NFPA® 318

Standard for the Protection of Semiconductor Fabrication Facilities

2009 Edition

NFPA, 1 Batterymarch Park, Quincy, MA 02169-7471
An International Codes and Standards Organization

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NFPA® 318

Standard for the

Protection of Semiconductor Fabrication Facilities

2009 Edition

This edition of NFPA 318, *Standard for the Protection of Semiconductor Fabrication Facilities*, was prepared by the Technical Committee on Cleanrooms and acted on by NFPA at its June Association Technical Meeting held June 2–5, 2008, in Las Vegas, NV. It was issued by the Standards Council on July 24, 2008, with an effective date of October 10, 2008, and supersedes all previous editions.

This edition of NFPA 318 was approved as an American National Standard on October 10, 2008.

Origin and Development of NFPA 318

The Committee on Cleanrooms was formed in 1988 and held its first meeting during May of that year. The Committee was organized into chapter subcommittees that separately prepared individual chapters and related appendix material for review by the full committee at meetings held October 1988, March 1989, September 1989, March 1990, September 1990, and June 1991.

The standard was submitted and adopted at the Fall Meeting in Montreal in 1991. The 1992 edition was the first edition of this standard.

The standard was revised in 1995.

The 1998 and 2000 editions were partial revisions of the standard.

The 2002 edition of this standard incorporated Article 51 of NFPA 1, *Uniform Fire Code,* and was reformatted to comply with the *Manual of Style for NFPA Technical Committee Documents*.

The 2006 edition contained a new chapter addressing quantity limits for hazardous materials following coordination of this information with *NFPA 5000, Building Construction and Safety Code*.

The 2009 edition clarifies the requirements for both Type 1 and Type 2 subatmospheric gas systems. Revisions also include the removal of seismic considerations, in order to focus the scope of the document.

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This list represents the membership at the time the Committee was balloted on the final text of this edition. Since that time, changes in the membership may have occurred. A key to classifications is found at the back of the document.

NOTE: Membership on a committee shall not in and of itself constitute an endorsement of the Association or any document developed by the committee on which the member serves.

Committee Scope: This Committee shall have primary responsibility for documents on fire protection for cleanrooms (now semiconductor manufacturing facilities). When bulk gas systems are involved the responsibility begins at a point downstream of the source valve.

Contents

NFPA 318

Standard for the

Protection of Semiconductor Fabrication Facilities

2009 Edition

NOTICE: An asterisk (*) following the number or letter designating a paragraph indicates that explanatory material on the paragraph can be found in Annex A.

Changes other than editorial are indicated by a vertical rule beside the paragraph, table, or figure in which the change occurred. These rules are included as an aid to the user in identifying changes from the previous edition. Where one or more complete paragraphs have been deleted, the deletion is indicated by a bullet (•) between the paragraphs that remain.

A reference in brackets [ ] following a section or paragraph indicates material that has been extracted from another NFPA document. As an aid to the user, the complete title and edition of the source documents for extracts in mandatory sections of the document are given in Chapter 2 and those for extracts in informational sections are given in Annex D. Extracted text may be edited for consistency and style and may include the revision of internal paragraph references and other references as appropriate. Requests for interpretations or revisions of extracted text shall be sent to the technical committee responsible for the source document.

Information on referenced publications can be found in Chapter 2 and Annex D.

Chapter 1 Administration

1.1 Scope. This standard applies to semiconductor fabrication facilities and comparable fabrication processes, including research and development areas in which hazardous chemicals are used, stored, and handled and containing what is herein defined as a cleanroom or clean zone, or both.

1.2* Purpose. This standard is intended to provide reasonable safeguards for the protection of facilities containing cleanrooms from fire and related hazards. These safeguards are intended to provide protection against injury, loss of life, and property damage.

1.3 Retroactivity. The provisions of this standard reflect a consensus of what is necessary to provide an acceptable degree of protection from the hazards addressed in this standard at the time the standard was issued.

1.3.1 Unless otherwise specified, the provisions of this standard shall not apply to facilities, equipment, structures, or installations that existed or were approved for construction or installation prior to the effective date of the standard. Where specified, the provisions of this standard shall be retroactive.

1.3.2 In those cases where the authority having jurisdiction determines that the existing situation presents an unacceptable degree of risk, the authority having jurisdiction shall be permitted to apply retroactively any portions of this standard deemed appropriate.

1.3.3 The retroactive requirements of this standard shall be permitted to be modified if their application clearly would be impractical in the judgment of the authority having jurisdiction, and only where it is clearly evident that a reasonable degree of safety is provided.

1.4 Equivalency. Nothing in this standard is intended to prevent the use of systems, methods, or devices of equivalent or superior quality, strength, fire resistance, effectiveness, durability, and safety over those prescribed by this standard.

1.4.1 Technical documentation shall be submitted to the authority having jurisdiction to demonstrate equivalency.

1.4.2 The system, method, or device shall be approved for the intended purpose by the authority having jurisdiction.

1.4.3* Alternative systems, methods, or devices approved as equivalent by the authority having jurisdiction shall be recognized as being in compliance with this standard.

1.5* Units. Metric units of measurement in this standard are in accordance with the modernized metric system known as the International System of Units (SI). The liter unit, which is not part of but is recognized by SI, is commonly used in international fire protection. Conversion factors for SI units are found in Table 1.5.

Table 1.5 SI Units of Measure

Name of Unit	Unit Symbol	Conversion Factor
millimeter	mm	1 in. = 25.4 mm
meter	m	1 ft = 0.3048 m
square meter	m^2	1 ft^2 = 0.093 m^2
kilopascal	kPa	1 psi = 6.895 kPa
liter	L	1 gal = 3.785 L
liter/minute	L/min	1 gal/min = 3.785 L/min 1 ft^3/min = 28.3 L/min
liter/minute/ square meter	L/min·m^2	1 gal/min·ft^2 = 40.746 L/min·m^2 (mm/min)
liter/second/ square meter	L/s·m^2	1 ft^3/min·ft^2 = 0.044 L/s·m^2

Chapter 2 Referenced Publications

2.1 General. The documents or portions thereof listed in this chapter are referenced within this standard and shall be considered part of the requirements of this document.

