

SEMI S8-0218

SAFETY GUIDELINE FOR ERGONOMICS ENGINEERING OF SEMICONDUCTOR MANUFACTURING EQUIPMENT

This Safety Guideline was technically approved by the Environmental Health & Safety Global Technical Committee. This edition was approved for publication by the global Audits and Reviews Subcommittee on August 18, 2017 and October 3, 2017. Available at www.semiviews.org and www.semi.org in February 2018; originally published in 1995; previously published November 2016.

NOTICE: The official values in this Safety 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.

NOTICE: Paragraphs entitled ‘NOTE’ are not an official part of this Safety Guideline and are not intended to modify or supersede the official Safety Guideline. These have been supplied by the committee to enhance the usage of the Safety Guideline.

1 Purpose

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

1.2 The purpose of these Safety 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: SEMI Standards and Safety Guidelines do not purport to address all safety issues associated with their use. It is the responsibility of the users of the Documents 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 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 and Safety Guidelines

SEMI E95 — Specification for Human Interface for Semiconductor Manufacturing Equipment

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

SEMI S10 — Safety Guideline for Risk Assessment and Risk Evaluation Process

4.2 Other Documents

DHHS (NIOSH) Publication Number 94-110 — Applications Manual for the Revised NIOSH Lifting Equation

Mital, A, Nicholson, A.S., Ayoub, M. M., *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

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* — manual controls (actuators) that are intentionally provided to reduce risk to personnel, equipment, or the environment to Low or Very Low (see SEMI S10) in response to a malfunction. Examples of critical controls include, but are not limited to: EMO actuators, emergency gas off actuators, and emergency stop actuators.

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 *ergonomic clearances* — the space that should remain clear around the equipment for ergonomics considerations related to tasks anticipated by the supplier. This can include pinch-point avoidance clearances, access space, component removal space, and room for doors to swing out.

NOTE 2: This definition is different from the concept of 'easement space' as provided in SEMI E72, "easement space — the floor space that must remain clear to the rear and sides of the equipment (but not in front of the load face plane). This includes safety aisles, ergonomic maintenance access space, component removal space, and room for doors to swing out." Ergonomic clearances includes all sides of the equipment, including the front of the load face plane.

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

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

5.2.16 *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.

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

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

5.2.19 *hand-object coupling point* — center of the interface between the hand and a handle or object. For the purposes of measuring, the intersection of a line through the center of the grip parallel to the axis of the large knuckles (metacarpophalangeal joints) and a perpendicular line that goes through the center of the large knuckle of the middle finger (metacarpophalangeal joint of the third finger). If object handling cannot be observed by the evaluator, then the center of the handle/hand grip or the center of the anticipated hand grasp location may be used as the coupling point. Figure 1 provides visual depictions for common applications.

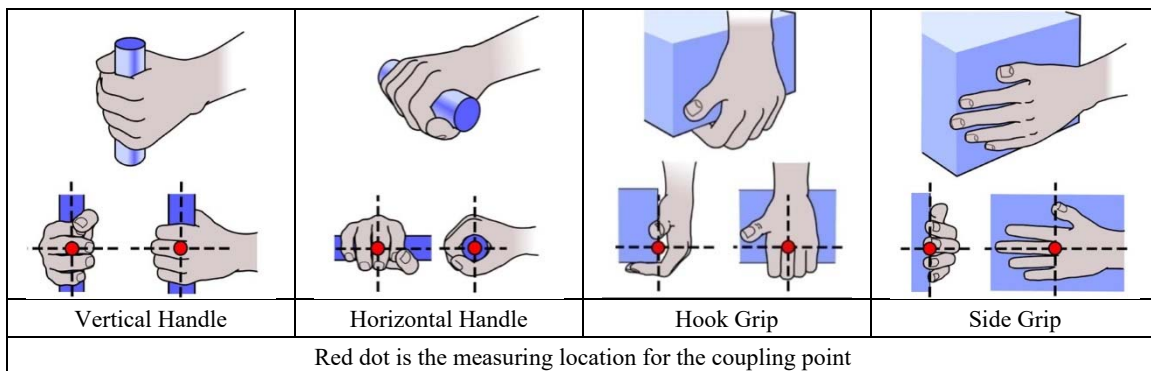


Figure 1
Hand-Object Coupling Point Examples

5.2.20 *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.

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

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

5.2.23 *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.

5.2.24 *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).

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

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

5.2.27 *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.

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

5.2.29 *normal line of sight* — the line extending from the eyes, perpendicular to the intraocular line and 15° below the horizontal position of the eye.

5.2.30 *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.

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

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

5.2.33 *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).

5.2.34 *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.

5.2.35 *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.

5.2.36 *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.

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

5.2.38 *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.

5.2.39 *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.

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

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

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

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

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

5.2.45 *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.

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

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

5.2.48 *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.

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

5.2.50 *WIP nest* — a storage structure for work in process (WIP).

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

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

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

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

5.2.55 *work surface* — a (typically horizontal) surface provided for the location of input devices, handwriting, assembly work, etc. that is part of a seated or standing workstation.

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 nonspecific 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.

