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DESIGN PRINCIPLES AND TEST METHODS FOR EVALUATING EQUIPMENT EXHAUST VENTILATION

This design and test method supplement provides specific technical information relating to the ventilation section of SEMI S2. In general, it provides information on hazard evaluation methods, examples of control strategies, and test validation criteria.

- This Appendix is intended to be used as a starting point for reference during tool design.
- This Appendix is not intended to limit hazard evaluation methods or control strategies (e.g. design principles) employed by equipment manufacturers.
- This Appendix is not intended to provide exhaustive methodology for determining final ventilation specifications. Other methodology may be used where it provides at least equivalent sensitivity and accuracy.
- The exhaust velocities, volume flow rates and pressures listed are derived from a mixture of successful empirical testing and regulatory requirements.
- Test validation criteria are generally referenced from the applicable internationally recognized standard. It is the users responsibility to ensure that the most current revision of the standard is used.

Hood Type	*Recommended Test Methods*	***Typical Design and Test Exhaust Parameters*****	*References*
Wet Station	Primary: Vapor visualization Supplemental: Face Velocity, Slot Velocity, Tracer Gas, Air sampling	60-100 fpm capture velocity for non-heated 100-150 fpm capture velocity for heated 110 - 125% of the laminar flow volume flow rate across the top of the deck	ACGIH SEMI F15
Gas Cylinder Cabinets	Primary: Face Velocity, Tracer Gas Supplemental: Vapor visualization	200-250 fpm face velocity air changes per minute? SP?	SEMI F-15 NFPA
Equipment Gas Panel Enclosure	Primary: Tracer Gas, Static Pressure Supplemental: Vapor visualization	4-5 air changes per minute -0.05 - -0.1 " H_2O	SEMI F-15
Diffusion Furnace Scavenger	Primary: Face Velocity, Vapor visualization Supplemental: Tracer Gas, Air Monitoring	100-150 fpm face velocity	SEMI F15

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Hood Type	*Recommended Test Methods*	***Typical Design and Test Exhaust Parameters***	*References*
Chemical Dispensing Cabinets	Primary: Static Pressure Supplemental: Vapor visualization	- 0.05 - -0.1" H2O 2-3 air changes per minute	
Parts Cleaning Hoods	Primary: Face Velocity, Vapor Visualization Supplemental: Tracer Gas, Air monitoring	80-125 fpm	ASHRAE Standard 110 SEMI F15
Pump and Equipment Exhaust Lines	Primary: Static Pressure	-0.25 - - 1.0 " H2O 125% maximum volume flow rate from pump	SEMI F15
Glove Boxes	Primary: Static Pressure, Tracer Gas Supplemental: vapor visualization, air monitoring	SP?	***SEMI F15***
Drying/ Bake/ Test Chamber Ovens	Primary: static pressure, Tracer gas Supplemental: Vapor visualization, Air monitoring	-0.05 - -0.1 " H2O	SEMI F-15
Spin-Coater (cup only)	Primary: vapor visualization, velometry Supplemental: Air sampling		
Supplemental or Maintenance Exhaust	Primary: Capture velocity, vapor visualization, air sampling	100-150 fpm capture velocity	

* For heated applications, do not use hot-wire anemometer

** no single measurement +/- 20 % of average for face velocity, +/- 10% along the length of each slot, and between slots

A4-1 EXHAUST OPTIMIZATION

Exhaust optimization is the use of good ventilation design to create efficient equipment exhaust. The design and measurement methods discussed below confirm that tool exhaust is acting as the manufacturer intended. This information is not meant to prohibit alternate methods of achieving or verifying good ventilation design. References for ventilation design are included at the end of this Appendix.

A4-1.1 Design Recommendations:

A4-1.1.1.Tool exhaust design can attempt to reduce inefficient static pressure losses caused by: friction losses from materials; openings, and duct geometry (elbows, duct expansions or contractions); turbulent air flow; fans; internal fittings such as blast gates and dampers; directional changes in airflow. Adequate capture and exhaust of airborne toxicants should be achievable with total tool exhaust static pressure requirement of 1.5" H2O or less (see also SEMI S6-93, paragraph 8.3.6.1)

A4-1.1.2.Other good design principles can include minimizing distance between the source and hood, and reducing enclosure volumes.