2.2 NFPA Publications. National Fire Protection Association, 1 Batterymarch Park, Quincy, MA 02169-7471.

NFPA 1, *Fire Code,* 2009 edition.

NFPA 13, *Standard for the Installation of Sprinkler Systems,* 2007 edition.

NFPA 30, *Flammable and Combustible Liquids Code,* 2008 edition.

NFPA 33, *Standard for Spray Application Using Flammable or Combustible Materials,* 2007 edition.

NFPA 70®, *National Electrical Code®*, 2008 edition.
NFPA 72®, *National Fire Alarm Code®*, 2007 edition.
NFPA 79, *Electrical Standard for Industrial Machinery,* 2007 edition.
NFPA *101®*, *Life Safety Code®,* 2009 edition.
NFPA 385, *Standard for Tank Vehicles for Flammable and Combustible Liquids,* 2007 edition.
NFPA 430, *Code for the Storage of Liquid and Solid Oxidizers,* 2004 edition.
NFPA 432, *Code for the Storage of Organic Peroxide Formulations,* 2002 edition.
NFPA 704, *Standard System for the Identification of the Hazards of Materials for Emergency Response,* 2007 edition.
NFPA 5000®, *Building Construction and Safety Code®*, 2009 edition.

2.3 Other Publications.

2.3.1 ASME Publications. American Society of Mechanical Engineers, Three Park Avenue, New York, NY 10016-5990.

ASME B31.3, *Process Piping*, 2004.

2.3.2 ASTM Publications. ASTM International, 100 Barr Harbor Drive, P.O. Box C700, West Conshohocken, PA 19428-2959.

ASTM D 5, *Standard Test Method for Penetration of Bituminous Materials*, 2005.

ASTM D 323, *Standard Test Method for Vapor Pressure of Petroleum Products*, 2001.

ASTM E 84, *Standard Test Method for Surface Burning Characteristics of Building Materials*, 2005.

ASTM E 136, *Standard Test Method for Behavior of Materials in a Vertical Tube Furnace at 750°C*, 2004.

2.3.3 ISO Publications. International Organization for Standardization, 1, ch. de la Voie-Creuse, Case postale 56, CH-1211 Geneva 20, Switzerland.

ISO 14644-1, *Cleanrooms and Associated Controlled Environments — Part 1: Classification of Air Cleanliness*, 1999.

2.3.4 SEMI Publications. Semiconductor Equipment and Materials International, 3081 Zanker Road, San Jose, CA 95134.

SEMI F1, *Specification for Leak Integrity of High-Purity Gas Piping Systems and Components*, 1996.

2.3.5 ANSI/UL Publications. Underwriters Laboratories Inc., 333 Pfingsten Road, Northbrook, IL 60062-2096.

ANSI/UL 723, *Standard for Test for Surface Burning Characteristics of Building Materials*, 2003.

ANSI/UL 900, *Standard for Air Filter Units*, 2004.

2.3.6 U.S. Government Publications. U.S. Government Printing Office, Washington, DC 20402.

Title 29, Code of Federal Regulations, Part 1910.1000, "Air Contaminants."

2.3.7 Other Publications.

Merriam-Webster's Collegiate Dictionary, 11th edition, Merriam-Webster, Inc., Springfield, MA, 2003.

2.4 References for Extracts in Mandatory Sections.
NFPA 69, *Standard on Explosion Prevention Systems,* 2008 edition.
NFPA *101®*, *Life Safety Code®*, 2009 edition.
NFPA 1670, *Standard on Operations and Training for Technical Search and Rescue Incidents,* 2004 edition.
NFPA 5000®, *Building Construction and Safety Code®,* 2009 edition.

Chapter 3 Definitions

3.1 General. The definitions contained in this chapter shall apply to the terms used in this standard. Where terms are not defined in this chapter or within another chapter, they shall be defined using their ordinarily accepted meanings within the context in which they are used. *Merriam-Webster's Collegiate Dictionary*, 11th edition, shall be the source for the ordinarily accepted meaning.

3.2 NFPA Official Definitions.

3.2.1* Approved. Acceptable to the authority having jurisdiction.

3.2.2* Authority Having Jurisdiction (AHJ). An organization, office, or individual responsible for enforcing the requirements of a code or standard, or for approving equipment, materials, an installation, or a procedure.

3.2.3* Listed. Equipment, materials, or services included in a list published by an organization that is acceptable to the authority having jurisdiction and concerned with evaluation of products or services, that maintains periodic inspection of production of listed equipment or materials or periodic evaluation of services, and whose listing states that either the equipment, material, or service meets appropriate designated standards or has been tested and found suitable for a specified purpose.

3.2.4 Shall. Indicates a mandatory requirement.

3.2.5 Should. Indicates a recommendation or that which is advised but not required.

3.2.6 Standard. A document, the main text of which contains only mandatory provisions using the word "shall" to indicate requirements and which is in a form generally suitable for mandatory reference by another standard or code or for adoption into law. Nonmandatory provisions shall be located in an appendix or annex, footnote, or fine-print note and are not to be considered a part of the requirements of a standard.

3.3 General Definitions.

3.3.1 Clean Zone. A defined space in which the concentration of airborne particles is controlled to specified limits.

3.3.2 Cleanroom. A room in which the concentration of airborne particles is controlled to specified limits, including areas below the raised floor and above the ceiling grid if these areas are part of the air path and within the rated construction.