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 3: 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 noncompliance. 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 Documents provided to the end user should illustrate all ergonomic clearances required by the supplier.

7.3.1 Space for ergonomic clearances should include room needed for all of the following:

- operator tasks (e.g., loading and unloading of product or other materials, interfacing with the equipment, and seating),

- opening of access panels and covers (e.g., room for doors to swing out, up, or down), and
- maintenance access and postures intended for maintenance activity (e.g., component removal/insertion and specialty equipment such as ladders, steps, seating, diagnostic equipment, and lifting equipment).

7.3.2 The space for ergonomic clearances should also include consideration of space required for the servicing of components (particularly large components) that could reasonably be expected to fail during the expected lifetime of the equipment, including tools and specialty equipment that might be required for their repair, removal, or installation.

7.3.3 Documents provided to the equipment user should also describe the allowable range of vertical foot adjustment that will keep ergonomics-related measurements within supplier requirements (e.g., to keep heights of various items within the SESC acceptable limits).

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

8 Related Documents

8.1 SEMI Standards and Safety Guidelines

SEMI S13 — Environmental, Health and Safety Guideline for Documents Provided to the Equipment User for Use with Manufacturing Equipment

8.2 ANSI Standards¹

ANSI Z535.4 — Product Safety Signs and Labels

ANSI/HFES 100 — Human Factors Engineering of Computer Workstations

8.3 CEN/CENELEC Standards²

8.3.1 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 614-1 — Safety of Machinery – Ergonomic Design Principles, Part 1 – Terminology and General Principles

EN 894-1 — Safety/Ergonomics for Operator Interaction

EN 894-2:1997 — Safety of Machinery: Ergonomics Requirements for the Design of Displays and Control Actuators, Part 2: Displays

EN 50099-2 — Safety/Marking Principles

8.4 ISO Standards³

ISO 7250 — Basic Human Body Measurements for Technological Design

ISO 14738 — Safety of Machinery— Anthropometric Requirements for the Design of Workstations at Machinery

8.5 United States Military Documents⁴

MIL-HDBK-759C — Department of Defense Handbook: Human Engineering Design Guidelines (31 Jul 1995)

¹ American National Standards Institute, 25 West 43rd Street, New York, NY 10036, USA; Telephone: +1.212.642.4900, Fax: +1.212.398.0023, <http://www.ansi.org>

² European Committee for Standardization, Avenue Marnix 17, B-1000 Brussels; Telephone: +32.2.550.08.11, Fax: +32.2.550.08.19, <http://www.cen.eu>

³ International Organization for Standardization, ISO Central Secretariat, 1, ch. de la Voie-Creuse, CP 56, CH-1211 Geneva 20, Switzerland; Telephone: +41.22.749.01.11, Fax: +41.22.733.34.30, <http://www.iso.org>

⁴ United States Military Documents, available from EverySpec, <http://www.everyspec.com>

MIL-STD-1472F — Department of Defense Design Criteria Standard: Human Engineering (23 Aug 1999)

8.6 JIS Standards⁵

JIS Z 8513 — Ergonomics – Office Work with Visual Display Terminals (VDTs) – Visual Display Requirements

8.7 NIOSH Documents⁶

DHHS (NIOSH) Publication Number 81-122 — Work Practices Guide for Manual Lifting

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

8.8 SAE Document⁷

SAE J833 — Human Physical Dimensions

8.9 SEMATECH Documents⁸

Application Guide for Manual Material-Handling Requirements in SEMI-S8. ISMI 2010. Available from <http://www.sematech.org/docubase/document/5029aeng.pdf>

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.

8.10 Other Documents

8.10.1 Bailey, Robert W. “Human Performance Engineering.” Prentice Hall, 1989.

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

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

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

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

8.10.6 Kroemer, K.H.E. “Engineering Anthropometry.” Occupational Ergonomics Handbook, eds. W. Karwowski & W.S. Marras, CRC Press, Boca Raton, 1999.

8.10.7 Pheasant, Stephen, Bodyspace “Anthropometry, Ergonomics and Design.” Taylor & Francis, 1988.

8.10.8 Salvendy, Gavriel (ed.) “Handbook of Human Factors.” Wiley, 1987.

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

8.10.10 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.

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

8.10.12 Human Hand Dimensions Data for Ergonomic Design 2010. Research Institute of Human Engineering for Quality Life. Osaka, Japan, 2010.

