SEMI S8-0705[E]
SAFETY GUIDELINES FOR ERGONOMICS ENGINEERING OF SEMICONDUCTOR MANUFACTURING EQUIPMENT

These safety guidelines were technically approved by the global EH&S Committee. This edition was approved for publication by the global Audits and Reviews Subcommittee on April 7, 2005. It was available at www.semi.org in June 2005 and on CD-ROM in July 2005. Originally published in 1995; previously published in 2003.

[E] This standard was editorially modified in May 2006 to correct an error. Changes were made to Related Information 7, ¶ 8.3.3.

NOTICE: The official values in this guideline are expressed in The International System of Units (SI). Values that:

- are expressed in inch-pound (also known as "US Customary" or "English") units,
- are enclosed in parentheses, and
- directly follow values expressed in SI units

are not official, are provided for reference only, and might not be exact conversions of the SI values.

1 Purpose

1.1 These guidelines provide ergonomics design principles and considerations for semiconductor manufacturing equipment.

1.2 The purpose of these guidelines is to promote compatibility between the user and the equipment in the manufacturing environment. The following general principles are integral to the ergonomics design and evaluation of equipment:

1.2.1 The equipment should be designed to optimize safety by distributing tasks. Tasks should be distributed among hardware, software, and users to make the best use of their respective capabilities and to minimize limitations and hazards. Appropriate distribution of tasks will also optimize performance.

1.2.2 Equipment should be designed to minimize potential for errors and mishaps, by conforming to users' expectations.

1.2.3 The equipment design should reduce fatigue and injury by fitting the equipment to the expected body size, strength, and range of motion characteristics of the user population. Such design will also facilitate task performance.

2 Scope

2.1 The guidelines address safety aspects of ergonomics engineering in the design of semiconductor manufacturing equipment. It should be noted that in order to ensure comprehensive coverage of potential safety hazards, some guidelines also address general design goals for effective human-machine performance. The guidelines apply to the design, operation, maintenance, and service of semiconductor manufacturing equipment, as well as, to a limited extent, equipment installation (see ¶ 7.3).

NOTICE: This safety guideline does not purport to address all of the safety issues associated with its use. It is the responsibility of the users of this safety guideline to establish appropriate safety and health practices and determine the applicability of regulatory or other limitations prior to use.

3 Limitations

3.1 International, national, and local standards, codes, and regulations must be consulted to ensure that equipment meets regulatory requirements.

3.2 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 sometimes based on studies using few subjects or are context-specific. Ergonomics experts should be consulted where data development or interpretation is required.

3.3 The equipment design should incorporate reasonable accommodations for users with special needs, such as left-handedness and color blindness. Where feasible the design should also accommodate users with hearing or vision impairments and/or physical disabilities. It should be understood that although designing for the target user

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population will accommodate some users with special needs, these guidelines cannot anticipate and fully accommodate all such users.

3.4 Existing models and subsystems that meet previous versions of SEMI S8 should continue to meet the guidelines of SEMI S8 in force at the time of design. Models with redesigns that significantly affect the ergonomic design of the equipment should include conformance to the latest version of SEMI S8 for the redesign.

NOTE 1: Conformance with this document is believed to be a suitable substitute for conformance with its predecessors.

3.5 Conformance with the guidelines in Appendix 1 (SESC) constitutes conformance with SEMI S8.

4 Referenced Standards and Documents

4.1 *SEMI Standards*

SEMI E95 — Specification for Human Interface for Semiconductor Manufacturing Equipment

SEMI S1 — Safety Guideline for Equipment Safety Labels

SEMI S2 — Environmental, Health, and Safety Guidelines for Semiconductor Manufacturing Equipment

4.2 *CEN/CENELEC Standards*[1]

4.2.1 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, provisional EN (prEN) standards are subject to revision prior to adoption.

EN 894-2 — Safety/Ergonomics for Displays

EN 894-3 — Safety/Ergonomics for Control Actuators

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

4.3 *Military Standard* [2]

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

4.4 *NFPA Standard*[3]

NFPA 79 — Electrical Standard for Industrial Machinery

4.5 *ISO Standard*[4]

ISO 9241 — Ergonomic Requirements for Office Work with Visual Display Terminals

4.6 *Other Standards and Documents*

Humanscale, The MIT Press, Massachusetts Institute of Technology, Cambridge, MA 02142, 1974

ANSI/IES RP7[5] — Practice for industrial lighting

Waters, Thomas, *et.al.*, *Application Manual for the Revised NIOSH Lifting Equation*, U.S. Department of Health and Human Services (NIOSH), Cincinnati, OH, 1994.

A. Mital, A.S. Nicholson, M.M. Ayoub: *A Guide to Manual Materials Handling*, Taylor and Francis, London, 1993.

NOTICE: Unless otherwise indicated, all documents cited shall be the latest published versions.

