



SEMI S8-95A

SAFETY GUIDELINES FOR ERGONOMICS/HUMAN FACTORS ENGINEERING OF SEMICONDUCTOR MANUFACTURING EQUIPMENT

NOTE: This document is provided for reference only. It has been superseded by a later version.

NOTICE: These guidelines do not purport to address all of the safety issues associated with their use. It is the responsibility of the user of these guidelines to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

NOTICE: These guidelines address aspects of ergonomic/human factors engineering and include numerous general design goals for effective human-machine performance. If and when applicable to safety and health practices, these guidelines do not purport to address all of the safety issues associated with their use. It is the responsibility of the users of these guidelines to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

NOTE: As listed or revised, all documents cited shall be the latest publications of adopted standards.

1 Purpose

This document provides ergonomic/human factors design principles and considerations for semiconductor manufacturing equipment. It was developed to provide guidelines for a flexible partnership between the equipment manufacturer and equipment purchaser. Adhering to these guidelines should promote compatibility in the integration of user personnel and equipment within a semiconductor manufacturing environment.

2 Scope

These guidelines apply to the design, installation, operation, maintenance, and service of semiconductor manufacturing equipment.

This document contains the following:

- Purpose
- Scope
- Limitations
- Referenced Documents
- Terminology
- Related Documents

- Human-Systems Integration Principles
- General Guidelines
- Workstation Design
- Design for Maintainability and Service
- Lifting, Strength and Materials Handling
- Hazard Alerts and Alarms
- Controls & Displays
- User-Computer Interface
- Documentation
- Related Information 1 — Anthropometric Resource Data
- Related Information 2 — Ergonomic Resource Data
- Related Information 3 — Manual Materials Handling Resource Information
- Related Information 4 — Three-Zone Rating System
- Related Information 5 — Supplier Ergonomics Success Criteria

NOTE: These guidelines address safety and non-safety aspects of ergonomics/human factors engineering, and include numerous general design goals for effective human-machine performance. Therefore, when using these guidelines to support a safety risk analysis (Section 4.2 of SEMI S2), only the portions of this document that directly relate to safety or are needed to analyze the hazards identified in the SEMI S2 analysis are applicable. The evaluator should make the determination of whether a non-conformance presents an unacceptable level of risk as part of the SEMI S2 safety evaluation.

3 Limitations

3.1 Except where required by statute, it is not intended that this document be evaluated for exact line by line compliance with every provision. National, international, and local standards, codes, and regula-



tions should be consulted to ensure that equipment meets regulatory requirements in each location of use.

3.2 Data Application Limitations — Human factors data compiled in references and specifications are influenced by the population from which they were drawn and the reason they were collected. Human factors design criteria are often based on studies using a limited number of subjects or are context-specific. Ergonomics experts should be consulted where data interpretation or development is required. (See Related Information 1, 2 & 3 for sample data.)

3.3 Special Populations — Suppliers are encouraged to design for the reasonable accommodation of equipment users with special needs, such as left-handedness, color blindness, hearing and vision impairment, physical disability, etc. While designing with flexibility to accommodate the largest practical portion of the user population may allow those with special needs to interface effectively with equipment, this guideline cannot anticipate and fully accommodate all such needs.

4 Referenced Documents

4.1 SEMI Document

SEMI S2 — Safety Guidelines for Semiconductor Manufacturing Equipment

4.2 ANSI Documents¹

ANSI/HFS 100 — American National Standard for Human Factors Engineering of Visual Display Terminal Workstations

ANSI Z535.4 — Product Safety Signs and Lab

4.3 EN Documents²

NOTE: European Norm (EN) standards are listed herein for application to semiconductor manufacturing equipment to be used in the European Union (EU). As EN standards are intended for use with a broad range of industrial and consumer products, conflicts with SEMI safety guidelines are likely. Additionally, proposed EN (prEN) standards are subject to revision prior to adoption. Therefore, actual and potential non-conformances to EN standards should be addressed

with regulatory authorities, competent bodies, or with the purchaser to ensure acceptance.