⁵ Japanese Standards Association, 4-1-24 Akasaka, Minato-ku, Tokyo 107-8440, Japan; Telephone: +81.3.3583.8005, Fax: +81.3.3586.2014, <http://www.jsa.or.jp>

⁶ National Institute for Occupational Safety and Health, Technical Information Branch, 4676 Columbia Pkwy, Cincinnati, OH 45226, USA; <http://www.niosh.com.my>

⁷ Society of Automotive Engineers, 400 Commonwealth Drive, Warrendale, PA 15096-0001, USA; Telephone: +1.724.776.4970, Fax: +1.724.776.0790, <http://www.sae.org>

⁸ SEMATECH, 257 Fuller Road, Suite 2200, Albany, NY 12203, USA; Telephone: +1.518.649.1000, <http://www.sematech.org>

- 8.10.13 Garrett, J.W. The adult human hand: some anthropometric and biomechanical considerations. *Human Factors* 13 (1971): pp 117–131.
- 8.10.14 Hall, Charlotte. “External pressure at the hand during object handling and work with tools.” *International Journal of Industrial Ergonomics* 20 (1997): pp. 191–206.
- 8.10.15 Gordon, Claire C. “1988 Anthropometric Survey of U.S. Army Personnel: Summary Statistics, Interim Report.” U.S. Army Natick Research, Development and Engineering Center, 1989.
- 8.10.16 Harrison, Catherine R., and Robinette, Kathleen M. “CAESAR: Summary Statistics for the Adult Population (Ages 18-65) of the United States of America.” Air Force Research Laboratory, Human Effectiveness Directorate, Crew System Interface Division, 2002.
- 8.10.17 Japanese Body Size Data 2004-2006. Research Institute of Human Engineering for Quality Life, Japan, 2008.
- 8.10.18 McDowell, M. A., *et al.* Anthropometric Reference Data for Children and Adults: United States, 2003–2006, National Health Statistics Reports, No. 10, October 22, 2008.

APPENDIX 1

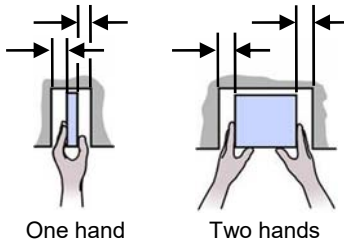
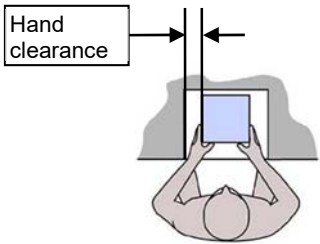
SUPPLIER ERGONOMIC SUCCESS CRITERIA (SESC)

NOTICE: The material in this Appendix is an official part of SEMI S8 and was approved by full letter ballot procedures on November 21, 2006.

A1-1 Introduction

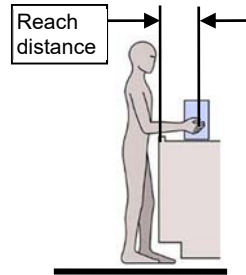
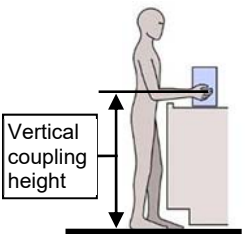
A1-1.1 Pictograms and text within the pictogram cells are provided for illustrative purposes only and are not normative. Also, the pictograms are not intended to depict every possible application of the guidelines.

Table A1-1 Supplier Ergonomic Success Criteria Checklist

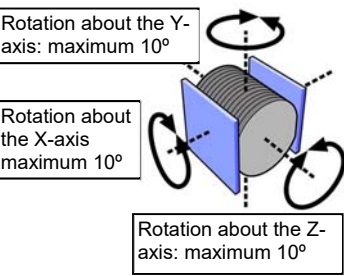
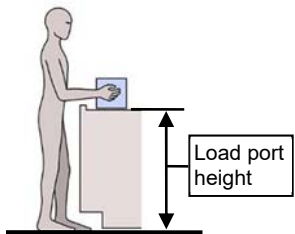
Section 1: Manual Material Handling				
<i>Section</i>	<i>Indicator</i>	<i>Acceptance Criteria Metric Units (US Customary Units)</i>		<i>Actual/ Conforms?</i>
1.1	Potentially hazardous manual material handling tasks performed as part of operations, maintenance, or service are analyzed utilizing appropriate 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 two-hand lift/lower analysis.		Measurement Conforms? Yes No N/A ☐ ☐ ☐
Section 2: Product Loading in a Standing Posture (Applicable to all media other than wafer cassettes including JEDEC trays, magazines and reticle cassettes.)				
<i>Section</i>	<i>Indicator</i>	<i>Acceptance Criteria Metric Units (US Customary Units)</i>	<i>Reference Pictogram</i>	<i>Actual/ Conforms?</i>
2.1	Clearance provided for finger thickness.	Minimum 38 mm (1.5 in.)	 One hand Two hands	Measurement Conforms? Yes No N/A ☐ ☐ ☐
2.2	Clearance provided for hand thickness.	Minimum 76 mm (3 in.)	 Hand clearance	Measurement Conforms? Yes No N/A ☐ ☐ ☐

Section 2: Product Loading in a Standing Posture

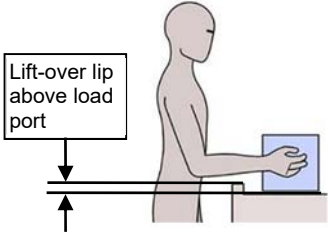
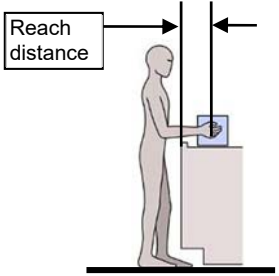
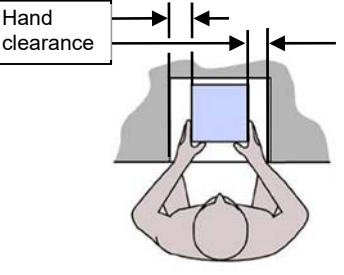
(Applicable to all media other than wafer cassettes including JEDEC trays, magazines and reticle cassettes.)