5 Terminology

5.1 *Abbreviations and Acronyms*

5.1.1 *MAWL* — Maximum Acceptable Weight of Lift

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1 European committee for standardization (CEN)/European Committee for Electrotechnical Standardization (CENELEC), Central Secretariat: rue de Stassart 35, B-1050 Brussels, Belgium, Website: www.cenelac.org

2 United States Military Standards, Available through the Naval Publications and Forms Center, 5801 Tabor Avenue, Philadelphia, PA 19120-5099, USA. Telephone: 215.697.3321

3 National Fire Protection Association, 1 Batterymarch Park, Quincy, MA 02269, Website: www.nfpa.org

4 International Organization for Standardization, ISO Central Secretariat, 1, rue de Varembé, Case postale 56, CH-1211 Geneva 20, Switzerland. Telephone: 41.22.749.01.11; Fax: 41.22.733.34.30, Website: www.iso.ch

5 American National Standards Institute, Headquarters: 1819 L Street, NW, Washington, DC 20036, USA. Telephone: 202.293.8020; Fax: 202.293.9287, New York Office: 11 West 42nd Street, New York, NY 10036, USA. Telephone: 212.642.4900; Fax: 212.398.0023, Website: www.ansi.org

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5.1.2 *MMH* — Manual Material Handling

5.1.3 *SESC* — Supplier Ergonomics Success Criteria (see Appendix 1)

5.2 *Definitions*

5.2.1 *administrative controls* — administrative controls modify the way in which a job is performed without involving equipment design. They are non-engineering controls which include: job rotation, job enlargement, work-rest scheduling, micro-breaks, and stretching exercises. Engineering controls are preferred over administrative controls.

5.2.2 *anthropometric considerations* — design considerations based upon anthropometric (e.g., size and strength) limitations of user personnel.

5.2.3 *anthropometry* — description of the physical measurement of humans (e.g., size and strength).

5.2.4 *cognitive* — relating to human information processing, perception, and attention.

5.2.5 *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 may occur. Emergency Off (EMO) switches, interlock defeat indicators, and malfunction alarms are examples of critical controls and displays.

5.2.6 *cumulative trauma disorder* — a disorder which results from the accumulation of stresses (e.g., forces, repetitive movements, etc.) to a body part over a period of time.

5.2.7 *duration* — the length of time of a cycle or the entire task, which represents the time of exposure to single or multiple risk factors.

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

5.2.9 *engineering control* — a method to eliminate or mitigate a hazard through equipment design.

5.2.10 *ergonomic-related hazard* — an equipment or workplace condition that creates stress to the user that contributes to the risk of developing either an acute injury or a cumulative trauma disorder.

5.2.11 *ergonomic 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 features of the human's working environment.

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

5.2.13 *excessive reach* — a reach which may result in biomechanical or other stress to the user.

5.2.14 *extended reach* — a reach which requires either stretching, stooping, crouching, bending forward at the waist greater than 20 degrees, or shoulder flexion or abduction greater than 45 degrees.

5.2.15 *force* — the mechanical effort to accomplish a specific movement or exertion. These include: static exertions, which produce no motion but have significant duration; dynamic exertions, which are motions including lifting, pushing, pulling; and contact stress, which is localized pressure exerted against the skin by an external force.

5.2.16 *frequency* — how often a task is performed over time.

5.2.17 *frequently used* — used in processing or job cycle at least once every hour. Multiple tool operation by a single operator should be considered.

5.2.18 *human error* — errors which include: failure to perform a required function; performing a function that has an undesirable consequence; failure to recognize and correct a hazardous condition; or inadequate or incorrect response to a contingency.

5.2.19 *inadvertent actuation* — accidental or unintentional activation or deactivation of a control.

5.2.20 *infrequently used* — used in processing or job cycle less frequently than once every hour. Multiple tool operation by a single operator should be considered.

5.2.21 *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.

5.2.22 *lateral pinch* — grip in which the object is held between the thumb and the side of the index finger (often referred to as key grip).

5.2.23 *maintenance* — planned or unplanned activities intended to keep equipment in good working order.

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

5.2.25 *neutral posture* — the position of the human body in which the joints are least stressed. Generally, the body in its neutral position is standing erect with the eyes looking forward, and the arms hanging by the sides.

5.2.26 *non-neutral (awkward) postures* — the position of a joint(s) away from its neutral, or least stressed, posture.

5.2.27 *normal line of sight* — the line extending from the eyes, perpendicular to the interoccular line and 15 degrees below the horizontal position of the eye.

5.2.28 *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.

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

5.2.30 *override* — to take precedence over the current control system state.

5.2.31 *palmar pinch* — grip where the fingers press against the palm of the hand, with the object held between the fingers and the palm. Thumb is not used (e.g., picking up a sheet of plywood).

5.2.32 *personal protective equipment (PPE)* — equipment and clothing worn to reduce potential for personal injury from hazards associated with the task to be performed (e.g., chemical gloves, respirators, safety glasses, etc.). In the context of this document, cleanroom attire (e.g., gloves, smocks, booties, hoods) is not considered personal protective equipment.

5.2.33 *power grip* — a grip in which the fingers and thumb wrap entirely around the handle such that the thumb contacts or overlaps the index finger.

5.2.34 *postural stress* — stress occurring when a body position places undue load on the muscles, tendons, nerves, and blood vessels, or produces pressure on a joint.

5.2.35 *primary viewing area* — the 30 degree cone around the normal line of site (15 degrees above, below, and to either side of the line of sight).

5.2.36 *problem tasks* — tasks which have been defined as presenting ergonomically incorrect conditions that are likely to cause biomechanical stresses or injury to personnel, misoperation, or damage to equipment or the product.

5.2.37 *risk factors* — those elements of the design which allow an increased potential for injury/illness to personnel, or for damage to equipment, environment, or product.

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

5.2.39 *service* — unplanned activities intended to return equipment, which has failed, to good working order.

5.2.40 *static posture* — a fixed position, with minimal movement of the particular body parts.

5.2.41 *stooping* — bending the head and shoulders, or the general body, forward and downward from an erect position.

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

5.2.43 *task analysis* — an analytical process employed to determine the specific actions required of the user when operating, maintaining, or servicing equipment, or doing work on single or multiple tools. 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.

5.2.44 *tip pinch* — grip in which the object is held between the tips of the thumb and index finger.