A4-1.1.3. For non-chemical issues such as heat from electrical equipment, heat recapture rather than exhaust may be an option.

A4-1.1.4. The possible impact of highly directional laminar airflow found in most fabs should be considered when designing tool exhaust.

A4-1.1.5. Manufacturers should be able to cite the rationale behind cfm or other ventilation specifications (e.g. If exhaust is required for heat dissipation, what is the temperature value the manufacturer used in reaching the cfm specified.)

A4-1.2 Recommended Equipment Controls:

The location of internal blast gates or dampers inside equipment, and their appropriate settings, should be clearly identified. The number of tool dampers and blast gates should be minimized. Gates/dampers should be lockable or otherwise securable. Static pressure or flow sensors installed on equipment by the equipment manufacturer should have sufficient sensitivity and accuracy to measure exhaust flow rate fluctuations which place the equipment out of prescribed ranges.

A4-1.3 Recommended Measurement/Validation Method

Measurements should be made to identify optimal exhaust levels and confirm that safety and process requirements are being addressed. The tool manufacturer should be able to identify any critical tool locations for chemical capture, and quantify appropriate exhaust values. Multiple validation/measurement methods may be needed.

A4-1.3.1 Measurements should be done after equipment components are assembled together.

A4-1.3.2 Computer modeling can be done to predict exhaust flow and hazardous material transport in equipment by solving fluid mechanics conservation of energy and mass equations. Modeling can be utilized in the tool design stage or to improve existing equipment. Computer models require experimental verification, using one or more of the methods discussed below.

A4-1.3.3 Tracer gas testing provides a method to test the integrity of hoods by simulating gas emission and measuring the effectiveness of controls. Testing until there is a failure, and then slightly increasing the flow rate until the test is successful can be used to help minimize air flow specifications.

A4-1.3.4 Chemical air or wipe monitoring can be used to confirm that chemical transport is not occurring into unintended areas of the tool.

A4-1.3.5 Velocity profiling will confirm expected air flow's, the direction of flow, and the effect of distance.

A4-1.3.6 Flow visualization will confirm expected air flow's, the direction of flow, and the effect of distance.

A4-2 CHEMICAL LABORATORY FUME HOODS, PARTS CLEANING HOODS:

Lab fume hoods and part cleaning hoods are designed to control emission by enclosing a process on five sides and containing the emission within the hood.

A4-2.1 Design Recommendations:

A4-2.1.1. Fully enclosed on five sides, open on one side for employee access and process / parts placement and removals.

A4-2.1.2. Front, employee access side, must be provided with sliding door and/or sash.

A4-2.1.3. Minimize size of the hood based on process size.

A4-2.1.4. Minimize front opening size based on size of process and employee access needs.

A4-2.1.5. Ensure hood construction materials are compatible with chemicals used.

A4-2.2 Control Specifications:

Face velocity is the specification generally used with hoods open on only one side.

A4-2.2.1. Generally acceptable laboratory fume hood face velocities range from 80-120 fpm with no single measurement ± 20 % of average. 125 - 150 fpm is recommended for hoods in which carcinogens or reproductive toxicants may be used.

A4-2.2.2. Velocities as low a 60 - 80 fpm can be effective but require no cross drafts or competing air movement in the work area.

A4-2.2.3. 100 fpm average face velocity is generally found to be acceptable in most applications.

A4-2.2.4. 125 to 150 fpm may be required when a lab hood is installed in an area with laminar air flow.

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A4-2.2.5. Face velocity above 150 fpm should be avoided to prevent eddying caused by a lower pressure area in front of an employee standing at the hood.

A4-2.3 Recommended Measurement/Validation Method:

A4-2.3.1 Preferred method is measurement of average face velocity and hood static pressure. Measurements taken with a Velometer or anemometer. Multiple measurements are taken in a grid, at least 1-4 per square foot of open area, in the plane opening of the hood, which will allow representative, evenly spaced measurements to be taken (see also open-surface tanks).

A4-2.3.2 Additional confirmation by visualization check of containment using smoke or vapor testing.