Section	Indicator	Acceptance Criteria Metric Units (US Customary Units)	Reference Pictogram	Actual/ Conforms?
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.)		Measurement Conforms? Yes No N/A ☐ ☐ ☐
2.4	Vertical coupling point of hand to product in load position.	Maximum 1010 mm (40 in.) Minimum 890 mm (35 in.)		Measurement Conforms? Yes No N/A ☐ ☐ ☐

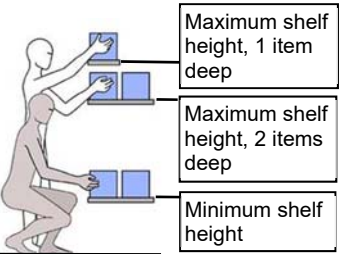
Section 3: Wafer Cassette Loading

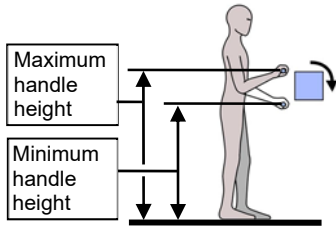
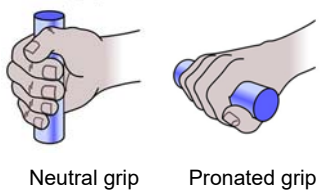
Section	Indicator	Acceptance Criteria Metric Units (US Customary Units)	Reference Pictogram	Actual/ Conforms?
3.1	Wafer cassette loading should not require greater than 10° cassette rotation in any axis. NOTE: Unless otherwise specified, you should assume that 200 mm or smaller wafers are transported in the vertical orientation and that 300 mm wafers are transported in the horizontal orientation.	Less than 10° rotation in any axis.	Wafer cassette shown in the manual carrying orientation 	Measurement Conforms? Yes No N/A ☐ ☐ ☐
3.2	Load port height, vertical distance from standing surface (150–200 mm wafers).	Maximum 960 mm (38 in.) Minimum 890 mm (35 in.)		Measurement Conforms? Yes No N/A ☐ ☐ ☐

Section 3: Wafer Cassette Loading

Section	Indicator	Acceptance Criteria Metric Units (US Customary Units)	Reference Pictogram	Actual/ Conforms?
3.3	Maximum lip height in front of cassette load port over which the cassette is lifted (150–200 mm wafer cassettes only). Measure lip height from the load surface.	Maximum 30 mm (1.2 in.)		Measurement Conforms? Yes No N/A ☐ ☐ ☐
3.4	Reach distance from the leading edge of the tool or obstruction to the coupling point(s) on a rotation device or the product grasp point.	Maximum 330 mm (13 in.)		Measurement Conforms? Yes No N/A ☐ ☐ ☐
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 in.)		Measurement Conforms? Yes No N/A ☐ ☐ ☐

Section 4: Work in Process Storage (specific to wafer cassettes)

Section	Indicator	Acceptance Criteria Metric Units (US Customary Units)	Reference Pictogram	Actual/ Conforms?
4.1	Integral wafer cassette/lot box storage shelf height (150 and 200 mm [6 and 8 in.] wafer cassette/lot boxes only).	Maximum (1 item deep) 1520 mm (60 in.) Maximum (2 items deep) 1220 mm (48 in.) Minimum 460 mm (18 in.)		Measurement Conforms? Yes No N/A ☐ ☐ ☐

Section 5: Manual Wafer Cassette Rotation Device Design				
Section	Indicator	Acceptance Criteria Metric Units (US Customary Units)	Reference Pictogram	Actual/ Conforms?
5.1	Handle height, couple point for hand(s) from standing surface.	Maximum 1206 mm (47.5 in.) Minimum 838 mm (33 in.)		Measurement Conforms? Yes No N/A ☐ ☐ ☐
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.	Power grip examples  Neutral grip Pronated grip	Measurement Conforms? Yes No N/A ☐ ☐ ☐
5.3	Single hand lift force	Maximum 37.8 N (8.5 lbf). This value includes a 15% capacity reduction due to cleanroom glove use. Wrist deviation reduces further strength capacity by 15%.	—	Measurement Conforms? Yes No N/A ☐ ☐ ☐
5.4	Two hand lift force	Maximum 64.5 N (14.5 lbf). This value includes a 15% capacity reduction due to cleanroom glove use. Wrist deviation reduces further strength capacity by 15%.	—	Measurement Conforms? Yes No N/A ☐ ☐ ☐

Section 6: Handle Design

Dimensions of handles and knobs to which one needs to apply less than:

- Linear force: 13 N (3 lbf)
- Torque: 0.43 N-m (3.8 lbf-in.)