3.3.3 Compressed Gas. In semiconductor fabrication facilities, any material or mixture having, when in its container, an absolute pressure exceeding 276 kPa (40 psia) at 21°C (70°F) or, regardless of the pressure at 21°C (70°F), having an absolute pressure exceeding 717 kPa (104 psia) at 54.4°C (130°F) or any flammable liquid having an absolute vapor pressure exceeding 275.8 kPa at 37.8°C (40 psia at 100°F) as determined by ASTM D 323, *Standard Test Method for Vapor Pressure of Petroleum Products.*

3.3.4 Compressed Gas Container. A pressure vessel designed to hold compressed gases at pressures greater than 1 atmosphere at 68°F (20°C) that includes cylinders, containers, and tanks. [**5000,** 2009]

3.3.5 Exempt Amount per Control Area. The amount of hazardous material allowed to be stored, used, or handled in a control area as set forth in NFPA 1, *Fire Code*, and *NFPA 5000, Building Construction and Safety Code*. The exempt amount per control area is based on the material state (solid, liquid, or gas) and the material storage or use conditions.

3.3.6 Exhausted Enclosure. In semiconductor fabrication facilities, exhausted enclosures provide secondary containment for pieces of equipment, mechanical fittings, or valves, providing a means of local exhaust for capturing potential gases, fumes, vapors, and mists resulting from abnormal conditions.

3.3.7 Explosion. The bursting or rupture of an enclosure or a container due to the development of internal pressure from a deflagration. [**69,** 2008]

3.3.8 Fabrication Area (Fab Area). An area within a semiconductor fabrication facility and related research and development areas in which there are processes using hazardous production materials; such areas include cleanrooms, process equipment support areas, parts clean and ancillary rooms that are directly related to the fab area processes.

3.3.9 Flammable Vapors or Fumes. The concentration of flammable constituents in air that exceed 25 percent of their flammability limit.

3.3.10 Gas Cabinet. A fully enclosed, noncombustible enclosure used to provide an isolated environment for compressed gas cylinders in storage or use. Doors and access ports for exchanging cylinders and accessing pressure-regulating controls are allowed to be included.

3.3.11* Hazardous Chemical. In semiconductor fabrication facilities, any solid, liquid, or gas that has a degree-of-hazard rating in health, flammability, or reactivity of Class 3 or 4 as ranked by NFPA 704, *Standard System for the Identification of the Hazards of Materials for Emergency Response*.

3.3.12 Immediately Dangerous to Life or Health (IDLH). Any condition that would pose an immediate or delayed threat to life, cause irreversible adverse health effects, or interfere with an individual's ability to escape unaided from a hazardous environment. [**1670,** 2004]

3.3.13 Incompatible Materials. Materials that, when making contact with each other in an upset condition, can react in a manner that generates heat, fumes, gases, or by-products that could cause damage to life or property.

3.3.14 Interface. That place at which independent systems meet and act on or communicate with each other.

3.3.15 Interlock. A device, or an arrangement of devices, in which the operation of one part or one mechanism of the device or arrangement controls the operation of another part of another mechanism.

3.3.16 Limit.

3.3.16.1 *Ceiling Limit.* The maximum concentration of an airborne contaminant to which one can be exposed; the ceiling limits used are those published in 29 CFR 1910.1000.

3.3.16.2* *Permissible Exposure Limit (PEL).* The maximum permitted 8-hour, time-weighted average concentration of an airborne contaminant. [**5000,** 2009]

3.3.17 Liquid. A material that has a fluidity greater than that of 300 penetration asphalt when tested in accordance with ASTM D 5, *Standard Test Method for Penetration of Bituminous Materials*. Unless otherwise specified, the term *liquid* includes both flammable and combustible liquids.

3.3.17.1 *Combustible Liquid.* A liquid that has a closed-cup flash point at or above 37.8°C (100°F).

3.3.17.2 *Flammable Liquid.* A liquid that has a closed-cup flash point that is below 37.8°C (100°F) and a maximum vapor pressure of 2068 mm Hg (absolute pressure of 40 psi) at 37.8°C (100°F).

3.3.18 Noncombustible. In semiconductor fabrication facilities, a material that, in the form in which it is used and under the conditions anticipated, will not ignite, burn, support combustion, or release flammable vapors when subjected to fire or heat. Materials that are reported as passing ASTM E 136, *Standard Test Method for Behavior of Materials in a Vertical Tube Furnace at 750°C*, shall be considered noncombustible materials.

3.3.19 Normal Temperature and Pressure (NTP). A temperature of 21.1°C (70°F) and a pressure of 1 atmosphere [101.3 kPa (14.7 psia)]. [**5000,** 2009]

3.3.20 Pass-Through. An enclosure, installed in a wall and with a door on each side, that allows chemicals, production materials, equipment, and parts to be transferred from one side of the wall to the other.

3.3.21 Pyrophoric. A chemical with an autoignition temperature in air at or below 54.4°C (130°F).

3.3.22 Restricted-Flow Orifice (RFO). A device located in the gas cylinder valve body that restricts the maximum flow rate to 30 L/min (1.06 ft^3/min).

3.3.23 Room.

3.3.23.1 *Gas Room.* A separately ventilated, fully enclosed room in which only compressed gases and associated equipment and supplies are stored or used.

3.3.23.2 *Hazardous Chemical Storage and Dispensing Room.* A room used in conjunction with or serving a fabrication area where hazardous chemicals are stored, used, or transferred from vessels in the room through piping systems to a fabrication area.

3.3.24 Semiconductor Fabrication Facility. Buildings or portions thereof used for the fabrication of semiconductors and related research containing quantities of hazardous materials exceeding the maximum allowable quantities of Level 5 contents permitted in control area.

