. Provide stairs and appropriately small platform (saddle) over pipes.
17D. To save time, operator walks through the dike of the tank that he/she just inspected in order to get to the next tank.	1. Operator avoids walking back out to the road and then around the entire perimeter of the first tank in order to get to the second tank.	a. Provide additional stairways over the dike at the point where operator exits the dike of the first tank and over the dike of the second where operator enters for the next inspection.

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Human Factors Issue	Example Situation	Comment / Potential Solution
17E. Stairs to top of tanks and onto floating roofs are used often by operating personnel.	1. Inspect for leakage or seal damage at top of tank floating roof.	a. Ensure that the stair maximum height, minimum tread depth, and maximum tread overlap are designed according to OSHA 1910.24 to minimize tripping hazards. b. Ensure stairs are out far enough from the tank so that sample draws and thermo wells do not engage the stair causing trip hazards.
17F. Grading around tank does not prevent the pooling of liquid.	1. Operator must walk through water (or product) to get to valves / pumps / stairs.	a. Slope grading to drain liquids away from piping, equipment, and access paths.
17G. Level indication is not visible from valve manifold for manual operation.	1. Overfill or complete de-inventory scenario.	a. Ensure level indication is visible from manual valving. b. Consider installing level alarms / controls.
17H. Tank must be entered for cleaning or maintenance.	1. Manway is not located for convenient entry.	a. Ensure manways are large enough to not only accommodate a healthy individual, but are also large enough to permit the evacuation of those who might be unconscious. b. Ensure access is sufficient to accommodate personnel wearing encumbering clothing and safety related equipment (e.g., SCBA).

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Human Factors Issue	Example Situation	Comment / Potential Solution
18. Valves		
18A. Valve is operated manually in an emergency, so the operator must be able to get at it quickly and operate it easily and without mistakes.	1. Battery Limit Valve. 2. Pump suction. 3. Pump discharge.	a. Mount at grade or on a platform. b. Orient so operator can access it easily. c. Mount larger valves to allow operation with both hands. d. Ensure that location of actuator complies with Figure 3.
18B. Valve is operated sequentially and its position and operation must be considered in relation to other valves.	1. Manifold. 2. Compressor startup.	a. Conduct Task Analysis to identify where valve lies in the sequence of operations. b. Conduct Link Analysis to determine how operator movements affect location of valves. c. Ensure valve lies close to others used.
18C. The incorrect operation of the valve will exceed safe operating envelope and no apparent mitigation strategy has been implemented into the design.	1. Block Valve. 2. Switch valve on a coker. 3. The valve manipulation is an integral part of a task exceeding 7 steps[6] and/or requires interaction with other operations.	a. Conduct Task Analysis to ensure that operator actions cannot inadvertently operate valve. b. Control valve position through an interlock.
18D. The valve is operated remotely from a field location, so the design of the control panel is important to consider.	1. Large MOVs 2. Small MOVs that control movement of pyrophoric material (catalyst)	a. Ensure valve open/close indication (actual position from a limit switch) is shown on the panel. b. Ensure valve movement is shown on the panel. c. Ensure valve is shown in mimic format as part of the process flow.

[6] Based on generally acceptable industry research that has shown that humans should not be expected to memorize and accurately perform more than 7 ±2 pieces of information. See Sanders, M.S. and McCormick, E.J., 1993, "Human Factors In Engineering and Design," Page 67, McGraw-Hill, Inc.

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Human Factors Issue	Example Situation	Comment / Potential Solution
18E. Several valves are located in close proximity to each other	1. Around heat exchangers.	a. Ensure minimum clearance of 3 in. (80 mm) between adjacent valve handwheels, equipment and structures; and 2 in. (50 mm) between the back of the handwheel and insulation on the line in order to avoid knuckle injuries. b. Provide additional clearance for wrench-assisted operation of valve handwheels and handles of ball-and-plug type valves. Valve wrenches may be used if approved by the plant. c. Ensure valve handles are oriented such that they do not turn to restrict the access or walk-through pathway in front of the valve.
18F. Large valve handwheels are operated manually.		a. Ensure manual operation of valve handwheels, manual gear operators, levers, or chain operators does not require application of force exceeding the forces provided in Figure 4, based on valve wheel height and stem orientation. b. Operating valves that require a greater force to turn, or that require more than 40 turns from open or close position, should be motor-operated to reduce the likelihood of musculoskeletal and repetitive motion injuries.
18G. Drain valves must remain open for long periods of time.	1. Due to fatigue, the operator either ties valve open or walks away for a period of time.	a. Install momentary contact (deadman) valve.