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

5.2.46 *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.

5.2.47 *validation testing* — testing to confirm effectiveness of design. An item's "effectiveness" is viewed in terms of its functional design, specific to SEMI S8.

5.2.48 *WIP nest* — a storage structure for Work in Process (WIP).

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

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

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

5.2.52 *workstation* — the location where equipment controls and displays are found or the location of loading/unloading of material.

6 General Guidelines

6.1 *Ergonomics-Related Safety Issues* — Ergonomics-related safety issues may exist whenever equipment 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, ergonomics-related safety issues may result from:

6.1.1 Static or awkward postures,

6.1.2 Repetitive motion,

6.1.3 Poor access, inadequate clearance, and excessive reach,

6.1.4 Lifting of heavy or bulky components,

6.1.5 Displays that are difficult to read or understand,

6.1.6 Controls that are confusing to operate or require too much force, and

6.1.7 Use of non-specific warnings or faults to communicate machine problems.

6.2 Safety-related issues should be designed out or otherwise reduced to an acceptable level prior to production. Ergonomics-related safety issues are reduced by implementing sound ergonomics engineering principles in design, and structuring job requirements around human performance capabilities and limitations.

6.3 Equipment should be designed to reduce or eliminate the potential types of error caused by human-machine or human-task mismatch (e.g., inadvertent actuation, errors of omission or commission).

6.4 Engineering controls are the preferred means to reduce hazards. Where an engineering approach to ergonomic hazard control is not feasible, the user should implement administrative controls to mitigate hazards by reducing the duration, frequency, or severity of exposure.

6.5 Highest priority should be placed on issues which have the potential of resulting in injury to personnel. Secondary priority should be placed on issues which have the potential of resulting in significant damage to equipment.

6.6 Information exchange between equipment suppliers and users regarding human-machine interface issues is encouraged during the development stage, as part of beta site testing, after equipment is in full production, and throughout the life cycle of the equipment.

6.7 Ergonomics evaluation should be performed throughout the conception, design, build, and install phases to determine whether ergonomics guidelines have been met. The examination should yield a completed SESC document (see Appendix 1).

6.7.1 Equipment evaluation should identify risk factors associated with equipment design that affect operation, training, installation, maintenance, or service tasks.

6.7.2 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.

6.7.3 The evaluation should include consideration of multiple pieces of equipment under the control of one individual, resulting in an operation being repeated several times sequentially. The supplier should state the criteria for this scenario and include it in the report.

6.8 The overall objective is to provide for equipment effectiveness and for worker safety, convenience, and comfort when operating and maintaining the equipment.

6.9 Damage or undue deterioration of required garments or PPE should not occur as a result of equipment operation. Controls, such as knobs and switches, should be designed to 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.

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6.10 Technical documentation (e.g., manuals) and on-equipment instructions (e.g., labels, indicators and screen menus) should be consistent in action, terminology, symbols, and format.

6.11 Equipment customized to meet specific customer requirements should not increase the level of ergonomic risk.

6.12 For recommendations on human interface design, see SEMI E95.

NOTE 2: SEMI E95 provides information on human computer interface. It is not the intent of SEMI S8 to incorporate the requirements of SEMI E95 by reference.

7 Documentation

7.1 The supplier should provide an evaluation of the equipment to SEMI S8 using Appendix 1, "Supplier Ergonomic Success Criteria" for measurable criteria. The evaluation should include a determination of the level of risk associated with non-conformance items. Evaluation of risk should be compatible with the SEMI S10 severity categories; catastrophic, severe, moderate, and minor.

7.1.1 For each item in Appendix 1 which does not meet the criteria, the evaluation report should include the measured actual dimensions, and state any supporting rationale for non-compliance. Supporting rationale may include test data or documented engineering judgment.

EXCEPTION: For § 1, the manual material handling analysis, the evaluation report should provide documented calculations regardless of the outcome of the analysis.

7.1.2 The evaluation report should also include the following information: manufacturer's model number, serial number of unit evaluated, date the equipment was evaluated, a list of all tasks which were evaluated as part of the analysis and the name of the person performing the evaluation.

7.2 Supplier provided documentation should include administrative controls intended by the supplier to mitigate ergonomic risks.

7.3 Supplier provided documentation should illustrate any installation requirement necessary to meet SEMI S8 guidelines (e.g., Diagram should show clearance area required for opening hinged panels, operator working area, allowable range of vertical foot adjustment to keep ergonomic measurements within SESC acceptable limits, etc.).

7.4 The evaluation should specify an installation reference point for each independently adjustable section of the equipment for vertical measures. If there is a supplier recommended installation height, the reference for the evaluation should be the same. This installation height should be included in the supplier's installation documentation.

NOTE 3: Installation documentation may include installation manuals and other information provided by supplier addressing installation concerns.

8 Related Documents

8.1 *SEMI Standard*

SEMI S13 — Safety Guidelines for Operation and Maintenance Manuals Used with Semiconductor Manufacturing Equipment

8.2 *ANSI Documents*

ANSI Z535.4 — Product Safety Signs and Labels

8.3 *CEN/CENELEC Standards*[6]

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

EN 894-1 — Safety/Ergonomics for Operator Interaction

EN 50099-2 — Safety/Marking Principles

8.4 *NIOSH Documents*[7]

NIOSH Publication No. 81-122 — *Work Practices Guide for Manual Lifting*, National Institute for Occupational Safety and Health, 1981.

Revised NIOSH Equation, *Ergonomics*, Vol. 36, No. 7, 1993.