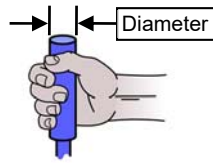
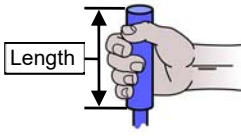
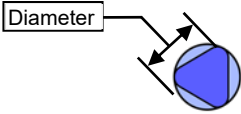
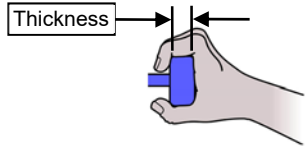
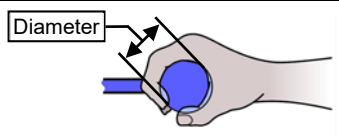
do not need to be assessed to the criteria in this section.

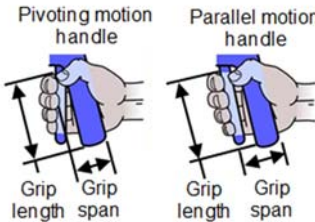
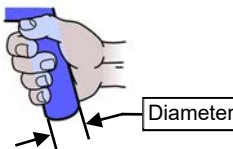
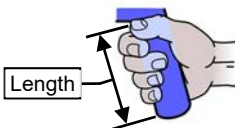
Sections 5.1 and 9 should be used to assess the location of all handles and knobs regardless of the force required.

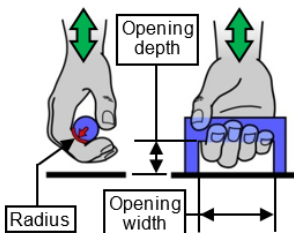
Unless otherwise noted, the provided dimensions are acceptable for use with or without gloves.

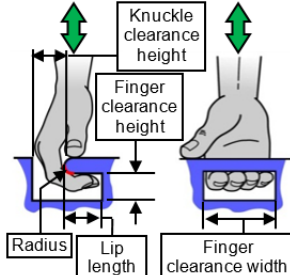
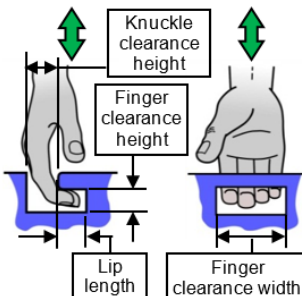
If a handle is used for both machine operation and maintenance/service tasks then apply the operational criteria.

Forces provided in sections 6.7.1, 6.8.1, and 6.9.1 are for hand-handle and hand-knob interface only and might exceed the maximum recommended forces for performing a task based on the appropriate analysis tool. See Appendix 2 for a list of lifting, strength, and material handling analysis tools.

Section	Indicator	Acceptance Criteria Metric Units (US Customary Units)	Reference Pictogram	Actual/ Conforms?
6.1	Handle surface finish	All edges radiused	—	Conforms? Yes No N/A ☐ ☐ ☐
6.2	<i>Cylindrical Handle</i>			—
6.2.1	Cylindrical handle diameter	Maximum 38 mm (1.5 in.) Minimum 25 mm (1 in.)		Measure- ment Conforms? Yes No N/A ☐ ☐ ☐
6.2.2	Cylindrical handle length	Minimum 127 mm (5 in.)		Measure- ment Conforms? Yes No N/A ☐ ☐ ☐
6.3	<i>Circular or Triangular Handle</i>			—
6.3.1	Circular or triangular handle diameter	Maximum 90 mm (3.5 in.) Minimum 50 mm (2 in.)		Measure- ment Conforms? Yes No N/A ☐ ☐ ☐
6.3.2	Circular or triangular handle height (thickness)	Maximum 25 mm (1 in.) Minimum 19 mm (0.75 in.)		Measure- ment Conforms? Yes No N/A ☐ ☐ ☐
6.4	<i>Ball Handle</i>			—
6.4.1	Ball handle diameter	Maximum 63 mm (2.5 in.) Minimum 38 mm (1.5 in.)		Measure- ment Conforms? Yes No N/A ☐ ☐ ☐

Section	Indicator	Acceptance Criteria Metric Units (US Customary Units)	Reference Pictogram	Actual/ Conforms?
6.5	Squeeze Grip Handle			—
6.5.1	Squeeze grip handle grip span Handle sections need not be cylindrical. Measurement taken at the maximum grip span of handle measured at the user's middle finger.	Maximum 89 mm (3.5 in.) open Minimum 38 mm (1.5 in.) closed		Measurement Conforms? Yes No N/A ☐ ☐ ☐
6.5.2	Squeeze grip handle grip length.	Minimum 127 mm (5 in.)		Measurement Conforms? Yes No N/A ☐ ☐ ☐
6.6	Pistol Grip Handle			—
6.6.1	Pistol grip handle diameter	Maximum 63 mm (2.5 in.) Minimum 38 mm (1.5 in.)		Measurement Conforms? Yes No N/A ☐ ☐ ☐
6.6.2	Pistol grip handle length	Minimum 127 mm (5 in.)		Measurement Conforms? Yes No N/A ☐ ☐ ☐