A4-2.3.3 ASHRAE method 110 (or equivalent)(use appropriate sections, probably method for use at manufacturers location) for tracer gas testing of Lab Hoods may be used as a supplemental verification provided that an accurate emission rate can be defined. (ASHRAE 110 lists 3 tests "as manufactured", "as used", "as installed")

A4-3 WET STATIONS:

Wet stations are slotted hoods designed to capture laminar air flow while also capturing wet process emissions from the work area. Wet stations can be open on the front, top and both sides (it is usually preferable to enclose as much as possible).

A4-3.1 Design Recommendations

A4-3.1.1.Slots provided uniformly along the length of the hood for even distribution of airflow.

A4-3.1.2.Additional lip exhaust slots around tanks or sinks to control emissions.

A4-3.1.3.Size plenum behind slots to ensure even distribution of Static Pressure.

A4-3.1.4.Velocity along length of slot should not vary by more than 10% of the average slot velocity.

A4-3.1.5.Additional use of end or side panels/baffles can reduce negative impact of side drafts.

A4-3.1.6.Exhaust volume settings should consider laminar air flow volumes and be balanced to minimize turbulence and ensure capture.

A4-3.1.7.The station design should consider airflow patterns in the operating zone to minimize turbulent horizontal airflow patterns into and across the work deck.

A4-3.1.8.Additional considerations to reduce exhaust demand include providing covered tanks, and recessing tanks below deck level.

A4-3.2 Control Specifications:

Wet station specifications are complicated by the fact that wet stations generally do not have a clean easily definable face velocity to measure. A number of methods have been used and are all acceptable if used consistently and provided documentation indicates chemical containment meets the 1% of the OEL at distances beyond the plane of penetration at the exterior of the wet station.

A4-3.2.1.Maintain an average capture velocity of 65 - 100 fpm immediately above a bath.

A4-3.2.2.Calculation of total exhaust volume requirement by determining the total volumetric flow of laminar air hitting the deck and increasing this value by 20 to 25%.

A4-3.2.3.For some wet stations which are partially enclosed from the top an artificial plane opening can be defined where the downward velocity of the laminar air flow penetrates the capture zone of the wet station. Depending on the hood design and laminar air flow provided average plane of penetration velocities can range from 70-100 fpm. This specification is not completely reliable because it is not easily reproducible.

A4-3.3 Recommended Measurement/Validation Method:

A4-3.3.1.Measurement of average capture velocity above bath. Measurements taken with a Velometer or anemometer. Multiple measurements taken in a grid, at least 1 - 4 per square foot of open area, two to three inches above liquid level

A4-3.3.2.Confirmation by visualization check of capture using vapor capture testing.

A4-3.3.3.Confirmation of laminarity of make up air into the station using vapor visualization.

A4-3.3.4.Tracer gas testing may be used as supplemental verification, provided an emission rate can be accurately defined.

A4-4 SUPPLEMENTAL OR MAINTENANCE EXHAUST:

Maintenance exhaust, if not designed into the tool, can be supplemented by the addition of a flexible duct provided with a tapered hood which can be placed in the work area to remove potential contaminants before they enter the work area and the employees breathing zone.

A4-4.1 Design Recommendations

A4-4.1.1.Retractable / movable non-combustible flex ducting for easy reach and placement within 6 to 12 inches of potential emissions to be controlled.

A4-4.1.2.Manual damper at hood to allow for local control, i.e., shut off when not required.

A4-4.1.3.Tapered hood with a plane opening as a minimum.

A4-4.1.4.The additional use of flanges or canopies to enclose the process will result in improved efficiency.

A4.4.2 Control Specifications: (NOTE: This is one equation that is most commonly used. Other equations may be appropriate; see also ACGIH Ventilation Manual and Semiconductor Exhaust Ventilation Guidebook).

A minimum capture velocity of 100 fpm is required at the contaminant generation point for releases of vapor via evaporation or passive diffusion. Ventilation should not be relied upon to prevent exposures to hazardous substances with release velocities (e.g. pressurized gases). For a freely suspended plane opened hood the CFM required at a given capture velocity can be calculated by:

$$Q = V(10X^2 + A)$$

Where: Q = Required Exhaust Air Flow in CFM

V = Capture Velocity in FPM at Distance X from hood

A = Hood Face Area in square feet

X = Distance from Hood face to farthest point of contaminant release in feet.

A4-4.3 Recommended Measurement/Validation Method:

A4-4.3.1.Measurement of capture velocity at farthest point of contaminant release. Measurements taken with a Velometer or anemometer.