prEN 894-1 — Safety/Ergonomics for Operator Interaction

prEN 894-2 — Safety/Ergonomics for Displays

prEN 894-3 — Safety/Ergonomics for Control Actuators

EN 60204-1 — Safety of Machinery — Electrical Equipment of Machines, Part 1. Specification for General Requirements

prEN 50099-2 — Safety/Marking Principles

prEN 614-1 — Safety of Machinery — Ergonomic Design Principles, Part 1. Terminology and General Principles

4.4 Military Standard³

MIL-STD-1472 — Human Engineering Design Criteria for Military Systems, Equipment and Facilities

4.5 NFPA Document⁴

NFPA 79 — Electrical Standard for Industrial Machinery

4.6 SAE Document⁵

SAE J833 — Human Physical Dimensions

4.7 Other Documents

NIOSH Publication No. 81-122⁶ — Work Practices Guide for Manual Lifting, National Institute for Occupational Safety and Health, 1981.

Pheasant, Stephen, *Bodyspace* — Anthropometry, Ergonomics and Design, Taylor & Francis, 1988.

Snook, Stover and V. Ciriello, *The Design of Manual Handling Tasks* — Revised Tables of Maximum Acceptable Weights and Forces, *Ergonomics*, Vol. 34, No. 9, 1991.

Lifting Tasks, *Ergonomics*, Vol. 36, No. 7, 1993.

³ Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20555 USA

⁴ National Fire Protection Association, Batterymarch Park, Quincy, MA 02269 USA

⁵ Society of Automotive Engineers, 400 Commonwealth Drive, Warrendale, PA 15096 USA

⁶ National Institute for Occupational Safety and Health, Technical Information Branch, 4676 Columbia Pkwy, Cincinnati, OH 45226 USA

¹ American National Standards Institute, 1430 Broadway, New York, NY 10018 USA

² European Committee for Standardization, Central Secretariat, Rue de Stassart 36, B-1050 Brussels, Belgium



Waters, Thomas, et. al., Revised NIOSH⁶ Equation for the Design and Evaluation of Manual Lifting Tasks, *Ergonomics*, Vol. 36, No. 7, 1993.

5 Terminology

5.1 *administrative control* — A method to protect personnel from hazards by using work practices to reduce the duration, frequency, or severity of exposure.

5.2 *alarm* — An auditory or visual signal indicative of a hazard alert.

5.3 *anthropometric considerations* — Design constraints based upon anthropometric (e.g., size and strength) limitations of user personnel.

5.4 *anthropometry* — Description of the physical variation in humans by measurement.

5.5 *awkward posture* — Posture which, if maintained or assumed frequently, will produce fatigue.

5.6 *cancel* — To acknowledge and eliminate the alarm signal.

5.7 *cognitive* — Relates to human information processing, perception, and attention.

5.8 *control* — A means or device to direct or regulate a process or sequence of events.

5.9 *critical* — Directly related to hazards to personnel or damage to product or equipment.

5.10 *critical controls and displays* — Controls and displays which prevent the equipment from entering or indicate that equipment is entering an unsafe condition in which hazards to personnel or damage to equipment or product may occur. Emergency Off (EMO) switches, interlock defeat indicators, and malfunction alarms are examples of critical controls and displays.

5.11 *display* — A visible representation of information in words, numbers, symbols, pictures, or drawings.

5.12 *emergency off (EMO)* — A control switch which, when activated, places the equipment into a safe shutdown condition.

5.13 *engineering controls* — Controls which eliminate or mitigate a hazard as an inherent aspect of the design.

5.14 *equipment supplier* — Agent through whom the equipment is sold to the owner. This may be the manufacturer, retailer, or importer of the equipment.

5.15 *ergonomic-related hazard* — Equipment or workplace condition that creates stress to the user that may contribute to the risk of developing either acute injury or cumulative trauma disorders.

5.16 *ergonomics* — The study of human mental and physical capability in relation to the working environment and the equipment operated by the worker.

5.17 *ergonomics/human factors issues* — Those issues dealing with the user's physical and cognitive needs, capabilities, and human performance limitations in relation to the design of machines, tasks, and other modifications of the human's working environment.