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Human Factors Issue	Example Situation	Comment / Potential Solution
19. Vessels (including Exchangers)		
19A. Vessel must be entered for cleaning or maintenance.	1. Manway is not located for convenient entry.	a. Ensure manways are large enough to not only accommodate a healthy individual, but are also large enough to permit the evacuation of those who might be unconscious. b. Ensure Access is sufficient to accommodate personnel wearing encumbering clothing and safety related equipment (e.g. SCBA).
19B. Vessel contents are hazardous, reactive, pyrophoric, decomposing and require wearing of PPE and/or other precautions.	1. Limited room for storage and handling. 2. Atmosphere may be contaminated.	a. Ensure that enough room is designed into the facility to permit staging vessel contents in preparation for removal or installation, depending on the task necessary. b. Provide lifting equipment designed for pallets or supersacks if contents are added or removed above grade. c. Install air ventilation and filtration systems. d. Ensure design for operation is compatible with the PPE that is being worn.
19C. Exchanger bundles must be removed for maintenance.	1. Limited space available for access to valves, flanges, lines, etc.	a. Ensure layout of heat exchangers allows sufficient clearance and access to enable removal with mobile hoisting equipment. Alternatively, provide fixed overhead lifting facilities.
19D. Atmospheric vents for flammable and toxic vapors are not routed to safe locations, away from personnel and ignition sources.	1. Vent at a location below or near a platform where people are present.	a. Route vent to a safe location away from personnel. b. Route vent to a closed drain system.

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Human Factors Issue	Example Situation	Comment / Potential Solution
20. Work Environment: Lighting, Noise, Heating/Cooling		
20A. Illumination levels are sufficient for walking through the unit, but not for reading labels and signs.	1. Operator turns the wrong valve because he cannot read the label at night.	a. Set levels of ambient illumination on the basis of tasks performed and the age of the user population. b. The levels of illumination must be adjusted to those required for the most difficult visual task. Otherwise, task lighting should be employed.
20B. Sunlight washes over the panel creating glare on the displays making them difficult to read.	1. Operator misses the out-of-limits reading because of glare on the displays.	a. Design lighting systems to minimize direct and indirect glare, maintain luminance ratios of less than 10:1 and optimize the color of the light source and reflecting surfaces. b. Field panels should face north (in the northern hemisphere) so bright sunlight will not fall on them. c. Field panels should be equipped with side panels to block sunlight.
20C. Inadequate emergency lighting.	1. During a blackout, employees found it difficult to follow the escape route from a building.	a. Design emergency lighting to provide illumination for safety, escape, and operation of vital services and to facilitate the restoration of main power. b. Emergency lighting must be located to guide employees to safety. c. In smoke-filled buildings, aisle-path lighting can assist employees who are crawling from the building to escape the smoke.
20D. Atmospheric conditions inside buildings where people work is not adequately regulated.	1. High temperatures combined with low airflow caused control room staff to be drowsy and less alert.	a. In occupied buildings, when performing light or sedentary work, maintain: (1) Temperatures between 64 and 80°F (18 and 27°C) (2) The temperature gradient between the floor and the head at 5 – 7°F (3 – 4°C) (3) Relative humidity between 20 and 60 % (4) Air replacement at 30 ft^3 (0.85 m^3) per minute, per person, with two-thirds consisting of fresh make-up air (5) Air velocity not to exceed 100 ft (30 m) per minute (6) At least six complete air changes of air per hour

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Human Factors Issue	Example Situation	Comment / Potential Solution
		b. Temperature and airflow can degrade performance to the extent that the number of decision and control errors increase.
20E. No special protection provided for workers in hot or cold environments.	1. Maintenance work on a skid unit is very difficult in extreme cold conditions.	a. In outside areas, protect personnel from the effects of extreme heat and cold. b. Skids should be oriented so operations and maintenance work is performed under protective shelters, or near sources of heat in cold weather.
20F. Radio communication with the control room is poor in a full body protection suit.	1. Outside operator cannot hear clearly the control room instructions because of hearing protection. Gloves make it difficult to operate the portable radios.	a. Install specialized headsets to improve communication. b. Test communication system for clarity using an Articulation Index protocol. c. Control noise levels so that: (1) Voice communication is clear both person-to-person and over radios (2) Background noise is not distracting, irritating or affects performance (3) Speech privacy is maintained as specified (4) Potential for hearing damage is minimized
20G. The sound pressure level in a compressor room is well above the safe exposure level for employees.	1. Employees cannot communicate clearly and ears may hurt.	a. In areas where noise levels cannot be controlled, ensure that personnel are notified and provided with personal protective equipment. b. Employees are fitted with earplugs and earmuffs to reduce exposure. c. Each employee should have a baseline hearing test and subsequent test to assess potential hearing loss.
20H. Heavy machinery and automobile vibration levels are excessive.	1. Whole body vibration levels in trucks are causing back pain complaints and absenteeism among drivers.	a. Control vibration levels so that: (1) Whole body vibration encountered in trucks and heavy equipment is within accepted standards (2) Exposure of hands and arms to vibration from pneumatic and impact tools and equipment is within accepted standards (3) Whole body vibration below that which would cause

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Human Factors Issue	Example Situation	Comment / Potential Solution
		injury is not distracting, irritating nor affects performance b. Measure whole body vibration levels under all driving conditions and estimate the daily exposure limits (in minutes) for each driving condition. c. Provide operators with improved seating and re-measure levels. d. Reduce exposure to the worst driving conditions to the levels recommended by the measurement. This might be done by re-scheduling driving tasks to share the exposure among several drivers.