A4-4.3.2.Confirmation by visualization check of capture using vapor capture testing.

A4-5 SECONDARY GAS PANEL ENCLOSURES:

Secondary Gas Panel Enclosure, also know as Gas Boxes, Jungle Enclosure, Gas Jungle, Jungle, Gas Control Valve are typically six sided fully enclosed hoods with access panels/doors on at least one side. These ventilated enclosures are designed to contain and remove toxic (HPM) gases from the work area in the event of a gas piping failure or leak. Gas panel enclosure are typically of two types, those requiring no access while gas systems are charged, and those which must be opened during processing while gas systems are charged. There is also a distinct difference in control specifications for those with pyrophorics vs. other HPM's

A4-5.1 Design Recommendations:

A4-5.1.1.Compartmentalize potential leak points.

A4-5.1.2.Minimize the total size of the panel and its enclosure.

A4-5.1.3.Minimize size and number of openings

A4-5.1.4.Minimize Static Pressure of the enclosure ; control has been shown to be achievable with -0.05 to -0.1 " wg.

A4-5.1.5.Design for sweep, Minimize the number and size of openings. Seal unnecessary openings (e.g. seams, utility holes.)

A4-5.1.6.Where routine access doors are required:

- Make the access door as small as possible
- Place the openings to the enclosure in the access door to minimize air flow requirements.

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- Provide baffles behind the door to direct leaks away from the door and openings.
- Compartmentalize the enclosure so that access to one area does not affect air flow control in other areas.

A4-5.2 Control Specifications:

Exhaust volumes as low as 4 - 5 air changes per minute or less can be specified and meet the S2 criteria in section 8.4 if the design principles listed above are considered when designing tool and enclosure.

A4-5.2.1.Non-access enclosure, specify CFM and static pressure only.

A4-5.2.2.Access enclosure should also provide a minimum intake velocity of 125-300 fpm face velocity at the door when open.

A4-5.2.3.Pyrophoric enclosures must be designed to prevent pocketing. This can be achieved through providing 5 air changes per minute and verified through exhaust visualization techniques. Note: Certain jurisdictions may have additional requirements such as a minimum air flow velocity of at least 200 fpm around valves and fittings.

A4-5.3 Recommended Measurement/Validation Method:

A4-5.3.1.Preferred validation by tracer gas testing, SEMI F15.

A4-5.3.2.Additional confirmation by visualization check of air flow, mixing and sweep using smoke or vapor testing.

A4-5.3.3.Measurement of average face velocity at the door or inlet. Measurements taken with a Velometer or anemometer. For larger openings multiple measurements are taken in a grid, at least 1-4 per square foot of open area

A4-7 EQUIPMENT EXHAUST VENTILATION SPECIFICATIONS AND MEASUREMENTS

A4-7.1.Specifications for tool exhaust should be provided by the supplier and define:

A5-7.1.1.The control specification or standard for the hood or enclosure, i.e., face velocity or capture velocity if applicable.

A5-7.1.2.The CFM in the duct required to maintain the control volume or flow required. Measurements must be made using the ACGIH Pitot traverse method described below.

A5-7.1.3.The location where the Pitot traverse measurement in the duct was made.

A5-7.1.4.Static pressure requirements.

A4-8 DUCT TRAVERSE METHOD

Because the air flow in the cross-section of a duct is not uniform, it is necessary to obtain an average by measuring velocity pressure (VP) at points in a number of equal areas in the cross-section. The usual method is to make two traverses across the diameter of the duct at right angles to each other. Reading are taken at the center of annular rings of equal area. Whenever possible, the traverse should be made 7.5 duct diameters downstream and 3 diameters upstream from obstructions or directional changes such as an elbow, hood, branch entry, etc. Where measurements are made closer to disturbances, the results must be considered subject to some doubt and checked against a second location. If agreement within 10% of the two traverses is obtained, reasonable accuracy can be assumed and the average of the two readings used. Where the variation exceeds 10%, a third location should be selected and the two air flows in the best agreement averaged and used. The use of a single centerline reading for obtaining average velocity is a very course approximation and is NOT recommended. If a traverse cannot be done, then the centerline duct velocity should be multiplied by 0.9 for a coarse estimate of actual average duct velocity. Center line duct velocity can never be used <5 duct diameters from an elbow, junction, hood opening, or other source of turbulence.