3.3.25 Service Corridor. A fully enclosed passage used for transporting HPM and for purposes other than required means of egress. [**5000,** 2009]

3.3.26 Smoke. The airborne solid and liquid particulates and gases evolved when a material undergoes pyrolysis or combustion, together with the quantity of air that is entrained or otherwise mixed into the mass.

3.3.27 Standby Mode. A mode wherein all flow of flammable gas or liquid ceases and heaters have power removed.

3.3.28 System.

3.3.28.1 ***Access Floor System.*** An assembly consisting of panels mounted on pedestals to provide an under-floor space for the installations of mechanical, electrical communication, or similar systems or to serve as an air supply or return-air plenum.

3.3.28.2 ***Compressed Gas System.*** An assembly of equipment designed to contain, distribute, or transport compressed gases.

3.3.28.3 ***Continuous Gas Detection System.*** A gas detection system where the instrument is maintained in continuous operation and the interval between sampling of any point does not exceed 30 minutes. [**5000,** 2009]

3.3.28.4 ***Emergency Alarm System.*** A system to provide indication and warning of emergency situations involving hazardous materials and to summon appropriate aid.

3.3.28.5 ***Subatmospheric Gas Systems (SAGS).***

3.3.28.5.1 ***Subatmospheric Gas Storage and Delivery System (Type 1 SAGS).*** A gas source package that stores and delivers gas at subatmospheric pressure and includes a container (e.g., gas cylinder and outlet valve) that stores and delivers gas at a pressure of less than 14.7 psia at NTP.

3.3.28.5.2 ***Subatmospheric Gas Delivery System (Type 2 SAGS).*** A gas source package that stores compressed gas and delivers gas subatmospherically and includes a container (e.g., gas cylinder and outlet valve) that stores gas at a pressure greater than 14.7 psia at NTP and delivers gas at a pressure of less than 14.7 psia at NTP.

3.3.29 Third Party. A professional, qualified as the result of training, education, and experience, who can perform a compliance and hazardous analysis of process equipment in accordance with this standard.

3.3.30 Tool. Any device, storage cabinet, workstation, or process machine used in the cleanroom.

3.3.31* Workstation. A defined space or an independent, principal piece of equipment using hazardous chemicals within a cleanroom or clean zone, where a specific function, a laboratory procedure, or a research activity occurs.

Chapter 4 Fire Protection

4.1 Automatic Fire-Extinguishing Systems.

4.1.1* General. Wet pipe automatic sprinkler protection shall be provided throughout facilities containing cleanrooms and clean zones.

4.1.2 Automatic Sprinkler Systems.

4.1.2.1* Automatic sprinklers for cleanrooms or clean zones shall be installed in accordance with NFPA 13, *Standard for the Installation of Sprinkler Systems*, and shall be hydraulically designed for a density of 8.15 L/min·m^2 (0.20 gpm/ft^2) over a design area of 278.8 m^2 (3000 ft^2).

4.1.2.2* Approved quick-response sprinklers shall be utilized for sprinkler installations within down-flow airstreams in cleanrooms and clean zones.

4.1.2.3* Gas Cabinets.

4.1.2.3.1 Sprinklers shall be installed in gas cabinets that contain hazardous chemical flammable gases.

4.1.2.3.2 Sprinklers shall not be required in gas cabinets located in a hazardous chemical room or gas room, other than in those cabinets containing pyrophoric gases.

4.1.2.4* Automatic quick-response sprinklers or a deluge system shall be provided in the proximity of and directed at individual silane cylinders in silane-dispensing areas, as described in Sections 8.4 and 8.5.

4.1.2.4.1 Where the open dispensing system is in accordance with Sections 8.4 and 8.5 and Chapter 9, and designed to mitigate the effects of detonation, the automatic deluge water spray system shall not be required.

4.1.2.5 Automatic sprinkler protection shall be designed and installed in the plenum and interstitial space above cleanrooms in accordance with NFPA 13, *Standard for the Installation of Sprinkler Systems*, for a density of 8.15 L/min·m^2 (0.20 gpm/ft^2) over a design area of 278.8 m^2 (3000 ft^2).

4.1.2.5.1* Automatic sprinklers shall be permitted to be omitted if the construction and occupancy of these spaces are noncombustible.

4.1.2.6 Exhaust Ducts. Interior automatic sprinklers shall be provided in exhaust ducts conveying vapors, fumes, or mists generated by hazardous chemicals as follows:

(1) Automatic sprinklers shall be provided in metallic and noncombustible, nonmetallic exhaust ducts when all of the following conditions are present:
   (a)*Largest interior cross-sectional area is equal to or greater than 0.048 m^2 (75 in.^{2}).
   (b) Ducts are located within the building.
   (c) Ducts are conveying flammable vapors or fumes.
(2) Automatic sprinklers shall be provided in combustible nonmetallic exhaust ducts when the largest interior cross-sectional area is equal to or greater than 0.048 m^2 (75 in.^{2}).

4.1.2.6.1 Internal sprinklers shall not be required where ducts are approved for use without internal automatic sprinklers.

4.1.2.6.2 Sprinklers installed in duct systems shall be hydraulically designed to provide 1.9 L/min (0.5 gpm) over an area derived by multiplying the distance between the sprinklers in a horizontal duct by the width of the duct.

4.1.2.6.2.1* Minimum discharge shall be 76 L/min (20 gpm) per sprinkler from the five hydraulically most remote sprinklers.

4.1.2.6.2.2 Sprinklers shall be spaced a maximum of 6.1 m (20 ft) apart horizontally and 3.7 m (12 ft) apart vertically.

4.1.2.6.3 A separate indicating control valve shall be provided for sprinklers installed in ductwork.

4.1.2.6.4* Drainage shall be provided to remove all sprinkler water discharged in ductwork.

4.1.2.6.5 Where corrosive atmospheres exist, duct sprinklers and pipe fittings shall be manufactured of corrosion-resistant materials or coated with approved materials.