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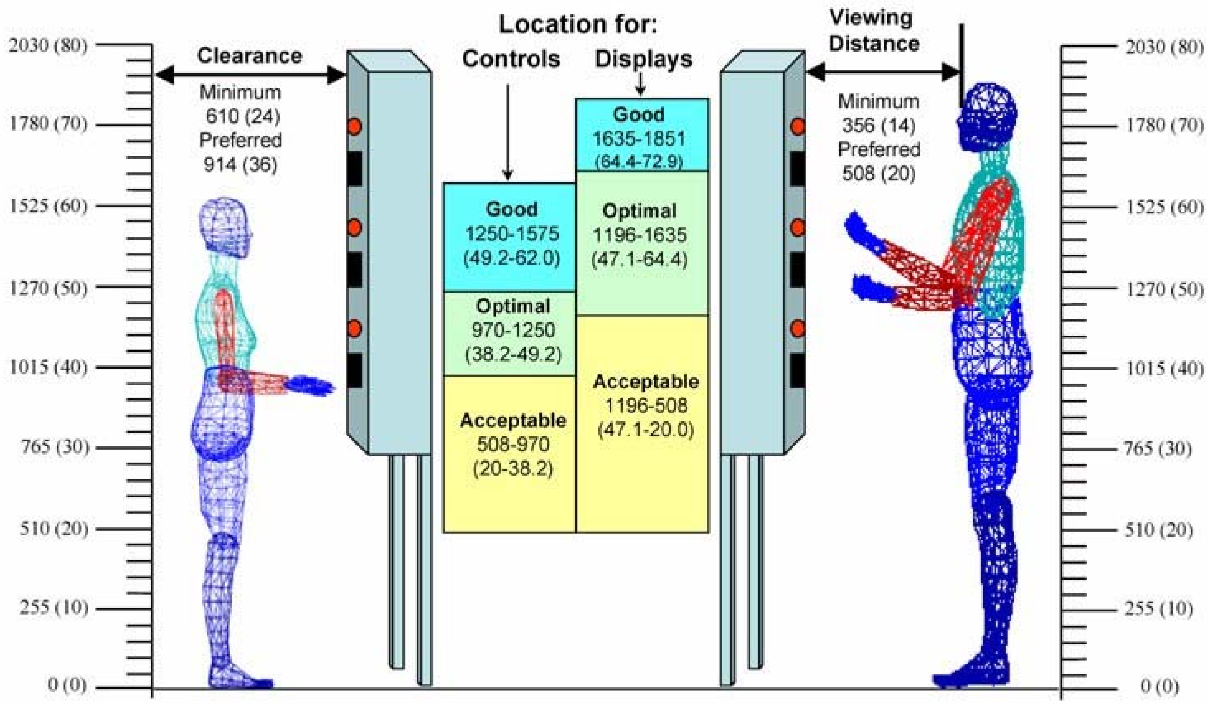
Figure 1—Location of controls and displays on local control panels

Standing Control Panel*

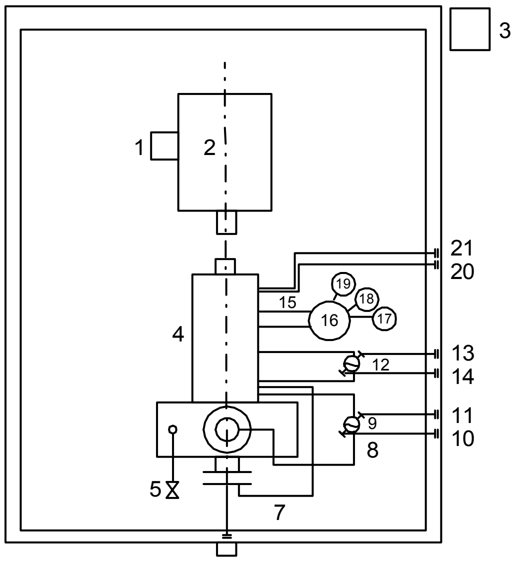


Notes:

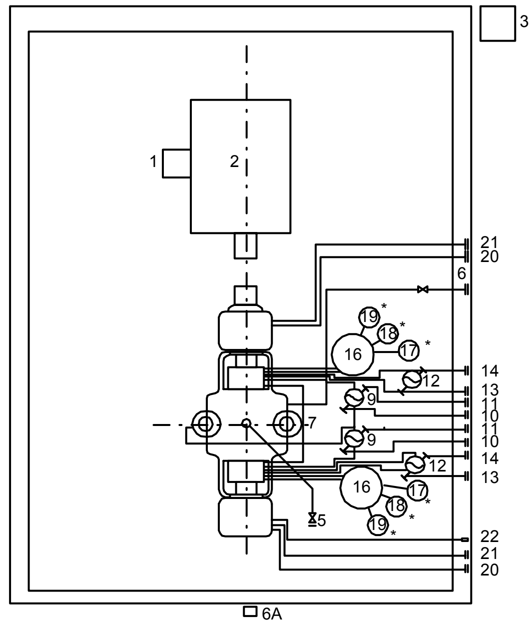
- Dimensions are in mm (inches)
- Figures represent the statures of North Americans: 5th percentile female and 95th percentile male (with shoes)
- Drawing developed by RRS Engineering, League City, TX