For ducts 6" and smaller, at least 6 traverse points should be used. For round ducts larger than 6" diameter, at least 10 traverse points should be employed. For very large ducts with wide variation in velocity, 20 traverse points will increase the precision of the air flow measurement.

For square or rectangular ducts, the procedure is to divide the cross-section into a number of equal rectangular areas and measure the velocity pressure at the center of each. The number of readings should not be less than 16. Enough readings should be made so the greatest distance between centers is less than six inches.

The following data are required:

The area of the duct at the traverse location

Velocity pressure at each point in the traverse and/or average Velocity and number of points measured.

Temperature of the air stream at the time and location of the traverse.

The velocity pressure readings obtained are converted to velocities and the velocities (not the velocity pressures) are averaged. Some monitoring instruments conduct this averaging internal to the instrument.

Flow measurement taken at other than standard air temperatures should be corrected to standard conditions.

A4-9 REFERENCES FOR GOOD VENTILATION DESIGN PRINCIPLES AND PRACTICES

- **ACGIH**, *Industrial Ventilation Manual*, 22nd Edition 1995, 6500 Glenway Avenue, Bldg. D-7 Cincinnati, Ohio 45211, USA
- **ACGIH**, *Hazard Assessment and Control Technology in Semiconductor Manufacturing*, 1989, distributed by Lewis Publishers, Chelsea, Michigan.
- **ASHRAE Standard 110 -** *Method of Testing Performance of Laboratory Fume Hoods.* 1791 Tullie Circle, NE, Atlanta, GA 30329
- **ANSI/AIHA ,** Standard Z9.5-1992 Laboratory Ventilation
- **Burgess, Ellenbecker, Treitman,** *Ventilation for Control of the Work Environment*, John Wiley, NY, 1989
- **Burton, D.J.,** IVE, Inc., *Industrial Ventilation Workbook*, 3rd Edition, 1995, *Lab Ventilation Workbook*, 1994, *Semiconductor Exhaust Ventilation Guidebook*, 1995; 2974 South Oakwood, Bountiful, Utah 84010
- **NFPA 45**
- **SEMI S6-93** Safety Guideline for Ventilation
- **SEMI F15-93** Test Method for Enclosures Using Sulfur Hexafluoride Tracer Gas and Gas Chromatography
- **Williams, M.** and **D.G. Baldwin,** *Semiconductor Industrial Hygiene Handbook*, Noyes Publications, Park Ridge, NJ, 1995, ESBN 0-8155-1369-0

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SEMICONDUCTOR SECONDARY GAS PANEL ENCLOSURES - AN OVERVIEW OF GOOD VENTILATION DESIGN PRINCIPLES

By

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BACKGROUND

The Semiconductor industry uses many compressed gases in the manufacture of semiconductors. Many of these gases are defined by the National Fire Protection Association (NAPA) to be Hazardous Production Materials (HPM). Gases are considered HPMs if they have a 3 or 4 rating in Health, Flammability or Reactivity based on the NFPA 704 Standard System for the Identification of the Fire Hazards of Materials. Because a leak of these gases could result in serious injury or damage, stringent control measures are required to prevent and control accidental release.

Most HPM gases used in semiconductor manufacturing are stored in pressurized cylinders in a special room separated from the semiconductor processing area or “clean room”. The gases are delivered to the clean room in delivery lines typically pressurized from 20 to 40 psi. As a primary control measure, to prevent accidental release of the HPM gases, the delivery lines are required to be continuous and seamless. At any point where threaded fittings, valves, regulators and/or controllers are in line, secondary containment in ventilated enclosures is required to capture an accidental release and remove it from the work area.

Valves, regulators, controllers, and other potential leak points are generally plumbed together in close proximity to limit the number of locations requiring secondary containment. The ventilated secondary enclosures placed around the fittings are ventilated continuously. The exhaust criteria for these “secondary gas panel enclosures” have not been well defined in the literature. As a result, exhaust specifications developed by industry and/or provided by equipment suppliers usually far exceed what is minimally necessary to control a potential worst-case leak. The cost associated with treating and removing the large volumes of air specified for these secondary enclosures has become prohibitive.