4.1.2.6.6 The sprinklers shall be accessible for periodic inspection and maintenance.

4.1.2.6.7* Where the branch exhaust ductwork is constructed of combustible material, automatic sprinkler protection shall be provided within the workstation transition piece or the branch exhaust duct.

4.1.2.6.8 Where the branch exhaust ductwork is subject to combustible residue buildup, regardless of the material of construction, automatic sprinkler protection shall be provided.

4.1.2.7* Automatic sprinklers shall be provided in pass-throughs used to convey combustible chemicals.

4.2 Alarm Systems.

4.2.1 The discharge of an automatic fire suppression system shall activate an audible fire alarm system on the premises and an audible or visual alarm at a constantly attended location.

4.2.2 Signal transmission for alarms designed to activate signals at more than one location shall be verified at each location during each test of the alarm system.

4.2.3 Manual Fire Alarm System.

4.2.3.1 A manual fire alarm system shall be installed throughout buildings containing fabrication areas.

4.2.3.2 Activation of the alarm system shall transmit a signal to the emergency control station.

4.2.3.3 Manual fire alarm systems shall be designed and installed in accordance with *NFPA 72, National Fire Alarm Code*.

4.3 Detection Systems.

4.3.1* A listed or approved smoke detection system shall be provided in the cleanroom return airstream at a point before dilution from makeup air occurs.

4.3.2* Smoke detection within a cleanroom air system shall result in an alarm transmission to a constantly attended location as well as a local alarm signal within the cleanroom that is distinctive from both the facility evacuation alarm signal and any process equipment alarm signals in the cleanroom.

4.3.3 Optical flame detectors that will respond to the flame signature of silane shall be provided at silane gas cylinders in the open dispensing systems described in Section 8.4. Activation of detectors shall result in the closing of the cylinder automatic shutoff valves described in 8.1.2.

4.3.4* Where the potential exists for flammable gas concentrations to exceed 25 percent of the lower flammability limit (LFL), a continuous gas detection system shall be provided.

4.3.5 Listed or approved smoke detectors shall be provided at the exit of both the makeup and air-handling units.

Chapter 5 Ventilation and Exhaust Systems

5.1 Air Supply and Recirculation Systems.

5.1.1 The location of outside air intakes shall be chosen to avoid drawing in hazardous chemicals or products of combustion coming either from the building itself or from other structures and devices.

5.1.2* High-efficiency particulate air (HEPA) modules, ultralow penetration air (ULPA) filter modules, and pre- or final filters in makeup and recirculation air-handling units shall all meet a Class I rating as outlined in ANSI/UL 900, *Standard for Air Filter Units*.

5.1.2.1 ANSI/UL 900 Class II filters shall be acceptable in makeup air handlers (MAHs) and recirculating air handlers (RAHs), provided that there are listed or approved smoke detectors in the makeup and recirculation air handlers where Class II filters are used.

5.1.3 Air supply and recirculation ducts shall have a flame spread index of not more than 25 and a smoke-developed index of not more than 50 when tested in accordance with ASTM E 84, *Standard Test Method for Surface Burning Characteristics of Building Materials,* or ANSI/UL 723, *Standard for Test for Surface Burning Characteristics of Building Materials*.

5.1.4 A manually operated remote switch(es) to shut off the affected areas of the cleanroom air recirculation system(s) shall be provided at an approved location(s).

5.1.5 Testing.

5.1.5.1* Where automatic detection devices are used to shut down ventilation systems and/or control smoke, they shall be periodically tested.

5.1.5.2 To avoid contamination of the cleanroom, the detection and control components shall be permitted to be tested separately to simulate functional operation without affecting fan energy.

5.2 Local Hazardous Chemical Exhaust System.

5.2.1 Exhaust air discharged from cleanrooms shall not be recirculated.

5.2.1.1 Ducts shall lead to the outside as directly as practicable and shall discharge above the roof at a location, height, and velocity sufficient to prevent re-entry of hazardous chemicals.

5.2.1.2 A hazardous chemical exhaust system of a fabrication area shall not connect to nonhazardous exhaust systems.

5.2.2 Energy conservation devices that create a risk of returning contaminants to the cleanroom air supply shall not be used in exhaust systems.

5.2.3 Air containing hazardous chemicals shall be conveyed through duct systems that are maintained at a negative pressure relative to the pressure of normally occupied areas of the building.

5.2.3.1 The requirements of 5.2.3 shall not apply to ducts downstream of fans, scrubbers, and treatment devices.

5.2.4 Workstation exhaust ventilation shall be designed to capture and exhaust contaminants generated in the station.

5.3 Local Hazardous Chemical Exhaust System Construction.

5.3.1* Flexible connections, unless listed for fume exhaust and for use without internal automatic sprinkler protection, shall not be used in exhaust ductwork that is connected to combustible workstations or to workstations where combustible chemicals are used.

5.3.2 The entire exhaust duct system shall be self-contained.

5.3.2.1 No portions of the building shall be used as an integral part of the system.

5.3.3 Two or more operations shall not be connected to the same exhaust system when the combination of the substances removed might create a fire, an explosion, or a chemical reaction hazard within the duct system.

5.3.4 Exhaust ducts penetrating fire resistance–rated construction shall be contained in an enclosure of equivalent fire-resistive construction. Fire resistance construction and enclosure with equivalent fire-resistive construction shall extend 1.8 m (6 ft) or a distance equivalent to two times the duct diameter, whichever is greater, on either side of the rated construction.

5.3.5 Fire dampers shall not be installed in exhaust ducts.

5.3.6* Exhaust duct systems shall be constructed of noncombustible materials or protected with sprinklers in accordance with 4.1.2.6.

