

SEMI S5-1121

SAFETY GUIDELINE FOR SIZING AND IDENTIFYING FLOW LIMITING DEVICES FOR GASES

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NOTICE: Conformance to the ‘should’ provisions of this Safety Guideline is necessary to declare conformance to this Document. Conformance to ‘may’, ‘suggested’, ‘preferred’, ‘recommended’, ‘NOTE’, or ‘Related Information’ provisions is not necessary to declare conformance.

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

NOTICE: The section symbol (§) is used to reference a numbered section, paragraph, or header and all subordinate paragraphs, headers, and embedded material (i.e., EXCEPTIONs, lists) therein. The paragraph symbol (§) is used to reference a particular numbered paragraph and embedded material therein. When duplicated (i.e., §§ and §§) the symbols are used to reference more than one section or paragraph, respectively.

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1 Purpose

1.1 The purpose of this Safety Guideline is to provide information and methods related to flow limiting devices (FLDs) that limit the rate of release of hazardous gases during transportation, storage, and use.

2 Scope

2.1 This Safety Guideline pertains to FLDs for hazardous gases. These devices are intended to limit the flow rate of uncontrolled releases of gases at or downstream of the FLDs.

NOTE 1: Generally, FLDs are not used for gases at gauge pressures less than 103 kPa (15 psig) because the size required to provide adequate flow for the process is so large that flow reduction resulting from the FLD would be minimal.

2.2 This Safety Guideline pertains to FLDs operating at critical flow rates that result from the ratio of the pressure upstream of the FLD to the pressure downstream of the FLD being at least the critical pressure ratio.

NOTE 2: For all gases with at least two atoms in each molecule, this ratio is less than two. For monatomic gases (He, Ar, Ne, Xe, Kr), it is 2.04 or 2.05. Related Information 1 contains a table of critical pressure ratios for several gases.

2.3 This Safety Guideline provides a method of identifying FLDs by size.

2.4 This Safety Guideline provides methods for calculating the approximate maximum and minimum flow rates of several gases, and their mixtures, through such devices.

2.5 This Safety Guideline provides a method for selecting the size FLD for an application, based on the gas and the needed flow.

NOTE 3: Specific safety guidance is contained in § 6.

NOTICE: SEMI Standards and Safety Guidelines do not purport to address all safety issues associated with their use. It is the responsibility of the users of the Documents to establish appropriate safety and health practices, and determine the applicability of regulatory or other limitations prior to use.

3 Limitations

3.1 This Safety Guideline does not pertain to gas releases caused by events upstream of an FLD, such as:

- failure of the cylinder or of the valve connection to the cylinder,
- actuation of the cylinder pressure relief device, or
- some failures of the cylinder valve.

3.2 This Safety Guideline does not pertain to FLDs at which the ratio of inlet pressure to outlet pressure is less than the critical pressure ratio.

NOTE 4: FLD manufacturers, gas suppliers, and other qualified personnel can provide assistance in determining FLD behavior for noncritical flow.

4 Referenced Standards and Documents

4.1 SEMI Standards and Safety Guidelines

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

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

SEMI S26 — Environmental, Health, and Safety Guideline for FPD Manufacturing Systems

4.2 NFPA Standard¹

NFPA 704 — Standard System for the Identification of the Hazards of Materials for Emergency Response

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

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5 Terminology

5.1 Abbreviations and Acronyms

5.1.1 *FLD* — flow limiting device

5.1.2 *SDS* — safety data sheet

5.1.3 *slm* — standard liters per minute [SEMI E56, SEMI E69, SEMI E77, SEMI F43, SEMI F70]

5.2 Definitions

5.2.1 *equivalent orifice* — a passage that will allow fluid flow equivalent to the fluid flow allowed by a round hole with an orifice coefficient of 80%.

5.2.2 *downstream, adj.* — on the side to which fluid flows.

5.2.3 *flow limiting device (FLD)* — a device that will reduce maximum flow rate under full flow conditions.

5.2.4 *flow rate* — the quantity of fluid passing a specified point per unit time. Flow rates in this Safety Guideline are given in standard liters per minute (slm) at the standard conditions of 0°C (32°F) and 101 kPa absolute (14.7 psia). This corresponds to the standard conditions used for calibration of mass flow controllers used in semiconductor processing systems.

5.2.5 *hazardous gases* — gases that have a degree of hazard rating in health, flammability, or reactivity of 3 or 4 in accordance with NFPA 704, or equivalent rating by a regional standard.

5.2.6 *mixing gas* — an inert gas used to dilute another gas.

5.2.7 *orifice coefficient* — the ratio of actual flow to the theoretical flow through an orifice.

NOTE 5: The orifice coefficient will typically vary from 65% (0.65) for a sharp entrance to 95% (0.95) for a well-rounded entrance. A flow rate tolerance of $\pm 20\%$ is used in Table 1 to allow for variations in the entrance geometry and passage size. Figure 1 illustrates the flow rate variation resulting from this tolerance for different equivalent orifice sizes.