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6 European Committee for Standardization (CEN)/European Committee for Electrotechnical Standardization (CENELEC), Central Secretariat, rue de Stassart 35, B-1050 Brussels, Belgium, Website: www.cenelec.com.

7 National Institute for Occupational Safety and Health, Technical Information Branch, 4676 Columbia Pkwy, Cincinnati, OH 45226. Website: www.niosh.com.my.

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8.5 *SAE Document*[8]

SAE J833 — Human Physical Dimensions

8.6 *SEMATECH Documents*[9]

Preventing User-Hostile Interfaces in IC-Fab Equipment — Ergonomic Approaches for Preventing Ten Frequent Interface Problems, Miller, Dwight P. and Whitehurst, Hugh, SEMATECH Technology Transfer #92091299NA-ENG, Nov. 1992.

SEMATECH SCC User interface Style Guide, 1.0. 92061179A-ENG, August 21, 1992.

8.7 *Other Documents*

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

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

EN ISO 7250 — *Basic human body measurements for technological design*

EN ISO 14738 — *Safety of Machinery, Anthropometric requirements for the design of workstations at machinery*

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

Grether W.F. and Baker C.A., 1972, Visual Presentation of Information in Van Cott and Kincade *Human Engineering to Equipment Design*, Washington DC, US Government Printing Office.

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

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

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.

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.

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

NOTICE: Unless otherwise indicated, all documents cited shall be the latest published versions.

8 Society of Automotive Engineers, 400 Commonwealth Drive, Warrendale, PA 15096 USA., Website: www.sae.org.

9 International SEMATECH, 2706 Montopolis Drive, Austin, TX 78741, USA., Website: www.sematech.org

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APPENDIX 1
SUPPLIER ERGONOMIC SUCCESS CRITERIA (SESC)

NOTICE: The material in this appendix is an official part of SEMI S8 and was approved by full letter ballot procedures by the North American Regional Standards Committee.

Table A1-1 Supplier Ergonomic Success Criteria Checklist

Section	*Indicator*	*Acceptance Criteria Metric Units (US Customary Units)*	*Actual*	*Conforms/Does Not Conform/Not Applicable*
1	**Manual Material Handling**			
1.1	Potentially hazardous manual material handling tasks performed as part of operations, maintenance, or service are analyzed utilizing appropriate procedures. NOTE: Two hand lifting or lowering tasks should be analyzed: if the object being handled weighs more than 44.5 N (10 lbf); OR, if the object weighs more than 22.2 N (5 lbf) and the anticipated frequency is greater than 1 lift every 5 minutes. See Appendix 2 for further information.	Analysis and results documentation. Table A2-2, Appendix 2, or the equivalent, should be used to document 2 hand lift/lower analysis.		
2	**Product Loading in a Standing Posture** (Applicable to all media other than wafer cassettes including JEDEC trays, magazines, and reticle cassettes.			
2.1	Clearance provided for finger thickness.	minimum 38 mm (1.5 in.)		
2.2	Clearance provided for hand thickness.	minimum 76 mm (3.0 in.)		
2.3	Reach distance measured from the leading edge of the tool or obstruction to the hand/product coupling point(s).	maximum 330 mm (13 in.)		
2.4	Vertical coupling point of hand to product in load position	maximum 1010 mm (40 in.) minimum 890 mm (35 in.)		
3	**Wafer Cassette Loading**			
3.1	Wafer cassette loading should not require greater than 10 degrees cassette rotation in any axis. NOTE: Unless otherwise specified, you should assume that 200 mm or smaller wafers are transported in the vertical orientation and that 300 mm wafers are transported in the horizontal orientation.	less than 10 degrees rotation in any axis		
3.2	Load port height, vertical distance from standing surface (150–200 mm wafers).	maximum 960 mm (38 in.) minimum 890 mm (35 in.)		
3.3	Maximum lip height in front of cassette load port over which cassette is lifted (150–200 mm wafer cassettes only). Measure lip height from the load surface.	maximum 30 mm (1.2 in.)		
3.4	Reach distance from the leading edge of the tool or obstruction to the coupling point(s) on rotation device or the product grasp point.	maximum 330 mm (13 in.)		

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Section	*Indicator*	*Acceptance Criteria Metric Units (US Customary Units)*	*Actual*	*Conforms/Does Not Conform/Not Applicable*
3.5	Minimum hand clearance on either side of the cassette, measured from the side of the cassette to the nearest adjacent object.	minimum 76 mm (3.0 in.)		
4	**Work in Process Storage** (specific to wafer cassettes)			
4.1	Integral wafer cassette/lot box storage shelf height (150 and 200 mm wafer cassette/lot boxes only)	maximum (1 box deep) 1520 mm (60 in.) maximum (2 boxes deep) 1220 mm (48 in.) minimum 460 mm (18 in.)		
5	**Manual Wafer Cassette Rotation Device Design**			
5.1	Handle height, couple point for hand(s) from standing surface.	maximum 1206 mm (47.5 in.) minimum 838 mm (33 in.)		
5.2	Hand grip(s) shall allow for a full "power grip" similar to grabbing a rung on a ladder or holding a pistol.	Allows for a full power grip in either pronated (palm facing down) or neutral (handshake position) posture.		
5.3	Single hand lift force	maximum 37.8 N (8.5 lb.) This value includes a 15% capacity reduction due to cleanroom glove use. Wrist deviation reduces further strength capacity by 15%.		
5.4	Two hand lift force	maximum 64.5 N (14.5 lb.) This value includes a 15% capacity reduction due to cleanroom glove use. Wrist deviation reduces further strength capacity by 15%.		
6	**Handle Design** (Handle dimensions are correct for use of bare hand or use of typical cleanroom gloves) NOTE: See Appendix 3 for depiction of handle types.			
6.1	Handle surface finish	all edges radiused		
6.2	Cylindrical handle			
6.2.1	Cylindrical handle diameter (D)	maximum 38 mm (1.5 in.) minimum 25 mm (1.0 in.)		
6.2.2	Cylindrical handle length (L)	minimum 127 mm (5.0 in.)		
6.3	Circular or triangular handle			
6.3.1	Circular or triangular handle diameter (D)	maximum 90 mm (3.5 in.) minimum 50 mm (2.0 in.)		
6.3.2	Circular or triangular handle height (thickness) (H)	maximum 25 mm (1.0 in.) minimum 19 mm (0.75 in.)		
6.4	Ball handle			
6.4.1	Ball handle diameter	maximum 63 mm (2.5 in.) minimum 38 mm (1.5 in.)		
6.5	Pliers handle			
6.5.1	Pliers handle grip span (S)	maximum 89 mm (3.5 in.) open minimum 38 mm (1.5 in.) closed		