This paper will review good design principles for secondary gas panel enclosures to ensure they can be cost efficient, while still effectively maintaining a worst-case leak when required. It has been shown through tracer gas testing that lower exhaust rates can be used safely if good design principles are followed. A well-designed enclosure can meet the requirements spelled out in SEMI S2-93, Safety Guidelines for Semiconductor Manufacturing equipment, while maintaining exhaust volume to a minimum.

BASIC DESIGN RULES:

A secondary gas panel enclosure is essentially a box with HPM gas piping running through it with an exhaust duct attached. Exhaust volumes as low as 4 - 5 air changes per minute or less can be specified if the following prioritized design principles are considered when designing the enclosure.

1. Compartmentalize potential leak points
2. Minimize size and number of openings
3. Maintain Static Pressure (≥ -0.1 "wg SP)
4. Design for sweep
5. Minimize total size

All of these principles are interrelated and in total can ensure the design of an effective but efficient gas panel enclosure. The enclosure design team should include both the enclosure designer and the gas piping layout designer because the size of the enclosure and location of exhaust outlets, baffles and exhaust inlets are dependent on the location and size of the piping being enclosed.

Compartmentalize potential leak points: One method to reduce the size of the enclosure is by designing the gas piping so that regulators, valves and other potential leak points are in close vicinity to each other. Do not design the piping without regard to

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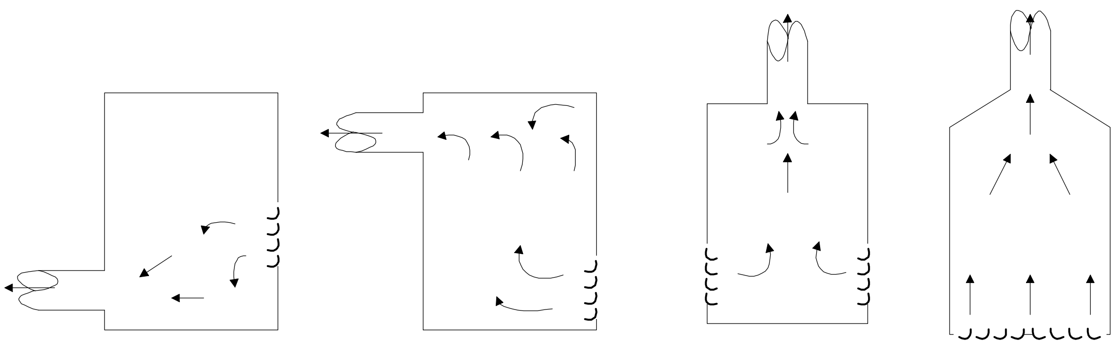
compartmentalization and then build a large cabinet around the entire process tool. Large cabinets ventilated in this manner will not maintain an HPM leak effectively at any reasonable exhaust level.

Minimize size and number of openings: To ensure sweep the air inlet openings must be strategically sized and located. All other openings should be sealed to prevent inadvertent inlet of make-up air. Openings where gas piping or electrical wiring penetrate the enclosure should be sealed with elastic grommets. Side panels should fit snug with minimum leakage. Permanent side panels should be sealed with an elastic caulk while removable panels should be provided with resilient sealing strips or gaskets. This is all intended to ensure the air flow into the enclosure comes from the designed inlet required for sweep, and not numerous locations throughout the enclosure.

Maintain Static Pressure: It has been found that if the size and number of openings are minimized and sized so that the enclosure's negative Static Pressure is maintained greater than or equal to a -0.1 inches water gauge the integrity of the enclosure will be maintained. As the static pressure approaches zero the opportunity for higher pressure gas releases inside the enclosure to escape increases, regardless of the exhaust volume on the enclosure. Enclosures with numerous and randomly located openings with no static pressure will not contain a worst-case HPM leak regardless of the exhaust volume. It is important to note that this is the enclosure static pressure and not the duct static pressure. To prevent inadvertent air inlets all side panels should be sealed closed and holes provided for piping and electrical should be sealed. Typical duct static pressures should range in the -0.5 to -1.5 "wg range.

Design for sweep: To reduce the potential for dead spots and pocketing, air must sweep through the enclosure from one end to the other. To ensure for good sweep the relative location of the air inlets and the exhaust duct must be considered. The inlets must be located so that the air stream passes through the entire enclosure. The exhaust duct opening should be as near the potential leak sources as possible and take into account the directionality of the potential leak. Distribution by baffles or splitter vanes may also improve sweep in larger enclosures. Tapered duct connections can also reduce static losses and the potential of generating turbulence.

