**Table 1 Dimensions of indicator placement zone for a load port per SEMI E15.1 Option1**

| *Symbol Used* | *Figure* | *Value Specified* | *Reference Measured From* |
|---|---|---|---|
| x400 | 1 | 237.5 mm (9.35 in.) | bilateral datum plane |
| z400 | 1 | 340 mm (13.39 in.) | horizontal datum plane |
| z401 | 1 | 486 mm (19.13 in.) | horizontal datum plane |

5.1.2 *Indicator placement zone for a load port per SEMI E15.1 Option 3* — It is recommended that load port status indicators should be positioned within a zone given by x401, x402, z402 and z403. The exact placement of them within this zone is at the direction of the load port supplier. They may be located at or behind (away from the operator) the load face plane. Clearances required by SEMI E15.1 cannot be violated.

NOTE 3: The indicator placement zone is not an exclusion zone. No assumption can be made that this zone needs to be kept empty by the load port supplier. Furthermore, no assumption can be made that a load port must have a physical surface representing the indicator placement zone.

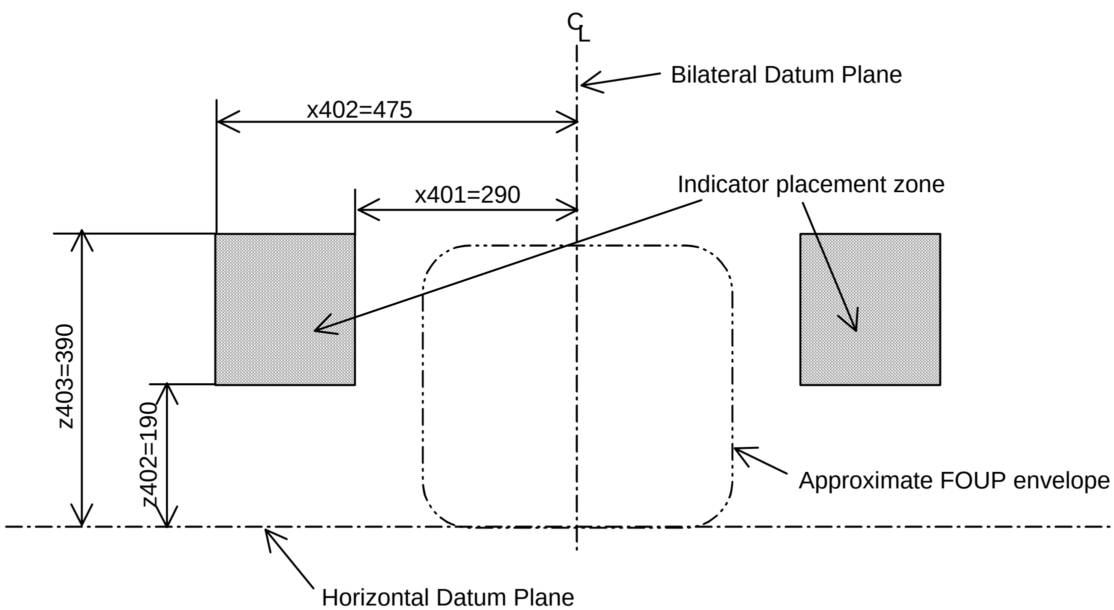


**Figure 2**
**Indicator Placement Zone for a Load Port Per SEMI E15.1 Option 3**

**Table 2 Dimensions of indicator placement zone for a load port per SEMI E15.1 Option3**

| *Symbol Used* | *Figure* | *Value Specified* | *Reference Measured From* |
|---|---|---|---|
| x401 | 2 | 290 mm (11.42 in.) | bilateral datum plane |
| x402 | 2 | 475 mm (18.79 in.) | bilateral datum plane |
| z402 | 2 | 190 mm (7.48 in.) | horizontal datum plane |
| z403 | 2 | 390 mm (15.35 in.) | horizontal datum plane |

5.2 *Switch Placement Volume* — For a load port according to option 1 and 3 per SEMI E15.1, it is recommended that load port operation switches should be positioned in a way, that the surface of the switch is within a volume given by x403, x404, r400, y402 (equal to the maximum values of r67 and y53 defined in SEMI E47.1 respectively), y400, y401 (equal to the maximum value of D defined in SEMI E15.1), z404, and z405. The exact placement of the switches within this volume is at the discretion of the load port supplier.

NOTE 4: The switch placement volume is not an exclusion volume. No assumption can be made that this volume needs to be kept empty by the load port supplier. Furthermore, no assumption can be made that a load port must have a physical surface representing the switch placement volume.

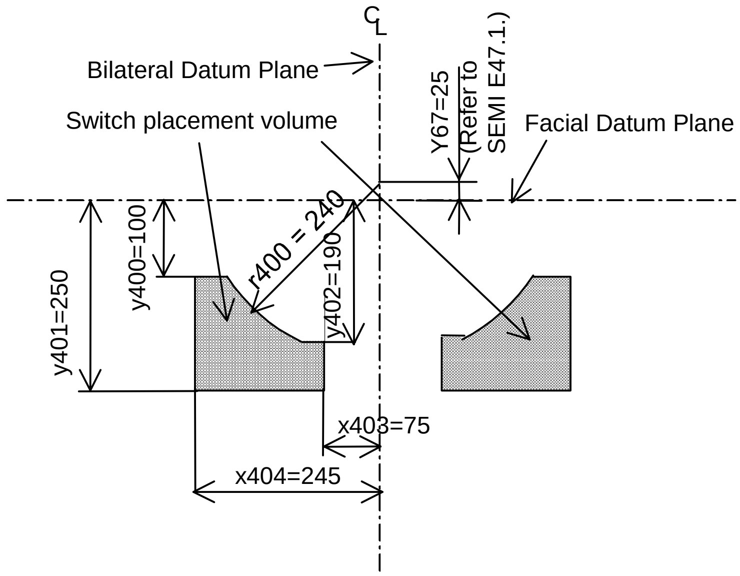


**Figure 3**
**Top View of Switch Placement Volume**

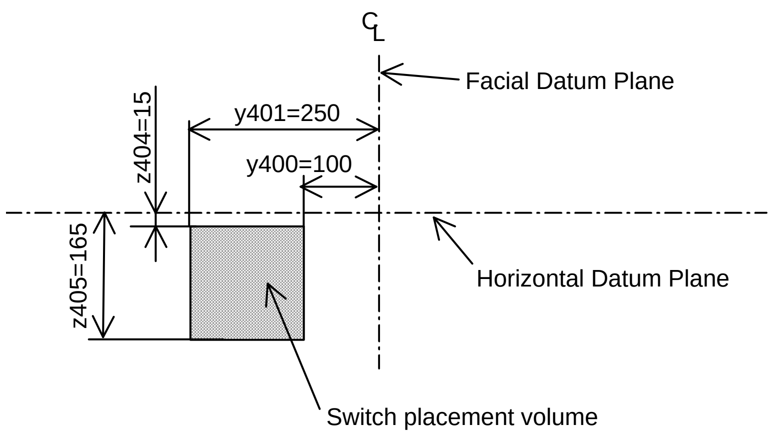


**Figure 4**
**Side View of Switch Placement Volume**

**Table 3 Dimensions of Switch Placement Volume**

| *Symbol Used* | *Figure* | *Value Specified* | *Reference Measured From* | *Remarks* |
|---|---|---|---|---|
| r400 | 3 | 240 mm (9.45 in) | y67 in front of nominal wafer center line | Equal to the maximum value of r67 defined in SEMI E47.1 |
| x403 | 3 | 75 mm (2.95 in.) | bilateral datum plane | - |
| x404 | 3 | 245 mm (9.65 in.) | bilateral datum plane | - |
| y400 | 3,4 | 100 mm (3.94 in) | facial datum plane (as shown in Figure 1 of SEMI E15.1) | - |
| y401 | 3,4 | 250 mm(9.843 in) | facial datum plane (as shown in Figure 1 of SEMI E15.1) | Equal to the maximum value of D defined in SEMI E15.1 |
| y402 | 3 | 190 mm (7.48 in) | facial datum plane (as shown in Figure 1 of SEMI E15.1) | Equal to the maximum value of y53 defined in SEMI E47.1 |
| z404 | 4 | 15 mm (0.59 in.) | horizontal datum plane | - |
| z405 | 4 | 165 mm (6.50 in.) | horizontal datum plane | - |

## 6 Related Documents

6.1 *SEMI Standards*

SEMI E62 — Provisional Specification for 300 mm Front-Opening Interface Mechanical Standard (FIMS)

SEMI E63 — Mechanical Specification for 300 mm Box Opener/Loader to Tool Standard (BOLTS-M) Interface

SEMI E92 — Provisional Specification for 300 mm Light Weight and Compact Box Opener/Loader to Tool-Interoperability Standard (BOLTS/Light)

SEMI S8 — Safety Guidelines for Ergonomics Engineering of Semiconductor Manufacturing Equipment

**NOTICE**: SEMI makes no warranties or representations as to the suitability of the standards set forth herein for any particular application. The determination of the suitability of the standard is solely the responsibility of the user. Users are cautioned to refer to manufacture' s instructions, product labels, product data sheets, and other relevant literature, respecting any materials or equipment mentioned herein. These standards are subject to change without notice.

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# SEMI E111-0305
# PROVISIONAL MECHANICAL SPECIFICATION FOR A 150 mm RETICLE SMIF POD (RSP150) USED TO TRANSPORT AND STORE A 6 INCH RETICLE

This specification was technically approved by the Global Physical Interfaces and Carriers Committee and is the direct responsibility of the North American Physical Interfaces and Carriers Committee. Current edition approved by the North American Regional Standards Committee on December 10, 2004. Initially available at www.semi.org February 2005; to be published March 2005. Originally published November 2001; last published November 2004.

## 1 Purpose

1.1 This standard specifies the 150 mm Reticle SMIF Pod (RSP150) used to transport and store a 6 inch reticle in an integrated circuit (IC) manufacturing facility.

## 2 Scope

2.1 This standard is intended to set an appropriate level of specification that places minimal limits on innovation while ensuring modularity and inter- changeability at all mechanical interfaces. Most of the requirements given in this specification are in the form of maximum or minimum dimensions with very few required surfaces. Only the physical interfaces for the RSP150 are specified; no materials requirements or micro-contamination limits are given in this specification.

2.2 The pellicle exclusion volume of this specification accommodates pellicles which extend the full length of the reticle and up to a maximum pellicle width of 124 mm.

2.3 The RSP150 has the following components, sub-components, and other features. A "●" symbol indicates components or features which are *required* and a "◊" symbol indicates components or features which are *optional*.

- Top
  - ◊ robotic handling flange
- Interior
  - supports for one 6 inch reticle
  - reticle capture
  - reticle contact surfaces
  - end-effector exclusion volumes
  - 2 safety rail exclusion volumes
  - pellicle exclusion volumes
  - lateral constraints
  - 2 reticle backstops
- Sides
  - ◊ 2 side handling flanges on the sides parallel to the bi-lateral reference plane
  - 2 side handling exclusion volumes
  - RFID placement zone
- Bottom
  - door compatible with SMIF as defined in SEMI E19.3

- pod latch-pin holes
- 2 conveyor rails on the sides parallel to the bi-lateral reference plane

2.4 This standard is provisional because of the issues detailed in the related information section. Once investigation of issues in the Related Information section has been completed, this standard should be upgraded from provisional status.

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

## 3 Referenced Standards

3.1 *SEMI Standards*

SEMI E19.3 — Port Standard for Mechanical Interface of Wafer Cassette Transfer, 150 mm (6 inch) Port

SEMI E30.1 — Inspection and Review Specific Equipment Model (ISEM)

SEMI E47.1 — Provisional Mechanical Specification for Boxes and Pods Used to Transport and Store 300 mm Wafers

SEMI P5 — Specification for Pellicles

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

## 4 Terminology

4.1 *Definitions*

4.1.1 *150 mm Reticle SMIF Pod* (RSP150) — a minienvironment compatible carrier capable of holding a 6 inch reticle in a horizontal orientation during transport and storage and is compatible with a Standard Mechanical Interface (SMIF) per SEMI E19.3.

4.1.2 *bilateral reference plane* — a vertical plane which bisects the RSP150 and is perpendicular to both the horizontal and facial reference planes and passes through the center of the 150 mm SMIF as defined in SEMI E19.3.

4.1.3 *facial reference plane* — a vertical plane which bisects the RSP150 and is parallel to the front side of the pod (where reticles are removed or inserted) and passes through the center of the 150 mm SMIF as defined in SEMI E19.3.

4.1.4 *horizontal reference plane* — a horizontal plane coplanar with the top surface of the port door as defined in SEMI E19.3.

4.1.5 *minienvironment* — a localized environment created by an enclosure to isolate the product from contamination and people.

4.1.6 *nominal reticle center line* — the line that is defined by the intersection of two perpendicular vertical planes each of which bisect the reticle at the mid-point of a side.

4.1.7 *pellicle* — as defined in SEMI P5.

4.1.8 *reticle* — as defined in SEMI E30.1.

4.1.9 *robotic handling flanges* — horizontal projections on the top of the box for lifting and rotating the box (as defined in SEMI E47.1).

4.1.10 *side handling flanges* — horizontal projections on the sides of the pod (sides parallel to the bilateral reference plane) for lifting, transportation or positioning of the pod.

## 5 Ordering Information

5.1 *Intended Use* — This standard is intended to specify reticle carriers over a reasonable lifetime of use, not just those in new condition. For this reason, the purchaser should specify a time period and the number and type of uses to which the carriers will be put. It is under these conditions that the carriers must remain in compliance with the requirements listed in §6.

5.2 *Reticle Thickness* — The purchaser needs to specify the reticle thickness to be accommodated in the RSP150.

5.3 *Optional Features* — The purchaser needs to specify whether optional components (identified in §2) are required.

5.4 *Temperature Ranges* — The purchaser needs to specify two sets of temperatures to which the RSP150s might be exposed. An operating temperature range is the set of environmental temperatures in which the RSP150s will remain in compliance with the requirements listed in §6. A temporary temperature range is the set of environmental temperatures to which the pods can be exposed such that when the RSP150s return to the operating temperature range, the RSP150s will be in compliance with the requirements listed in §6. Limits on exposure times to elevated temperatures should be specified.

5.5 *Electrostatic Dissipation* — The end user may require a continuous path to ground from the reticle to the carrier registration and handling features. The purchaser needs to specify whether electrostatic dissipation is required.

5.6 *Contamination Requirements* — The purchaser needs to specify their contamination requirements.

## 6 Requirements

6.1 *Symmetry* — Most of the dimensions of the RSP150 are determined with respect to the three orthogonal reference planes defined in this document: the facial reference plane, the horizontal reference plane and the bilateral reference plane. All dimensions are symmetric about the bilateral reference plane.

6.2 *Door* — The pod door, and its frame on the bottom of the pod, must be compatible with a port which conforms to SEMI E19.3.

6.3 *Positioning* — The nominal reticle seating plane is defined by *z*291, as shown in Figure 4 and Table 2. The entire bottom surface of a reticle must lie within the *z*276 dimension of its nominal seating plane shown in Figure 6 and Table 2.

6.4 *Reticle Capture* — When the carrier is closed, a bisecting plane through the reticle, parallel to the bilateral reference plane must be constrained by the carrier within *x*114 of the bilateral reference plane of the load port when the reticle is seated in the carrier. A bisecting plane through the reticle, parallel to the facial reference plane must be constrained by the carrier within *y*228 of the facial reference plane of the load port when the reticle is seated in the carrier.

6.5 *Reticle Contact Surfaces* — The reticle contact surfaces are the only 4 locations where the RSP150 may contact the pellicle side of the reticle. These surfaces are shown in Figures 9 and 10 with dimensions given in Table 2. The contact surfaces are defined by *x*245, *x*246, *y*233, *y*234 and *y*235.

6.6 *Exclusion Volumes* — The interior of the RSP150 must never intrude into the pellicle exclusion volume, and must not intrude into the end-effector exclusion volumes, lift clearance exclusion volume or safety rail exclusion volumes when the carrier is open.

6.6.1 *End-Effector Exclusion Volumes* — Volumes in an opened pod which must be free for the end-effector to enter and handle the reticle as defined by *x*238, *x*239, *x*240, *y*227, *y*232, *y*238, *z*297, *z*299 and *z*302. No obstructions should exist in the end-effector exclusion volumes which extend in the y direction (normal to the facial reference plane.) Table 2 defines the dimensions for the end-effector exclusion volumes shown in Figures 4, 6, 7 and 9.

6.6.2 *Pellicle Exclusion Volume* — Volume in the pod below the reticle which must remain free from intrusion to accommodate the pellicle mounted on the reticle. No obstructions should exist in the pellicle exclusion volume as defined by *x*119 and *z*290 which extends in the y direction (normal to the facial reference plane). The pellicle exclusion volume is defined in Table 2 and shown in Figure 4.

6.6.3 *Reticle Lift Clearance Exclusion Volume* — Volume in an opened pod which must be free above the reticle to allow the end-effector to lift and handle the reticles, having a width defined by *x*243 as shown in Table 2 and Figure 4. No obstructions should exist in the reticle lift clearance exclusion volumes which extend in the y direction (normal to the facial reference plane).

6.6.4 *Safety Rail Exclusion Volumes* — Volumes in an opened pod which must remain free from intrusion to accommodate safety rails which may be used on end-effectors to protect the edge of the reticle during handling. No obstructions should exist in the safety rail exclusion volumes which extend in the y direction (normal to the facial reference plane) as defined by *x*241 and *z*301 in Table 2 and shown in Figure 4.

6.6.5 *Rear Retainer Volume* — Volume in an opened pod in which any reticle rear retainer must exist. The volume is defined by *x*242, *y*231 and *z*312 as shown in Figure 7 and Figure 8 and Table 2.

NOTE 1: This volume is never to be accessed by an end-effector.

6.6.6 *Reticle Backstops* — The interior of the RSP150 shall have a reticle backstop which may be used by end-effectors to position the reticle when being removed from the RSP150.

NOTE 2: These are the minimum required backstops, the backstops may be larger than this minimum specification, occupying any part of the rear retainer volume. The dimensions are defined by *x*249, *x*250, *y*239 and *z*313 as shown in Table 2 and in Figure 7.

6.6.7 *RFID Placement Zone* — Zone in the pod where the RFID transponder is placed, which may be used for RF communications during reticle handling. The entire RFID transponder must be positioned within the zone defined by *x*251, *x*252, *y*240, *y*241, *z*308, *z*314, *z*315 in Table 2 and shown in Figures 1, 3, 12. Pod suppliers may also place other features in this placement zone (such as the pod wall, RFID transponder support brackets, etc).

6.7 *External Dimensions* — Figures 1, 2, 3, 5 and 11 show, respectively, the external top view, a detail, the rear view, the robotic handling flange and the conveyor rails of the RSP150. Table 2 defines the external dimensions of the RSP150.

6.8 *Internal Dimensions* — Figures 4, 6, 7, 8, 9 and 10 show internal dimensions of the RSP150. Table 2 defines the internal dimensions of the RSP150.

6.9 *Robotic Handling Flange* — On the top of the pod is an optional robotic handling flange for automated manipulation of the RSP150. Figures 1, 3 and 5 show dimensions for the robotic handling flange. Table 2 defines the dimensions for the robotic handling flange.

6.10 *Recess* — Surface on the top of the pod defined by dimensions *x*100, *y*106 and *z*303. Figures 1 and 3 show dimension for the recess. The recess provides clearance for use of robotic handling flange.

NOTE 3: The raised surface around the recess is not required.

6.11 *Side Handling Flanges* — On the sides of the pod parallel to the bilateral reference plane are optional handling flanges for automated manipulation of the RSP150. Figures 1, 2 and 3 show dimensions for the side handling flanges. Table 2 defines the dimensions for the side handling flanges. No obstructions may exist in the side handling exclusion volumes which extend in the y direction (normal to the facial reference plane) as defined by *x*236 and *z*308.

6.12 *Conveyor Rails* — Surfaces on the bottom of the RSP150 used to transport the RSP on conveyors. The rails consist of smooth portions of the bottom periphery, parallel with each other, on two opposite sides, and extending at least *y*236 from the facial reference plane (optionally the full length) on those sides. Surfaces on these portions of the bottom periphery should be uninterrupted (i.e. no notches in the surface along the bottom or the side). No other feature of the carrier may extend below the plane defined by the surfaces of the conveyor rails. The conveyor rail surfaces are bounded by *x*247, *x*248 and *y*236 as shown in Figure 11. Table 2 defines the dimensions for the conveyor rails.