Section	Indicator	Acceptance Criteria Metric Units (US Customary Units)	Reference Pictogram	Actual/ Conforms?																		
6.7	Enclosed Handles Guidelines for the design of optimum enclosed handles with a round section are provided in section 6.7.1. Use of cleanroom gloves with knit liners is assumed. Enclosed handles that do not meet the design criteria in section 6.7.1 should be assessed using the instructions and data provided in Appendix 3, Enclosed Handle Assessment Criteria.			—																		
6.7.1	Enclosed handle, full hand power grip (suitcase handle).	Opening width, minimum 122 mm (4.8 in.) Opening depth, minimum 41 mm (1.6 in.) Maximum push/pull force <table><thead><tr><th colspan="2">Operational tasks</th></tr><tr><th>Radius, min.</th><th>Force, max.</th></tr></thead><tbody><tr><td>3.1 mm (0.12 in.)</td><td>33 N (7.4 lbf)</td></tr><tr><td>6.5 mm (0.25 in.)</td><td>72 N (16.1 lbf)</td></tr><tr><td>10 mm (0.39 in.)</td><td>110 N (24.8 lbf)</td></tr><tr><th colspan="2">Maintenance/service tasks</th></tr><tr><td>3.1 mm (0.12 in.)</td><td>88 N (19.8 lbf)</td></tr><tr><td>6.5 mm (0.25 in.)</td><td>191 N (42.9 lbf)</td></tr><tr><td>10 mm (0.39 in.)</td><td>294 N (66.1 lbf)</td></tr></tbody></table>	Operational tasks		Radius, min.	Force, max.	3.1 mm (0.12 in.)	33 N (7.4 lbf)	6.5 mm (0.25 in.)	72 N (16.1 lbf)	10 mm (0.39 in.)	110 N (24.8 lbf)	Maintenance/service tasks		3.1 mm (0.12 in.)	88 N (19.8 lbf)	6.5 mm (0.25 in.)	191 N (42.9 lbf)	10 mm (0.39 in.)	294 N (66.1 lbf)		Force Opening depth Opening width Radius Conforms? Yes No N/A ☐ ☐ ☐
Operational tasks																						
Radius, min.	Force, max.																					
3.1 mm (0.12 in.)	33 N (7.4 lbf)																					
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Section	Indicator	Acceptance Criteria Metric Units (US Customary Units)	Reference Pictogram	Actual/ Conforms?																		
6.8	Hook Grasp Handle Hook grasp handles that do not meet the design criteria in section 6.8.1 should be assessed using the instructions and data provided in Appendix 3, Enclosed Handle Assessment Criteria.			—																		
6.8.1	Hook grasp handle (four fingers).	Finger clearance width, minimum 97 mm (3.8 in.) Finger clearance height, minimum 28 mm (1.1 in.) Knuckle clearance height, minimum 48 mm (1.9 in.) Lip length, minimum 49 mm (1.9 in.) Maximum push/pull force <table><thead><tr><th colspan="2">Operational tasks</th></tr><tr><th>Radius, min.</th><th>Force, max.</th></tr></thead><tbody><tr><td>6.3 mm (0.25 in.)</td><td>15 N (3.5 lbf)</td></tr><tr><td>13 mm (0.5 in.)</td><td>33 N (7.5 lbf)</td></tr><tr><td>19 mm (0.75 in.)</td><td>51 N (11.5 lbf)</td></tr></tbody></table> <table><thead><tr><th colspan="2">Maintenance/service tasks</th></tr></thead><tbody><tr><td>6.3 mm (0.25 in.)</td><td>41 N (9.3 lbf)</td></tr><tr><td>13 mm (0.5 in.)</td><td>89 N (20.1 lbf)</td></tr><tr><td>19 mm (0.75 in.)</td><td>137 N (30.9 lbf)</td></tr></tbody></table>	Operational tasks		Radius, min.	Force, max.	6.3 mm (0.25 in.)	15 N (3.5 lbf)	13 mm (0.5 in.)	33 N (7.5 lbf)	19 mm (0.75 in.)	51 N (11.5 lbf)	Maintenance/service tasks		6.3 mm (0.25 in.)	41 N (9.3 lbf)	13 mm (0.5 in.)	89 N (20.1 lbf)	19 mm (0.75 in.)	137 N (30.9 lbf)		Force Finger clearance height Finger clearance width Radius Lip Knuckle clearance height Conforms? Yes No N/A ☐ ☐ ☐
Operational tasks																						
Radius, min.	Force, max.																					
6.3 mm (0.25 in.)	15 N (3.5 lbf)																					
13 mm (0.5 in.)	33 N (7.5 lbf)																					
19 mm (0.75 in.)	51 N (11.5 lbf)																					
Maintenance/service tasks																						
6.3 mm (0.25 in.)	41 N (9.3 lbf)																					
13 mm (0.5 in.)	89 N (20.1 lbf)																					
19 mm (0.75 in.)	137 N (30.9 lbf)																					
6.9	Finger Pull Handle Finger pull handles that do not meet the design criteria in section 6.9.1 should be assessed using the instructions and data provided in Appendix 3, Enclosed Handle Assessment Criteria.			—																		
6.9.1	Finger pull handles (four fingers)	Finger clearance width, minimum 91 mm (3.6 in.) Finger clearance height, minimum 22 mm (0.8 in.) Knuckle clearance height, minimum 28 mm (1.1 in.) Lip length, minimum 18 mm (0.7 in.) Maximum push/pull force <table><thead><tr><th colspan="2">Operational tasks</th></tr></thead><tbody><tr><td colspan="2">36 N (8.1 lbf) all radii</td></tr></tbody></table> <table><thead><tr><th colspan="2">Maintenance/service tasks</th></tr></thead><tbody><tr><td colspan="2">97 N (21.7 lbf) all radii</td></tr></tbody></table>	Operational tasks		36 N (8.1 lbf) all radii		Maintenance/service tasks		97 N (21.7 lbf) all radii			Force Finger clearance height Finger clearance width Lip Knuckle clearance height Conforms? Yes No N/A ☐ ☐ ☐										
Operational tasks																						
36 N (8.1 lbf) all radii																						
Maintenance/service tasks																						
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Section 7: Clearance Criteria