5.18 *excessive reach* — An extended reach which may result in a biomechanical stress to the user.

5.19 *extended reach* — Reaches which require leaning, stretching, stooping, or crouching.

5.20 *frequent task* — A task with a cycle time of 30 seconds or less, where 50% or more of the total job cycle is spent performing a fundamental cycle; piece rates at or exceeding twice per minute, 2000 or more manipulations per day, or four or more hours performing repetitious Video Display Terminal (VDT) tasks.

5.21 *function* — Actions or tasks that the human-equipment system must accomplish to meet its performance objectives and specifications.

5.22 *inadvertent actuation* — Accidental or unintentional activation or deactivation of a control.

5.23 *infrequent tasks* — Tasks that are performed less than once every two hours.

5.24 *installation* — The activities performed after the equipment is received at a user site through preparation for initial service, including transportation, lifting, uncrating, placement, leveling, and facilities fit up.

5.25 *maintenance* — Functions performed by the user to assure equipment performance; these may include cleaning and replenishment of expendables.

5.26 *mock up* — A full size physical model of the equipment, generally made of relatively inexpensive materials, used for human factors evaluation.



5.27 *normal line of sight* — The line extending from the eye, perpendicular to the interocular line and 15 degrees below the horizontal position of the eye.

5.28 *occasional tasks* — Tasks performed more often than “infrequent tasks,” but less often than “frequent tasks.”

5.29 *operation* — Consists of functions by which the operator causes the equipment to perform its intended purpose; these may include loading product and setting or manipulating external controls.

5.30 *operator* — A user that interacts with the equipment only to the degree necessary for the equipment to perform its intended function.

5.31 *override* — To take precedence over the current control system state.

5.32 *personal protective equipment (PPE)* — Equipment and clothing worn to reduce potential for personal injury from hazards associated with the task to be performed. In the context of this document, clean-room attire (e.g., gloves, smocks, booties, hoods, etc.) is not considered personal protective equipment.

5.33 *primary viewing area* — The area included in the 30 degree cone around the normal line of sight of the user when at the primary work area.

5.34 *problem tasks* — Tasks which have been defined as presenting ergonomic conditions that are likely to cause biomechanical stresses or injury to personnel, misoperation or damage to equipment and/or the product.

5.35 *risk factors* — Those elements of the design which allow a potential for injury/illness to personnel, damage to equipment, environment, or product.

5.36 *semiconductor manufacturing equipment* — Equipment used in the design, development, manufacture, assembly, measurement and test of semiconductors and associated semiconductor support processes.

5.37 *service* — Usually means repair. Service may be performed by specifically trained service personnel or by sophisticated users following instructions specifically indicated as service instructions. Certain maintenance procedures may be defined as service if they are infrequent, complex or highly specialized.

5.38 *static posture* — A fixed position, without movement of the particular body part.

5.39 *task* — A group of related job elements performed within the work cycle and directed toward a specific objective.

5.40 *task analysis* — An analytical process employed to determine the specific actions required of the user when operating equipment or doing work. Within each task, steps are described in terms of the perception, decision-making, memory storage, posture and biomechanical requirements, as well as the expected errors.

5.41 *user* — Person interacting with the equipment. Users may include operators, maintainers, service personnel, and others.

5.42 *user population* — A specific cross section of persons that may reasonably be expected to interact with the equipment to perform operation, maintenance, or service tasks.

5.43 *validation testing* — Testing to confirm effectiveness of design.

5.44 *warning* — Instruction (e.g., labels, text, messages) provided to inform the user of a hazardous condition. In general, a warning should identify the hazard(s); provide detailed information on how to avoid the hazard; and explain the consequences of not following these instructions.

5.45 *WIP nest* — A storage structure for Work in Process (WIP).

5.46 *work environment* — The location where semiconductor devices and associated support processes are designed, developed, manufactured, assembled, measured, and tested.

5.47 *workplace layout* — The physical arrangement of equipment in the facility.