6.13 *Inner and Outer Radii* — All required concave features may have a radius of up to *r*65 to allow cleaning and to prevent contaminant build-up. All required convex features may also have a radius of up to *r*66 to prevent small contact patches with large stresses that might cause wear and particles.

NOTE 4: These limits on the radius of all required features are specified as a maximum (not a minimum) to ensure that the required features are not rounded off too much. The lower bound on the radius is up to the carrier supplier.

NOTE 5: This radius applies to every required feature unless another radius is called out specifically. Here a required feature is an area on the surface of the carrier specified by a dimension (or intersections of dimensions) that has a tolerance and not just a maximum or minimum (such as the edges of the robotic handling flange).

6.14 *Info Pads* — When the RSP is placed on a port, the info pads A, B, C, and D communicate information about the RSP configuration. Figure 11 shows the dimensions of the info pads. Table 2 defines the info pad dimensions.

A pad in the up position must be z26 above the horizontal reference plane. A pad in the down position must be z2 above the horizontal reference plane. Info pad assignments are shown in Table 1. Info pads that are “not defined” can be at either the up or down position unless specified by the end user. RSP configurations “to be assigned” may be assigned by the end user.

**Table 1**

| *RSP Configuration* | *Info Pad* | | | |
|---|---|---|---|---|
| | *A* | *B* | *C* | *D* |
| 6 inch reticle | not defined | not defined | up | down |
| to be assigned | not defined | not defined | down | down |
| to be assigned | not defined | not defined | up | up |
| to be assigned | not defined | not defined | down | up |

## 7 Related Documents

7.1 *SEMI Standards*

SEMI P1 — Specification for Hard Surface Photomask Substrates

SEMI S8 — Safety Guidelines for Ergonomics Engineering of Semiconductor Manufacturing Equipment