Figure 2—Recommended Layout of Equipment and Piping at Pumps

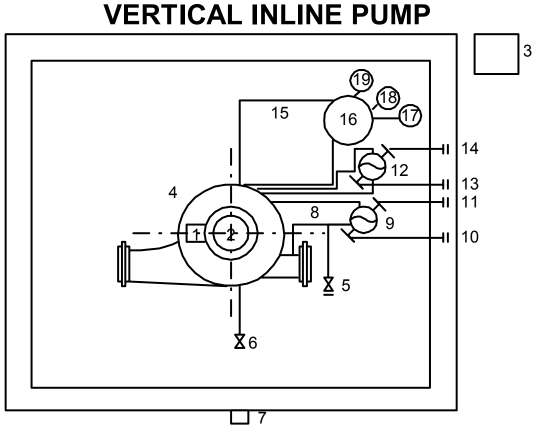
OVERHUNG PUMP



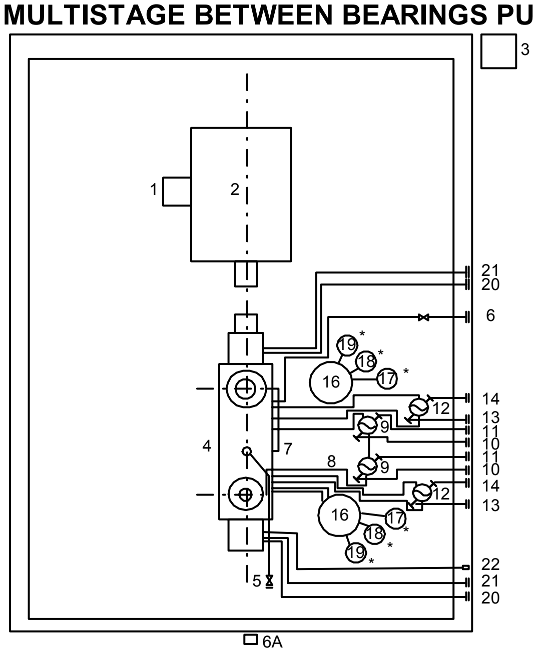
SINGLE STAGE BETWEEN BEARINGS PUMP



VERTICAL INLINE PUMP



MULTISTAGE BETWEEN BEARINGS PUMP



NOTES:

The intent of these layouts is to keep one side of the base plate clear of all obstructions for maintenance access and to orient instrumentation such that it is clearly visible from the on/off switch or the driver control station.

1. Terminal Box
2. Motor
3. Start/Stop Switch (By Contractor)
4. Pump
5. Vent Connection
6. Casing Drain

6a. Baseplate Drain

7. Plan 13* Seal Flush Piping
8. Plan 11* Seal Flush Piping
9. Plan 21* Seal Flush Piping
10. Plan 21* Cooling Water Out
11. Plan 21* Cooling Water In
12. Plan 23* Seal Flush Piping
13. Plan 23* Cooling Water Out
14. Plan 23* Cooling Water In
15. Plan 52/53* Seal Flush Piping
16. Seal Pot
17. Pressure Gauge **
18. Temperature Gauge**
19. Level Gauge **
20. Bearing Housing Cool. Water Out
21. Bearing Housing Cooling Water In

(*) Plan numbers refer to API 610 Seal Flush and Cooling Water Plans

(**) Local instrument readable from the Start/Stop switch

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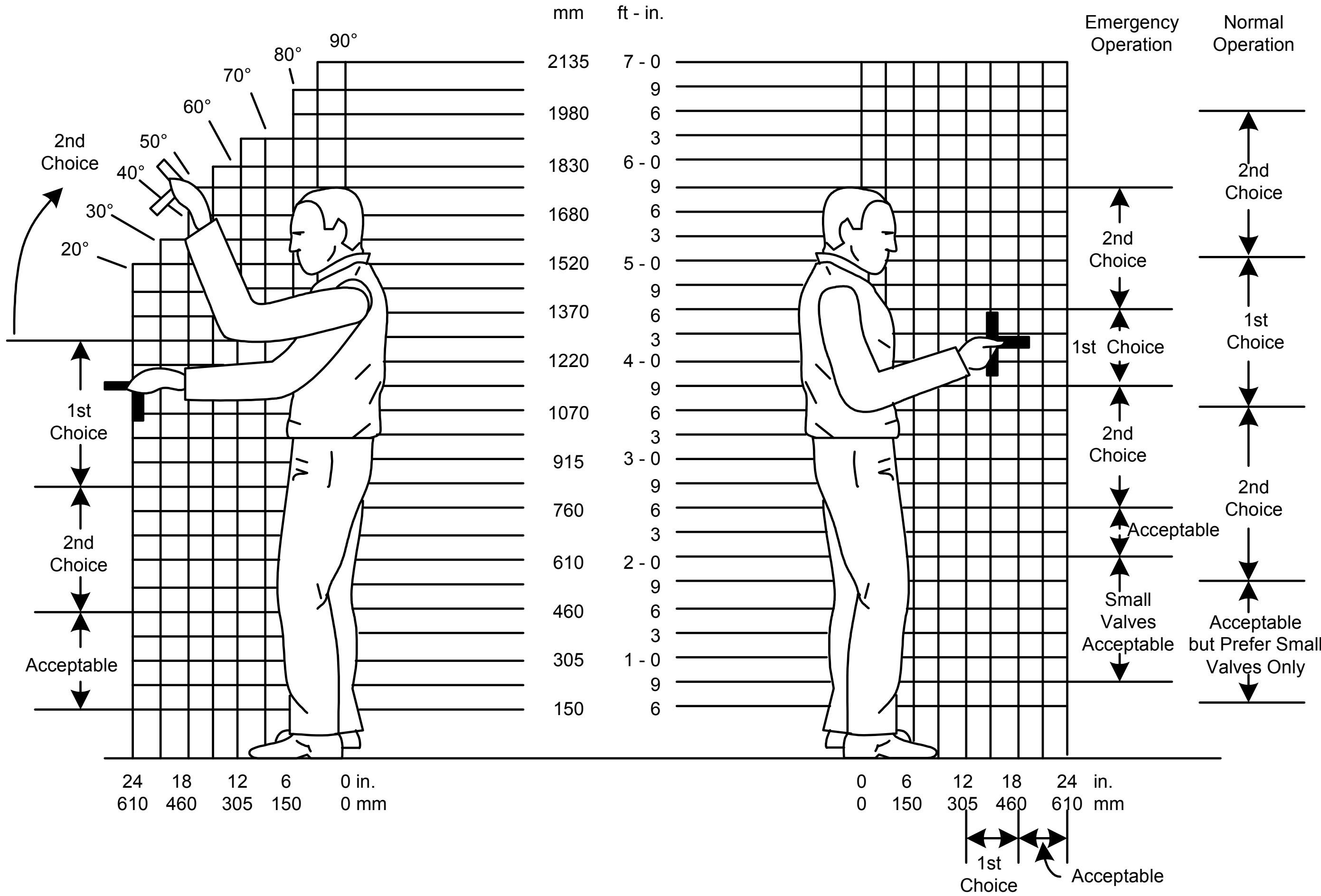
Figure 3—Location of Valve Handwheels*