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Section	*Indicator*	*Acceptance Criteria Metric Units (US Customary Units)*	*Actual*	*Conforms/Does Not Conform/Not Applicable*
6.5.2	Pliers handle length (L)	minimum 127 mm (5.0 in.)		
6.6	Pistol grip handle			
6.6.1	Pistol grip handle diameter (D)	maximum 63 mm (2.5 in.) minimum 38 mm (1.5 in.)		
6.6.2	Pistol grip handle length (L)	minimum 127 mm (5.0 in.)		
6.7	Enclosed handles NOTE: Handle diameter refers to the surface of the handle presented to the inside of the curled fingers. Enclosed handles need not be made solely from cylindrical stock.			
6.7.1	Enclosed handle, full hand power grip (suitcase handle) Width (W) Depth (D) Diameter (d)	 minimum 127 mm (5.0 in.) minimum 45 mm (1.75 in.) maximum 25 mm (1.0 in.)		
6.7.1.1	Diameter (d), requiring no greater than 71 N (16 lbf) force	minimum 6.3 mm (0.25 in.)		
6.7.1.2	Diameter (d), requiring no greater than 89 N (20 lbf) force	minimum 13 mm (0.5 in.)		
6.7.1.3	Diameter (d), requiring no greater than 180 N (40 lbf) force	minimum 19 mm (0.75 in.)		
6.7.2	Enclosed handle, three fingers Width (W) Depth (D) Diameter (d) Force	 minimum 90 mm (3.5 in.) minimum 38 mm (1.5 in.) minimum 6.3 mm (0.25 in.) maximum 71 N (16 lbf)		
6.7.3	Enclosed handle, two fingers Width (W) Depth (D) Diameter (d) Force	 minimum 60 mm (2.5 in.) minimum 38 mm (1.5 in.) minimum 6.3 mm (0.25 in.) maximum 51 N (11.5 lbf)		
6.7.4	Enclosed handle, one finger Width (W) Depth (D) Diameter (d) Force	 minimum 38 mm (1.5 in.) minimum 38 mm (1.5 in.) minimum 3.2 mm (0.13 in.) maximum 27 N (6 lbf)		
6.8	Hook grasp handle			
6.8.1	Hook grasp handle (four fingers) Opening length (L) Opening width (W) Depth (d) Lip length (l)	 minimum 90 mm (3.5 in.) minimum 38 mm (1.5 in.) minimum 50 mm (2.0 in.) minimum 50 mm (2.0 in.)		
6.8.2	Hook grasp handle pull force (four fingers)	maximum 80 N (18.0 lbf)		
6.9	Finger pull handle			
6.9.1	Finger pull handles (four fingers) Opening length (L) Opening width (W) Depth (d) Lip length (l)	 minimum 90 mm (3.5 in.) minimum 25 mm (1.0 in.) minimum 19 mm (0.75 in.) minimum 19 mm (0.75 in.)		

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Section	Indicator	Acceptance Criteria Metric Units (US Customary Units)	Actual	Conforms/Does Not Conform/Not Applicable
6.9.2	Finger pull handles pull force (four fingers)	maximum 9.8 N (2.2 lbf)		
7	**Maintainability and Serviceability**			
7.1	Minimum lighting level in routine maintenance areas is required where the operator has to read information, use a hand tool, or make a connection. This provision can be met by providing integral lighting or portable lighting which can be temporarily attached such that it does not have to be hand held.	minimum 300 lux (30 fc)		
7.2	Full Body Clearance NOTE: Clearances should be approached from a task analysis point of view. Clearances should be provided based on the nature of the tasks performed in the designated area.			
7.2.1	Any posture: upper body clearance (shoulder width)	minimum 610 mm (24 in.)		
7.2.2	Standing: overhead clearance, measured from the floor forward horizontal clearance [#3]	 minimum 1980 mm (78 in.) minimum 690 mm (27 in.)		
7.2.3	Sitting-on-Floor: overhead clearance, measured from the floor forward horizontal clearance [#3] working height	 minimum 1000 mm (39 in.) minimum 690 mm (27 in.) minimum 280 mm (11 in.)		
7.2.4	Squatting: overhead clearance, measured from the floor forward horizontal clearance [#3] working height	 minimum 1220 mm (48 in.) minimum 790 mm (31 in.) minimum 460 mm (18.1 in.)		
7.2.5	Kneeling: overhead clearance, measured from the floor forward horizontal clearance [#3] working height	 minimum 1450 mm (57 in.) minimum 1220 mm (48 in.) minimum 640 mm (25.2 in.)		
7.2.6	Kneeling Crawl: overhead clearance, measured from the floor forward horizontal clearance [#3]	 minimum 740 mm (29 in.) minimum 1520 mm (60 in.)		
7.2.7	Stooping: overhead clearance, measured from the floor forward horizontal clearance [#3] working height	 minimum 1450 mm (57 in.) minimum 1020 mm (40 in.) minimum 640 mm (25.2 in.)		
7.2.8	Supine (lying on back): height length	 minimum 430 mm (17 in.) minimum 1980 mm (78 in.)		
7.2.9	Prone or crawl space: height length	 minimum 510 mm (20 in.) minimum 2440 mm (96 in.)		
7.3	Hand/Arm Clearance (where appropriate to do so, dimensions have been adjusted for the use of cleanroom gloves)			