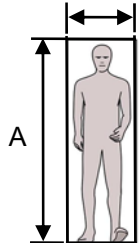
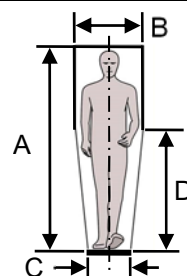
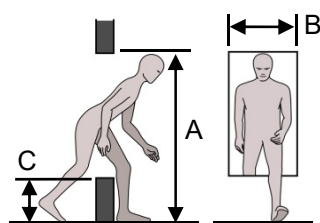
Equipment may extend into the recommended clearance envelopes provided that the assessor captures in the assessment report a rationale demonstrating that the impinging object(s) will not interfere with the task or tasks for which clearance is being evaluated. The rationale should give consideration to at least the following points:

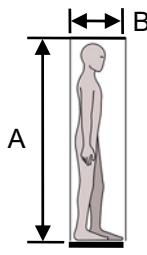
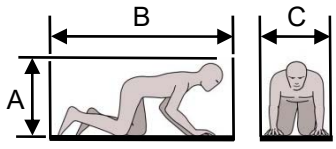
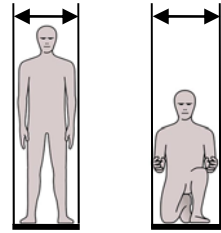
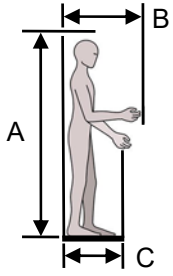
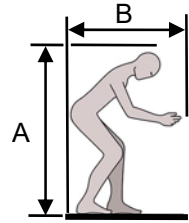
- 95th percentile North American male body dimensions,
- Line-of-sight vision required throughout the task(s),
- Anticipated body motions (e.g., turning, reaching) during the task(s).

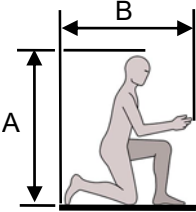
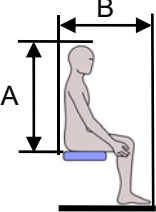
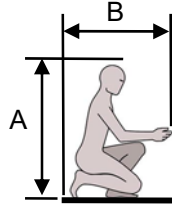
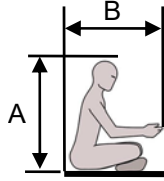
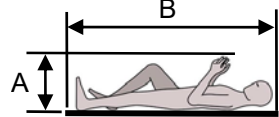
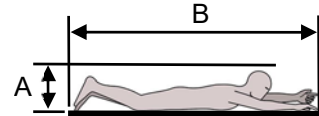
The following clearance criteria for design and assessment do not include consideration of the tools, materials, and devices identified by the supplier to be moved and used in the course of the task, and personal protective equipment recommended by the supplier to be worn by workers during the task(s). Additional clearance should be provided for these considerations.

These criteria are limited to the equipment structure as provided, and installed per supplier instructions. If a horizontal dimension extends outside the envelope of the equipment, as provided, then the excursion should be included in the equipment ergonomics clearances (see for example SEMI S8, ¶ 7.3). Clearance around the equipment (ergonomic clearance), per the supplier's specifications, may be considered in determining conformance as applicable.

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.

Section	Indicator	Acceptance Criteria Metric Units (US Customary Units)	Reference Pictogram	Actual/ Conforms?
7.1	Whole Body Clearance for Walking and Crawling (point-to-point access only and not work activities).			
7.1.1	Clearance for walking (operator tasks)	A. Vertical clearance, minimum. 1980 mm (78 in.) B. Passage width, minimum 610 mm (24 in.)		Measurements A. _____ B. _____ Conforms? Yes No N/A ☐ ☐ ☐
7.1.2	Clearance for walking (maintenance and service activity only)	A. Vertical clearance, minimum 1900 mm (74.8 in.) B. Upper body passage width, minimum 610 mm (24 in.) C. Walking surface width minimum 457 mm (18 in.) D. Elbow/hip clearance height, maximum height of sloped area 1002 mm (39.8 in.)		Measurements A. _____ B. _____ C. _____ D. _____ Conforms? Yes No N/A ☐ ☐ ☐
7.1.3	Clearance for walking through vertical hatchways (maintenance and service activity only)	A. Overhead clearance, minimum 1524 mm (60 in.) B. Upper body passage width, minimum 610 mm (24 in.) C. Height of threshold, maximum 406 mm (16 in.)		Measurements A. _____ B. _____ C. _____ Conforms? Yes No N/A ☐ ☐ ☐