Notes:

(1) Valves operated more than four times per year should be located in the “1st Choice” reach area

(2) Dimensions in this chart are for the male Caucasian population

*** American Society For Testing And Materials (ASTM), Standard Practice For Human Engineering Design For Marine Systems, Equipment And Facilities, ASTM Designation: F-1166-95a, (reapproved 2000); copyright American Society for Testing and Materials, 100 Barr Harbor Drive, West Conshohock, PA 19428-2959.**

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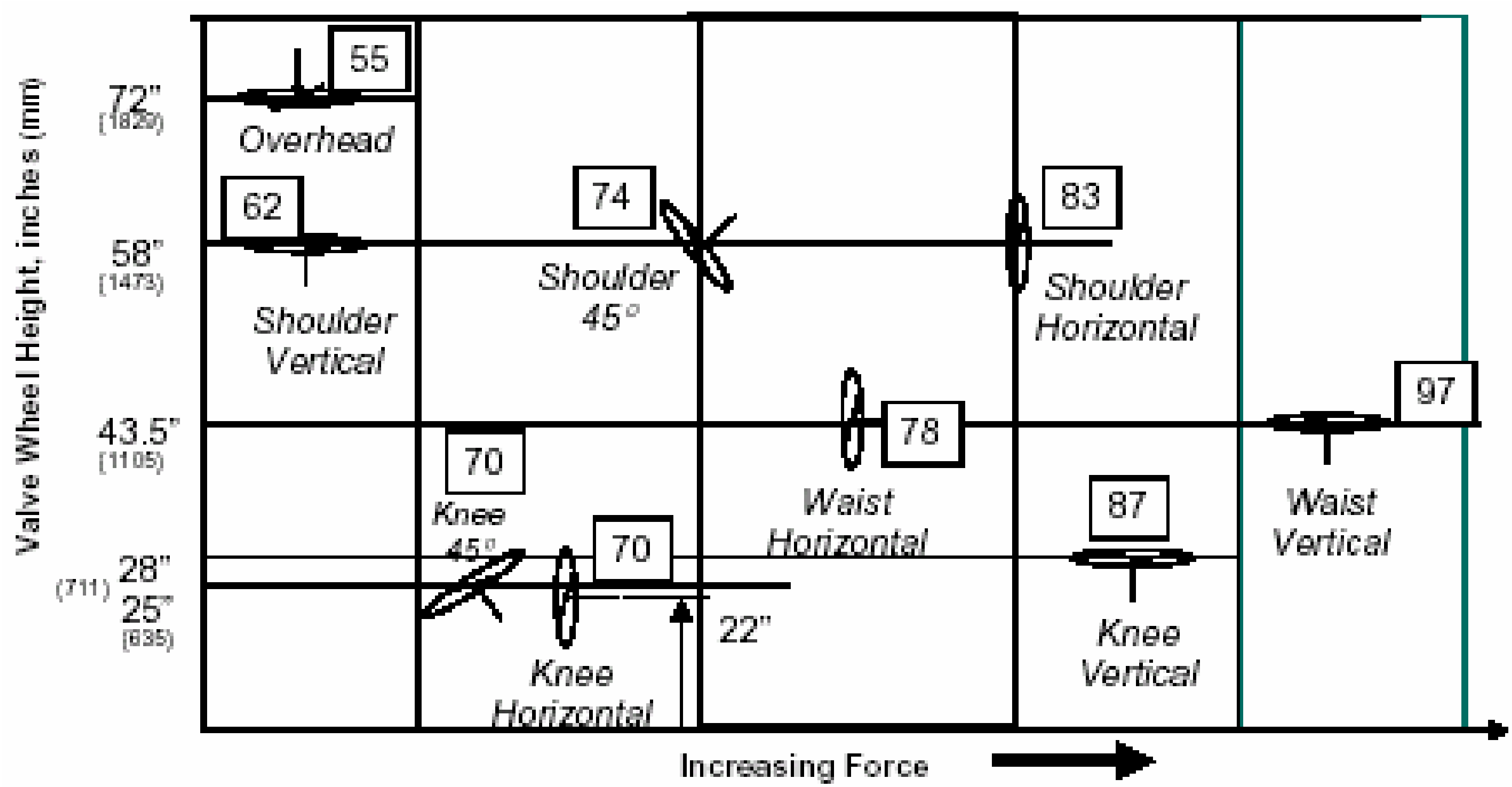
Figure 4—Force as Function of Valve Wheel Height & Stem Orientation*