DESIGN FOR SWEEP



Bad **Good** **Better** **Best**

Minimize total size: The smaller the box the less air is required. Remove all wasted space in the enclosure design. Allow for enough room to conduct any required maintenance while minimizing the overall size of the enclosure. Ensure that fitting and other leak points are not located close to inlet.

ACCESS VERSUS NON-ACCESS ENCLOSURES:

All of the criteria discussed above will work for enclosures that are normally closed. They assume that work and/or adjustments will not be made on the equipment inside the enclosure with the door open and the gas systems under pressure. If it is necessary to open an enclosure while gas systems are under pressure it will be necessary to provide enough exhaust volume when the door is open to ensure an average face velocity great enough to ensure control. For pyrophorics, the current Uniform Fire Code, requirements must be maintained. For other, non-pyrophoric HPM's, face velocities as low as 100 fpm may be appropriate if the directionality of the leak is not facing the door opening. However, the potential for failure is great with the door is open. The use of deflection barriers or compartmentalizing potential leak points away from door should be considered.

In order to achieve a substantial face velocity across an access door, additional design considerations must be met. The first consideration is to ask why access is necessary. If it is simply to adjust a manual valve, consider designing in an electronic controller that could be adjusted remotely. Another option would be to place a small hole in the enclosure so that an elongated tool could be used for adjustments or simply extend the valve handle through the enclosure so manual adjustment may be made from outside.

If access can not be designed out, the following criteria must be incorporated to ensure the effectiveness and efficiency of enclosures that must be accessed.

- Make the access door only as large as required for the work being conducted. If doors are much greater than one square foot in area it is difficult to establish the control velocities required without significant exhaust volume.

- Ensure directional leak points are not positioned toward the door, and/or provide guards/baffles between door and potential leak points so directional flow will be diverted.

- Compartmentalize the enclosure so that access to one area will not affect control in another.

- Distribution baffles or plenum in the back of the enclosure will provide for more even distribution at the door.

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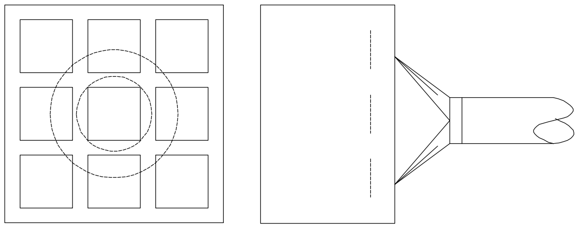
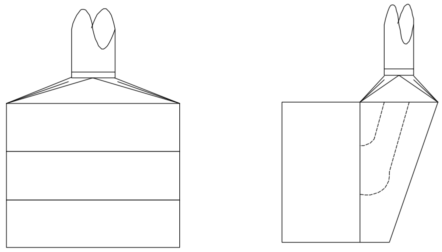
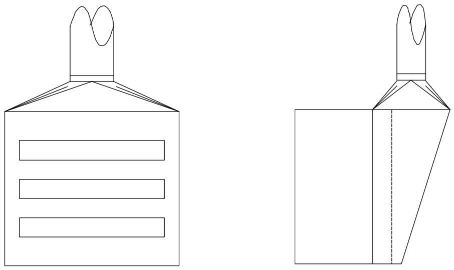
PROVIDE EVEN DISTRIBUTION FOR ACCESS ENCLOSURES