5.48 *workspace* — The available area where the user is expected to operate, maintain, and service the equipment.

5.49 *workstation* — The location where equipment controls and displays are found and the point of loading/unloading of material.

6 Related Documents

Bailey, Robert W., Human Performance Engineering, Prentice Hall, 1989.

Bass, Lewis (ed.), Products Liability — Design and Manufacturing Defects, Shepards/McGraw-Hill, 1986.



Eastman Kodak Company, *Ergonomic Design for People at Work*, Vols. 1 and 2, Van Nostrand-Reinhold, 1983.

Grandjean, E., *Fitting the Task to the Man: A Textbook of Occupational Ergonomics* (4th Ed.), Taylor & Francis, 1988.

Konz, S., *Work Design: Industrial Ergonomics* (3rd Ed), Publishing Horizons, 1990.

Miller, Dwight P. and Whitehurst, Hugh, *Preventing User-Hostile Interfaces in IC-Fab Equipment — Ergonomic Approaches for Preventing Ten Frequent Interface Problems*⁷ SEMATECH Technology Transfer #92091299NA-ENG, Nov. '92.

Salvendy, Gavriel (ed.), *Handbook of Human Factors*, Wiley, 1987.

Sanders, Mark S. and McCormick, Ernest, *Human Factors in Engineering and Design* (7th Ed), McGraw-Hill Book Company, 1993.

Schneiderman, Ben, *Designing the User Interface*, Addison-Wesley, 1987.

VanCott, Harold P. and Kinkade, Robert (eds.), *Human Engineering Guide to Equipment Design*, U. S. Government Printing Office, 1972.

Woodson, W. E., et al., *Human Factors Design Handbook*, McGraw-Hill Book Company, 1992.

7 Human-Systems Integration Principles

The following general principles are integral to equipment ergonomics/human factors design and evaluation:

7.1 Human-Machine Function Allocation — The equipment should be designed to optimize safety and performance by distributing tasks (typically derived from an analysis) among hardware, software, and users to make the best use of their respective capabilities and to minimize limitations and hazards.

7.2 User Expectancy — Equipment should be designed to minimize potential for errors and mishaps, by conforming to users' expectations which are based on their experience and current practice.

7.3 Human Physical Capabilities — The equipment should be designed to facilitate task performance, min-

imize fatigue and injury by fitting equipment to the body size, strength, and range of motion characteristics of the user population.

8 General Guidelines

8.1 Ergonomics-Related Safety Issues — Ergonomics-related safety issues may exist whenever system design, installation, operation, service, or maintenance factors result in task demands that exceed the information processing or physical capabilities of properly trained users. For example, safety issues may result from:

- static or awkward postures;
- repetitive motion
- poor access, inadequate clearance, and excessive reach
- lifting of heavy or bulky components
- displays that are difficult to read or understand
- controls that are confusing to operate or require too much force
- use of non-specific warnings or faults to communicate machine problems

8.1.2 Ergonomics-related safety issues should be designed out or otherwise reduced to the maximum extent practicable prior to production. Ergonomics-related safety issues are reduced by implementing sound human factors engineering principles in design, and structuring job requirements around human performance capabilities and limitations.

8.1.3 Human error probability should be minimized by equipment design that reduces or eliminates the potential types of error caused by human-machine or human-task mismatch (e.g., inadvertent actuation, errors of omission or commission).

8.1.4 Engineering controls, not administrative procedures, are the preferred means to reduce ergonomic hazards. Where an engineering approach to ergonomic hazard control is not feasible, the system owner may be required to implement administrative controls to mitigate hazards by reducing the duration, frequency or severity of exposure.

8.2 Equipment Design Program — Equipment suppliers should establish formal procedures to identify, eliminate, or control ergonomics-related hazards.

⁷ SEMATECH, *Technology Transfer*, 2706 Montopolis Dr., Austin, TX 78741 USA



8.2.1 A comprehensive ergonomics program should typically include:

- Characterization of human-machine interaction requirements, including user personnel physical and cognitive needs
- Inclusion of human factors engineering considerations in design guidelines or specifications
- Input to detailed design of hardware and software controlled systems, procedures, and training
- Human factors testing and evaluation

8.2.3 Priority should be placed on ergonomics issues that might result in injury to personnel or significant equipment or product damage.