* Force values inside rectangular boxes in pound-force (lbf) [Conversion: 4.448 Newton/lbf]

Reference: ATTWOOD, D.A. NICOLICH, M. J., DONEY, K.P., SMOLAR T. J. AND SWENSEN, E. E. Valve Wheel Rim Force Capabilities of Process Operators, Journal of Loss Prevention in the Process Industries (Elsevier), Vol. 15/3, May/2002, PP 233-239

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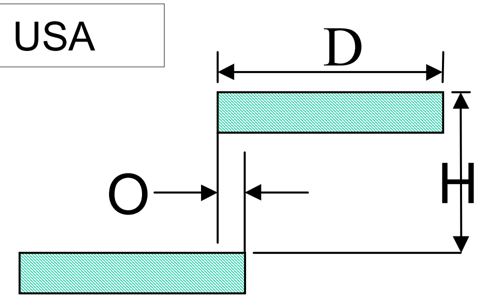
Figure 5—Stair Design

Design stairs consistent with local population and standards:

Example: ANSI A1264.1 - 1995 in the USA



Maximum riser height (H):
+ USA: 24 cm (9.5 in)
[Asia: 20 cm (8 in)]

Tread depth (D):
+ 24 cm (9.5 in)-- min.
+ 27 cm (10.5 in)-- prefer.

Tread overlap (O):
+ 3.8 cm (1.5 in) -- max.

Excessive overlap is a tripping hazard

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Figure 6—Extended Safety Cage Bars

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Figure 7—DCS Monitor Glare from Control Room Lighting