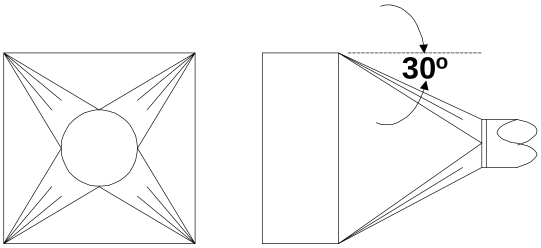
Distribution by Baffles



Distribution by Splitter Vanes



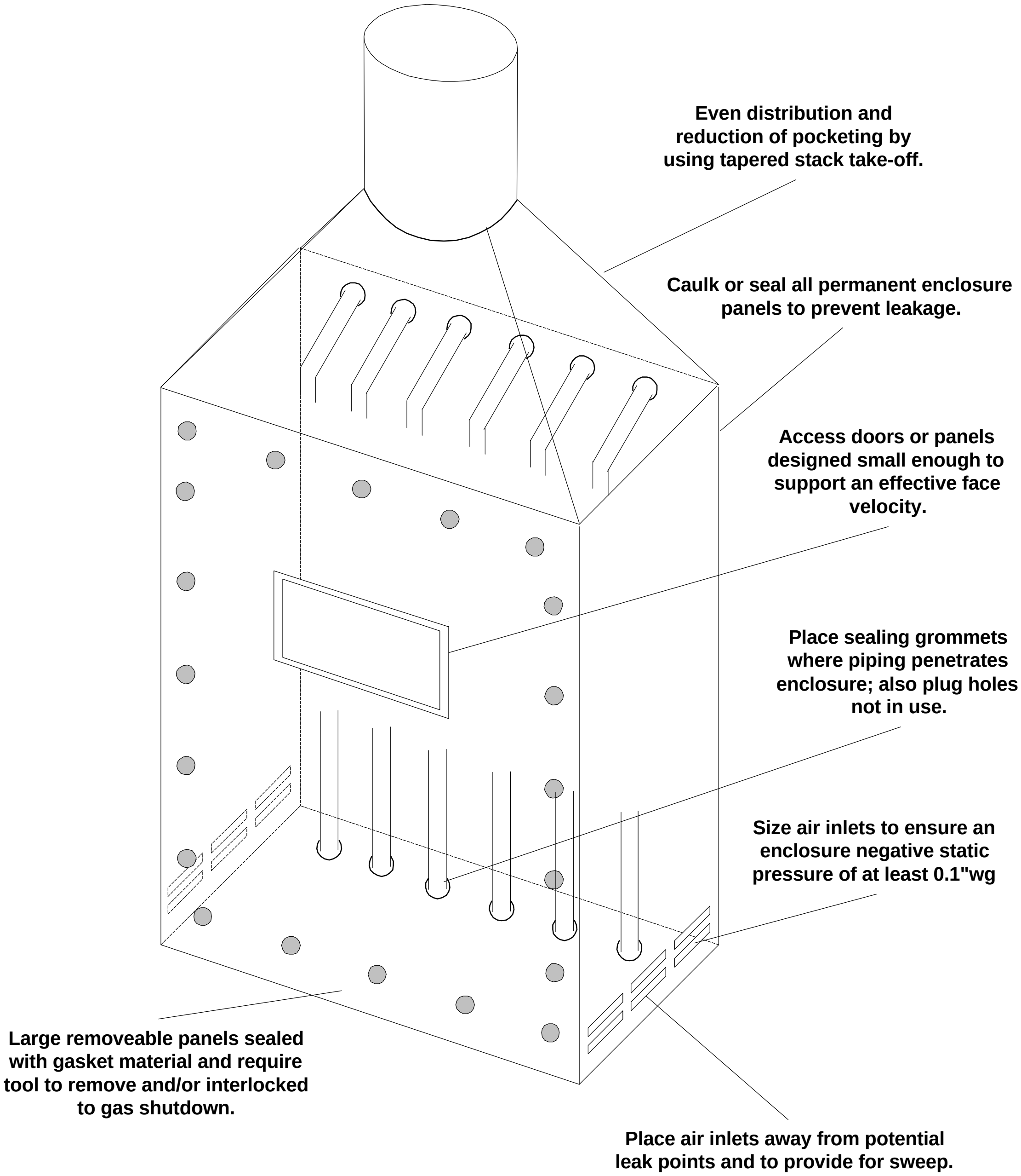
Distribution by Slot (or Baffles)



Distribution by Taper

CONCLUSION:

Today's business environment requires reducing energy cost associated with the manufacturer of semiconductors. This paper has provided a number of design principles for secondary gas panel enclosures to ensure they can be cost efficient, while still effectively maintaining a worst-case leak. A well-designed enclosure, as described, can meet the requirements spelled out in SEMI S2-93, Safety Guidelines for Semiconductor Manufacturing Equipment, while maintaining exhaust volume to a minimum. The following figure provides a pictorial example of how these principles can be designed into a typical secondary gas panel enclosure.



Secondary Gas Panel Enclosure