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

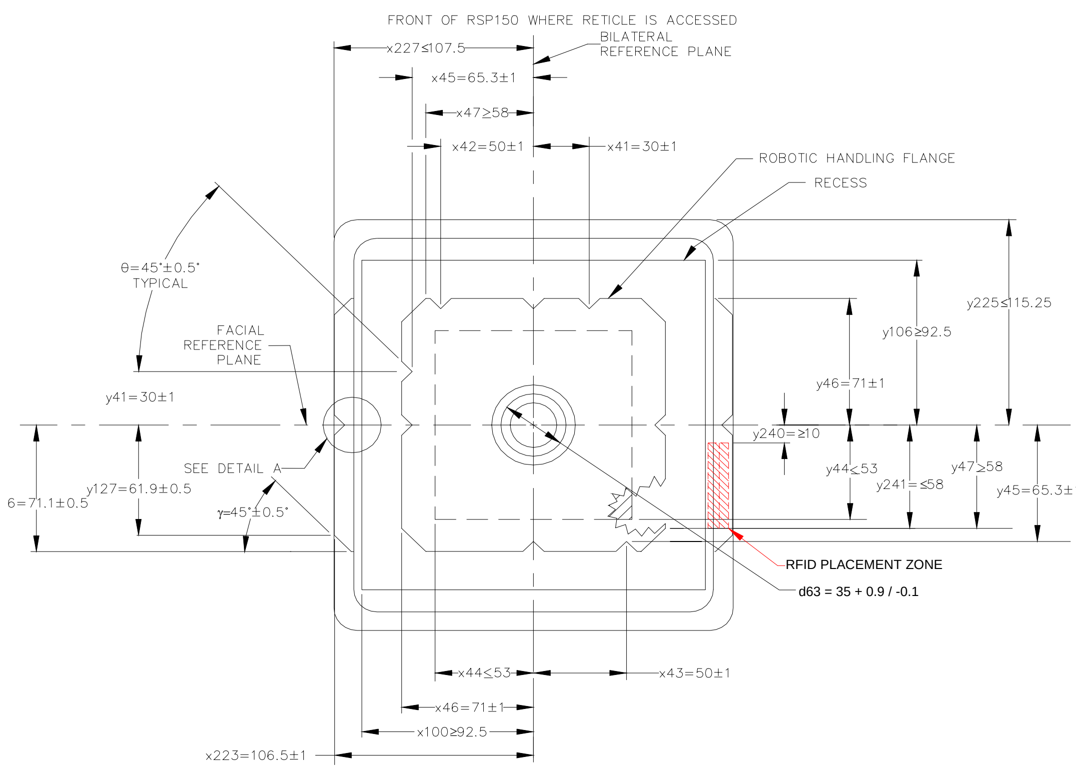



**Figure 1**
**External Top View of RSP150**

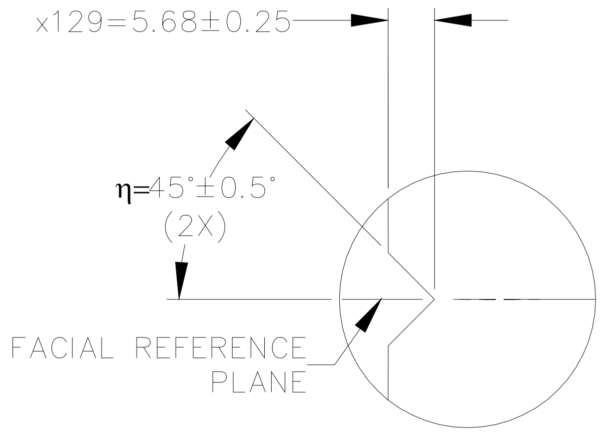



**Figure 2**
**Detail A: External Top View of Side Handling Flange Alignment Notch**

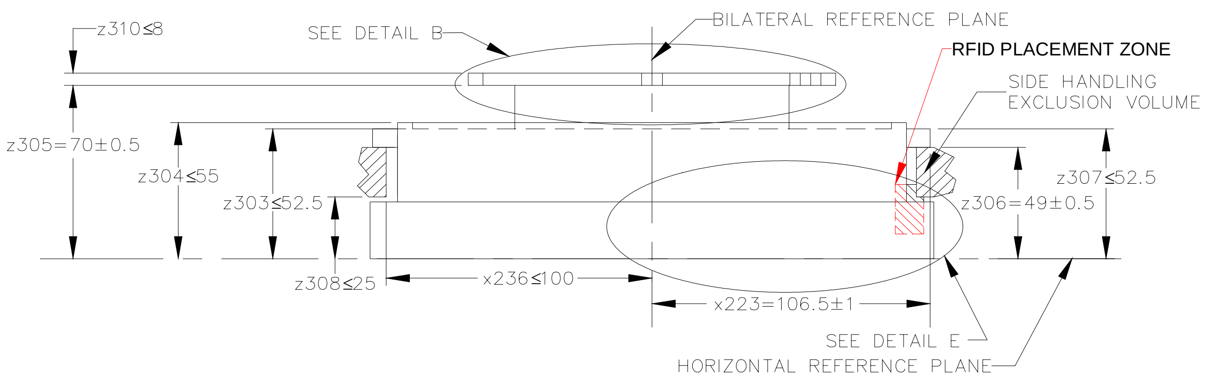



**Figure 3**
**External Rear View of RSP150**

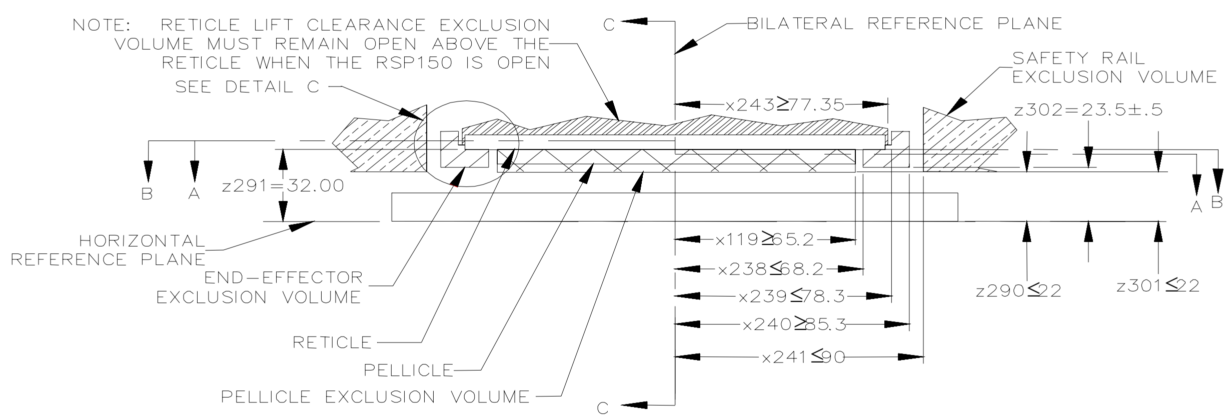



**Figure 4**
**Internal Front View of RSP150**

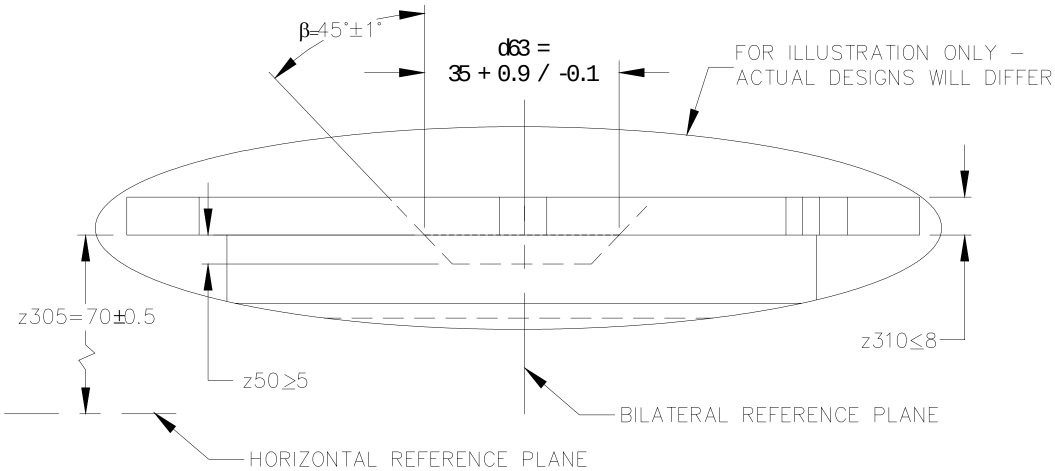



**Figure 5**
**Detail B: Top Robotic Handling Flange Hole Feature**

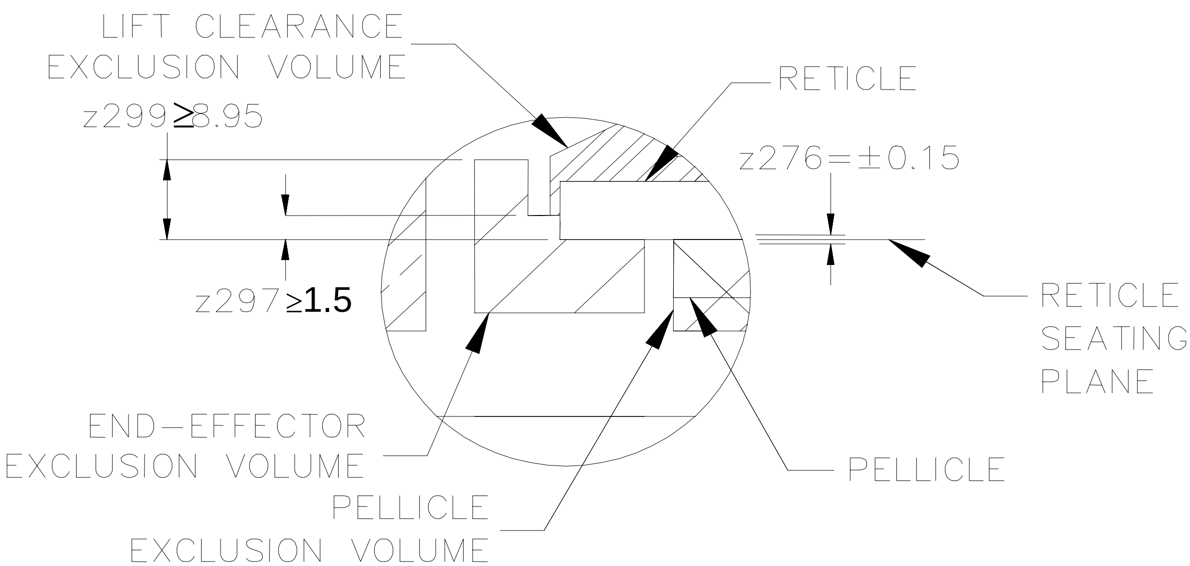



**Figure 6**
**Detail C: Reticle Seating and Capture Detail**

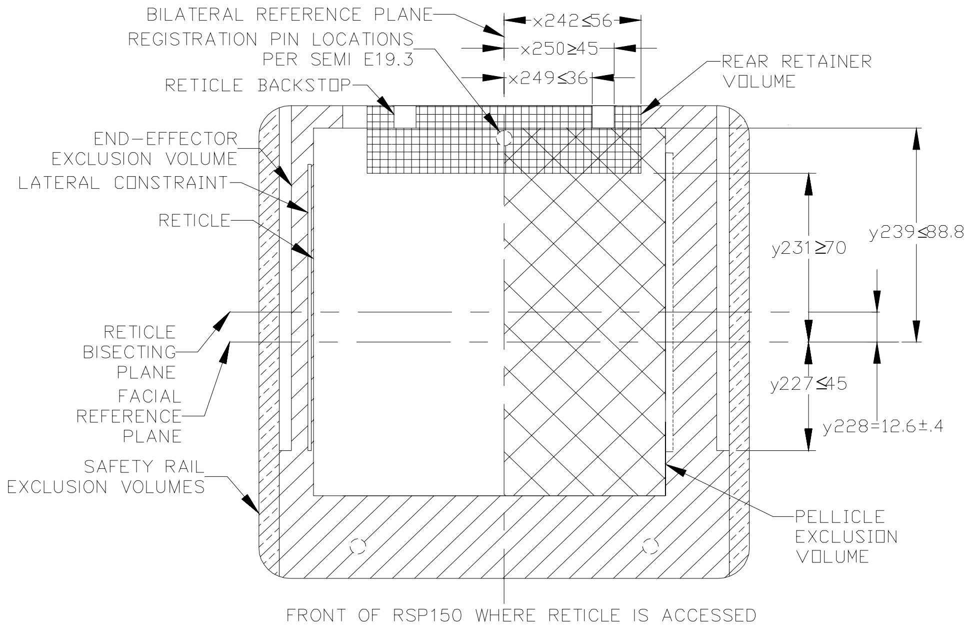



**Figure 7**
**Section A-A: Door Only Top View of RSP150**

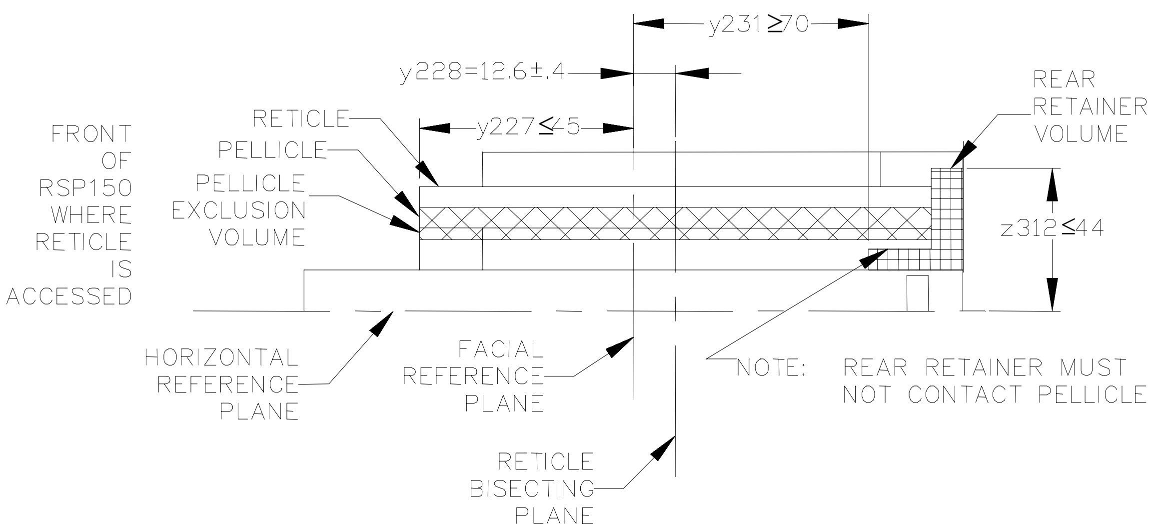



**Figure 8**
**Section C-C: Door Only Side View of RSP150**

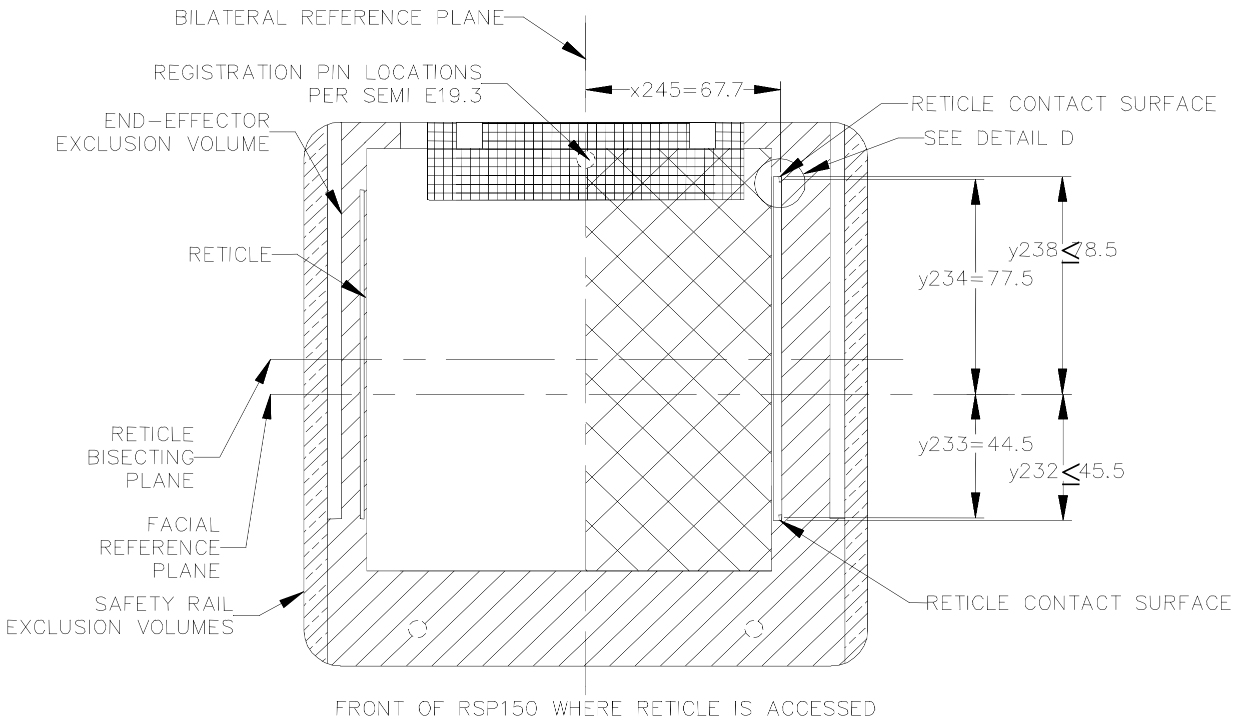



**Figure 9**
**Section B-B: Door Only Top View of RSP150 with Reticle Contact Surfaces**

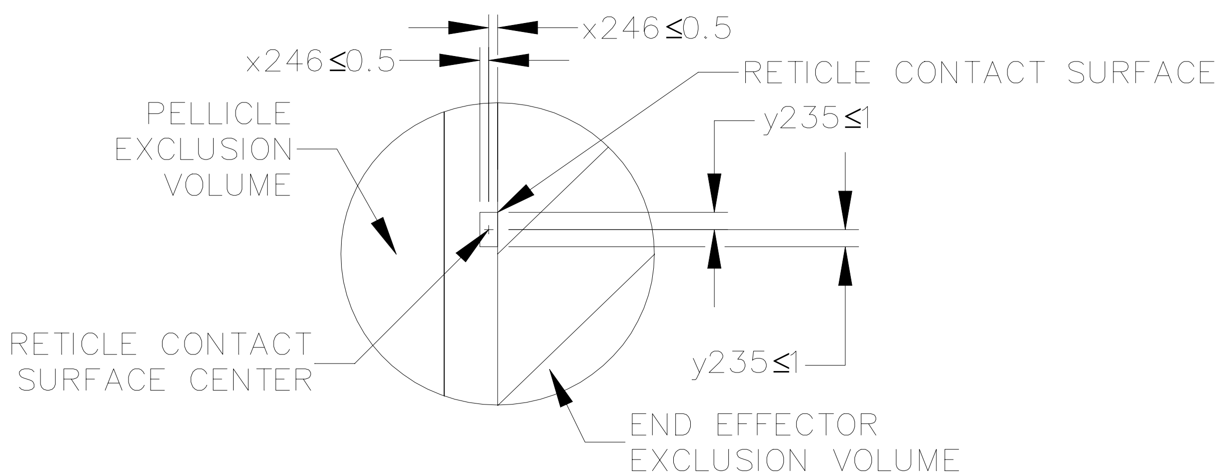



**Figure 10**
**Detail D: Reticle Contact Surface**

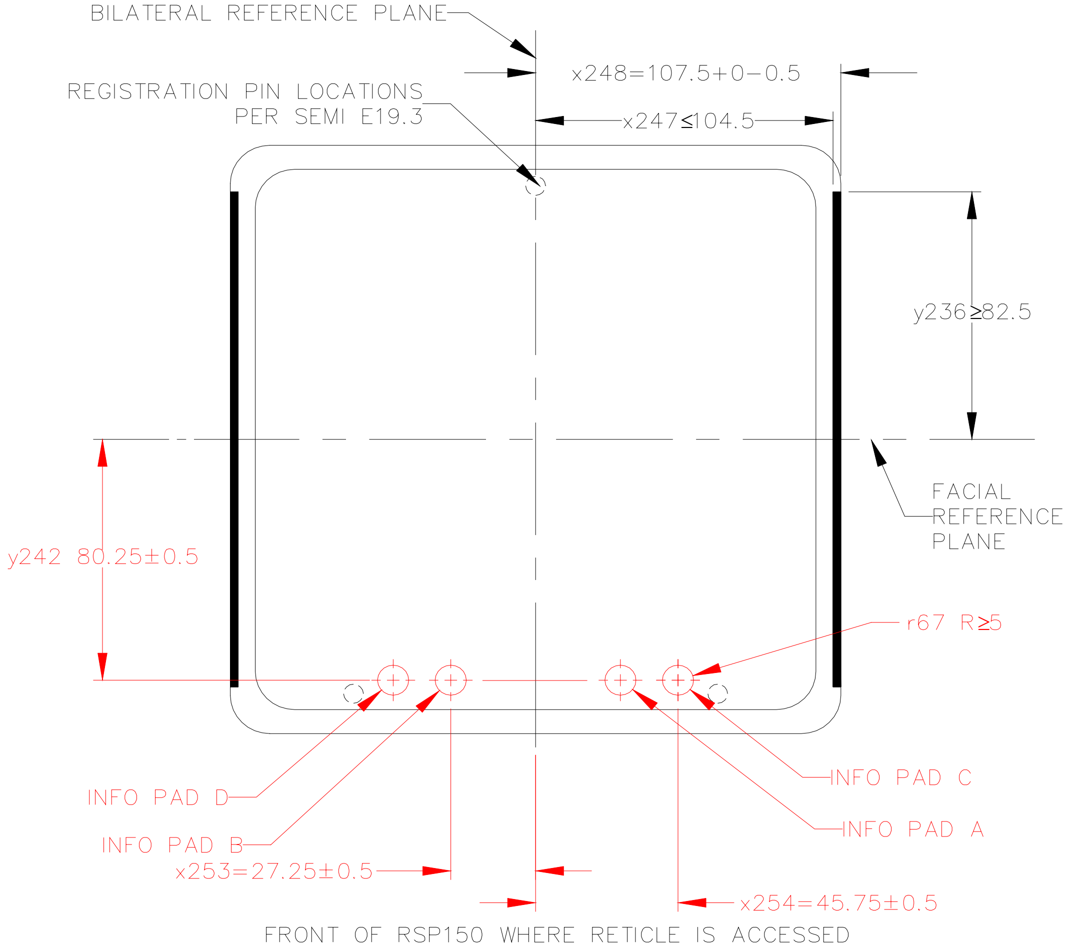



**Figure 11**
**Exterior Bottom View of RSP150**

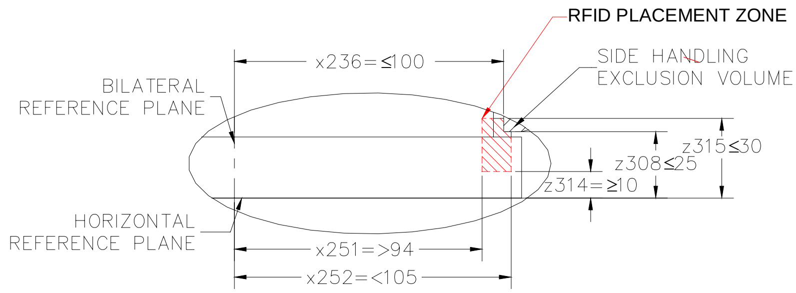



**Figure 12**
**Detail E: RFID Placement Zone**

**Table 2 External and Internal Dimensions for RSP150**

| *Symbol Used* | *Figure* | *Value Specified* | *Reference Measured From* | *Feature Measured To* |
|---|---|---|---|---|
| θ | 1 | 45° ± 0.5° | facial reference plane | sides of orientation notches |
| γ | 1 | 45° ± 0.5° | facial reference plane | edge of side handling flange chamfer |
| η | 2 | 45° ± 0.5° | facial reference plane | sides of side handling flange orientation notches |
| β | 5 | 45° ± 1° | bilateral and facial plane intersection | surface of the center hole in the top robotic handling flange |
| *r*65 | n/a | 1 mm (0.039 in.) maximum | not applicable | all required concave features (radius) |
| *r*66 | n/a | 2 mm (0.079 in.) maximum | not applicable | all required convex features (radius) |
| *r*67 | 11 | 5 mm (0.197 in.) minimum | info pad center | perimeter of info pad |
| *d*63 | 5 | 35.0 + 0.9 / - 0.1 mm (1.378 + 0.035 / - 0.004 in.) | centered on bilateral and facial plane intersection | top robotic handling flange hole design feature |
| *x*41 | 1 | 30 ± 1 mm (1.181 ± 0.039 in.) | bilateral reference plane | orientation notch center |
| *x*42 | 1 | 50 ± 1 mm (1.969 ± 0.039 in.) | bilateral reference plane | orientation notch center |
| *x*43 | 1 | 50 ± 1 mm (1.969 ± 0.039 in.) | bilateral reference plane | orientation notch center |
| *x*44 | 1 | 53 mm (2.087 in.) maximum | bilateral reference plane | side of robotic handling flange column |
| *x*45 | 1 | 65.3 ± 1 mm (2.571 ± 0.039 in.) | bilateral reference plane | orientation notch tip |
| *x*46 | 1 | 71 ± 1 mm (2.795 ± 0.039 in.) | bilateral reference plane | edge of robotic handling flange |
| *x*47 | 1 | 58 mm (2.283 in.) minimum | bilateral reference plane | edge of robotic handling flange corner beveling |
| *x*100 | 1 | 92.5 mm (3.642 in.) minimum | bilateral reference plane | edge of recess |
| *x*114 | None | 0 ± 1 mm (0 ± 0.039 in.) | bilateral reference plane | reticle bisecting plane |
| *x*119 | 4 | 65.2 mm (2.567 in.) minimum | bilateral reference plane | edge of pellicle exclusion volume |
| *x*129 | 2 | 5.68 ± 0.25 mm (0.224 ± 0.010 in.) | side edge of side handling flange | side handling flange alignment notch tip |
| *x*223 | 1, 3 | 106.5 ± 1 mm (4.193 ± 0.039 in.) | bilateral reference plane | edge of side handling flange |
| *x*227 | 1 | 107.5 mm (4.232 in.) maximum | bilateral reference plane | side of pod |
| *x*236 | 3 | 100 mm (3.937 in.) maximum | bilateral reference plane | edge of side handling exclusion volume |
| *x*238 | 4 | 68.2 mm (2.685 in.) maximum | bilateral reference plane | edge of end-effector exclusion volume |
| *x*239 | 4 | 78.3 mm (3.083 in.) maximum | bilateral reference plane | edge of end-effector exclusion volume |
| *x*240 | 4 | 85.3 mm (3.358 in.) minimum | bilateral reference plane | edge of end-effector exclusion volume |
| *x*241 | 4 | 90 mm (3.543 in.) maximum | bilateral reference plane | edge of safety rail exclusion volume |

| *Symbol Used* | *Figure* | *Value Specified* | *Reference Measured From* | *Feature Measured To* |
|---|---|---|---|---|
| *x*242 | 7 | 56 mm (2.205 in.) maximum | bilateral reference plane | edge of rear retainer volume |
| *x*243 | 4 | 77.35 mm (3.045 in.) minimum | bilateral reference plane | edge of lift clearance exclusion volume |
| *x*245 | 9 | 67.7 mm (2.665 in.) | bilateral reference plane | center of reticle contact surface |
| *x*246 | 10 | 0.5 mm (0.019 in.) maximum | center of reticle contact surface | edge of reticle contact surface |
| *x*247 | 11 | 104.5 mm (4.114 in.) maximum | bilateral reference plane | edge of conveyor rail surface |
| *x*248 | 11 | 107.5 +0 –0.5 mm (4.232 +0 –0.020 in.) | bilateral reference plane | edge of conveyor rail surface |
| *x*249 | 7 | 36 mm (1.417 in.) maximum | bilateral reference plane | edge of reticle backstops |
| *x*250 | 7 | 45 mm (1.772 in.) minimum | bilateral reference plane | edge of reticle backstops |
| *x*251 | 12 | 94 mm (3.700 in.) minimum | bilateral reference plane | edge of RFID exclusion volume |
| *x*252 | 12 | 105mm (4.134 in.) maximum | bilateral reference plane | edge of RFID exclusion volume |
| *x*253 | 11 | 27.25 ± 0.5 mm (1.073 ± 0.039 in.) | bilateral reference plane | center of info pads A and B |
| *x*254 | 11 | 45.75 ± 0.5 mm (1.801 ± 0.039 in.) | bilateral reference plane | center of info pads C and D |
| *y*44 | 1 | 53 mm (2.087 in.) maximum | facial reference plane | side of robotic handling flange column |
| *y*45 | 1 | 65.3 ± 1 mm (2.571 ± 0.039 in.) | facial reference plane | orientation notch tip |
| *y*46 | 1 | 71 ± 1 mm (2.795 ± 0.039 in.) | facial reference plane | edge of robotic handling flange |
| *y*47 | 1 | 58 mm (2.283 in.) minimum | facial reference plane | edge of robotic handling flange corner beveling |
| *y*106 | 1 | 92.5 mm (3.642 in.) minimum | facial reference plane | edge of recess |
| *y*126 | 1 | 71.1 ± 0.5 mm (2.799 ± 0.020 in.) | facial reference plane | depth of side handling flange |
| *y*127 | 1 | 61.9 ± 0.5 mm (2.437 ± 0.020 in.) | facial reference plane | edge of side handling flange corner bevel |
| *y*225 | 1 | 115.25 mm (4.537 in.) maximum | facial reference plane | side of pod |
| *y*227 | 7, 8 | 45 mm (1.771 in.) maximum | facial reference plane | edge of end-effector exclusion volume |
| *y*228 | 7, 8 | 12.6 ± 0.4 mm (0.496 ± 0.016 in.) | facial reference plane | reticle bisecting plane |
| *y*231 | 7, 8 | 70 mm (2.756 in.) minimum | facial reference plane | edge of rear retainer volume |
| *y*232 | 9 | 45.5 mm (1.791 in.) maximum | facial reference plane | edge of end effector exclusion volume |
| *y*233 | 9 | 44.5 mm (1.752 in.) | facial reference plane | center of reticle contact surface |
| *y*234 | 9 | 77.5 mm (3.051 in.) | facial reference plane | center of reticle contact surface |
| *y*235 | 10 | 1 mm (0.039 in.) maximum | center of reticle contact surface | edge of reticle contact surface |

| *Symbol Used* | *Figure* | *Value Specified* | *Reference Measured From* | *Feature Measured To* |
|---|---|---|---|---|
| *y*236 | 11 | 82.5 mm (3.248 in.) minimum | facial reference plane | end of conveyor rail surface |
| *y*238 | 9 | 78.5 mm (3.091 in.) maximum | facial reference plane | edge of end effector exclusion volume |
| *y*239 | 7 | 88.8 mm (3.496 in.) maximum | bilateral reference plane | edge of reticle backstops |
| *y*240 | 1 | 10 mm (0.394 in.) minimum | facial reference plane | edge of RFID placement zone |
| *y*241 | 1 | 58 mm (2.283 in.) maximum | facial reference plane | edge of RFID placement zone |
| *y*242 | 11 | 80.25 ± 0.5 mm (3.159 ± 0.020 in.) | facial reference plane | center of info pads |
| *z*2 | None | 2 mm (0.079 in.) maximum | horizontal reference plane | surface of info pads (when down) |
| *z*26 | None | 9 mm (0.354 in.) minimum | horizontal reference plane | surface of info pads (when up) |
| *z*276 | 6 | ± 0.15 mm (0.006 in.) | each nominal reticle seating plane | entire bottom surface of the reticle |
| *z*290 | 4 | 22 mm (0.866 in.) maximum | horizontal reference plane | edge of first reticle pellicle exclusion volume |
| *z*291 | 4 | 32 mm (1.260 in.) | horizontal reference plane | nominal reticle seating plane |
| *z*297 | 6 | 1.5 mm (0.059 in.) minimum | each nominal reticle seating plane | edge of end-effector exclusion volume |
| *z*299 | 6 | 8.95 mm (0.352 in.) minimum | each nominal reticle seating plane | edge of end-effector exclusion volume |
| *z*301 | 4 | 22 mm (0.866 in.) maximum | horizontal reference plane | edge of safety rail exclusion volume |
| *z*302 | 4 | 23.5 ± 0.5 mm (0.945 ± 0.020 in.) | horizontal reference plane | edge of first reticle end-effector exclusion volume |
| *z*303 | 3 | 52.5 mm (2.067 in.) maximum | horizontal reference plane | top surface of dome recess |
| *z*304 | 3 | 55 mm (2.165 in.) maximum | horizontal reference plane | top surface of dome |
| *z*305 | 3, 5 | 70 ± 0.5 mm (2.756 ± 0.020 in.) | horizontal reference plane | bottom surface of robotic handling flange |
| *z*306 | 3 | 49 ± 0.5 mm (1.929 ± 0.020 in.) | horizontal reference plane | bottom edge of side handling flange |
| *z*307 | 3 | 52.5 mm (2.067 in.) maximum | horizontal reference plane | top surface of side handling flange |
| *z*308 | 3, 12 | 25 mm (0.984 in.) maximum | horizontal reference plane | edge of side handling exclusion volume and RFID placement zone |
| *z*310 | 3, 5 | 8 mm (0.315 in.) maximum | bottom surface of robotic handling flange | top of robotic handling flange |
| *z*312 | 8 | 44 mm (1.732 in.) maximum | horizontal reference plane | top of rear retainer exclusion volume |
| *z*313 | n/a | 43 ± 1 mm (1.1693 ± 0.039 in.) | horizontal reference plane | top of reticle backstops |
| *z*314 | 12 | 10 mm (0.394 in.) minimum | horizontal reference plane | bottom of RFID placement zone |
| *z*315 | 12 | 30 mm (1.181 in.) maximum | horizontal reference plane | top of RFID placement zone |

# APPENDIX 1
# APPLICATION NOTES

**NOTICE**: This appendix is an official part of SEMI E111 and was approved by full letter ballot procedures on August 27, 2001, but the recommendations in this appendix are optional and are not required to conform to this standard.

A1-1 Skewness, warp, rock, and stiffness are implicitly defined in the dimensional tolerances.

A1-2 Features on the RSP150 which enable stacking may be required by end users. It is preferred that these features allowing stacking in only one orientation.

A1-3 Features on the RSP150 which provide visual orientation of the RSP150 top and RSP150 door may be required by end users.

# RELATED INFORMATION 1

**NOTICE**: This related information is not an official part of SEMI E111, and it is not intended to modify or supercede the official standard. This information was inserted by the North America Physical Interfaces and Carriers Committee to alert the readers to potential changes to this provisional standard.

R1-1 In the event end-effector and pellicle exclusion volumes can be developed which would satisfy all lithography equipment manufacturers and allow for a 126 mm pellicle, then the appropriate changes would be balloted to update the standard.

SEMI

# SEMI E112-0305
# PROVISIONAL MECHANICAL SPECIFICATION FOR A 150 mm MULTIPLE RETICLE SMIF POD (MRSP150) USED TO TRANSPORT AND STORE MULTIPLE 6 INCH RETICLES

This specification was technically approved by the Global Physical Interfaces and Carriers Committee and is the direct responsibility of the North American Physical Interfaces and Carriers Committee. Current edition approved by the North American Regional Standards Committee on Decmber 10, 2004. Initially available at www.semi.org January 2005; to be published March 2005. Originally published November 2001; previously published November 2004.

## 1 Purpose

1.1 This standard specifies the 150 mm Multiple Reticle SMIF Pod (MRSP150) used to transport and store six 6 inch reticles in an integrated circuit (IC) manufacturing facility.

## 2 Scope

2.1 This standard is intended to set an appropriate level of specification that places minimal limits on innovation while ensuring modularity and inter- changeability at all mechanical interfaces. Most of the requirements given in this specification are in the form of maximum or minimum dimensions with very few required surfaces. Only the physical interfaces for the MRSP150 are specified; no materials requirements or micro-contamination limits are given in this specification.

2.2 The pellicle exclusion volumes of this specification accommodates pellicles which extend the full length of the reticle and up to a maximum pellicle width of 124 mm.

2.3 The MRSP150 has the following components, sub-components, and other features. A "●" symbol indicates components or features which are *required* and a "◊" symbol indicates components or features which are *optional*.

- Top
  - ◊ robotic handling flange
- Interior
  - supports for six 6 inch reticles
  - reticle capture
  - reticle contact surfaces
  - end-effector exclusion volumes
  - 2 safety rail exclusion volumes
  - pellicle exclusion volumes
  - lateral constraints
  - reticle backstop
- Sides
  - ◊ 2 side handling flanges on the sides parallel to the bi-lateral reference plane
  - 2 side handling exclusion volumes
  - RFID placement zone
- Bottom
  - door compatible with SMIF as defined in SEMI E19.3

- pod latch-pin holes
- 2 conveyor rails on the sides parallel to the bi-lateral reference plane

2.4 This standard is provisional because of the issues detailed in the related information section. Once investigation of issues in the related information section has been completed, this standard should be upgraded from provisional status.

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

## 3 Referenced Standards

3.1 *SEMI Standards*

SEMI E19.3 — Port Standard for Mechanical Interface if Wafer Cassette Transfer, 150 mm (6 inch) Port

SEMI E30.1 — Inspection and Review Specific Equipment Model (ISEM)

SEMI E47.1 — Provisional Mechanical Specification for Boxes and Pods Used to Transport and Store 300 mm Wafers

SEMI P5 — Specification for Pellicles

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

## 4 Terminology

4.1 *Definitions*

4.1.1 *150 mm Multiple Reticle SMIF Pod* (MRSP150) — a minienvironment compatible carrier capable of holding six 6 inch reticles in a horizontal orientation during transport and storage and is compatible with a Standard Mechanical Interface (SMIF) per SEMI E19.3.

4.1.2 *bilateral reference plane* — a vertical plane which bisects the MRSP150 and is perpendicular to both the horizontal and facial reference planes and passes through the center of the 150 mm SMIF as defined in SEMI E19.3.

4.1.3 *facial reference plane* — a vertical plane which bisects the MRSP150 and is parallel to the front side of the pod (where reticles are removed or inserted) and passes through the center of the 150 mm SMIF as defined in SEMI E19.3.

4.1.4 *horizontal reference plane* — a horizontal plane coplanar with the top surface of the port door as defined in SEMI E19.3.

4.1.5 *minienvironment* — a localized environment created by an enclosure to isolate the product from contamination and people.