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7.3.1	Clearance provided for finger access, round (dia) or square: one finger 2, 3, or 4 finger twist of small knob	minimum 32 mm (1.25 in.) minimum object diameter + 58 mm (2.3 in.)		
7.3.2	Clearance provided for flat hand to wrist access: height, palm thickness width, palm width	minimum 89 mm (3.5 in.) minimum 114 mm (4.5 in.)		
7.3.3	Clearance provided for fist to wrist access: height, palm thickness width, palm width	minimum height 89 mm (3.5 in.) minimum width 127 mm (5.0 in.)		
7.3.4	Clearance provided for two hands arm to shoulders access (does not ensure visual access): reach width height	maximum 610 mm (24.0 in.) minimum 483 mm (19 in.) minimum 114 mm (4.5 in.)		
7.3.5	Clearance provided for two hands, hand to wrist access (does not ensure visual access): reach width height	maximum 203 mm (8.0 in.) minimum 191 mm (7.5 in.) minimum 114 mm (4.5 in.)		
7.3.6	Clearance provided for one arm to shoulder access, diameter or square area (does not ensure visual access).	minimum 132 mm (5.2 in.)		
7.3.7	Clearance provided for one arm to elbow access, diameter or square area (does not ensure visual access).	minimum 119 mm (4.7 in.)		
7.4	Maintenance and Service Access			
7.4.1	Enclosures or covers must, unless fully removable, be self-supporting, in the open position, and not require manual support during maintenance. Exceptions may be allowed for self closing doors for fire safety or compliance reasons.	Supports present		
7.4.2	Access covers should be equipped with full-handed grasp areas or other means for opening them.	Handles present, refer to Section 6 for design criteria.		
7.4.3	Height of access cover handle over the entire range of motion required for operation or maintenance. There should be no greater than a 254 mm (10 in.) deep obstruction in front of the handle.	maximum 1700 mm (67 in.)		
7.5	Replaceable Components			
7.5.1	Serviceable components are replaceable as modular packages, and are configured for rapid removal and replacement.	Serviceable components configured as described.		
7.5.2	Serviceable components should not be stacked directly on one another (*i.e.*, a lower layer should not support an upper layer).	Serviceable components independently accessible.		

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Section	*Indicator*	*Acceptance Criteria Metric Units (US Customary Units)*	*Actual*	*Conforms/Does Not Conform/Not Applicable*
7.5.3	Heavy components (objects which have a lifting index of 0.5 or greater, see SESC, § 1.0) or bulky components (greater than 36 inches in length) requiring frequent removal/installation should include guide/locating aids to assist in positioning.	Guide/locating pins present.		
7.5.4	Cables, connectors, plugs, and receptacles should be labeled, keyed, color coded, or otherwise configured to make connection easier and prevent cross connection. This feature is assessed only if a SEMI S2 assessment is not being conducted.	Identification present, keyed where needed.		
7.5.5	Circuit boards mounted in a card cage configuration should have gripping or ejecting aids for mounting and removal.	Finger access, gripping, or ejecting aids available.		
8	**Display Location**			
8.1	Location for operator primary interface, standing station. [#1]			
8.1.1	Height of video display terminal (single monitor). Does not include touchscreens, measured from floor to center of screen.	maximum 1470 mm (58 in.) minimum 1320 mm (52 in.)		
8.1.2	Height of video display terminal (stacked monitors). Does not include touchscreens, measured from floor to top line of the top monitor.	maximum 1680 mm (66 in.) The primary monitor in a stacked configuration is the bottom monitor.		
8.1.3	Height of infrequently used video display terminal (viewed briefly less often than once per hour) measured to top line of monitor.	maximum 1680 mm (66 in.)		
8.1.4	Height of very infrequently used video display terminal (viewed briefly less often than once per day) measured to top line of monitor.	maximum 1880 mm (74 in.)		
8.1.5	Height of infrequently viewed visual signal measured to the top of the signal. This guideline does not apply to light towers.	maximum 2130 mm (84 in.)		
8.1.6	Height of touch screen monitor.	maximum 1470 mm (58 in.), measured from floor to uppermost active pad on screen minimum 910 mm (36 in.), measured from floor to lowest active pad on the screen See § 9 for horizontal reach criteria.		
8.1.7	Tilt angle of touch screen monitor between 41 and 48 inches in height to top of screen.	Upward minimum 30 degrees		
8.1.8	Tilt angle of touch screen monitor less than 41 inches in height to top of screen.	Upward minimum 45 degrees		
8.2	Location for operator primary interface, seated station [#2]			
8.2.1	Height of video display terminal (single monitor), does not include touchscreens, measured from floor to centerline of monitor.	maximum 1190 mm (47 in.) minimum 940 mm (37 in.)		