8.2.4 Information exchange between equipment suppliers and system owners or users regarding human-machine interface issues is encouraged during the development stage, as part of beta site testing, and after equipment is in full production.

8.3 Ergonomics/Human Factors Test & Evaluation — Ergonomics test and evaluation involves the examination of equipment to determine whether human factors requirements have been met. The examination should yield documentation of ergonomic design characteristics.

8.3.1 Equipment evaluation identifies problem tasks and risk factors associated with equipment design, operation, training needs, installation, maintenance, and service. The evaluation should use recognized methods such as task analysis, human performance assessments, questionnaires and checklists. It should be performed and documented by a team of qualified persons trained in ergonomics, safety, industrial hygiene, industrial and design engineering, etc. Subject Matter Experts (e.g., operators, process specialists, maintenance personnel) can also contribute significantly to the test and evaluation activity.

8.3.2 Use of mock-ups and simulations are beneficial to identify and resolve ergonomic issues before the design is finalized. Testing should be performed with individuals who are representative of the user population under anticipated working conditions.

8.4 Equipment-Fab Interface — Equipment design should be compatible with the user work environment and required facilities services.

8.4.1 Facility requirements that impact human-machine performance of the equipment should be clearly identified. Equipment installation should avoid degrading ergonomic features of the equipment.

8.4.2 The most effective workplace arrangement can be determined by carefully analyzing the interrelationships between equipment, operators, and related processes. Consideration should be given to product flow, operator duties, maintenance/service procedures, multiple machine operation, principles of motion economy, and materials handling in the workplace. The overall objective is to provide for system effectiveness and for worker convenience, safety and comfort when operating and maintaining the equipment.

8.5 Clothing-Equipment Integration — Equipment design should consider operator limitations imposed by the use of special garments and personal protective equipment (PPE). Equipment operation should not result in damage or undue deterioration of required user clothing. Controls, such as knobs and switches, should be compatible with gloves worn by users for contamination control or personal protection. For example, cleanroom gloves typically reduce grip strength by 15%. Equipment displays should consider the potential for impaired vision and hearing that may occur with the use of cleanroom hoods, chemical goggles or face shields.

8.6 Training Systems Integration — Training systems should be coordinated with technical documentation (e.g., manuals) and on-system instructions (e.g., labels, indicators and screen menus) for consistency in terminology, symbology and format.

8.7 Customer Engineering Specials — It is common for semiconductor manufacturing equipment to be customized for specific applications and to meet unique customer requirements. Where ergonomic design features of the equipment might be degraded by customization, the supplier should inform the system owner early-on and work jointly to minimize negative impacts.

9 Workstation Design

9.1 **Anthropometry** — To enable good system performance, equipment and workspaces should be designed to accommodate the physical dimensions of 90 percent of user personnel (e.g., 5th percentile Asian Female through 95th percentile North American Male). Refer to Related Information 1, Table 1, Figures 1 & 2.



Where impairment of safety might result in danger to life, such as the inability to exit or escape under emergency conditions, wider percentile ranges should be used (e.g., 1st through 99th percentile range).

9.1.1 Anthropometric data generally report unclothed body dimensions. Therefore, allowances should be made for working attire (e.g., cleanroom clothing) and PPE.

9.1.2 Reach distances or other limiting dimensions should be based upon 5th percentile Asian female values for applicable body dimensions.

9.1.3 Seats, work surfaces, and equipment that require adjustment for comfort or performance should be readily adjustable over the range of 5th percentile Asian female to 95th percentile North American male values for the applicable body member(s).

9.1.4 Critical and frequently used equipment, tools and work items should be placed in the operator's primary viewing area.

9.1.5 Provision for placement of required materials and informational items used during operation should be accommodated in the design.