4.1.6 *nominal reticle center line* — the line that is defined by the intersection of two perpendicular vertical planes each of which bisect the reticle at the mid-point of a side.

4.1.7 *pellicle* — as defined in SEMI P5.

4.1.8 *reticle* — as defined in SEMI E30.1.

4.1.9 *robotic handling flanges* — horizontal projections on the top of the box for lifting and rotating the box (as defined in SEMI E47.1).

4.1.10 *side handling flanges* — horizontal projections on the sides of the pod (sides parallel to the bilateral reference plane) for lifting, transportation or positioning of the pod.

## 5 Ordering Information

5.1 *Intended Use* — This standard is intended to specify reticle carriers over a reasonable lifetime of use, not just those in new condition. For this reason, the purchaser should specify a time period and the number and type of uses to which the carriers will be put. It is under these conditions that the carriers must remain in compliance with the requirements listed in §6.

5.2 *Reticle Thickness* — The purchaser needs to specify the reticle thickness to be accommodated in the MRSP150.

5.3 *Optional Features* — The purchaser needs to specify whether optional components (identified in §2) are required.

5.4 *Temperature Ranges* — The purchaser needs to specify two sets of temperatures to which the MRSP150s might be exposed. An operating temperature range is the set of environmental temperatures in which the MRSP150s will remain in compliance with the requirements listed in §6. A temporary temperature range is the set of environmental temperatures to which the pods can be exposed such that when the MRSP150s return to the operating temperature range, the MRSP150s will be in compliance with the requirements listed in §6. Limits on exposure times to elevated temperatures should be specified.

5.5 *Electrostatic Dissipation* — The end user may require a continuous path to ground from the reticle to the carrier registration and handling features. The purchaser needs to specify whether electrostatic dissipation is required.

5.6 *Contamination Requirements* — The purchaser needs to specify their contamination requirements.

## 6 Requirements

6.1 *Symmetry* — Most of the dimensions of the MRSP150 are determined with respect to the three orthogonal reference planes defined in this document: the facial reference plane, the horizontal reference plane and the bilateral reference plane. All dimensions are symmetric about the bilateral reference plane.

6.2 *Door* — The pod door, and its frame on the bottom of the pod, must be compatible with a port which conforms to SEMI E19.3.

6.3 *Numbering* — The reticles are numbered in increasing order from bottom to top (so the bottom reticle is reticle number 1, to the top reticle which is reticle number 6).

6.4 *Positioning* — The nominal reticle seating planes are defined by *z*291 through *z*296 as shown in Figure 4 and Table 2. The entire bottom surface of a reticle must lie within the *z*276 dimension of its nominal seating plane shown in Figure 6 and Table 2.

6.5 *Reticle Contact Surfaces* — The reticle contact surfaces are the only 4 locations where the MRSP150 may contact the pellicle side of the reticle. These surfaces are shown in Figures 8 and 9 with dimensions given in Table 2. The contact surfaces are defined by *x*245, *x*246, *y*233, *y*234 and *y*235.

6.6 *Reticle Capture* — When the carrier is closed, a bisecting plane through the reticle, parallel to the bilateral reference plane must be within *x*114 of the bilateral reference plane of the load port when the reticle is seated in the carrier. A bisecting plane through the reticle, parallel to the facial reference plane must be within *y*228 of the facial reference plane of the load port when the reticle is seated in the carrier.

6.7 *Exclusion Volumes* — The interior of the MRSP150 must never intrude into the pellicle exclusion volume, and must not intrude into the end-effector exclusion volumes, lift clearance exclusion volumes or safety rail exclusion volumes when the carrier is open.

6.7.1 *End-Effector Exclusion Volumes* — Volumes in an opened pod which must be free for the end-effector to enter and handle the reticle as defined by *x*238, *x*239, *x*240, *y*227, *y*232, *y*238, *z*297, *z*299, *z*302 (first reticle) and *z*300 (second through sixth reticle). No obstructions should exist in the end-effector exclusion volumes which extend in the y direction (normal to the facial reference plane.) Table 2 defines the dimensions for the end-effector exclusion volumes shown in Figures 4, 6, 7 and 8.

6.7.2 *Pellicle Exclusion Volume* — Volume in the pod below the reticle which must remain free from intrusion to accommodate the pellicle mounted on the reticle. No obstructions should exist in the pellicle exclusion volume as defined by *x*119, *z*290 (first reticle) and the previous reticle lift clearance exclusion volume (second through sixth reticle) which extends in the y direction (normal to the facial reference plane). The pellicle exclusion volume is defined in Table 2 and shown in Figure 4.

6.7.3 *Reticle Lift Clearance Exclusion Volumes* — Volumes in an opened pod which must be free to allow the end-effector to lift and handle the reticles, as defined by *x*243, *z*298 and *z*311 (sixth reticle) as shown in Table 2 and

Figures 4 and 6. No obstructions should exist in the reticle lift clearance exclusion volumes which extend in the y direction (normal to the facial reference plane).

6.7.4 *Safety Rail Exclusion Volumes* — Volumes in an opened pod which must remain free from intrusion to accommodate safety rails which may be used on end-effectors to protect the edge of the reticle during handling. No obstructions should exist in the safety rail exclusion volumes which extend in the y direction (normal to the facial reference plane) as defined by *x*241 and *z*301 in Table 2 and shown in Figure 4.

6.7.5 *Rear Retainer Volume* — Volume in an opened pod in which any reticle rear retainer must exist. The volume is defined by *x*242 and *y*226 as shown in Figure 7 and Table 2.

NOTE 1: This volume is never to be accessed by an end-effector.

6.7.6 *Reticle Backstops* — The interior of the MRSP150 shall have reticle backstops which may be used by end-effectors to position the reticle when being removed from the MRSP150.

NOTE 2: These are the minimum required backstops, the backstops may be larger than this minimum specification, occupying any part of the rear retainer volume. The dimensions are defined by *x*249, *x*250, *y*239 and *z*314 as shown in Table 2 and in Figure 7.

6.7.7 *RFID Placement Zone* — Zone in the pod where the RFID transponder is placed, which may be used for RF communications during reticle handling. The entire RFID transponder must be positioned within the zone defined by *x*251, *x*252, *y*239, *y*240, *z*308, *z*315, *z*316 in Table 2 and shown in Figures 1, 3, 11. Pod suppliers may also place other features in this placement zone (such as the pod wall, RFID transponder support brackets, etc).

6.8 *External Dimensions* — Figures 1, 2, 3, 5 and 10 show, respectively, the external top view, a detail, the rear view, the robotic handling flange and the conveyor rails of the MRSP150. Table 2 defines the external dimensions of the MRSP150.

6.9 *Internal Dimensions* — Figures 4, 6 and 7 show internal dimensions of the MRSP150. Table 2 defines the internal dimensions of the MRSP150.

6.10 *Robotic Handling Flange* — On the top of the pod is an optional robotic handling flange for automated manipulation of the MRSP150. Figures 1, 3 and 5 show dimensions for the robotic handling flange. Table 2 defines the dimensions for the robotic handling flange.

6.11 *Recess* — Surface on the top of the pod defined by dimensions *x*100, *y*106 and *z*281. Figures 1 and 3 show dimension for the recess. The recess provides clearance for use of robotic handling flange.

NOTE 3: The raised surface around the recess is not required.

6.12 *Side Handling Flanges* — On the sides of the pod parallel to the bilateral reference plane are optional handling flanges for automated manipulation of the MRSP150. Figures 1, 2 and 3 show dimensions for the side handling flanges. Table 2 defines the dimensions for the side handling flanges. No obstructions may exist in the side handling exclusion volumes which extend in the y direction (normal to the facial reference plane) as defined by *x*236 and *z*286.

6.13 *Conveyor Rails* — Surfaces on the bottom of the MRSP150 used to transport the MRSP on conveyors. The rails consist of smooth portions of the bottom periphery, parallel with each other, on two opposite sides, and extending at least *y*236 from the facial reference plane (optionally the full length) on those sides. Surfaces on these portions of the bottom periphery should be uninterrupted (ie. no notches in the surface along the bottom or the side). No other feature of the carrier may extend below the plane defined by the surfaces of the conveyor rails. The conveyor rail surfaces are bounded by *x*247, *x*248 and *y*236 as shown in Figure 10. Table 2 defines the dimensions for the conveyor rails.

6.14 *Inner and Outer Radii* — All required concave features may have a radius of up to *r*65 to allow cleaning and to prevent contaminant build-up. All required convex features may also have a radius of up to *r*66 to prevent small contact patches with large stresses that might cause wear and particles.

NOTE 4: These limits on the radius of all required features are specified as a maximum (not a minimum) to ensure that the required features are not rounded off too much. The lower bound on the radius is up to the carrier supplier.

NOTE 5: This radius applies to every required feature unless another radius is called out specifically. Here a required feature is an area on the surface of the carrier specified by a dimension (or intersections of dimensions) that has a tolerance and not just a maximum or minimum (such as the edges of the robotic handling flange).

6.15 *Info Pads* — When the MRSP is placed on a port, the info pads A, B, C, and D communicate information about the RSP configuration. Figure 10 shows the dimensions of the info pads. Table 2 defines the info pad dimensions. A pad in the up position must be *z*26 above the horizontal reference plane. A pad in the down position must be *z*2 above the horizontal reference plane. Info pad assignments are shown in Table 1. Info pads that are "not defined" can be at either the up or down position unless specified by the end user. RSP configurations "to be assigned" may be assigned by the end user.

**Table 1**

| *MRSP Configuration* | *Info Pad* | | | |
|---|---|---|---|---|
| | *A* | *B* | *C* | *D* |
| 6 inch reticle | not defined | not defined | up | down |
| to be assigned | not defined | not defined | down | down |
| to be assigned | not defined | not defined | up | up |
| to be assigned | not defined | not defined | down | up |

## 7 Related Documents

7.1 *SEMI Standards*

SEMI P1 — Specification for Hard Surface Photomask Substrates

SEMI S8 — Safety Guidelines for Ergonomics Engineering of Semiconductor Manufacturing Equipment