5.3.6.1 Ducts approved for use without automatic sprinklers shall not require sprinkler protection.

5.3.6.2 Carbon dioxide systems shall not be used to protect exhaust ducts.

5.3.7 The interior and exterior surface of nonmetallic exhaust ducts shall have a flame spread index of 25 or less, and the exterior surface of nonmetallic exhaust ducts shall have a smoke-developed index of 25 or less when the interior or exterior of the duct is exposed to fire, when tested in accordance with ASTM E 84, *Standard Test Method for Surface Burning Characteristics of Building Materials*, or ANSI/UL 723, *Standard for Test for Surface Burning Characteristics of Burning Materials*.

5.4 General Conditions.

5.4.1 Fabrication Areas and Cleanrooms. Mechanical exhaust ventilation shall be provided throughout a fabrication area or cleanroom at the rate of not less than 0.044 L/sec·m^2 (1 ft^3/min·ft^2) of floor area.

5.4.2 Workstations. Workstations shall be in accordance with Sections 5.2 and 5.3 of this standard.

5.4.3 Hazardous Chemical Rooms. Exhaust ventilation shall be provided in hazardous chemical rooms in accordance with NFPA 1, *Fire Code*.

5.4.4 Gas Cabinets. Exhaust ventilation shall be provided for gas cabinets in accordance with NFPA 1, *Fire Code*. For silane and silane mixes, also see 8.5.3(B) of this standard.

5.4.5 Exhausted Enclosures. Exhaust ventilation shall be provided for exhausted enclosures in accordance with NFPA 1, *Fire Code*.

5.4.6 Gas Rooms. Exhaust ventilation shall be provided in gas rooms in accordance with NFPA 1, *Fire Code*.

5.5 Hazardous Chemical Exhaust Duct Airflow and Dilution.

5.5.1* Airflow in cleanroom exhaust systems shall be designed to ensure dilution such that flammable vapors are not conveyed in the ducts.

5.5.2* To determine the presence of flammable vapors in ductwork, calculations shall be made at, but not prior to, the point where the process effluent enters ductwork with a cross-sectional area equal to or greater than 480 cm^2 (75 in.^{2}).

5.6 Hazardous Chemical Exhaust Controls.

5.6.1* The emergency power shall operate the exhaust system at not less than 50 percent capacity when it is demonstrated that the level of exhaust maintains a safe atmosphere.

5.6.2 Fire detection and alarm systems shall not be interlocked to shut down local exhaust fans automatically.

5.6.3 Exhaust dampers, where required for balancing or control of the exhaust system, shall be of the locking type.

Chapter 6 Construction

6.1 Classification of Occupancy. Semiconductor manufacturing facilities containing cleanrooms and associated support facilities shall be considered to be general or special purpose industrial occupancies as defined in NFPA *101*, *Life Safety Code*.

6.2* Noncombustible Construction Components. Cleanrooms rated ISO Class 5 or cleaner in accordance with ISO 14644-1, *Cleanrooms and Associated Controlled Environments — Part 1: Classification of Air Cleanliness*, or cleanrooms having clean zones rated ISO Class 5 or cleaner shall have approved, noncombustible components for walls, floors, ceilings, and partitions.

6.3 Fire Resistance Rating.

6.3.1 Fabrication areas shall be separated from each other by 1-hour fire resistance–rated construction.

6.3.2 Fabrication areas shall be separated from adjacent occupancies by not less than 1-hour fire resistance–rated construction and not less than the fire resistance rating required in *NFPA 5000*, *Building Construction and Safety Code*.

• **6.4* Electrical Classification.**

6.4.1 General. The fabrication area or cleanroom shall be considered unclassified electrically with respect to Article 500 of *NFPA 70*, *National Electrical Code*, where all of the following requirements are met:

(1) Chemical storage and handling meet the requirements of Chapter 7 of this standard.
(2) Ventilation and exhaust systems meet the requirements of Chapter 5 of this standard.
(3) The average air change is not less than 0.176 L/sec·m^2 (4 ft^3/min·ft^2) of floor area, and the number of air changes at any location is not less than 0.132 L/sec·m^2 (3 ft^3/min·ft^2) of floor area. The use of recirculated air shall be allowed.

6.4.2 Workstations. Workstations shall be in accordance with 10.3.2.

6.5 Emergency Power System. An emergency power system shall be provided for electrically operated equipment and connected control circuits for the following systems:

(1) Hazardous chemical exhaust ventilation systems
(2) Hazardous chemical gas cabinet ventilation systems
(3) Hazardous chemical exhausted enclosure ventilation systems
(4) Hazardous chemical gas room ventilation systems
(5) Hazardous chemical room ventilation systems
(6) Hazardous chemical gas-detection systems
(7) Emergency alarm systems
(8) Manual fire alarm systems
(9) Automatic fire sprinkler system monitoring and alarm systems
(10) Electrically operated systems required elsewhere in this standard, NFPA 1, *Fire Code*, or *NFPA 5000*, *Building Construction and Safety Code*, applicable to the use, storage, or handling of hazardous chemicals

6.6 Occupied Levels of Fabrication Areas. Occupied levels of fabrication areas shall be located at or above grade.

6.7 Pass-Throughs in Existing Exit Access Corridors.

6.7.1 Self-closing doors having a fire protection rating of not less than 1 hour shall separate pass-throughs from existing exit access corridors.