5.2.8 *safety data sheet (SDS)* — document that describes a chemical's properties and hazards and provides appropriate safety precautions and protective measures for handling, storing, and transporting it.

NOTE 6: The specific requirements are stated in regulations. In most jurisdictions of interest, the regulations are consistent with the UN Globally Harmonized System of Classification and Labelling of Chemicals (GHS). GHS is available at <https://unece.org/about-ghs>

NOTE 7: 'Safety data sheet' has replaced the term 'materials safety data sheet'.

5.2.9 *size* — designation of an FLD, stated as the nominal internal diameter of an equivalent orifice.

NOTE 8: Table 2 lists several sizes and provides flow rates for several pressures.

5.2.10 *upstream, adj.* — on the side from which fluid flows.

6 Safety Guidance

6.1 General

6.1.1 *Verification and Identification* — When an FLD is required (e.g., ¶ 7.1.1), the user should always verify that the size is identified by tag, label, or marking and verify that:

- an FLD is installed,
- the FLD size is identified by tag, label, or marking, and
- the FLD size identified matches the requirement.

If a required FLD is missing or is not properly identified, the cylinder should not be installed and flow should not be permitted.

6.1.2 *Blockage* — Some hydrides, such as diborane (B_2H_6), can polymerize and cause partial or total obstruction of FLDs. Some hydrides, such as silane (SiH_4), can react with oxygen or water vapor in air to form liquids or solids. Some hydrides can exhibit both behaviors. Care should be taken with containers, piping, and devices that seem to be empty, but can contain product.

6.1.3 *Purging* — An FLD can restrict gas flow during purging. The user should assure that adequate purging methods are used to prevent plugging the flow limiting device.

NOTE 9: This is important to prevent contamination downstream of the FLD and reduce the probability of creating a risk of Medium, High, or Very High, as evaluated in accordance with SEMI S10.

6.2 Gas Cylinder Valves

6.2.1 *Installation* — Only the gas supplier or cylinder owner should install, remove, or otherwise service the FLD. Special equipment and procedures can be required to perform any installation or service operation safely. No person should install, remove, replace, clean, adjust, or otherwise alter the flow limiting device unless authorized by the cylinder owner.

6.2.2 *Verification* — If a required FLD is missing, the cylinder should not be used and the person who found that the FLD is missing should notify the gas supplier to install the required FLD or to replace the cylinder with one that has the required FLD.

6.2.3 *Purging* — As a minimum, the person changing a gas cylinder should ensure that the valve outlet of the cylinder that is to be removed has been purged after use and before disconnection, using the same procedure used for purging the valve outlet after installation of the cylinder.

7 FLD Criteria

7.1 *Where Used* — Table 1 lists hazardous gases for which devices are known to be feasible by reason of testing and experience. SEMI encourages testing by its members of hazardous gases not listed in Table 1 so that new information can be added.

7.1.1 FLDs should be installed or incorporated into cylinder valves that are used for gas cylinders containing the hazardous gases listed in Table 1.

Table 1 Hazardous Gases for Which FLDs Should be Used

Hazardous Gas	Standard Density (D), 1 atm., 0°C [kg/m ³] ([lbs/ft ³])	Cylinder Pressure (P _{cyl}) Typical Max. @ Room Temp. ^{#1} [kPa_gauge] ([psig])	Compressibility Factor (Z) @ Typ. Max. Cylinder Pressure ^{#2}	Compressibility Factor (z) @ 10% Typ. Max. Cylinder Pressure ^{#2}	Max. Flow Rate (q) for a 0.25 mm (0.01 in.) Equiv. Orifice [slm]
Arsine, AsH ₃	3.45 (0.216)	1,410 (205)	0.81	0.98	5.5
Carbon Monoxide, CO	1.250 (0.078)	11,385 (1,650)	0.97	1.0	63
Diborane, B ₂ H ₆	1.250 (0.078)	12,410 (1,800) (1% in N ₂)	0.29 @ 7,000 kPa (1,015 psi)	0.93 @ 700 kPa (103 psi)	68 (1% in N ₂)
Germane, GeH ₄	3.415 (0.213)	607 (88)	0.94	0.99	2.4
Hydrogen, H ₂	0.090 (0.0056)	15,180 (2,200)	1.03	1.0	303
Nitrogen Trifluoride, NF ₃	3.200 (0.199)	10,000 (1,450)	0.64	0.96	43
Phosphine, PH ₃	1.519 (0.095)	4,095 (594)	0.52	0.95	29
Silane, SiH ₄	1.433 (0.090)	8,280 (1,200)	0.36	0.94	70
Stibine, SbH ₃	1.444 (0.090)	---	---	---	---

#1 Cylinder pressures will vary, consult gas supplier to verify the actual cylinder pressure.

#2 Compressibility factors are interpolated from available data, consult gas supplier for alternate pressures.