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

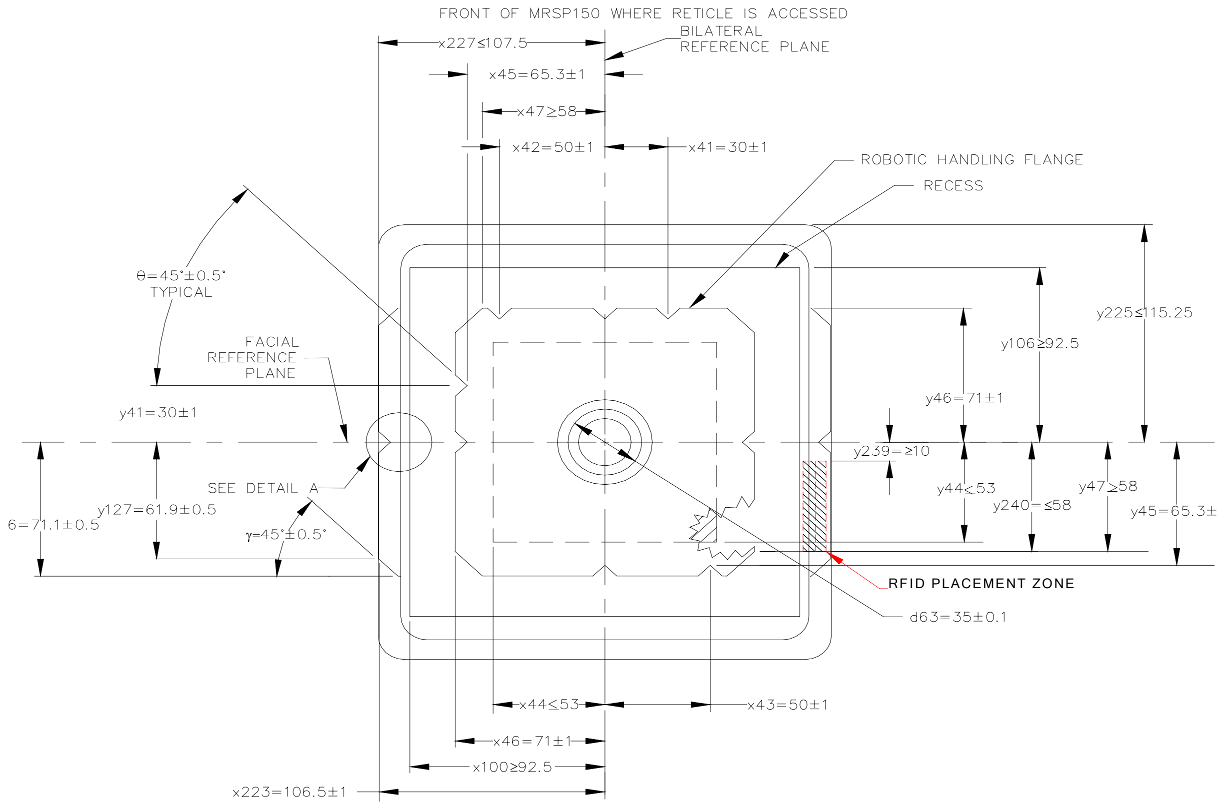



**Figure 1**
**External Top View of MRSP150**

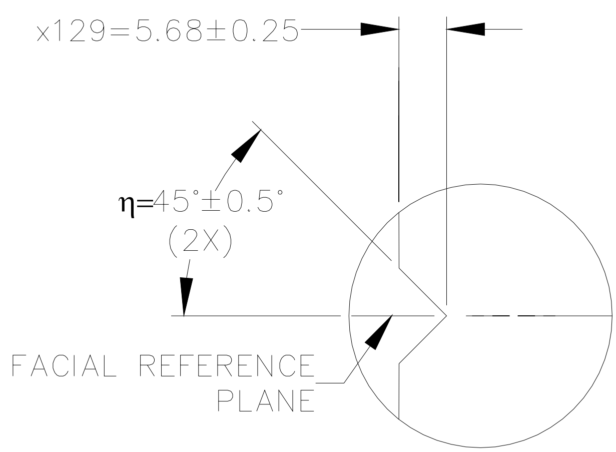



**Figure 2**
**Detail A: External Top View of Side Handling Flange Alignment Notch**

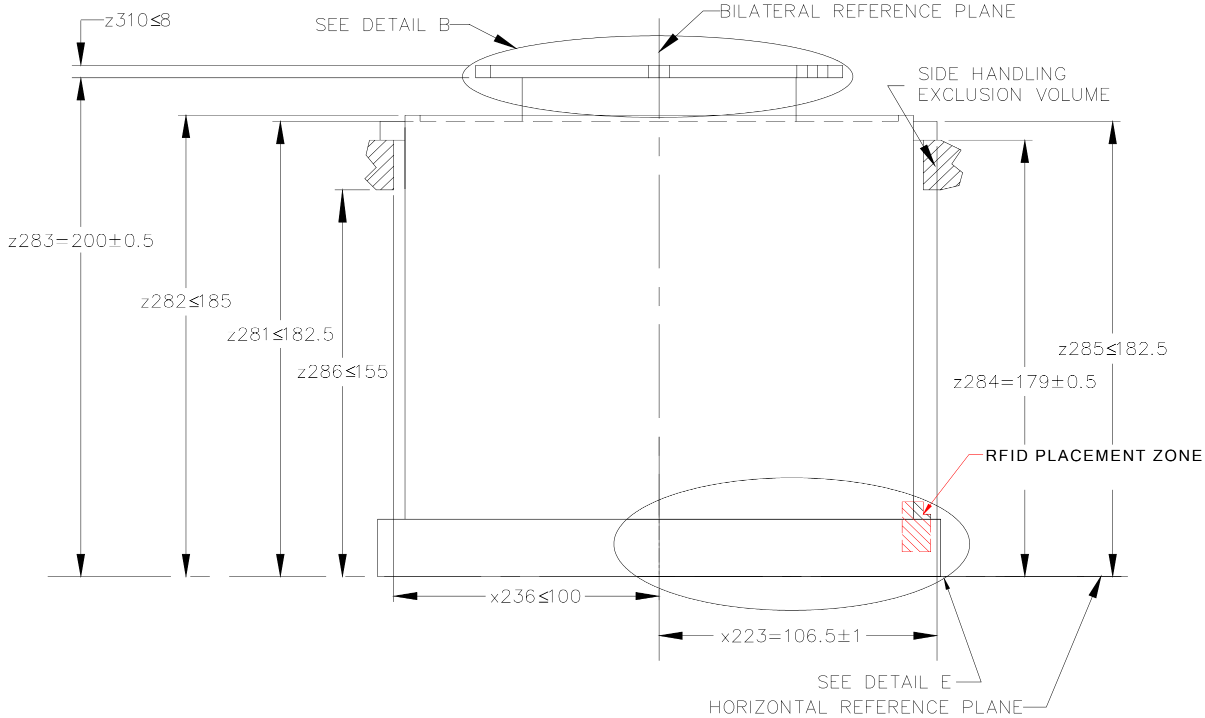



**Figure 3**
**External Rear View of MRSP150**

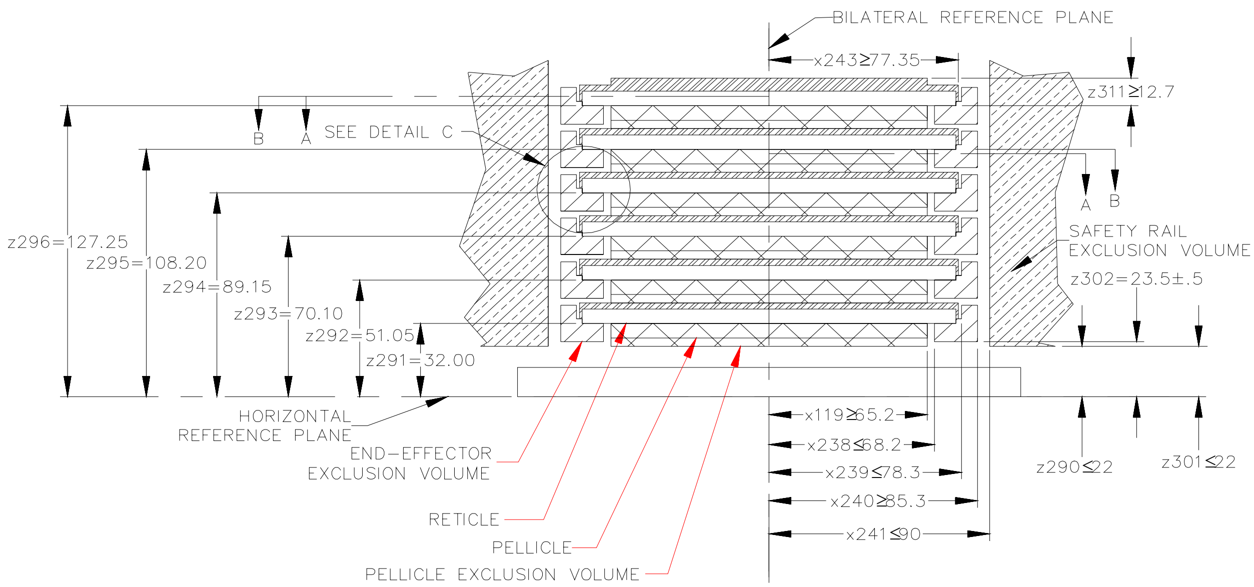



**Figure 4**
**Internal Front View of MRSP150**

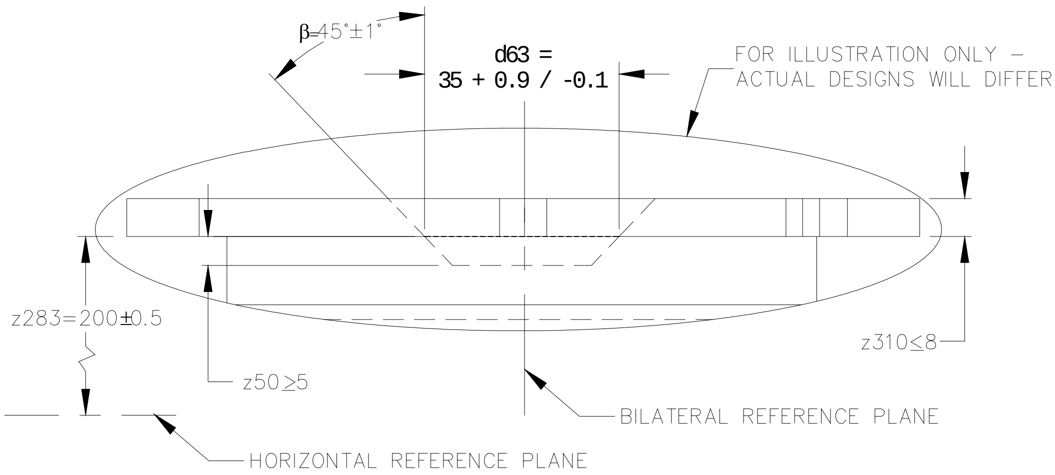



**Figure 5**
**Detail B: Top Robotic Handling Flange Hole Feature**

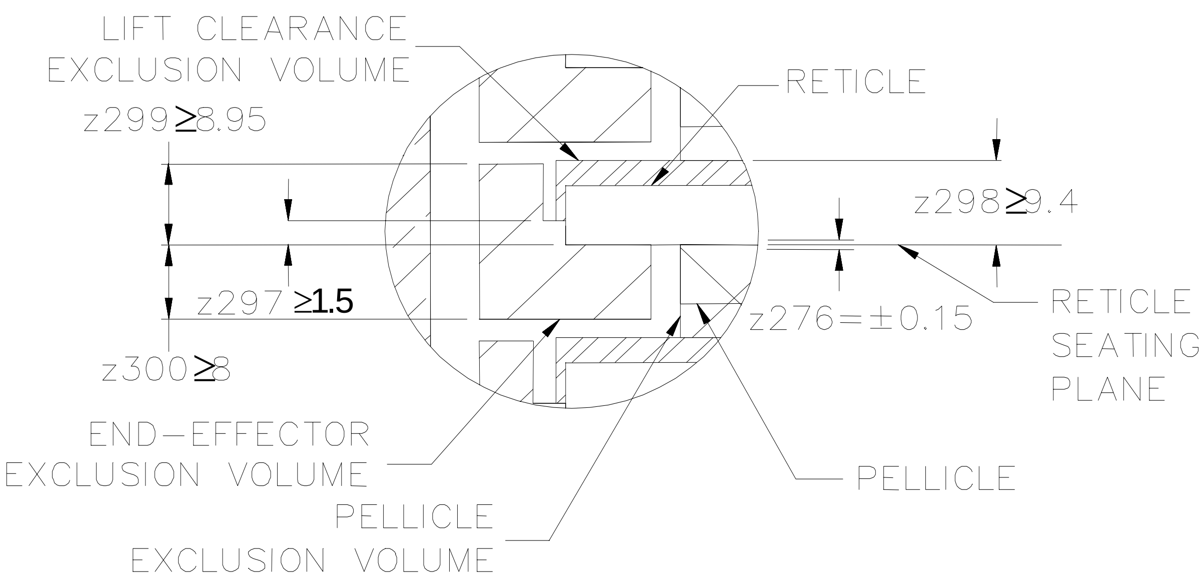



**Figure 6**
**Detail C: Reticle Seating and Capture Detail**

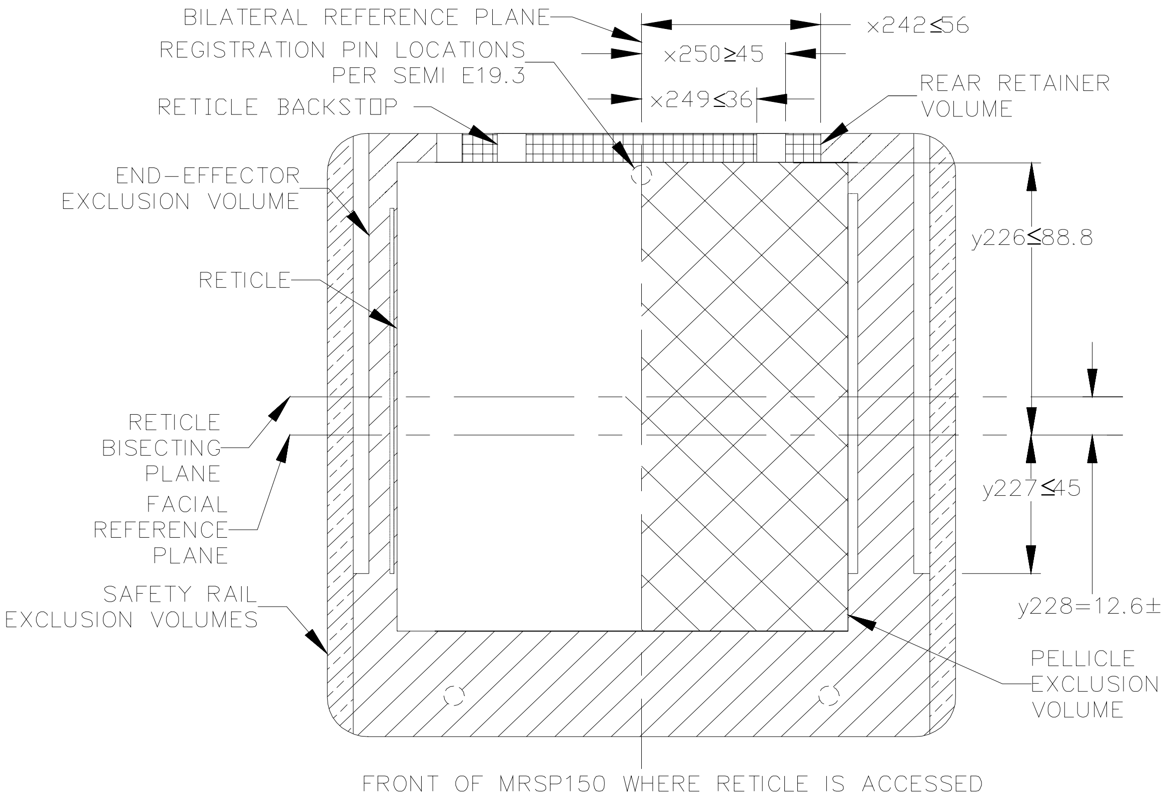



**Figure 7**
**Section A-A: Door Only Top View of MRSP150**

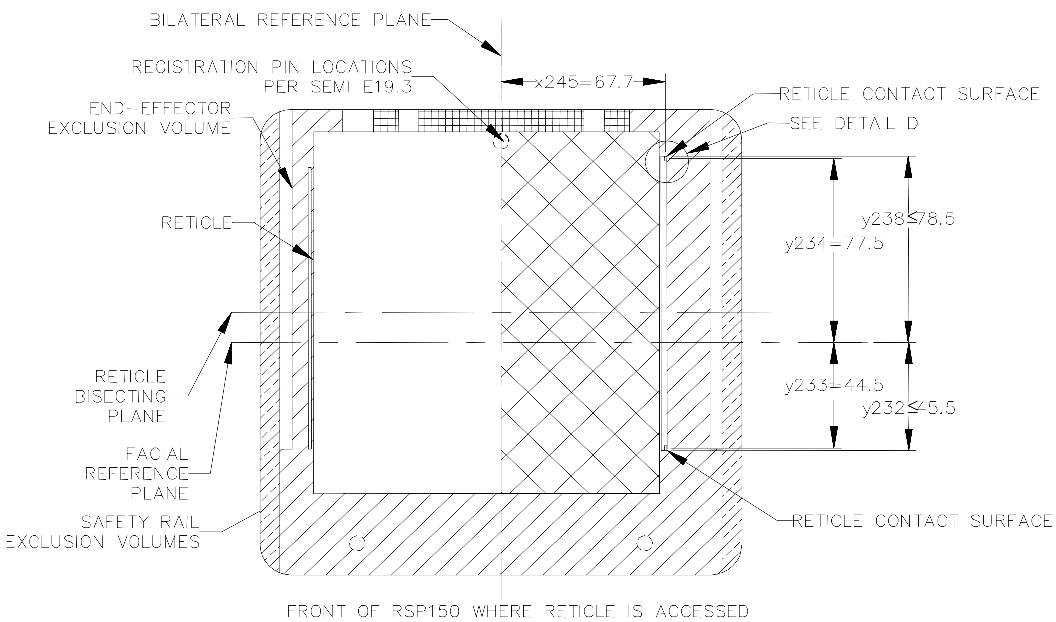



**Figure 8**
**Section B-B: Door Only Top View of MRSP150 with Reticle Contact Surfaces**

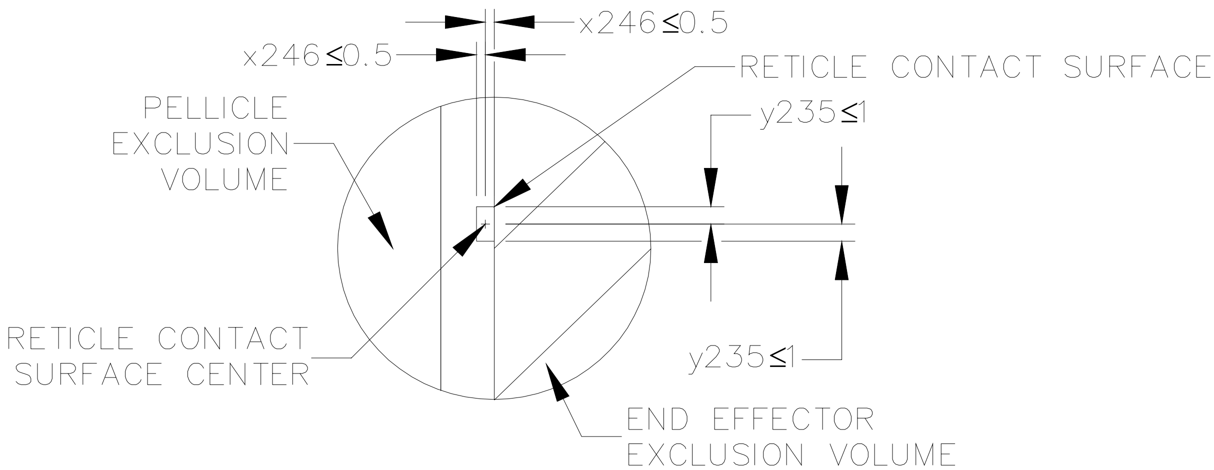



**Figure 9**
**Detail D: Reticle Contact Surface**

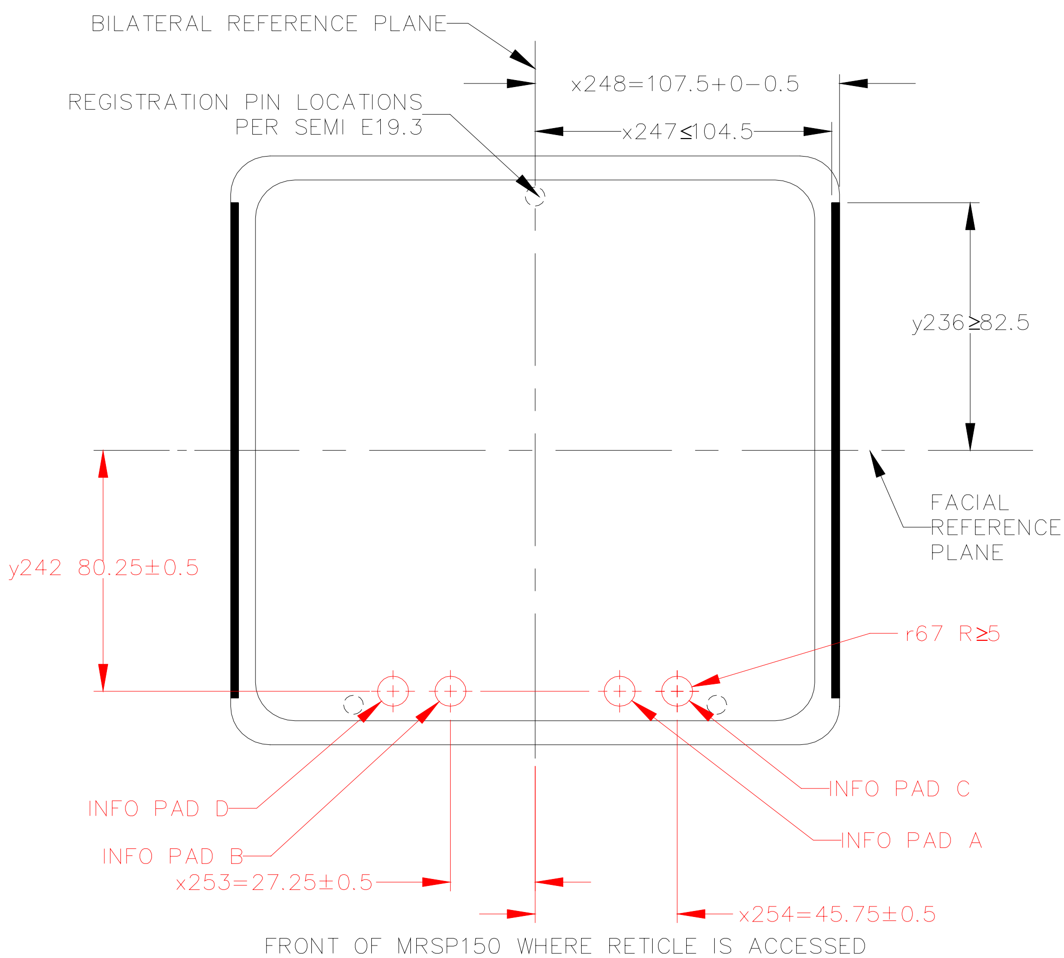



**Figure 10**
**Exterior Bottom View of MRSP150**

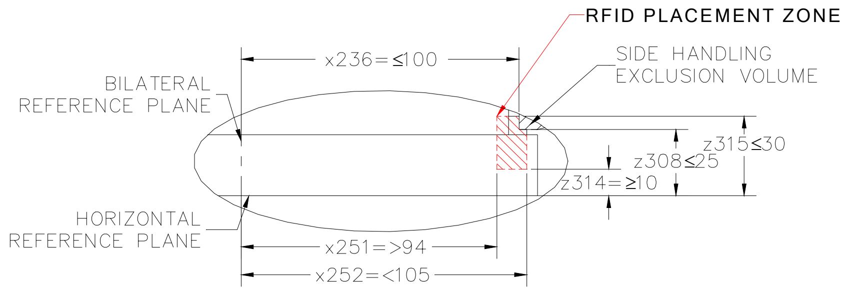



**Figure 11**
**Detail E: RFID Placement Zone**

**Table 2 External and Internal Dimensions for MRSP150**

| *Symbol Used* | *Figure* | *Value Specified* | *Reference Measured From* | *Feature Measured To* |
|---|---|---|---|---|
| θ | 1 | 45° ± 0.5° | facial reference plane | sides of orientation notches |
| γ | 1 | 45° ± 0.5° | facial reference plane | edge of side handling flange chamfer |
| η | 2 | 45° ± 0.5° | facial reference plane | sides of side handling flange orientation notches |
| β | 5 | 45° ± 1° | bilateral and facial plane intersection | surface of the center hole in the top robotic handling flange |
| *r*65 | n/a | 1 mm (0.039 in.) maximum | not applicable | all required concave features (radius) |
| *r*66 | n/a | 2 mm (0.079 in.) maximum | not applicable | all required convex features (radius) |
| *r*67 | 11 | 5 mm (0.197 in.) minimum | info pad center | perimeter of info pad |
| *d*63 | 5 | 35.0 + 0.9 / − 0.1 mm (1.378 + 0.035 / − 0.004 in.) | centered on bilateral and facial plane intersection | top robotic handling flange hole design feature |
| *x*41 | 1 | 30 ± 1 mm (1.181 ± 0.039 in.) | bilateral reference plane | orientation notch center |
| *x*42 | 1 | 50 ± 1 mm (1.969 ± 0.039 in.) | bilateral reference plane | orientation notch center |
| *x*43 | 1 | 50 ± 1 mm (1.969 ± 0.039 in.) | bilateral reference plane | orientation notch center |
| *x*44 | 1 | 53 mm (2.087 in.) maximum | bilateral reference plane | side of robotic handling flange column |
| *x*45 | 1 | 65.3 ± 1 mm (2.571 ± 0.039 in.) | bilateral reference plane | orientation notch tip |
| *x*46 | 1 | 71 ± 1 mm (2.795 ± 0.039 in.) | bilateral reference plane | edge of robotic handling flange |
| *x*47 | 1 | 58 mm (2.283 in.) minimum | bilateral reference plane | edge of robotic handling flange corner beveling |
| *x*100 | 1 | 92.5 mm (3.642 in.) minimum | bilateral reference plane | edge of recess |
| *x*114 | None | 0 ± 1 mm (0 ± 0.039 in.) | bilateral reference plane | reticle bisecting plane |
| *x*119 | 4 | 65.2 mm (2.567 in.) minimum | bilateral reference plane | edge of pellicle exclusion volume |

| *Symbol Used* | *Figure* | *Value Specified* | *Reference Measured From* | *Feature Measured To* |
|---|---|---|---|---|
| *x*129 | 2 | 5.68 ± 0.25 mm (0.224 ± 0.039 in.) | side edge of side handling flange | side handling flange alignment notch tip |
| *x*223 | 1, 3 | 106.5 ± 1 mm (4.193 ± 0.039 in.) | bilateral reference plane | edge of side handling flange |
| *x*227 | 1 | 107.5 mm (4.232 in.) maximum | bilateral reference plane | side of pod |
| *x*236 | 3 | 100 mm (3.937 in.) maximum | bilateral reference plane | edge of side handling exclusion volume |
| *x*238 | 4 | 68.2 mm (2.685 in.) maximum | bilateral reference plane | edge of end-effector exclusion volume |
| *x*239 | 4 | 78.3 mm (3.083 in.) maximum | bilateral reference plane | edge of end-effector exclusion volume |
| *x*240 | 4 | 85.3 mm (3.358 in.) minimum | bilateral reference plane | edge of end-effector exclusion volume |
| *x*241 | 4 | 90 mm (3.543 in.) maximum | bilateral reference plane | edge of safety rail exclusion volume |
| *x*242 | 7 | 56 mm (2.205 in.) maximum | bilateral reference plane | edge of rear retainer volume |
| *x*243 | 4 | 77.35 mm (3.045 in.) minimum | bilateral reference plane | edge of lift clearance exclusion volume |
| *x*245 | 8 | 67.7 mm (2.665 in.) | bilateral reference plane | center of reticle contact surface |
| *x*246 | 9 | 0.5 mm (0.019 in.) maximum | center of reticle contact surface | edge of reticle contact surface |
| *x*247 | 10 | 104.5 mm (4.114 in.) maximum | bilateral reference plane | edge of conveyor rail surface |
| *x*248 | 10 | 107.5 +0 − 0.5 mm (4.232 +0 − 0.020 in.) | bilateral reference plane | edge of conveyor rail surface |
| *x*249 | 7 | 36 mm (1.417 in.) maximum | bilateral reference plane | edge of reticle backstops |
| *x*250 | 7 | 45 mm (1.772 in.) minimum | bilateral reference plane | edge of reticle backstops |
| *x*251 | 11 | 94 mm (3.700 in.) minimum | bilateral reference plane | edge of RFID exclusion volume |
| *x*252 | 11 | 105 mm (4.134 in.) maximum | bilateral reference plane | edge of RFID exclusion volume |
| *x*253 | 11 | 27.25 ± 0.5 mm (1.073 ± 0.039 in.) | bilateral reference plane | center of info pads A and B |
| *x*254 | 11 | 45.75 ± 0.5 mm (1.801 ± 0.039 in.) | bilateral reference plane | center of info pads C and D |
| *y*44 | 1 | 53 mm (2.087 in.) maximum | facial reference plane | side of robotic handling flange column |
| *y*45 | 1 | 65.3 ± 1 mm (2.571 ± 0.039 in.) | facial reference plane | orientation notch tip |
| *y*46 | 1 | 71 ± 1 mm (2.795 ± 0.039 in.) | facial reference plane | edge of robotic handling flange |
| *y*47 | 1 | 58 mm (2.283 in.) minimum | facial reference plane | edge of robotic handling flange corner beveling |
| *y*106 | 1 | 92.5 mm (3.642 in.) minimum | facial reference plane | edge of recess |
| *y*126 | 1 | 71.1 ± 1 mm (2.799 ± 0.039 in.) | facial reference plane | depth of side handling flange |