9.1.6 Exposed edges or corners in contact with users should be rounded and surfaces smooth.

9.2 Working Postures

9.2.1 Workspace configurations that require sustained or repeated awkward postures (where the limbs or torso deviate from a neutral position) should be avoided.

9.2.2 Tasks which require the user to keep upper limbs extended or elevated should be avoided.

9.2.3 If tasks require a static posture, appropriate supports (e.g., arm rests and sleeves) should be provided.

9.2.4 Where applicable to tasks performed, equipment should be designed to allow both sitting and standing operation.

9.2.5 Controls, tools and materials should be located so that the most frequent activities are performed from a neutral posture (e.g., with the elbows bent 90-120 degrees from full extension and held comfortably close to the body).

9.2.6 To prevent users bending at the waist, the design should place users close to the point of opera-

tion by providing adequate leg and foot clearance and keeping work materials at an appropriate height.

9.3 Standing Workstations

9.3.1 Standing Workstation Recommendations (See Related Information 2 - Table 1)

9.3.2 Displays requiring precise or frequent reading should be within the primary viewing area.

9.3.3 Frequently used controls, tools and materials should be placed within the minimum elbow-grip length of the 5th percentile Asian female.

9.3.4 Infrequently used controls, tools, and materials should be placed:

- within the forward reach of 5th percentile Asian female
- below the standing overhead reach of 5th percentile Asian female
- no lower than standing knuckle height of 95th percentile North American male

9.4 Sitting Workstations

9.4.1 Sitting Workstation Recommendations (See Related Information 2, Table 2)

9.4.2 Displays requiring precise or frequent reading should be within the primary viewing area.

9.4.3 Frequently used controls, tools and materials should be placed within the elbow-grip length of the 5th percentile Asian female.

9.4.4 Infrequently used controls, tools, and materials should be placed:

- within the forward reach of 5th percentile Asian female
- below the seated overhead reach of 5th percentile Asian female

9.5 *Sit/Stand Workstations* — (See Related Information 2, Table 3 for recommendations)

9.6 Workspace Envelopes

9.6.1 Recommendations for Workspace Envelopes (See Related Information 2, Table 4)

9.6.2 Optimal Vertical Working Zone (See Related Information 2, Table 5)



10 Design for Maintainability and Service

10.1 *General* — Equipment design should facilitate rapid and positive fault detection and isolation of defective items.

10.1.1 Standard parts should be used whenever practicable. Components should be replaceable as modular packages and configured for rapid removal and replacement.

10.1.2 Equipment requiring periodic calibration and adjustment should be readily accessible without disassembly.

10.1.3 Equipment should be designed for servicing by people in the work environment wearing appropriate cleanroom garments and necessary PPE.

10.1.4 Component design should preclude improper mounting and installation of any given component.

10.1.5 Guides, tracks, or stops should be provided as necessary to facilitate handling and prevent damage to equipment or injury to personnel.

10.1.6 Sharp edges and corners that present a personnel safety hazard or potential damage to clothing or equipment should be suitably protected or rounded.

10.1.7 Equipment should have integral lighting in maintenance areas which would otherwise be poorly illuminated.

10.2 *Accessibility* — Structural members or permanently installed equipment should not visually or physically prevent adjustment, servicing, removal of replaceable equipment, or other required maintenance tasks.

10.2.1 *Clearance Guidelines* — See Related Information 2, Table R2-6.

10.2.2 Items which require rapid or frequent maintenance should be most accessible. Predicted or known high failure-rate items should be accessible for replacement without removing non-failed items.

10.2.3 Sufficient space should be provided for the use of standard test equipment and required maintenance tools without difficulty or hazard. Self-checking or built-in test features are recommended.

10.2.4 Sliding, rotating, or hinged equipment to which rear access is required should be free to open its full distance.

10.2.5 Serviceable components should not be stacked directly on one another (i.e., a lower layer should not support an upper layer).

10.3 *Cables, Connectors, Plugs, Receptacles, and Circuit Boards*

10.3.1 Cables, connectors, plugs, and receptacles should be labeled, keyed, color-coded, or otherwise configured to make connection easier and prevent cross connection.