Section	Indicator	Acceptance Criteria Metric Units (US Customary Units)	Reference Pictogram	Actual/ Conforms?
7.1.4	Clearance for moving sideways (maintenance and service activity only)	A. Overhead clearance, minimum 1900 mm (74.8 in.) B. Forward horizontal clearance, minimum 477 mm (18.8 in.)		Measurements A. _____ B. _____ Conforms? Yes No N/A ☐ ☐ ☐
7.1.5	Kneeling crawl	A. Overhead clearance measured from floor, minimum 740 mm (29 in.) B. Forward horizontal clearance, minimum 1520 mm (60 in.) C. Elbow clearance, minimum 635 mm (25 in.)		Measurements A. _____ B. _____ C. _____ Conforms? Yes No N/A ☐ ☐ ☐
7.2	Whole Body Clearance for Work Activities These criteria apply to tasks that are anticipated by the supplier to involve manual and visual activity lasting longer than 5 minutes, or having multiple occurrences with a total duration of greater than 1 hour per 8-hour shift. Clearances should be provided based on the nature of the tasks performed in the designated area. When determining the working space required for a given task, first estimate where the hands, tools and equipment will be, the line-of-sight needed, and if the body will be supported (for example, sitting on a stool) for the envisioned task. Also consider space needed for movement such as squatting to lift an item or applying push/pull forces. Once this is done, estimate the posture(s) that will be associated with the task and use sections 7.2.1 through 7.2.9 to determine the various minimum clearance dimensions required for that posture. Clearances required for displays and controls in sections 8 and 9 should also be considered.			
7.2.1	Horizontal clearance for upper body (all postures)	Minimum 610 mm (24 in.)		Measurement _____ Conforms? Yes No N/A ☐ ☐ ☐
7.2.2	Standing	A. Overhead clearance, minimum 1980 mm (78 in.) B. Forward horizontal clearance ^{#1} , minimum 690 mm (27 in.) C. Lower body clearance ^{#1} , minimum 508 mm (20 in.)		Measurements A. _____ B. _____ C. _____ Conforms? Yes No N/A ☐ ☐ ☐
7.2.3	Stooping	A. Overhead clearance, minimum 1450 mm (57 in.) B. Forward horizontal clearance ^{#1} , minimum 1020 mm (40 in.)		Measurements A. _____ B. _____ Conforms? Yes No N/A ☐ ☐ ☐

Section	Indicator	Acceptance Criteria Metric Units (US Customary Units)	Reference Pictogram	Actual/ Conforms?
7.2.4	Kneeling	A. Overhead clearance (from floor), minimum 1450 mm (57 in.) B. Forward horizontal clearance ^{#1} , minimum 1220 mm (48 in.)		Measurements A. _____ B. _____ Conforms? Yes No N/A ☐ ☐ ☐
7.2.5	Sitting The given clearance dimensions do not provide room for movement of seating devices. Thickness of chair backrest is not included. Room for movement of the seating device is not included.	A. Overhead clearance measured from sitting surface, minimum 1010 mm (39.8 in.) B. Forward horizontal clearance (as measured from any obstruction, or front [user] side of backrest, if present) ^{#1} B1. Clearance for operation tasks (relaxed posture), minimum 1034 mm (40.7 in.) B2. Clearance for maintenance tasks (upright posture), minimum 867 mm (34.1 in.)		Measurements A. _____ B1. _____ B2. _____ Conforms? Yes No N/A ☐ ☐ ☐
7.2.6	Squatting	A. Overhead clearance, minimum 1220 mm (48 in.) B. Forward horizontal clearance ^{#1} , minimum 790 mm (31 in.)		Measurements A. _____ B. _____ Conforms? Yes No N/A ☐ ☐ ☐
7.2.7	Sitting-on-floor	A. Overhead clearance, minimum 1000 mm (39 in.) B. Forward horizontal clearance ^{#1} , minimum 690 mm (27 in.)		Measurements A. _____ B. _____ Conforms? Yes No N/A ☐ ☐ ☐
7.2.8	Supine (lying on back)	A. Vertical clearance (overhead), minimum 430 mm (17 in.) If the supplier specifies the use of a mechanic's-type creeper for a task, measure from the top surface of the creeper to the overhead obstruction. B. Length (forward), minimum 1980 mm (78 in.)		Measurements A. _____ B. _____ Conforms? Yes No N/A ☐ ☐ ☐
7.2.9	Prone (lying on stomach)	A. Vertical clearance (overhead), minimum 510 mm (20 in.) If the supplier specifies the use of a mechanic's-type creeper for a task, measure from the top surface of the creeper to the overhead obstruction. B. Length (forward), minimum 2440 mm (96 in.)		Measurements A. _____ B. _____ Conforms? Yes No N/A ☐ ☐ ☐