| *Symbol Used* | *Figure* | *Value Specified* | *Reference Measured From* | *Feature Measured To* |
|---|---|---|---|---|
| *y*127 | 1 | 61.9 ± 0.5 mm (2.437 ± 0.020 in.) | facial reference plane | edge of side handling flange corner bevel |
| *y*225 | 1 | 115.25 mm (4.537 in.) maximum | facial reference plane | side of pod |
| *y*226 | 7 | 88.5 mm (3.484 in.) minimum | facial reference plane | edge of rear retainer volume |
| *y*227 | 7 | 45 mm (1.772 in.) maximum | facial reference plane | edge of end-effector exclusion volume |
| *y*228 | 7 | 12.6 ± 0.4 mm (0.496 ± 0.016 in.) | facial reference plane | reticle bisecting plane |
| *y*232 | 8 | 45.5 mm (1.791 in.) maximum | facial reference plane | edge of end effector exclusion volume |
| *y*233 | 8 | 44.5 mm (1.752 in.) | facial reference plane | center of reticle contact surface |
| *y*234 | 8 | 77.5 mm (3.051 in.) | facial reference plane | center of reticle contact surface |
| *y*235 | 9 | 1 mm (0.039 in.) maximum | center of reticle contact surface | edge of reticle contact surface |
| *y*236 | 10 | 82.5 mm (3.248 in.) minimum | facial reference plane | end of conveyor rail surface |
| *y*238 | 8 | 78.5 mm (2.941 in.) maximum | facial reference plane | edge of end effector exclusion volume |
| *y*239 | 1 | 10 mm (0.394 in.) minimum | facial reference plane | edge of RFID placement zone |
| *y*240 | 1 | 58 mm (2.283 in.) maximum | facial reference plane | edge of RFID placement zone |
| *y*242 | 11 | 80.25 ± 0.5 mm (3.159 ± 0.020 in.) | facial reference plane | center of info pads |
| *z*2 | None | 2 mm (0.079 in.) maximum | horizontal reference plane | surface of info pads (when down) |
| *z*26 | None | 9 mm (0.354 in.) minimum | horizontal reference plane | surface of info pads (when up) |
| *z*149 | 3, 5 | 5 mm (0.197 in.) maximum | bottom surface of robotic handling flange | top of robotic handling flange |
| *z*276 | 6 | ± 0.15 mm (0.006 in.) | each nominal reticle seating plane | entire bottom surface of the reticle |
| *z*281 | 3 | 182.5 mm (7.185 in.) maximum | horizontal reference plane | top surface of dome recess |
| *z*282 | 3 | 185 mm (7.283 in.) maximum | horizontal reference plane | top surface of dome |
| *z*283 | 3, 5 | 200 ± 0.5 mm (7.874 ± 0.020 in.) | horizontal reference plane | bottom surface of robotic handling flange |
| *z*284 | 3 | 179 ± 0.5 mm (7.047 ± 0.020 in.) | horizontal reference plane | bottom edge of side handling flange |
| *z*285 | 3 | 182.5 mm (7.185 in.) maximum | horizontal reference plane | top surface of side handling flange |
| *z*286 | 3 | 155 mm (6.102 in.) maximum | horizontal reference plane | edge of side handling exclusion volume |
| *z*290 | 4 | 22 mm (0.866 in.) maximum | horizontal reference plane | edge of first reticle pellicle exclusion volume |
| *z*291 | 4 | 32 mm (1.260 in.) | horizontal reference plane | nominal reticle seating plane |
| *z*292 | 4 | 51.05 mm (2.010 in.) | horizontal reference plane | nominal reticle seating plane |
| *z*293 | 4 | 70.10 mm (2.760 in.) | horizontal reference plane | nominal reticle seating plane |
| *z*294 | 4 | 89.15 mm (3.510 in.) | horizontal reference plane | nominal reticle seating plane |

| *Symbol Used* | *Figure* | *Value Specified* | *Reference Measured From* | *Feature Measured To* |
|---|---|---|---|---|
| *z*295 | 4 | 108.20 mm (4.260 in.) | horizontal reference plane | nominal reticle seating plane |
| *z*296 | 4 | 127.25 mm (5.010 in.) | horizontal reference plane | nominal reticle seating plane |
| *z*297 | 6 | 1.5 mm (0.059 in.) minimum | each nominal reticle seating plane | edge of end-effector exclusion volume |
| *z*298 | 6 | 9.4 mm (0.370 in.) minimum | each nominal reticle seating plane | edge of lift clearance exclusion volume |
| *z*299 | 6 | 8.95 mm (0.352 in.) minimum | each nominal reticle seating plane | edge of end-effector exclusion volume |
| *z*300 | 6 | 8 mm (0.315 in.) minimum | each nominal reticle seating plane | edge of end-effector exclusion volume |
| *z*301 | 4 | 22 mm (0.866 in.) maximum | horizontal reference plane | edge of safety rail exclusion volume |
| *z*302 | 4 | 23.5 ± 0.5 mm (0.925 ± 0.020 in.) | horizontal reference plane | edge of first reticle end-effector exclusion volume |
| *z*308 | 11 | 25 mm (0.984 in.) maximum | horizontal reference plane | edge of RFID placement zone |
| *z*310 | 3, 5 | 8 mm (0.315 in.) maximum | bottom surface of robotic handling flange | top of robotic handling flange |
| *z*311 | 4 | 12.7 mm (0.500 in.) maximum | nominal reticle seating plane | edge of lift clearance exclusion volume |
| *z*314 | n/a | 133 mm (5.236 in.) minimum | horizontal reference plane | top of reticle backstops |
| *z*315 | 11 | 30 mm (1.181 in.) maximum | horizontal reference plane | top of RFID placement zone |
| *z*316 | 11 | 10 mm (0.394 in.) minimum | horizontal reference plane | bottom of RFID placement zone |

# APPENDIX 1
# APPLICATION NOTES

**NOTICE**: This appendix is an official part of SEMI E112 and was approved by full letter ballot procedures on August 27, 2001, but the recommendations in this appendix are optional and are not required to conform to this standard.

A1-1 Edge contact only with the photomask is preferred when handling, transporting or storing.

A1-2 Skewness, warp, rock, and stiffness are implicitly defined in the dimensional tolerances.

A1-3 Features on the MRSP150 which enable stacking may be required by end users. It is preferred that these features allow stacking in only one orientation.

A1-4 Features on the MRSP150 which provide visual orientation of the MRSP150 top and MRSP150 door may be required by end users.

# RELATED INFORMATION 1

**NOTICE**: This related information is not an official part of SEMI E112, and it is not intended to modify or supercede the official standard. This information was inserted by the North America Physical Interfaces and Carriers Committee to alert the readers to potential changes to this provisional standard.

R1-1 In the event end-effector and pellicle exclusion volumes can be developed which would satisfy all lithography equipment manufacturers and allow for a 126 mm pellicle, then the appropriate changes would be balloted to update the standard.

# SEMI E113-1104
# SPECIFICATION FOR SEMICONDUCTOR PROCESSING EQUIPMENT RF POWER DELIVERY SYSTEMS

This specification was technically approved by the Global Metrics Committee and is the direct responsibility of the North American Metrics Committee. Current edition approved by the North American Regional Standards Committee on July 11, 2004. Initially available at www.semi.org September 2004; to be published November 2004. Originally published November 2001; previously published November 2003.

## 1 Purpose

1.1 Process plasmas are used throughout the semiconductor industry for the etching and deposition of thin films. The majority of the process chambers use RF power to produce and sustain the plasmas. Because the reliability and repeatability of the plasma directly impacts wafer-processing results, RF power delivery systems are a key element of semiconductor manufacturing technology. The accurate and reproducible performance of the entire RF power generation system, including the RF influenced parameters of the plasma, must be within commonly accepted tolerances.

1.2 Design criteria for RF reliability and repeatability demand standardized testing and evaluation of the performance of the RF power delivery systems and control instrumentation on a chamber. Not only must the subsystems (i.e., the generator, cable assemblies, matching network, chuck/coil) be characterized, but the performance of the integrated system must also be characterized over the intended operating range.

1.3 It is the intent of this standard to provide RF power delivery specifications for semiconductor processing equipment that leads to improved system and subsystem performance. It outlines performance criteria as well as required documentation that must be supplied with the system or subsystem components. The goal of the document is to provide the specifications needed to produce a well-characterized RF power delivery system, where stability, repeatability, and important electrical parameters such as delivered power, current/voltage, and the impedance of the system can be determined within the operating space.

## 2 Scope

2.1 This document specifies the minimum performance criteria for RF equipment used in the semiconductor industry. It does not address specific test methods or procedures for performance verification.

2.2 The primary focus for this specification is semiconductor processing equipment including, but not limited to, the following tool types:

- Dry etch equipment, and
- Film deposition equipment (CVD and PVD).

2.3 This specification applies to semiconductor processing equipment RF power delivery systems whose power is directly used to produce and sustain the plasma.

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

## 3 Limitations

3.1 This standard is meant to address RF systems that primarily operate in the frequency range of 0.2–100 MHz. It does not address higher frequency RF systems or microwave systems.

3.2 This standard is not meant to address pulsed-power RF systems.

3.3 This standard is intended to be a performance specification and is not intended to address design issues related to safety, which are covered elsewhere in the SEMI Standards.

3.4 This standard does not address any safety or performance issues related to RF emissions or electrical codes (e.g., Underwriter's Laboratory, Inc. (UL), the National Electrical Code (NEC®), Federal Communications Commission (FCC)). It is the responsibility of the users of this standard to conform to the appropriate local codes and regulations as applied to this type of equipment, some of which are covered by referenced documents.

## 4 Referenced Standards

4.1 *SEMI Standards*

SEMI E10 — Specification for Definition and Measurement of Equipment Reliability, Availability, and Maintainability (RAM)

SEMI E78 — Electrostatic Compatibility - Guide to Assess and Control Electrostatic Discharge (ESD) and Electrostatic Attraction (ESA) for Equipment

SEMI E114 — Test Method for RF Cable Assemblies Used in Semiconductor Processing Equipment RF Power Delivery Systems

SEMI E115 — Test Method for Determining the Load Impedance and Efficiency of Matching Networks Used in Semiconductor Processing Equipment RF Power Delivery Systems

SEMI E135 — Test Method for RF Generators to Determine Transient Response for RF Power Delivery Systems used in Semiconductor Processing Equipment

4.2 *IEEE Standard*[1]

IEEE-STD-383 — IEEE Standard for Type Test of Class 1E Electrical Cables, Field Splices, and Connections for Nuclear Power Generating Stations

4.3 *MIL-Specification*[2]

MIL-C-17G — General Specification for Cables, Radio Frequency, Flexible and Semirigid

MIL-PRF-39012D — General Specification for Connectors, Coaxial, Radio Frequency

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

## 5 Terminology

5.1 *Abbreviations and Acronyms*

5.1.1 *CVD* — Chemical Vapor Deposition

5.1.2 *PVD* — Physical Vapor Deposition

5.1.3 *VSWR* — Voltage Standing Wave Ratio

5.2 *Definitions*

5.2.1 *cable assembly* — the section of cable (transmission line), including the connectors, used to connect various parts of the RF power delivery system.

5.2.2 *electrical length* — the length of the cable assembly at the operating frequency expressed in terms of degrees, where one wavelength at the nominal operating frequency is equal to 360°.

5.2.3 *harmonic frequency* — the harmonic frequencies are defined as integer multiples of the fundamental frequency. For example, the second harmonic of 13.56 MHz is 27.12 MHz.

5.2.4 *load Q* — the quality factor, Q, of the load is defined here as the magnitude of the reactive part of the load divided by the real part of the load. For example, a load impedance of 2 – j20 ohms would have a load Q of 10.

5.2.5 *matched load* — a matched load impedance is defined as typically having a magnitude of 50 ± 3.3 ohms at a phase angle of up to ± 3.8°. In other words, the load is considered matched if the reflection coefficient is no greater than 0.032 at any phase angle.

5.2.6 *matching network* — the device used to transform the impedance of the load (chamber/chuck) to match the impedance of the generator/cable assembly, which is typically 50 ohms.

5.2.7 *matching network load impedance* — the impedance of the load to which the matching network is matched.

5.2.8 *$MTBF_p$* — mean (productive) time between failures; the average time the equipment performed its intended function between failures; productive time divided by the number of failures during that time. Only productive time is included in this calculation.

5.2.9 *power efficiency* — the power efficiency of a matching network is defined as the power exiting the network (output power) divided by the power entering the network (input power).

5.2.10 *RF applicator/interface* — the part of the chamber where the RF system is terminated. This interface can either be a chuck (driven electrode) or the coil/antenna part of a plasma source.

5.2.11 *RF system* — the RF system is defined as the combination of the generator, matching network, chamber interface, and the associated connecting cable assemblies that are specific to a particular tool/chamber.

5.2.12 *tap point* — for some systems, partial tuning of the matching network is achieved by switching in a combination of fixed tuning elements, such as different values of capacitors. The tap point is defined as the position of the switch(es) that connect or disconnect tuning elements in the matching network circuit.

5.2.13 *tuning element position* — the position of the tuning element is defined as the output voltage or

1 Institute of Electrical and Electronics Engineers, IEEE Operations Center, 445 Hoes Lane, P.O. Box 1331, Piscataway, New Jersey 08855-1331, USA. Telephone: 732.981.0060; Fax: 732.981.1721 website: www.ieee.org

2 Available from Naval Publication and Forms Center, 5801 Tabor Avenue, Philadelphia PA 19120 U.S.A website: www.dodssp.daps.mil/products.htm.

output encoder value that corresponds to the position of a variable tuning element in a Matching Network. For example, the voltage from a rotary potentiometer on the rotating shaft of a variable capacitor (the "Tuning Element") would be referred to as the capacitor's "Position". In this example, the position/voltage corresponds to a certain shaft location or position.

## 6 Ordering Information

6.1 Semiconductor manufacturers may use this standard when procuring processing equipment to specify RF power delivery system performance and documentation. The equipment suppliers may also use this document to specify the RF system components and subassemblies.

6.2 Orders for equipment in accordance with this standard shall include:

6.2.1 This specification number and date of issue.

6.2.2 Any certification showing passage of qualification tests required to be provided (optional).

6.2.3 Any test results required to be included in reports to be provided (optional).

## 7 Requirements

7.1 Semiconductor processing equipment shall be designed and built with a reliable RF power delivery system. The requirements defined in this specification address the integrated RF system as well as the following RF power delivery system components: the RF cable assemblies, the matching network, the generator, and the RF applicator/interface, as well as specific components of these assemblies or systems.

7.2 The mean (productive) time between failures ($MTBF_p$), as outlined in SEMI E10, of the generator, matching network, and the RF power delivery system as a whole shall be provided by the supplier, as well as the test method used to determine $MTBF_p$.

7.3 *RF Cable Assemblies (Transmission Lines)*

7.3.1 Many RF power delivery systems use RF cable assemblies to transfer power from the generator to the input of the matching network and, in some cases, from the output of the matching network to the process chamber (e.g., the chuck assembly). All cable assemblies shall adhere to industry standards for cables and connectors (e.g., MIL-C-17G, MIL-PRF-39012D, IEEE-STD-383) in terms of rated power/voltage/ current, allowed bending radius, expected variation in characteristic impedance, and attenuation at the expected operating frequency(s) for the specific cable type (e.g., RG-217, RG-218) per the cable manufacturer's specifications. SEMI E114 or an equivalent test method(s) shall be used to determine the electrical length, power dissipation (loss), and characteristic impedance of the RF cable assemblies.

7.3.2 The length of the cable assemblies used to connect portions of the RF power delivery system shall be specified in terms of electrical length at the nominal operating frequency, in addition to the nominal physical length. The electrical length shall be given in terms of degrees of phase shift. Variations in the dielectric properties (e.g., phase velocity, characteristic impedance) of the cable assemblies can cause the electrical length to differ between assemblies.

7.3.3 The electrical length of cables used between the matching network and the chamber (if any) shall be specified to within 0.25° of the standard electrical length value at the operating frequency for fixed frequency systems or at the midpoint frequency for variable frequency systems, for frequencies less than or equal to 13.56 MHz. For frequencies above 13.56 MHz, the length should be specified to a value (in degrees) equal to the frequency in MHz multiplied by 0.018 (e.g., the specification for 60 MHz would be $60 \times 0.018 = 1.1°$). For example, at 13.56 MHz, the physical length of typical cable (RG-217) corresponding to 0.25° of phase shift (0.5° of reflection coefficient phase shift) would be approximately 1 cm. This specification would result in impedance variations seen by the matching network of less than approximately 1 percent between processing chambers.

7.3.4 The length of cables used between the matching network and the generator shall be specified to within 1.0° of the standard electrical length value at the operating frequency for fixed frequency systems or at the midpoint frequency for variable frequency systems, for frequencies less than or equal to 13.56 MHz. For frequencies above 13.56 MHz, the length shall be specified to a value (in degrees) equal to the frequency in MHz multiplied by 0.074 (e.g., the specification for 60 MHz would be $60 \times 0.074 = 4.44°$). For example, at 13.56 MHz, the physical length of typical cable (RG-217) corresponding to 1.0° of phase shift (2.0° of reflection coefficient phase shift) would be approximately 4 cm. This specification would minimize the impedance transformation at the harmonic frequencies (10° of phase shift at the $10^{th}$ harmonic frequency).

7.3.5 The expected power dissipation in the cable assembly(s) supplied with the system shall be provided as a function of the operating frequency(s) of the system. The amount of power transmitted through the cable assembly shall be given in terms of dB (decibels) and percentage. The relationship between dB and percentage is given as:

Percentage = $100 \times 10^{(dB/10)}$.

For example, approximately 94.8% (–0.232 dB of loss) of the power at 13.56 MHz will be transmitted through a cable assembly made from RG-217 cable with a physical length of 15.24 meters (electrical length of 375.74°). In other words, 5.2% of the power is dissipated in the cable assembly at 13.56 MHz.

7.4 *Matching Networks*

7.4.1 Matching networks transform the impedance of the plasma load to match the impedance of the generator, which is nominally 50 ohms. The transformation is achieved by the use of various reactive components, such as capacitors and inductors, that "tune" the matching network by transforming the impedance at the output of the network to the input of the matching network. For a given frequency, there is a fixed relationship between the impedance at the input of the matching network and the impedance at the output of the matching network (the load impedance). In other words, the impedance to which the matching network is matched (the load impedance) can be determined if the transform properties of the network are known for a given frequency. Typically, there are two methods of impedance transformation. The first method uses a fixed frequency (e.g., 13.56 MHz) and variable tuning elements, while the second method uses a variable frequency and fixed tuning elements. Specifications for both methods are given below. SEMI E115 or an equivalent test method(s) shall be used to determine the load impedance and efficiency of matching networks that are designed to operate at fixed frequency with a 50-ohm input impedance.

7.4.2 For those systems that use fixed frequency operation, matching networks typically have two variable tuning elements, which are usually variable capacitors and/or inductors. These variable tuning elements typically have an output voltage or encoder value that corresponds to a certain value of the element (i.e., an output voltage will correspond to a specific value of capacitance or inductance in the matching network). The value of the output voltage or encoder value is referred to as the tuning element position. To obtain information on the operation and performance of the matching network, the tuning element positions must be provided as outputs.

7.4.3 For those systems that use variable frequency operation, matching networks typically have fixed tuning elements (no variation) or tap points between fixed tuning elements, and the frequency is varied to obtain the best matched condition. In some cases, the tap points are also varied for matching. To obtain information on the operation and performance of these types of networks, the operating frequency and the input impedance (or reflection coefficient magnitude and phase angle) shall be provided. For those systems that have variable tap points, the tap point position shall also be provided as an output.

7.4.4 For matching networks run at a fixed frequency with variable tuning elements, the load impedance shall be provided as a function of the tuning element positions. In addition, the efficiency of the matching network shall be provided as a function of the tuning element positions. The information shall be provided in tabular form. The increment of the tuning element positions shall be in steps equal to or less than 10% of the full range. For example, a voltage increment of 1 volt or less shall be used in the case where the full range of the tuning element position is 10 volts. A plot providing an example of the real part of the load transformed to 50 ohms by the matching network as a function of tuning element position indicator is shown in Figure 1 and a plot of the reactive part of the load impedance is shown in Figure 2. A plot of the power efficiency is shown in Figure 3. An example of data to be provided in tabular form is shown in Table 1. The required uncertainty of the magnitude of the impedance is ± 1.5%, the required uncertainty in the phase angle of the impedance is ± 0.35°, and the required uncertainty of the power efficiency is ± 2.0%. For example, a load impedance of 2.0 – j20 ohms would have an uncertainty in the real part of ± 0.15 ohms and an uncertainty in the reactive part of ± 0.32 ohms.