6.7.2 Pass-throughs shall be constructed as required for exit access corridors.

6.8 Fabrication Areas. Floors of fabrication areas separating fabrication areas from other uses shall be liquid-tight. [**5000**:34.3.7.2.1.4(B)]

6.9 Vertical Openings.

6.9.1 Openings through floors of fabrication areas shall be permitted to be unprotected, in accordance with 6.9.2, where the interconnected levels are used solely for mechanical equipment directly related to the fabrication areas. [**5000**:34.3.7.2.1.5]

6.9.1.1 Mechanical, duct, and piping penetrations within a fabrication area shall not extend through more than two floors. [**5000**:34.3.7..2.1.5(A)]

6.9.1.2 The annular space around equipment passing through the penetrations shall be sealed at the floor level to restrict the movement of air. [**5000**:34.3.7.2.1.5(B)]

6.9.1.3 The fabrication area, including levels interconnected with ductwork and piping, shall be regulated as a single conditioned environment. [**5000**:34.3.7.2.1.5(C)]

6.9.2 Unenclosed vertical openings not concealed within the building construction shall be permitted as follows:

(1) Such openings shall connect not more than two adjacent stories (one floor pierced only).
(2) Such openings shall be separated from unprotected vertical openings serving other floors by a barrier.
(3) Such openings shall be separated from corridors.
(4) Such openings shall not serve as a required means of egress. [**5000**:8.12.4.2]

Chapter 7 Chemical Storage and Handling

7.1* Hazardous Chemicals.

7.1.1 Storage and handling of hazardous chemicals shall comply with applicable NFPA standards, including the following:

(1) NFPA 30, *Flammable and Combustible Liquids Code*
(2) NFPA 33, *Standard for Spray Application Using Flammable or Combustible Materials*
(3) *NFPA 70, National Electrical Code*
(4) NFPA 385, *Standard for Tank Vehicles for Flammable and Combustible Liquids*
(5) NFPA 430, *Code for the Storage of Liquid and Solid Oxidizers*
(6) NFPA 432, *Code for the Storage of Organic Peroxide Formulations*

7.1.1.1 Hazardous chemical rooms and gas rooms shall be separated from the fabrication area by not less than 2-hour fire resistance–rated construction, with the fire resistance rating in accordance with *NFPA 5000, Building Construction and Safety Code*, Chapter 8.

7.1.1.2* Separation of Hazardous Chemicals. Hazardous chemicals stored in hazardous chemical rooms shall be separated from incompatible materials in accordance with Table 7.1.1.2.

7.1.2 Hazardous chemical storage and dispensing rooms shall have a drainage system to an approved location, or the room shall serve as secondary containment for a hazardous chemical spill and fire protection water for a period of 20 minutes.

7.1.3 Hazardous chemicals in the fabrication area shall be limited to those needed for operations and maintenance and as required by 7.1.3.1 and 7.1.3.2, with quantities not exceeding the limitations specified in Table 7.1.3. The limits of Table 7.1.3 shall be permitted to be exceeded, provided a submittal using alternate methods and materials is approved by the authority having jurisdiction (AHJ).

7.1.3.1 Quantities of hazardous chemicals shall be limited to those in use within the tool or the daily (24-hour) supply of chemicals needed, with quantities not exceeding the limitations specified in Table 7.1.3.1 unless a risk assessment determines that a significant fire is unlikely to take place.

7.1.3.1.1* The amounts in Table 7.1.3.1 shall be permitted to be exceeded if a risk assessment is performed and approved by the AHJ.

7.1.3.2 Storage of hazardous chemicals in the fabrication area shall be within approved or listed storage cabinets, gas cabinets, or exhausted enclosures, or within a tool.

7.1.4 Hazardous chemical storage and dispensing rooms shall have mechanical exhaust ventilation as follows:

(1) Mechanical exhaust ventilation shall be at a minimum rate of 0.31 $m^3/min{\cdot}m^2$ (1 $ft^3/min{\cdot}ft^2$) of floor area.
(2) Exhaust and inlet openings shall be arranged to prevent accumulation of vapors.

7.1.5 Incompatible Storage.

7.1.5.1 Hazardous chemicals shall be stored within enclosed storage cabinets or workstations.

7.1.5.1.1 Within hazardous materials storage or dispensing rooms, enclosures shall not be required.

7.1.5.2 Incompatible chemicals shall not be stored in the same cabinet.

7.1.5.3 Storage cabinets shall be constructed of not less than 1.2 mm (18 gauge) steel.

7.1.5.3.1 Doors shall be self-closing and shall be provided with a latching device.

7.1.6 Approved safety containers shall be used to store flammable liquids.

7.1.6.1 Where needed for purity, glass or plastic containers shall be permitted for quantities of 4 L (1 gal) or less per individual container.

7.1.7 Containers of chemicals shall be labeled to identify their contents.

7.1.8 Incompatible hazardous materials shall be separated from each other in accordance with NFPA 1, *Fire Code*.

7.2* Flammable and Combustible Liquid Delivery Systems.

7.2.1 Class I and Class II liquids shall not be piped to deliver by gravity from tanks, drums, barrels, or similar containers.

7.2.2 Dispensing devices for flammable and combustible liquids shall be of an approved type.

7.2.3 When pressurized systems are utilized, all materials used in the system shall be compatible with the chemicals being dispensed.

Table 7.1.1.2 Minimum Separation of Hazardous Production Materials (HPMs)

Material	Highly Toxic	Toxic	Acid	Base	Flammable	Oxidizer	Water-Reactive	Pyrophoric	Unstable (Reactive)	Organic Peroxide
Highly toxic		NR	1 hr	1 hr	1 hr	1 hr	1 hr	1 hr	1 hr	1 hr
Toxic	NR		S	S	S	S	S	S	S	S
Acid	1 hr	S		S	S*	S	S	S*	S	S
Base	1 hr	S	S		S	S	S	S	S	S
Flammable	1 hr	S	S*	S		S	R	S	S	S
Oxidizer	1 hr	S	S	S	S		S	S*	S	S
Water- reactive	1 hr	S	S	S	R	S		S	S	S
Pyrophoric	1 hr	S	S*	S	S	S*	S		S	S
Unstable (reactive)	1 hr	S	S	S	S	S	S	S		S
Organic peroxide	1 hr	S	S	S	S	S	S	S	S	

NR = Not required.
1 hr = 1-hour fire resistance–rated construction.
S = Separation by a partial noncombustible partition extending not less than 18 in. (457 mm) above and to the sides of the stored material.
R = Separate rooms, which are not required to have a fire resistance rating.
Note: HPM gases are required to be separated from HPM liquids and solids by 1-hour fire resistance–rated construction or are required to be kept in approved gas cabinets. HPM gases also are required to be separated from gases in other HPM hazard categories as required by Table 7.1.1.2, or are required to be kept in approved gas cabinets.
*Separation by not less than 20 ft (6 m) is permitted in lieu of a noncombustible partition.