10.3.2 Connectors mounted in close proximity should have clearance so that each one can be easily removed and reinstalled.

10.3.3 Circuit boards mounted in a "card cage" configuration should have finger access and gripping aids for mounting and removal.

10.4 *Equipment Enclosures*

10.4.1 Equipment enclosures should be easily removable or sufficiently larger than the item they cover to facilitate installation and removal of components.

10.4.2 Cover or shield holes should be large enough for fastener clearance without precise alignment.

10.4.3 Enclosures or covers should be self-supporting in the open position and not require manual support during maintenance. Exceptions may be needed for self-closing doors for fire safety or containment reasons.

10.5 *Access Openings* — Access openings should be provided whenever frequent maintenance would otherwise require removing a cover, opening an enclosure, or dismantling a piece of equipment.

10.5.1 Access openings should be designed to permit unobstructed physical and visual operation. Size and shape of the access should allow for easy passage of equipment, body parts of a 95th percentile North American male with necessary PPE and tools, as appropriate.

10.5.2 Access covers should be equipped with full-handed grasp areas (e.g., handles) or other means for opening them.

10.5.3 Unless prohibited from a microcontamination standpoint, access covers with an area of more than 0.3 m² (3 ft²) should be hinged or sliding. Hinged covers that swing horizontally should open a minimum of 165 degrees.



10.5.4 Hinged or sliding access covers that are likely to present a hazard when opened should be self-supporting or provided with a fail-safe device to prevent injury to personnel.

10.6 *Fasteners* — The number and diversity of fasteners used should be minimized. Fasteners requiring non-standard tools should be avoided, except where access is to be restricted.

10.6.1 Hinges, tongue-and-slot catches, and mounting pins should be used to minimize the number of fasteners required. Pin and hook arrangements are preferred to hinges for contamination control.

10.6.2 Captive fasteners should be used where dropping or loss of such items could cause damage to equipment or create difficult or hazardous removal. Captive fasteners should also be provided for access covers requiring frequent removal.

10.6.3 Fasteners should require the minimum number of turns compatible with mechanical stress, alignment, positioning, and load considerations. Items requiring removal for daily or more frequent inspection and servicing should use quick release fasteners.

11 Lifting, Strength, and Materials Handling

11.1 *General* — The application of force or lifting that exceeds the strength capabilities of the user may result in musculoskeletal stress and injury.

11.2 *Strength* — The percentage of a user's maximum strength to be exerted in execution of a task should comply with the following guidelines. Use female strength data at 45 years or older.

- exertions greater than 60 percent of maximum capability should be avoided
- occasional effort, up to 50 percent, is acceptable
- frequent effort should be kept below 30 percent
- continuous effort should be kept below 15 percent

Note: Maximum Grip Forces are provided for reference in Related Information 2, Table R2-7.

11.3 *Product (Wafer) Handling* — Where standard product or containers are to be handled at equipment load and unload stations, mechanization should be considered for orientation and handling. Where manual handling is necessary, the design should discourage extended reaching, lifting, pulling, and manual orientation of product and/or containers. Simultaneous lifting

and twisting should be avoided. Load, unload, and lift-over points for manual product handling should be 89 to 97 cm (35 to 38 inches) from the standing surface, with a horizontal distance of 18 to 46 cm (7 to 18 inches) measured from the front of the body to the product grasp point.

11.4 *Handles* — Handles or cutouts should be designed to facilitate use of the power grip (e.g., similar to that used to hold a pistol). Avoid handles that require pinch grips or deviated wrist postures. Handles should allow carrying in front of the body.

11.5 *Biomechanics* — Lifting and handling tasks performed in a stooping position should be avoided. Two-handed pushing or pulling tasks should be performed at or slightly below elbow height. Full consideration should be given to the standing surface and friction capacity between the user and standing surface. Motions should center around the midpoint in the range of motion for any body joint.

12 Hazard Alerts and Alarms

12.1 General

12.1.1 Actual and potential hazards to users or of damage to equipment or product that require warnings should be determined. Evaluations should include those hazards listed in SEMI S2.