7.4.5 For matching networks run at a variable frequency with fixed tuning elements and/or tap points, the efficiency and load impedance as a function of its output parameters (frequency, input impedance, and tap point value (if any)) shall be provided. The information shall be provided in tabular form. The increment of the output parameters shall be in steps equal to or less than 10% of the full range. For example, if the operating frequency parameter is given as an output voltage, a voltage increment of 1 volt or less shall be used in the case where the full range of the output parameter is 10 volts. The required uncertainty of the magnitude of the impedance is ± 1.5%, the required uncertainty in the phase angle of the impedance is ± 0.35°, and the required uncertainty of the power efficiency is ± 2.0%.

7.4.6 The tuning element positions/values for each matching network (of the same type/model) shall be adjusted to provide consistent efficiency and matching network input impedance when the matching network is connected to a fixed load impedance. The load impedance used shall be one that is typically encountered by the matching network during processing and/or shall be an impedance that is near the mid-range of the tuning space (e.g., 2 – j20 ohms). A simple way to ensure network-to-network consistency is to adjust the tuning element positions/values to have consistent values between matching networks when connected to a common/fixed load impedance. The variation in tuning element positions between matching networks shall be less than 1% of full scale for a common fixed load impedance and shall be less than 2% of full scale over 80% of the operating range. For example, if the fixed load impedance is chosen such that the tuning element positions on matching network A are both 5 volts (for a 10 volt range), the tuning element positions for matching network B shall be within 0.1 volts of 5.0 volts.

7.4.7 The maximum power that the system can safely sustain during nominal, steady state processing conditions shall be provided as a function of the positions of the tuning elements (i.e., the plasma load conditions). The operating specifications of the components used in the matching network shall be provided (voltage and current capability), and peak values of voltage and current shall not exceed 80% of the rated voltage and current at the operating frequency for these components over the operating range of the matching network. This specification does not pertain to transient (e.g., plasma strike) conditions.

7.4.8 The maximum power the system can safely sustain without plasma (pre-ignition conditions) shall be provided to the end user, as well as the maximum time limit allowed at the peak power.

7.4.9 To reduce variation between matching networks, the frequency response of the matching network at the harmonic frequencies shall be repeatable between networks up to the 5th harmonic frequency (inclusive). Over the expected operating range of the network, the reflection coefficient measured at the output of the matching network, when the input of the network is terminated with both an open and a short circuit, shall vary less than 5% in magnitude and phase at the harmonic frequencies. Comparisons between networks shall be made at three operating points, which include a nominal operating point (e.g., at the midpoint of the tuning range), a point within 10% of the maximum of the tuning range, and a point within 10% of the minimum operating range. Unless specifically designed to, power dissipation in the network of greater than 10% (reflection coefficient of 0.95) at the harmonic frequencies shall be avoided.

7.4.10 The matching network shall be able to reach a stable tuning solution for any given available preset condition (tuning element position/frequency) in less than 3 seconds when the network is operated into a test load that is in the middle of the network's tuning range. Measurements of the time to tune shall be taken with the preset conditions (tuning elements positions/ frequency) varied in increments equal to 20% or less of full scale. The input power level during this bench test shall be in the range of 20% to 100% of the nominal power rating of the matching network.

7.4.11 There shall be only one tuning solution over the entire tuning range of the matching network. In other words, multiple tuning points for the same loading conditions shall be avoided.

7.5 *Generators*

7.5.1 To maintain consistent process conditions, the generators providing RF power to establish and sustain process plasmas and provide required wafer bias conditions must deliver power to load that can vary in time and value. In general, testing the generator output when driving a 50-ohm load is not sufficient to determine proper operation. In the semiconductor process environment, the generator may be exposed to power from the match/plasma system at the harmonics of the generator output frequency and needs to provide stable output power when operating into typical processing conditions.

7.5.2 The generator shall maintain consistent output impedance at each of the harmonic frequencies. The value of the reflection coefficient measured at the output of the generator shall be consistent at each frequency to within ± 5% in both magnitude and phase up to at least the $10^{th}$ harmonic frequency (i.e., up to $10 \times$ fundamental frequency) over the lifetime of the generator. This specification should not be interpreted as meaning that the reflection coefficient shall be the same value for all the harmonic frequencies, but the reflection coefficient shall maintain its particular value at each particular harmonic frequency to within 5% over time.

7.5.3 Generators shall deliver power to a nominal 50 ohm fixed load within ± 2.0% of true power from 10% to 100% of the maximum rated output power.

7.5.4 Generators shall provide consistent power delivery with a variation of less than ± 1.0% of the requested power level (over time and during steady state wafer processing conditions) when operated into a matched load.

7.5.5 Generators shall deliver power with a power variation of less than ± 1.5% when operated into a load impedance with a reflection coefficient of at least 0.33 at any phase angle (VSWR of at least 2.0) from 10% to 100% of the maximum rated output power. For example, a 25-ohm resistive load with various lengths of transmission line between the load and the generator can be used to produce the required phase shift variation. An example plot of forward power output vs reflection coefficient phase angle is shown in Figure 4.

7.5.6 The output power spectrum of a generator shall have harmonic content of –40 dB or less when operated into a load impedance with a reflection coefficient of at least 0.33 at any phase angle (VSWR of at least 2.0) from 10% to 100% of the maximum rated output power.

7.5.7 The generator output circuit shall be provided with high VSWR protection.

7.5.8 The transient response of the generator operating into a nominal 50-ohm load shall be provided as a function of the change in set point, including the time delay between the request for power (RF enable signal) and the start of the RF output signal. Data for set point changes from zero power to full power and back to zero power as well as set point changes in increments of 33% of full scale shall be provided. For example, data for a 1 kW generator would include changes from 0 W to 1000 W, 1000 W to 0 W, 0 W to 333 W, 333 W to 667 W, 667 W to 1000 W, 1000 W to 667 W, 667 W to 333 W, 333 W to 0 W. SEMI E135 or an equivalent test method(s) shall be used to determine the transient response of the RF generator.

7.5.9 The ramp rate for power changes shall be provided in terms of W/second over the power range of the generator.

7.6 *RF Applicator/Interface*

7.6.1 The RF applicator/interface (the driven electrode or the coil/antenna) shall be designed, built, and maintained to provide a high degree of process repeatability. The RF impedance that the applicator/interface presents to the matching network must have minimal variation in order to maintain consistent process conditions. A minimum requirement for consistent operation is for the capacitance between the interface and ground and the inductance (for coil/antenna systems) to vary less that 1.5% through maintenance cycles, during operation and over the expected lifetime of the applicator/interface.

7.6.2 The frequency response of the RF applicator/interface (chuck assembly or coil/antenna) shall be measured to determine the resonance frequency of the assembly up to 10 times the fundamental frequency. If possible, the frequency response should be measured at the operating temperature of the assembly. The increment of the frequency step shall be no greater than 4% of the fundamental frequency (e.g., for 13.56 MHz, incremental frequency step = 0.54 MHz). The data shall be presented in tabular form in terms of the reflection coefficient magnitude and phase angle. An example of tabular data is given in Table 2 and a graphical example is shown in Figures 5 and 6.

7.6.3 For wafer chuck assemblies, the DC leakage current shall be measured to determine the deterioration of the dielectric coating over time. Increased leakage current will flow if the water that cools the chuck has a low resistivity or if the anodization or other dielectric coating has deteriorated.

7.6.4 The RF plasma environment within the tool is a charged environment that alters the charge level on the product being processed. The RF power delivery system, in conjunction with the chamber hardware, shall be compatible with the user-specified sensitivity level(s) per SEMI E78.

7.7 *Tuning and Matching Control Circuits*

7.7.1 Automated matching networks require sensing circuits to determine how to drive their tuning elements in order to reach a matched condition. The performance of these control circuits and the error signals they generate are critical to the proper function of the matching network. For those networks that are designed to match to a nominal 50 ohm input impedance, the matching network input impedance magnitude shall be 50 ± 3.3 ohms with a phase angle of ± 3.8° when the automatic matching algorithm has driven the matching network to achieve a matched condition.

7.7.2 The sensing circuits in a generator and an automated matching network shall ensure that the control signals are insensitive to power in the harmonics of the drive frequency. For example, additional filtration (low pass or band pass filters) can be added to the sensing circuit to achieve this goal.

7.8 *RF System Tests*

7.8.1 The output power spectrum of a generator shall have a harmonic frequency content of –40 dB or less when operated into a matched system (matching network plus test load) that contains a load impedance with a Q of at least 10. In other words, the magnitude of reactive part of the load must be at least ten times greater than the real part of the load (e.g., 2 – j20 ohms). The cable assembly used during testing shall nominally be the specific type to be used between the output of the generator and the input of the matching network.

7.8.2 To reduce variation between matching networks on those systems that have multiple RF frequencies (i.e., one frequency for the source and another frequency for the bias), the frequency response of the matching network at the other operating frequencies and at the harmonics of the other frequencies shall be repeatable between networks (of the same type/model) up to the 5th harmonic frequency (inclusive). Over the expected operating range of the network, the reflection coefficient measured at the output of the matching network, when the input of the network is terminated with both an open and a short circuit, shall vary less than five percent in magnitude and phase at the harmonic frequencies. Comparisons between networks shall be made at three operating points, which include a nominal operating point (e.g., at the midpoint of the tuning range), a point within 10% of the maximum of the tuning range, and a point within 10% of the minimum operating range. Unless specifically designed to, power dissipation in the network greater than 10% (reflection coefficient of 0.95) at the harmonic frequencies shall be avoided.

7.8.3 On those systems that have multiple RF frequencies (i.e., one frequency for the source and another frequency for the bias), the sensing circuits in an automated matching network and the rf generators shall ensure that the control signals are insensitive to power in the other system frequencies and the harmonics of all the system frequencies.

7.8.4 The supplier shall provide system verification hardware (i.e., test fixtures/interfaces) for system verification after assembly and delivery. Nominally, this hardware shall be in the form of a nominal coaxial connector interface (e.g., type "N" connector) for ease of measurement. Example fixtures would include those for interfacing with the RF applicator/interface (i.e., chuck assembly or coil input) and the output of the matching network. The supplier shall provide recommended test methods and/or procedures for system verification.

## 8 Related Documents

8.1 *IEEE Standards*[3]

IEE-STD-572 — IEEE Standard for Qualification of Class 1E Connection Assemblies for Nuclear Power Generating Stations

IEEE C95.1 — IEEE Standard for Safety Levels with Respect to Human Exposure to Radio Frequency Electromagnetic Fields, 3 kHz to 300 GHz

8.2 *Federal Communications Commission (FCC)*[4]

FCC 47CFR1.1310 — Radio frequency radiation exposure limits

FCC 47CFR2 Part 2 — Frequency Allocations and Radio Treaty Matters; General Rules and Regulations

FCC 47CFR2 Part 2 Subpart J — Equipment Authorization Procedures

8.3 *MIL-Specifications*[5]

MIL-PRF-31031A — General Specification for Connectors, Electrical, Plugs and Receptacles, Coaxial, Radio Frequency, High Reliability, for Flexible and Semirigid Cables

MIL-STD-348A — Radio Frequency Connector Interfaces for MIL-C-3643, MIL-C-3650, MIL-C-3655, MIL-C-25516, MIL-C-26637, MIL-PRF-39012, MIL-PRF-49142, MIL-PRF-55339, and MIL C-83517

MIL-DTL-28875A — General Specification for Amplifiers, Radio-Frequency and Microwave, Solid-State

MIL-T-28732C — General Specification for Transformer, Impedance Matching, Balanced to Unbalanced (Balun)

MIL-STD-220B — Test Method Standard: Method of Insertion Loss Measurement

8.4 *International Emissions Standards*

FCC CFR47 Part 18 — Industrial, Scientific and Medical (ISM) Equipment (United States)[4]

DIN EN 55011 — Industrial, scientific and medical (ISM) radio-frequency equipment - Radio disturbance characteristics - Limits and methods of measurement[6]

V-2/97.04 — Regulations for Voluntary Control Measures[7]

CNS 13438 — Limits and Methods of Measurement of Radio Disturbance Characteristics of Information Technology Equipment[8]

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

3 Institute of Electrical and Electronics Engineers, IEEE Operations Center, 445 Hoes Lane, P.O. Box 1331, Piscataway, New Jersey 08855-1331, USA. Telephone: 732.981.0060; Fax: 732.981.1721 website: www.ieee.org

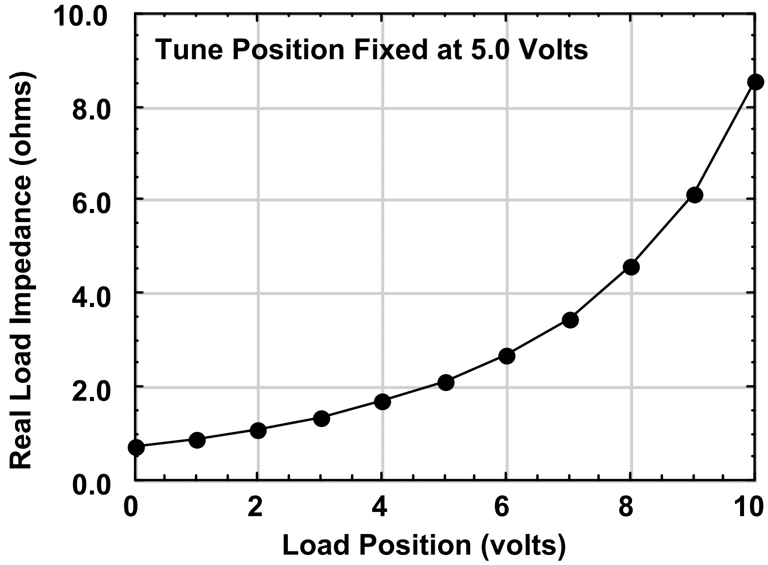
4 United States Federal Communications Commission, 445 12th St. S.W., Washington DC 20554, Website: www.fcc.gov

5 Naval Publication and Forms Center, 5801 Tabor Avenue, Philadelphia PA 19120 U.S.A Available from website: www.dodssp.daps.mil/products.htm

6 Available from Deutches Institut für Normung e.V., Beuth Verlag GmbH, Burggrafenstrasse 4-10, D-10787 Berlin, Germany, website: www.din.de

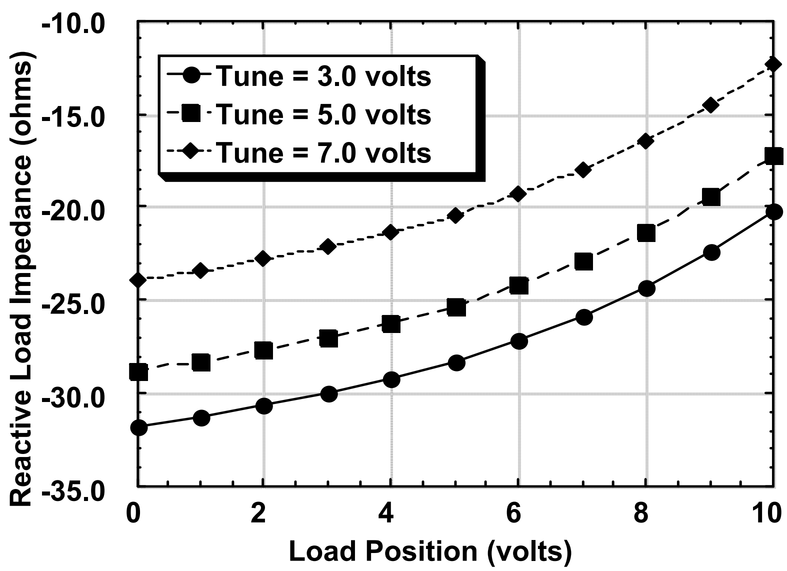
7 Voluntary Control Council for Interference by Information Technology Equipment, website: http://www.vcci.or.jp

8 Chinese National Standards, Available from NSSN (http://www.nssn.org) as Document CNS C6035700



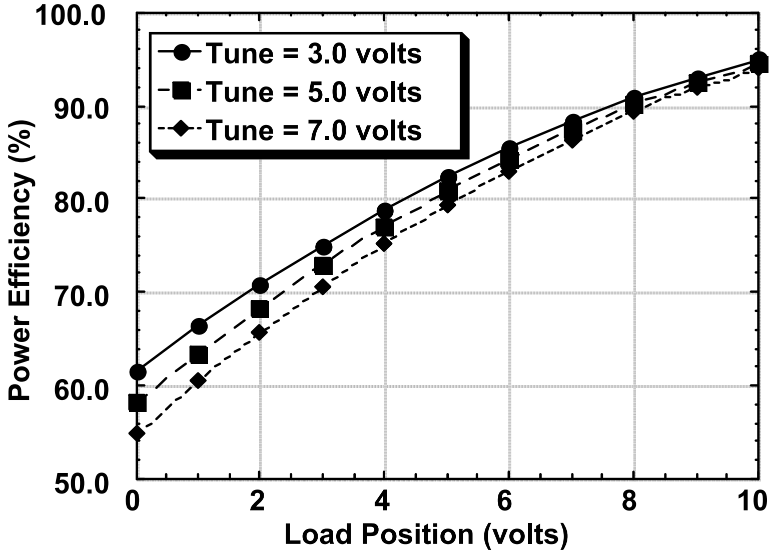

NOTE: For this example, the full-scale voltage for both the Tune and Load Positions is 10 V (i.e., Tune = 5.0 V corresponds to 50% of full scale).

**Figure 1**
**Example Plot of the Real Part of the Load Impedance as a Function of the Load Position Tuning Element in the Matching Network**




NOTE: The Tune Position is at the indicated fixed value for each set of data. For this example, the full-scale voltage for both the Tune and Load Positions is 10 V (i.e., Tune = 3.0 V corresponds to 30% of full scale).

**Figure 2**
**Example Plot of the Reactive Part of the Load Impedance as a Function of the Load Position Tuning Element in the Matching Network**



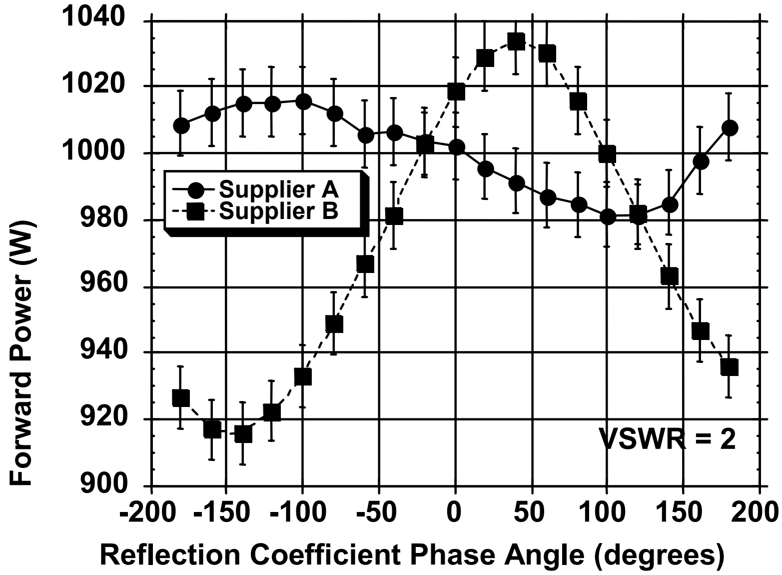

NOTE 1: The Tune Position is at the indicated fixed value for each set of data. For this example, the full-scale voltage for both the Tune and Load Positions is 10 V (i.e., Tune = 3.0 V corresponds to 30% of full scale).

**Figure 3**
**Example Plot of the Power Efficiency as a Function of the Load Position Tuning Element in the Matching Network**

**Table 1 Example Data Table Showing the Matching Network Load Impedance and Power Efficiency as a Function of the Positions of the Tuning Elements**

| *Load Position, volts* | *Tune Position, volts* | *Real Load, ohms* | *Reactive Load, ohms* | *Power Efficiency, %* |
|---|---|---|---|---|
| 0 | 3 | 0.74 | –31.75 | 61.51 |
| 1 | 3 | 0.91 | –31.23 | 66.36 |
| 2 | 3 | 1.12 | –30.64 | 70.86 |
| 3 | 3 | 1.38 | –29.96 | 75.04 |
| 4 | 3 | 1.72 | –29.18 | 78.88 |
| 5 | 3 | 2.15 | –28.26 | 82.38 |
| 6 | 3 | 2.72 | –27.17 | 85.56 |
| 7 | 3 | 3.50 | –25.87 | 88.39 |
| 8 | 3 | 4.59 | –24.31 | 90.90 |
| 9 | 3 | 6.18 | –22.42 | 93.07 |
| 10 | 3 | 8.57 | –20.15 | 94.91 |

NOTE 1: For this example, the full-scale voltage for both the Tune and Load Positions is 10 V (i.e., Tune = 3.0 V corresponds to 30% of full scale). This example only shows data for a fixed Tune position of 3.0 volts. Data is also required at a Tune position of 0.0 V, 1.0 V, etc.