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Section	*Indicator*	*Acceptance Criteria Metric Units (US Customary Units)*	*Actual*	*Conforms/Does Not Conform/Not Applicable*
8.2.2	Height of video display terminal (stacked monitors), does not include touchscreens, measured from floor to top line of top monitor.	maximum 1400 mm (55 in.) minimum 940 mm (37 in.) The primary monitor in a stacked configuration is the bottom monitor.		
8.2.3	Tilt angle of video display terminal greater than 55 inches in height to top of screen. This line item becomes significant in the event that the maximum height criteria cannot be met.	Downward minimum 15 degrees		
8.2.4	Height of touch screen monitor.	maximum 1070 mm (42 in.) measured from floor to highest active pad on the screen minimum 760 mm (30 in.) measured from floor to lowest active pad on the screen See § 9 for horizontal reach criteria.		
8.3	Display characteristics			
8.3.1	Lateral distance from the centerline of the display to the centerline of the input device(s). See MIL-STD-1472 for a depiction of this.	maximum 320 mm (12.6 in.)		
8.3.2	Character height (Specific to Chinese, Korean, and Japanese characters.)	Character height is greater than or equal to the viewing distance divided by 143. Recommended viewing distance is between 457 mm (18 in.) and 762 mm (30 in.)		
8.3.3	Character height (All characters other than Chinese, Korean, and Japanese.)	Character height is greater than or equal to the viewing distance divided by 215. Recommended viewing distance is between 457 mm (18 in.) and 762 mm (30 in.)		
9	**Hand Control Location** (These criteria only apply to controls, tools, and materials accessed for routine production operation and maintenance.)			
9.1	Standing station [#1]			
9.1.1	Vertical location of very infrequently used controls (controls used less often than once every 24 hours) measured from the standing surface to the centerline of the control.	maximum 1640 mm (64.5 in.) minimum 0 mm (0 in.)		

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9.1.2	Location of infrequently used and/or critical controls. Maximum reaches are indicated for various heights. Reaches are measured from the leading edge of the equipment or obstacle. Controls should not be located above 1638 mm (64.5 in.) or below 838 mm (33 in.). Interpolate for intermediate values.			
	Height of 1638 mm (64.5 in.)	reach 254 mm (10.0 in.)		
	Height of 1524 mm (60 in.)	reach 368 mm (14.5 in.)		
	Height of 1422 mm (56 in.)	reach 432 mm (17.0 in.)		
	Height of 1321 mm (52 in.)	reach 470 mm (18.5 in.)		
	Height of 1219 mm (48 in.)	reach 483 mm (19.0 in.)		
	Height of 1118 mm (44 in.)	reach 470 mm (18.5 in.)		
	Height of 1016 mm (40 in.)	reach 394 mm (15.5 in.)		
	Height of 914 mm (36 in.)	reach 292 mm (11.5 in.)		
	Height of 838 mm (33 in.)	reach 178 mm (7.0 in.)		
9.1.3	Location of frequently used controls. Maximum reaches are indicated for various heights. Reaches are measured from the leading edge of the equipment or obstacle. Controls should not be located above 1270 mm (50 in.) or below 940 mm (37 in.). Interpolate for intermediate values.			
	Height of 1270 mm (50 in.)	reach 292 mm (11.5 in.)		
	Height of 1219 mm (48 in.)	reach 330 mm (13.0 in.)		
	Height of 1168 mm (46 in.)	reach 368 mm (14.5 in.)		
	Height of 1118 mm (44 in.)	reach 394 mm (15.5 in.)		
	Height of 1067 mm (42 in.)	reach 406 mm (16.0 in.)		
	Height of 1016 mm (40 in.)	reach 394 mm (15.5 in.)		
	Height of 940 mm (37 in.)	reach 318 mm (12.5 in.)		
9.2	Seated station [#2]			
9.2.1	Location of infrequently used and/or critical controls. Maximum reaches are indicated for various heights. Reaches are measured from the leading edge of the work surface or obstacle. Controls should not be located above 1397 mm (55 in.) or below 533 mm (21 in.). Interpolate for intermediate values.			
	Height of 1397 mm (55 in.)	reach 356 mm (14.5 in.)		
	Height of 1270 mm (50 in.)	reach 432 mm (17.0 in.)		
	Height of 1168 mm (46 in.)	reach 470 mm (18.5 in.)		
	Height of 1067 mm (42 in.)	reach 483 mm (19.0 in.)		
	Height of 965 mm (38 in.)	reach 483 mm (19.0 in.)		
	Height of 864 mm (34 in.)	reach 470 mm (18.5 in.)		
	Height of 762 mm (30 in.)	reach 445 mm (17.5 in.)		
	Height of 660 mm (26 in.)	reach 381 mm (15.0 in.)		
	Height of 533 mm (21 in.)	reach 254 mm (10.0 in.)		