12.1.2 An evaluation should be made as to the appropriate method(s) of warning, warning content, and location. More than one method of hazard alert may be necessary.

12.1.3 Hazard alerts should be designed, constructed, and located such that they indicate or announce an impending or present hazard by visual or audible means.

12.1.4 Hazard alerts can be provided by labels, signs, placards; visual alerts, auditory alarms; status indicators; or hazard alert system integral with the equipment's operating system (e.g., displayed through the video display).

12.1.5 Hazard alerts should be consistent with information provided in operator and maintenance manuals and other training and information materials.

12.1.6 Hazard alerts and fault messages should be specific and communicate the consequences of ignoring or overriding.

12.2 Labels



12.2.1 Hazard alert labels should be easily understood by the user and conform to local regulatory requirements where installed.

12.2.2 Hazard alert labels should be located such that they may be seen by the user when performing the task(s) related to the hazard being warned against.

12.2.3 Hazard alert labels should conform to ANSI Z535.4. Equipment to be operated in the European Union should also conform to prEN 50099-2-1992.

12.3 Audible Alarms

12.3.1 To avoid noise pollution, alarms should be reserved for situations requiring immediate intervention to prevent personal injury, equipment damage, process disruption, or product damage.

12.3.2 Alarms should have a distinctive sound and intensity such that they will be readily distinguishable from other sounds of the tool and nearby equipment. They should take into account impairments that may be caused by clothing and hearing protection.

12.3.3 Users should be provided with a means of acknowledging and canceling alarms without erasing information that accompanies the alarm. The capability to cancel alarms should be evaluated for its impact on safety.

12.3.4 Acknowledgment of an alarm should not inhibit or slow user response to the alarm condition.

13 Controls and Displays

13.1 *General* — The selection or design of controls and displays should be based on careful analysis of equipment functional requirements. This will determine what information the operator needs to make appropriate decisions and responses, thus reducing potential design-induced error.

13.1.1 Potential errors due to inattention, stress, fatigue, boredom, sensory overload, etc., need to be considered during system design by ensuring that critical controls and displays attract the user's attention and that controls and displays are clearly labeled and arranged to reduce confusion. Whenever possible, functionally related controls and displays should be grouped together.

13.2 *Controls* — In general, controls should be designed considering the following criteria:

13.2.1 Required movement should be natural and minimize awkward motion or unnatural body positions. Control design should account for restrictions of PPE or special clothing, including that worn by emergency response personnel.

13.2.2 Control shape and dimensions should be compatible with the hands, fingers, or feet of 5th percentile Asian female – 95th percentile North American male.

13.2.3 Control movement or activation should be compatible with users' expectations and provide positive evidence that an input has been accepted or that control action is being accomplished. Feedback can be visual, auditory, tactile, or a combination thereof.

13.2.4 Controls should be designed, positioned, or protected to prevent inadvertent actuation.

13.2.5 Controls should be located where they can be easily reached by the operator. At a console they should be within the reach envelope and not exceed force requirements of the 5th percentile Asian female.

13.2.6 Controls should be located away from chemical, thermal, radiation, electrical or mechanical hazards. If such a location cannot be avoided, controls should be appropriately shielded and labeled.

13.2.7 Controls that require immediate access but are infrequently used (e.g., EMO) should not exceed 164 cm (63.5 inches) for a standing station, or 100 cm (39 inches) for a sitting station.

13.3 *Visual Displays* — The type of visual display selected depends on the nature of information conveyed and use conditions. The effectiveness and utility of a visual display generally depends on visibility, legibility and meaningfulness.

13.3.1 The visibility of a display is determined by the viewing distance, the size of the display, the location, angle of view, local illumination characteristics, obstructions, or reflections.

- The typical recommended viewing distance for most displays is 46 to 61 cm (18 to 24 inches). However, the optimum viewing distance will vary with the task and legibility of the display.
- Critical and frequently used displays should be placed in the operator's primary viewing area.
- The display should be positioned so the user has a clear line of sight. Displays should not be located where they are obstructed (by controls, equipment,