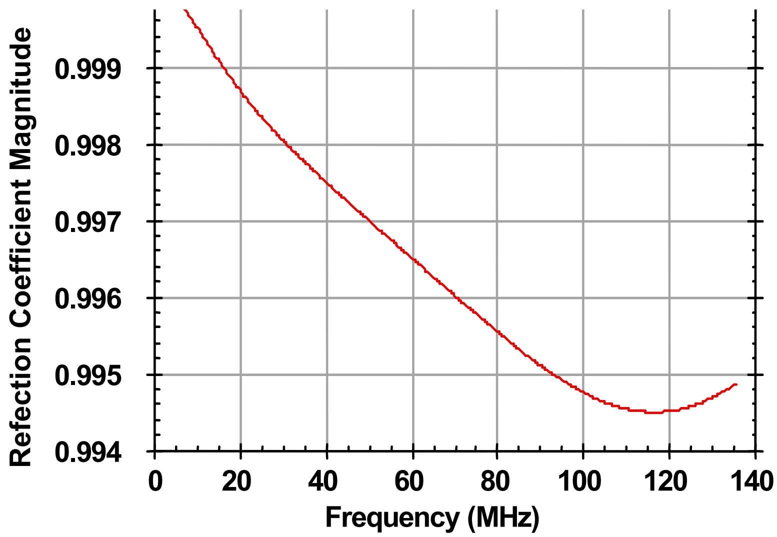

NOTE 1: The requested power was 1000 W. This plot shows a comparison of two different generators. The “Supplier A” data (circles with solid curve) is within the required ± 1.5% variation from requested power (within the error bars), while the “Supplier B” data (squares with dashed line) is not within the required ± 1.5% variation from requested power.

**Figure 4**
**Example Data for the Forward Power as a Function of the Reflection Coefficient Phase Angle for a Nearly Constant Value of VSWR/Reflection Coefficient magnitude (VSWR = 2)**

**Table 2 Example Data Table (Partial) Showing the Frequency Response of a Chuck Assembly**

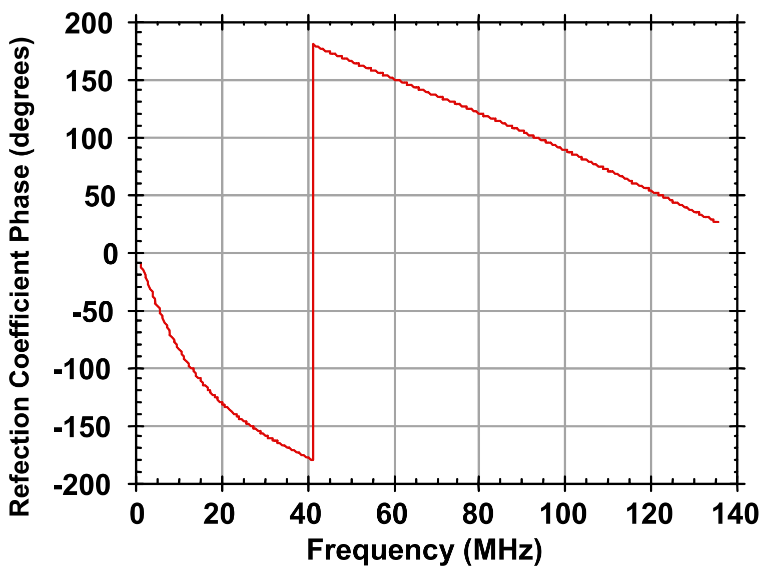
| *Test Frequency, MHz* | *Refection Coefficient Magnitude* | *Refection Coefficient. Phase, degrees* |
|---|---|---|
| 1.0 | 0.99973 | –9.702 |
| 1.3365 | 0.99969 | –12.95 |
| 1.673 | 0.99959 | –16.18 |
| .<br>.<br>. | .<br>.<br>. | .<br>.<br>. |
| 41.097 | 0.9974 | –180 |
| .<br>.<br>. | .<br>.<br>. | .<br>.<br>. |
| 135.2635 | 0.99488 | 25.94 |
| 135.6 | 0.99490 | 25.36 |

NOTE 1: The first column is the test frequency, the second column is the magnitude of the reflection coefficient, and the third column is the phase angle of the reflection coefficient.




NOTE 1: This plot is the graphical form of the data shown in Table 2.

**Figure 5**
**Example Data of the Magnitude of the Reflection Coefficient of the Chuck Assembly Plotted as a Function of Frequency**




NOTE 1: This plot is the graphical form of the data shown in Table 2.

**Figure 6**
**Example Data of the Phase Angle of the Reflection Coefficient of the Chuck Assembly Plotted as a Function of Frequency**

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# SEMI E114-0302[E]
# TEST METHOD FOR RF CABLE ASSEMBLIES USED IN SEMICONDUCTOR PROCESSING EQUIPMENT RF POWER DELIVERY SYSTEMS

This test method was technically approved by the Global Metrics Committee and is the direct responsibility of the North American Metrics Committee. Current edition approved by the North American Regional Standards Committee on March 20, 2002. Initially available at www.semi.org June 2002; to be published July 2002.

[E] This document was editorially modified in May 2002. A change was made to Section 1.1.

## 1 Purpose

1.1 The purpose of this document is to define a test method used to determine the electrical length, power losses, and characteristic impedance variation of RF cable assemblies used in RF power delivery systems for semiconductor processing equipment.

## 2 Scope

2.1 This document specifies the testing procedures and test equipment required for the following:

- Determining the electrical length of RF cable assemblies at the nominal operating frequency in terms of degrees of phase shift.
- Determining the power dissipation (loss) in the RF cable assembly at the nominal operating frequency.
- Verifying the characteristic impedance of the RF cable assembly.

2.2 The primary focus for this specification is semiconductor processing equipment including, but not limited to, the following tool types:

- Dry etch equipment,
- Film deposition equipment (CVD and PVD).

2.3 This standard does not address any safety or performance issues related to RF emissions or electrical codes (e.g., Underwriter's Laboratory, Inc. (UL), the National Electrical Code (NEC®), Federal Communications Commission (FCC)). It is the responsibility of the users of this standard to conform to the appropriate local codes and regulations as applied to this type of equipment, some of which are covered by referenced documents.

2.4 This standard does not purport to address safety issues, if any, associated with its use. It is the responsibility of the users of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

## 3 Limitations

3.1 This standard is meant to address RF Cable Assemblies used in RF systems that primarily operate in the frequency range of 0.2–100 MHz. It does not address higher frequency RF systems or microwave systems.

3.2 This standard assumes that the cable assemblies to be tested have a nominal characteristic impedance of 50 ohms. This standard can be used with cable assemblies with a different characteristic impedance if the appropriate standard termination loads are used.

3.3 International, national, and local codes, regulations and laws should be consulted to ensure that the equipment and procedures meet regulatory requirements in each location.

## 4 Referenced Standards

4.1 *SEMI Standards*

SEMI E113 — Specification for Semiconductor Processing Equipment RF Power Delivery Systems

4.2 *IEEE Standards*[1]

IEEE-STD-383 — IEEE Standard for Type Test of Class 1E Electrical Cables, Field Splices, and Connections for Nuclear Power Generating Stations

4.3 *Military Standards*[2]

MIL-C-17G — General Specification for Cables, Radio Frequency, Flexible and Semirigid

MIL-PRF-39012D — General Specification for Connectors, Coaxial, Radio Frequency

1 Institute of Electrical and Electronics Engineers, IEEE Operations Center, 445 Hoes Lane, P.O. Box 1331, Piscataway, New Jersey 08855-1331, USA. Telephone: 732.981.0060; Fax: 732.981.1721

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

## 5 Terminology

5.1 *Abbreviations and Acronyms*

5.1.1 *CVD* — Chemical Vapor Deposition

5.1.2 *PVD* — Physical Vapor Deposition

5.1.3 *VSWR* — Voltage Standing Wave Ratio

5.2 *Definitions of Terms*

5.2.1 *cable assembly* — the section of cable (transmission line), including the connectors, used to connect various parts of the RF power delivery system.

5.2.2 *device under test (DUT)* — the cable assembly intended to be tested.

5.2.3 *electrical length* — the length of the cable assembly at the operating frequency expressed in terms of degrees, where one wavelength at the nominal operating frequency is equal to 360 degrees.

5.2.4 *half wave resonant frequency* — the frequency of the cable assembly where the electrical length of the assembly is equal to one half (0.5) of a wavelength. For example, the half wave resonant frequency of a cable assembly with an electrical length of 2 meters would be 74.95 MHz ((c/2-meters)/2).

5.2.5 *harmonic frequency* — the harmonic frequencies are defined as integer multiples of the fundamental frequency. For example, the second harmonic of 13.56 MHz is 27.12 MHz.

5.2.6 *quarter wavelength* — the length equal to one quarter of the wavelength at a given frequency, where the wavelength is equal to the speed of light divided by the frequency.

5.2.7 *S-parameters* — the scattering matrix used to describe a network. The reflection coefficient is the S11 parameter and the transmission coefficient is the S21 parameter.

5.2.8 *speed of light (c)* — the speed of light in free-space is assumed to be $2.9979 \times 10^8$ meters/second.

5.2.9 *velocity of propagation (VP)* — the velocity of propagation, *VP*, is defined as the ratio of the speed of an electrical signal down a length of cable divided by the speed in free space. It is the reciprocal of the square root of the relative dielectric constant of the dielectric material between the inner and outer conductor of a coaxial assembly. For example, the *VP* for cable type RG-217 is nominally 0.66.

## 6 Test Apparatus

6.1 *RF Vector Network Analyzer* — The network analyzer is used to measure the electrical length and can also be used to determine the attenuation (power losses). The network analyzer requires vector capability so that both the magnitude and phase of the reflection coefficient and transmission coefficient can be measured as a function of frequency. The frequency range shall include the operating frequency and the quarter-wave resonant frequency of the RF cable assembly.

6.2 *Time Domain Reflectometer (TDR)* — The TDR is used to measure and verify the characteristic impedance as a function of distance along the transmission line.

6.3 *RF Adapters and Terminations* — Various adapters may be necessary to convert between different types of coaxial connectors (e.g., type N to type HN adapters, etc.). All adapters used shall have the same nominal characteristic impedance as the cable assembly to be tested (DUT), which is typically 50 ohms. For some measurements, additional coaxial cable assemblies may be necessary. These cable assemblies, which should not be confused with the DUT cable assembly, shall be of the same nominal characteristic impedance as the DUT cable assembly. Standard terminations will also be used, such as shorts, opens, and precision 50-ohm loads.

## 7 Safety Precautions

7.1 Work should be conducted in accordance with local safety requirements and test device manufacturer recommended safety procedures. The tests described in this document involve using low output power test instrumentation (typically less than 10 milli-Watt).

7.2 The area immediately surrounding the Test Setup should be keep free and clear of unnecessary equipment and materials. Some of the cable assemblies to be tested may be long and can be trip and lift/weight hazards.

## 8 Test Setup for Electrical Length Test

8.1 The Test Setup for the electrical length test consists of the Network Analyzer, the cable assembly to be tested (DUT), the appropriate adapter (if any) to connect the DUT to the network analyzer, and the appropriate adapter (if any) to connect a coaxial short circuit termination to the output of the DUT. A schematic of the Test Setup is shown in Figure 1. Care should be taken to ensure that the cable assemblies to be tested do not exceed the vendor specified bending radius, which is typically 5 times the outer diameter of the cable.

8.2 Prior to making any measurements, the Network Analyzer shall be turned on and allowed to warm up before the testing is to take place. This time allows for electronics to come to a stable operating condition for the measurements.

## 9 Test Procedure for Determining Electrical Length

9.1 Two test procedures can be used to determine the electrical length of a cable assembly. One method measures it directly at the operating frequency and the other measures the half-wave resonant frequency to determine the electrical length. Each method has advantages, depending on the length of the cable assembly. Prior to choosing a method, the equivalent free-space length of the DUT shall be estimated in units of distance (i.e., meters). This length can be estimated by dividing the physical length of the DUT by the velocity of propagation for the particular type of cable. For example, a DUT made from RG-217 cable with a physical length of 20 meters and a velocity of propagation of 0.66 would have an equivalent free-space length of 30.303 meters (20/0.66 = 30.303). A flow chart showing the steps for choosing which test method to use is shown in Figure 2.

9.2 The equivalent free-space length of the DUT shall be compared with the wavelength of the nominal operating frequency. Test Method 1 (Section 9.3) shall be used if the equivalent free-space length is less than a quarter wavelength of the nominal operating frequency. Test Method 2 shall be used if it is equal to or greater than a quarter wavelength of the nominal operating frequency. For example, if the estimated free-space length is 3 meters and the nominal operating frequency is 13.56 MHz (quarter wavelength = $0.25 \times c/13.56 \times 10^6$ = 5.527 meters), then Test Method 1 is recommended. If the estimated free-space length is 25 meters, then Test Method 2 is recommended.

9.3 *Test Method 1 for Determining Electrical Length*

9.3.1 This test method measures the phase angle of the reflection coefficient at the nominal operating frequency of the DUT when the DUT is terminated by a short circuit.

9.3.2 Calibrate the Network Analyzer at the desired operating frequency (e.g., 13.56 MHz). If adapters are to be used to connect the DUT to the Network Analyzer and/or to the short circuit termination, then the calibration shall be made with the adapters in place. The Network Analyzer shall be calibrated for measuring the reflection coefficient at test Port 1 (see Figure 1) using the calibration kit provided with the Network Analyzer. This measurement is equivalent to measuring the S11 S-parameter. The calibration shall be performed at fixed frequency (continuous-wave operation) using the lowest bandwidth possible (typically 10 Hz).

9.3.3 After calibration, the cable assembly to be tested (DUT) shall be attached to Port 1 on the Network Analyzer. The other end of the DUT shall be terminated with a short circuit. After all connections have been visually inspected to ensure proper contact and the Network Analyzer measurement has stabilized, the value of the reflection coefficient phase angle shall be recorded.

9.3.4 If the indicated phase angle of the reflection coefficient is positive, then the electrical length of the DUT is equal to one half of the value of the difference between 180 and the measured phase angle. For example, if the measure reflection coefficient phase angle is 120 degrees, then the electrical length is 30 degrees ((180-120)/2).

9.3.5 If the indicated phase angle of the reflection coefficient is negative, then the electrical length of the DUT is greater than a quarter wavelength. For this case, the electrical length is equal to one half of the absolute value of the measured value of the reflection coefficient phase angle plus 90. For example, if the measure reflection coefficient phase angle is -10 degrees, then the electrical length is 95 degrees (90 + 10/2).

9.4 *Test Method 2 for Determining Electrical Length*

9.4.1 This test method determines the electrical length of the cable assembly DUT by measuring the half wave resonant frequency when the DUT is terminated by a short circuit. For this measurement, the frequency of the network analyzer is swept. The frequency range of the sweep is determined from the estimated free-space length of the DUT.

9.4.2 Estimate the half wave resonant frequency of the DUT. This frequency is equal to one half of the ratio of the speed of light divided by the estimated free space length determined in Section 9.2. For example, if the estimated free space length of the DUT is 25 meters, then the estimated half wave resonant frequency is 5.996 MHz ($0.5 \times c/25$).

9.4.3 Calibrate the Network Analyzer. If adapters are to be used to connect the DUT to the Network Analyzer and/or to the short circuit termination, then the calibration shall be made with the adapters in place. The center frequency of the frequency sweep shall be at the estimated half wave resonant frequency calculated in Section 9.4.2, and the frequency span of the sweep shall be no greater than 10% of the estimated frequency. For example, if the estimated half wave resonant frequency is 6.0 MHz, then the frequency span shall be no greater than 0.6 MHz. The Network Analyzer shall be calibrated for measuring the reflection coefficient at test Port 1 (see Figure 1) using the calibration kit provided with the Network Analyzer. This measurement is equivalent to measuring the S11 S-parameter. The calibration shall be performed using the lowest bandwidth possible (typically 10 Hz).

9.4.4 After calibration, the cable assembly to be tested (DUT) shall be attached to Port 1 on the Network Analyzer. The other end of the DUT shall be terminated with a short circuit. After all connections have been visually inspected to ensure proper contact and the Network Analyzer measurement has stabilized, the value of the reflection coefficient phase angle can be examined.

9.4.5 The indicated frequency where the reflection coefficient phase angle is ± 180 degrees shall be recorded. The electrical length of the DUT at the desired nominal operating frequency (for example, 13.56 MHz) is equal to 180 degrees multiplied by the ratio of the nominal operating frequency divided by the measured frequency where the phase angle of the DUT is equal to ± 180 degrees. For example, if the measured frequency where the reflection coefficient is ± 180 degrees is 6.1 MHz, then the electrical length of the DUT at 13.56 MHz is 400.13 degrees (180 × 13.56 / 6.1).

## 10 Test Setup for Power Dissipation (Loss) Test

10.1 The Test Setup for the power dissipation (loss) test consists of the Network Analyzer, the cable assembly to be tested (DUT), an additional short test cable (for transmission calibration), the appropriate adapter (if any) to connect the DUT input to the network analyzer, and the appropriate adapter (if any) to connect the DUT output to the network analyzer. A schematic of the Test Setup is shown in Figure 3.

## 11 Test Procedure for Determining Power Dissipation

11.1 The test procedure for determining power dissipation in cable assemblies will also use a Network Analyzer. In this case, both Ports of the Network Analyzer will be used. The transmission coefficient will be measured (also called the S21 S-parameter).

11.2 Calibrate the Network Analyzer at the desired operating frequency (for example, 13.56 MHz). If adapters are to be used to connect the DUT to the Network Analyzer and/or to the short circuit termination, then the calibration shall be made with the adapters in place, along with the additional section of test cable needed for the calibration. The Network Analyzer shall be calibrated for measuring the transmission coefficient, S21 (see Figure 3). The calibration shall be performed at fixed frequency (continuous-wave operation) using the lowest bandwidth possible (typically 10 Hz).

11.3 Connect the cable assembly DUT between the two test Ports on the Network Analyzer (including the additional test cable used for calibration). After visually inspecting the connections to ensure proper contact and the Network Analyzer measurement has stabilized, the value of the transmission coefficient (S21) shall be recorded.

11.4 The recorded number shall be expressed in terms of dB (decibels) and percentage of power transferred in the DUT. The conversion between dB and percentage is expressed as:

$$\textit{Power Transfer}\ \% = 100 \times 10^{(\text{loss in dB}/10)}$$

For example, if the transmission coefficient is measured to be –0.4 dB, then the power transfer percentage would be 91.2%. In other words, 8.8% of the power is lost in the DUT.

## 12 Test Setup for Characteristic Impedance Variation Measurement

12.1 The Test Setup for the Characteristic Impedance variation measurement consists of a Time Domain Reflectometer (TDR), the cable assembly to be tested (DUT), the appropriate adapter (if any) to connect the DUT input to the TDR, and a standard 50-ohm load termination (see Figure 4).

12.2 Prior to making any measurements, the TDR shall be turned on and allowed to warm up. This time allows for electronics to come to a stable operating condition for the measurements.

## 13 Test Procedure for Determining Characteristic Impedance

13.1 Connect a standard 50-ohm load termination to the input of the TDR and measure the impedance. This measurement determines the normalization factor for the measured impedances. All reported measurements shall be scaled by this factor by multiplying subsequent measurements by the ratio of 50 divided by the impedance value measured with the 50-ohm standard load.

13.2 Prior to measuring the DUT, the nominal velocity of propagation of the cable shall be entered into the TDR. For example, the velocity of propagation is 0.66 for cable type RG-217.

13.3 Connect one end of the DUT to the TDR and terminate the other end of the DUT with a short circuit. Measure the characteristic impedance as a function of distance along the DUT by moving the measurement distance indicator of the TDR. Record the minimum and maximum impedance measured over the length of the cable assembly. The measurement shall be made throughout the length of the DUT, including the connectors, up to the short circuit termination.