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Section	*Indicator*	*Acceptance Criteria Metric Units (US Customary Units)*	*Actual*	*Conforms/Does Not Conform/Not Applicable*
9.2.2	Location of frequently used controls. Maximum reaches are indicated for various heights. Reaches are measured from the leading edge of the work surface or obstacle. Controls should not be located above 1067 mm (42 in.) or below 762 mm (30 in.). Interpolate for intermediate values. Height of 1067 mm (42 in.) Height of 1016 mm (40 in.) Height of 965 mm (38 in.) Height of 914 mm (36 in.) Height of 864 mm (34 in.) Height of 813 mm (32 in.) Height of 762 mm (30 in.)	 reach 330 mm (13.0 in.) reach 368 mm (14.5 in.) reach 394 mm (15.5 in.) reach 406 mm (16.0 in.) reach 419 mm (16.5 in.) reach 419 mm (16.5 in.) reach 419 mm (16.5 in.)		
10	**Workstation Design**			
10.1	Standing station [#1]			
10.1.1	Work surface edge radius where the operator can assume a static posture in contact with the edge.	minimum 6.4 mm (0.25 in.) radius		
10.1.2	Height of keyboard, trackball, or mouse (to home row, top of ball/mouse). NOTE: In applications where input devices (keyboard, trackball, or mouse) are used more like machine controls (intermittent one finger entry on the keyboard, intermittent short term use of the mouse or trackball) than for standard typing (continuous use of keyboard for entry of long character strings, extended use of trackball or mouse in graphical environment), it is appropriate to use the height and reach locations described in § 9, Hand Control Location (standing station).	maximum 1020 mm (40 in.) minimum 970 mm (38 in.)		
10.1.3	Height of microscope eyepieces. Should be adjustable through at least this range.	Range includes 1270 mm (50 in.) to 1730 mm (68 in.)		
10.2	Seated station [#2]			
10.2.1	Height of keyboard, trackball, or mouse. (to home row, top of ball/mouse). NOTE: In applications where input devices (keyboard, trackball, or mouse) are used more like machine controls (intermittent one finger entry on the keyboard, intermittent short term use of the mouse or trackball) than for standard typing (continuous use of keyboard for entry of long character strings, extended use of trackball or mouse in graphical environment), it is appropriate to use the height and reach locations described in § 9, Hand Control Location (seated station).	maximum 760 mm (30 in.) minimum 710 mm (28 in.)		
10.2.2	Vertical leg clearance.	minimum 673 mm (26.5 in.)		
10.2.3	Horizontal leg clearance, depth at knee level.	minimum 508 mm (20 in.)		
10.2.4	Horizontal leg clearance, depth at foot level.	minimum 660 mm (26 in.) depth × 254 mm (10 in.) vertical foot clearance		

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10.2.5	Horizontal leg clearance, width.	minimum 610 mm (24 in.)		
10.2.6	Height of microscope eyepiece. Should be adjustable through at least this range. NOTE: Assumes a 711 mm (28 in.) to 762 mm (30 in.) worksurface.	Range includes 1220 mm (48 in.) to 1370 mm (54 in.)		
10.2.7	Thickness of work surface.	maximum 51 mm (2.0 in.)		
10.2.8	Work surface edge radius where the operator can assume a static posture in contact with the edge.	minimum 6 mm (0.25 in.) radius		

#1 A standing station is one where the operator can assume a standing posture or a seated posture in a tall stool which places the operator at approximately the same stature.

#2 A seated station is one where a short cylinder office style chair is used.

#3 Distance measured away from the equipment or obstruction for body clearance in the given posture.

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APPENDIX 2
LIFTING, STRENGTH, AND MATERIALS HANDLING

NOTICE: The material in this appendix is an official part of SEMI S8 and was approved by full letter ballot procedures by the North American Regional Standards Committee.

A2-1 General Considerations

A2-1.1 For recommended guidelines regarding the percentage of a user's maximum grip strength to be exerted in execution of a task see Related Information 1, Table R1-3.

A2-1.2 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 reduce extended reaching, lifting, pulling, and awkward postures. Simultaneous lifting and twisting should be avoided. Load, unload, and lift over points should be located such that the floor to hand height is 84–107 cm (33–42 in.), optimal design target is 102 cm (40 in.).

A2-1.3 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 awkward postures. Handles should allow carrying close to the body.

A2-1.4 Lifting and handling tasks performed in a stooping position should be avoided. Stooping occurs when the vertical material handling height is less than 84 cm (33 in.), or the horizontal reach distance is greater than 46 cm (18 in.) in front of body.

A2-1.5 For two handed push/pull activities the floor to hand height should be between 97 cm (38 in.) and 112 cm (44 in.).

A2-1.6 Consideration should be given to the standing surface to minimize the risk of slips and falls.

A2-1.7 Awkward postures should be avoided. Refer to Related Information 1, Table R1-2 for a list of recommended ranges of awkward postures to avoid.

A2-1.8 For a 2-person handling task, there should be adequate coupling locations and adequate body clearance for the activity. Analyses need to be performed and documented for each person lifting if any of the parameters (e.g., horizontal reach) are different.

A2-2 Selecting and Using the Appropriate MMH Analysis Tool(s)

A2-2.1 Three general MMH evaluation tools are identified in the following matrix. The three tools are the "Application manual for the Revised NIOSH Lifting Equation" lifting equation, biomechanical models, and psychophysical capacity tabular data. Table A2-1 was designed to assist in determining which analysis tools are appropriate for a particular task. For each unique characteristic of the task, a checkmark in the analysis tool column indicates that the analysis tool is appropriate. If there is any aspect of the task that does not show a check mark in a particular tools column, that analysis tool is not appropriate to evaluate the task. Note that in many situations multiple tools are appropriate. In situations where the 1991 NIOSH equation is appropriate, the assessor should use it, because it typically will provide the most conservative results. In other situations, the assessor may use any of the appropriate tools.

A2-2.2 Correct application of the 1991 NIOSH equation is described in Waters, Thomas, et. al., Application manual for the Revised NIOSH Lifting Equation, U.S. Department of Health and Human Services (NIOSH), Cincinnati, OH, 1994.

A2-2.3 There are many sources of psychophysical data. One such source is A. Mital, A.S. Nicholson, M.M. Ayoub, A Guide to Manual Materials Handling, Taylor and Francis, London, 1993.

A2-2.4 Biomechanical analysis can be completed using biomechanical modeling software.

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