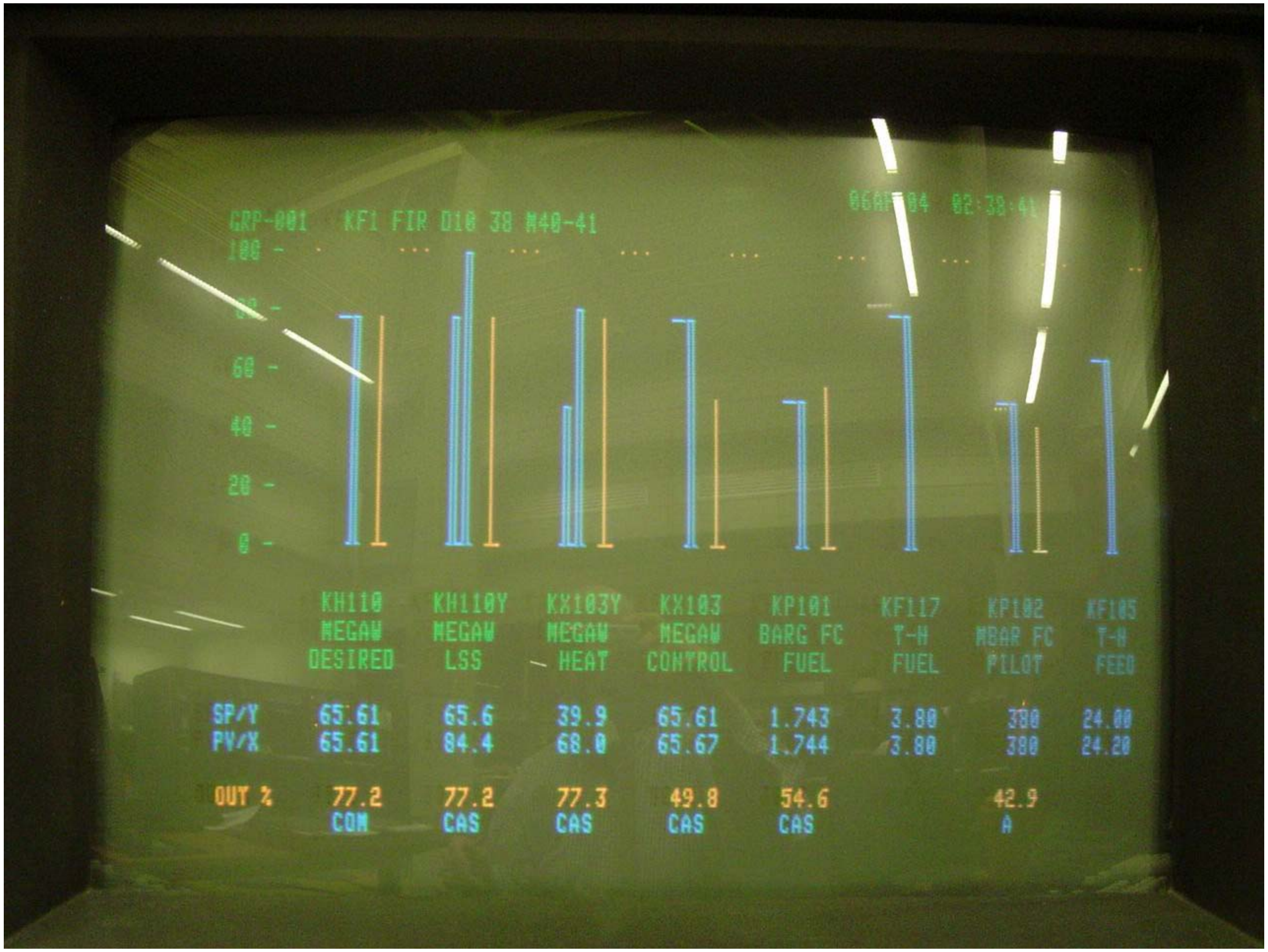

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Figure 8—Indirect Lighting Applications Can Control Reflected Glare

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Figure 9—Operator's View of Wall Displays is Obstructed by DCS Console

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Figure 10—Console Orientation

Console orientation can affect nuisance value of alarms

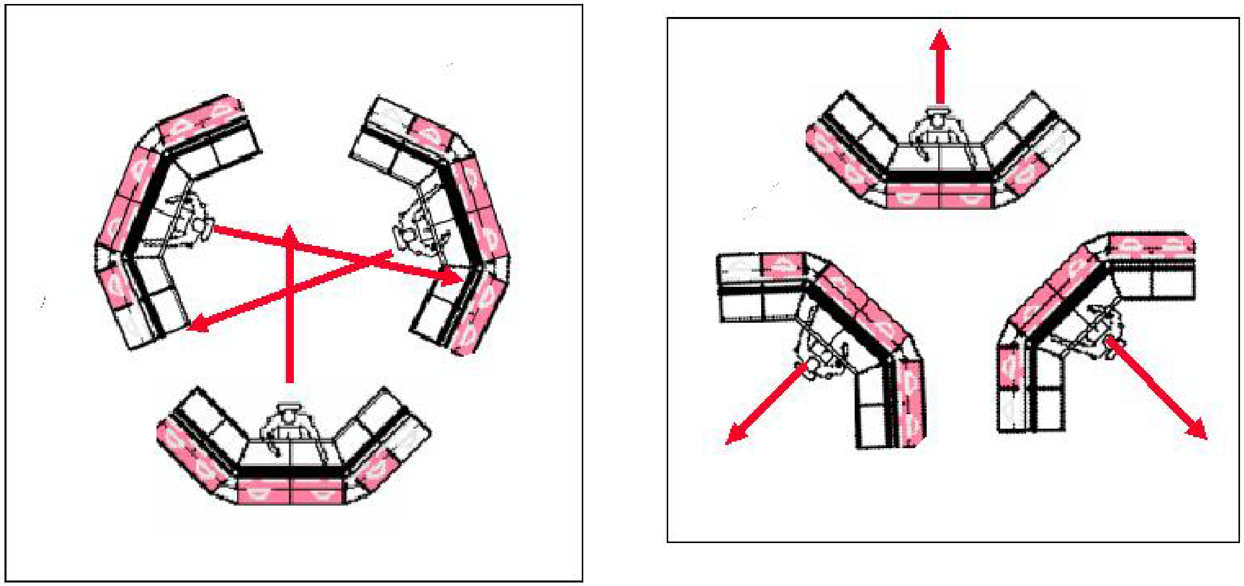

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Figure 11—Use of Sit/Stand Consoles to Reduce Operator Fatigue

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Figure 12—Security Monitors Mounted Above and Behind the Control Room Operator's Position

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Figure 13—Avoid Head Knockers Adjacent to Analyzer Building Work Area

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Figure 14—Locks on an Instrument Cabinet are Difficult to Reach by a Short Technician

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Figure 15—Gas Bottle Access is Obstructed by Bottle Arrangement

GLOSSARY OF TERMS

Access: An approach to equipment for reaching, inspecting or removing it, characterized by sufficient space to allow unobstructed movement of the body and by acceptable reach of personnel interacting with it.

Accessibility: The relative ease that a piece of equipment may be reached, operated, monitored, or removed.

Accessible from grade: Characterized by local population anthropometric maximum horizontal reach (e.g. about 20 in, or 510 mm, for 5th percentile of female North American Population) or overhead grip reach (e.g. 6 ft, or 1820 mm, for 5th percentile of female North American Population) when standing at grade level or on the top of rolling stairs. Typically the maximum elevation of the stairs platform is around 4 ft (1220 mm) so its railing can pass below pipes and structures. (Reference Pheasant, S., "Body Space", Taylor and Francis, 1994).

