
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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TABLE OF CONTENTS

Purpose.....	1
Scope.....	1
Applicability.....	1
Structure of Tool	1
How to Use the Tool	1
Economic Discussion.....	3
Application of Tool in Existing Facilities	4
1. Alarm Management	5
2. Blinds and Blanks	9
3. Control House Ergonomics.....	11
4. Electrical Substations and Field Housing for Instruments	19
5. Emergency Equipment	23
6. Field Analyzer Buildings	25
7. Field Display Panels	27
8. Filters.....	29
9. Furnaces and Fired Heaters.....	31
10. Instrumentation Systems	33
11. Labeling / Signage of Process Equipment.....	34
12. Loading / Unloading Facilities.....	36
13. Pumps and Compressors	38
14. Reactors / Dryers.....	40
15. Sample Points	41
16. Structural: Ladders, Stairs, Guards, and Handrails	42
17. Tanks.....	44
18. Valves.....	46
19. Vessels (including Heat Exchangers).....	48
20. Work Environment: Lighting, Noise, Heating/Cooling.....	49
Glossary.....	67
References.....	70
Figures	
1 Location of Controls and Displays on Local Control Panels	52
2 Recommended Layout of Equipment and Piping at Pumps	53

3	Location of Valve Handwheels	54
4	Force as Function of Valve Wheel Height & Stem Orientation	55
5	Stair Design	56
6	Extended Safety Gage Bars	57
7	DCS Monitor Glare from Control Room Lighting	58
8	Indirect Lighting Applications Can Control Reflected Glare.....	59
9	Operator's View of Wall Displays is Obstructed by DCS Console.....	60
10	Console Orientation	61
11	Use of Sit/Stand Consoles to Reduce Operator Fatigue	62
12	Security Monitors Mounted Above & Behind the Control Room Operator's Position	63
13	Avoid Head Knockers Adjacent to Analyzer Building Work Area	64
14	Locks on an Instrument Cabinet are Difficult to Reach by a Short Technician.....	65
15	Gas Bottle Access is Obstructed by Bottle Arrangement	66

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

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

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.

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 be 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

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%

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.

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.

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.

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—H₂S/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.

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)]

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).

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.

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.

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.

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

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

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.

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.

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. 2. Lack of outside access to permit counter requires contractors to walk into the control space and disturb the console activities.	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. 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.