Annunciator: An illuminated display that is used to provide dichotomous (on-off) status information about a piece of equipment. Annunciators are often used as alarms to notify the operator of an equipment problem.

Anthropometric data: Data on human body sizes and dimensions to design or assess the appropriate size of equipment for access and reach purposes. (Reference Pheasant, S., "Body Space", Taylor and Francis, 1994).

Articulation Index: The percentage of words or sentences that can be understood by a listener.

B/L (or BL): Battery limit of unit.

BLS: Battery Limit Station.

Clearance: Space allowed for the passing of two parts, as it relates to headroom, knee room, elbowroom, and access through passageways, around and between equipment.

Color rendering index: A number between 1 and 100 that describes the effect of a light source on the color appearance of objects, compared with the effect produced by a reference light source of comparable color temperature.

Controls: devices an operator uses to change the status of equipment or process.

Critical valve: an Emergency Block Valve (EBV).

Decibel: A unit of sound pressure level.

Displays: Devices informing an operator about the status of equipment or process.

DCS: Distributed control system.

EBV: Emergency Block valve.

ESD: Emergency Shutdown.

Functional grouping: A group or cluster of controls and displays that are all related to a particular system.

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Glare: dazzling brightness within the field of vision that causes annoyance, discomfort, or loss of visual performance and visibility.

Handrail: A railing or pipe along a passageway or stair that serves to support or guard.

Horizontal reach: the distance a specified group of people would be expected to reach, measured from the shoulder to the fingertips with the arm extended out in a horizontal plane.

Illumination level: Amount of light, measured in Lux or foot-candles, falling on an object or surface. One foot-candle equals 10.76 Lux.

Indirect lighting: General lighting that is produced by light that is reflected from ceilings or walls.

Input dialogue: means of interaction between an operator and the control system, such as menus, direct interaction with graphics, typed commands, and selection of function keys.

Label: a placard displaying several words and a code that is used to identify equipment or components.

LCD: liquid crystal diode.

LED: light emitting diode.

Legibility: The property of a character, word, or symbol that determines how well it can be read and understood.

Line of site: A direct line from the eye of the observer to the object being observed. Line of sight is used to determine whether an object can be seen from the observer's position.

Link Analysis: a technique identifying the links between system components in terms of order, frequency and priority of use by the operator, and optimizing these links.

Luminance: The brightness of an object.

Lux: An International System of Units (SI) measure of luminance.

MOV: Motor Operated Valve.

NIOSH: National Institute for Occupational Safety and Health.

NRR: Noise Reduction Rating for personnel hearing protection (e.g., canal caps, ear plugs and muffs) -- This is the amount of potential noise reduction that the protection provides to the individual. For example, when working in an environment of 110 dBA, wearing earplugs with a 29 NRR will reduce the noise level to 81, assuming the fit is proper.

Operational frequency for valves: the following terms infer the indicated frequency of use:

a. Operating valve - at least four times a year
b. Frequently operated valve - more than twice a month

Operator interface: the combination of display and controls devices that enable an operator to communicate with the control system and to obtain information on the process and equipment status.

Overview displays: A display that illustrates the status of the entire process, not just a piece of it.

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OSHA: Occupational Safety and Health Administration.

Parabolic lens: A plastic or glass device fitted over the housing of a fluorescent fixture the focuses the light produced.

PC: Personal Computer.

P&ID: Piping (or Process) and Instrumentation Diagram.

Plenum: The space between the drop ceiling and the floor above.

Population stereotype: A convention adopted by a particular group of people (e.g., in the USA people expect to switch up for on, in Europe people expect to switch up for off).

Pot lighting: A circular lighting fixture that is recessed into the ceiling and is used to light small circular areas of work surface.

PPE: Personnel Protective Equipment.

Reach envelope: A space between the operator's body and hands that is outlined by the arcs of the operator's outstretched arms inside of which, the operator can grasp items.

Reflected ceiling plan: A scale, plan view of a building interior complete with the layout of the furniture and with the location and type of all lighting fixtures.

Relative humidity: The ratio of the amount of water vapor contained in the air to the maximum amount of vapor that the air can hold at a given temperature before precipitation occurs.

Safety critical: controls and displays - Devices that inform about abnormal conditions and which control variables requiring rapid change to avoid serious consequences such as loss of containment, or injury.

SCBA: Self-contained breathing apparatus.

Sign/Signage: A placard that displays text used to communicate instructions or information.

Sound Pressure Level (A-weighted): Sound pressure measured in decibels that are filtered according to a weighting curve that closely approximates the response characteristics of the human ear.

Task Analysis: A systematic and structured break down of a task into its component steps for the purpose of identifying potential hazards of the steps and respective risk reducing measures.

Task lighting: Lighting that is intended to provide illumination to a specific work area.

Viewing distance: The distance from the eye to the face of the display or other observed item.

VDU: visual display unit.

Visual angle: The angle subtended at the eye by the object being viewed.

Wayfinding: Ability of an individual to arrive with ease at his or her destination.

Work surface: The working surface of a workstation, table or bench.

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