Table 7.1.3 Quantity Limits for Hazardous Materials in a Single Fabrication Area

Hazard Category	Solids		Liquids		Gas	
	kg/m²	lb/ft²	L/m²	gal/ft²	m³ @ NTP/m²	ft³ @ NTP/ft²
Physical Hazard Materials						
Combustible liquid						
Class II			0.8	0.02		
Class III-A			1.6	0.04		
Class III-B			Not limited	Not limited		
Combination Class I, II, and III-A			3.26	0.08		
Cryogenic						
Flammable					Note c	Note c
Oxidizing					0.76	2.5
Flammable gas						
Gaseous					Note c	Note c
Liquefied					Note c	Note c
Flammable liquid						
Class I-A			2.04	0.05		
Class I-B			2.04	0.05		
Class I-C			2.04	0.05		
Combination Class I-A, I-B, and I-C			2.04	0.05		
Combination Class I, II, and III-A			3.26	0.08		
Flammable solid	0.032	0.002				

(continues)

Table 7.1.3 ***Continued***

Hazard Category	Solids		Liquids		Gas	
	kg/m^2	lb/ft^2	L/m^2	gal/ft^2	m^3 @ NTP/m^2	ft^3 @ NTP/ft^2
Organic peroxide						
Unclassified detonable	Note b	Note b	Note b	Note b		
Class I	Note b	Note b	Note b	Note b		
Class II	0.8	0.05	0.1	0.0025		
Class III	3.2	0.2	0.8	0.02		
Class IV	Not limited	Not limited	Not limited	Not limited		
Class V	Not limited	Not limited	Not limited	Not limited		
Oxidizing gas						
Gaseous					0.76	2.5
Liquefied					0.76	2.5
Combination of gaseous and liquefied					0.76	2.5
Oxidizer						
Class 4	Note b	Note b	Note b	Note b		
Class 3	0.096	0.006	2.44	0.06		
Class 2	0.096	0.006	2.44	0.06		
Class 1	0.096	0.006	2.44	0.06		
Combination oxidizer Class 1, 2, 3	0.096	0.006	2.44	0.06		
Pyrophoric	Note b	Note b	0.1	0.0025	Notes c and d	Notes c and d
Unstable reactive						
Class 4	Note b	Note b	Note b	Note b	Note b	Note b
Class 3	0.8	0.05	0.2	0.005	Note b	Note b
Class 2	3.2	0.2	0.8	0.02	Note b	Note b
Class 1	Not limited	Not limited	Not limited	Not limited	Not limited	Not limited
Water reactive						
Class 3	Note b	Note b	0.1	0.0025		
Class 2	8.0	0.5	2.04	0.05		
Class 1	Not limited	Not limited	Not limited	Not limited		
Health Hazard Materials						
Carcinogens	Not limited	Not limited	Not limited	Not limited	Not limited	Not limited
Corrosives	Not limited	Not limited	Not limited	Not limited	Not limited	Not limited
Highly toxics	Not limited	Not limited	Not limited	Not limited	Note c	Note c
Irritants	Not limited	Not limited	Not limited	Not limited	Not limited	Not limited
Sensitizers	Not limited	Not limited	Not limited	Not limited	Not limited	Not limited
Other health hazards	Not limited	Not limited	Not limited	Not limited	Not limited	Not limited
Toxics	Not limited	Not limited	Not limited	Not limited	Note c	Note c

[a] Hazardous materials within piping not to be included in the calculated quantities.
[b] Quantity of hazardous materials in a single fabrication not to exceed exempt amounts in NFPA 1, *Fire Code*.
[c] The aggregate quantity of flammable, pyrophoric, toxic, and highly toxic gases not to exceed 254.9 m^3 (9000 ft^3) at NTP.
[d] The aggregate quantity of pyrophoric gases in the building limited to the amounts for which detached storage is not required as set forth in NFPA 1, *Fire Code*.

7.2.4 Systems for point-of-use dispensing from pressurized canisters shall be equipped with the following safeguards:

(1) Automatic depressurization vents, vented to a safe location, in case of fire
(2) Manual vents, to allow for the removal of canisters vented to a safe location
(3) Manual shutoff valves at the point of use
(4) The use of inert gas only

7.2.5 Only inert gas shall be used for pressurization of gas-over-liquid delivery systems.

7.2.6 Pressurized delivery systems for flammable or combustible liquids shall be hydrostatically tested to 150 percent of the working pressure for 2 hours with no visible leakage or loss of pressure.

7.2.6.1 An inert gas shall be permitted to be used to pressure test systems in which water or water residue would be damaging or cost-restrictive.

7.2.7 All wetted parts in pressurized delivery systems for flammable liquids shall be constructed of a metal with a melting point above 1093.3°C (2000°F).

7.2.7.1 Flammable liquids shall be permitted to be conveyed in nonmetallic tubing provided the tubing is directly contained in a metal enclosure with a melting point above 1093.3°C (2000°F).

Table 7.1.3.1 Maximum Quantities of Hazardous Chemicals at a Workstation

Hazardous Chemical	State	Maximum Amount
Flammables, highly toxics, and pyrophorics and toxics combined[a]	Gas	3 cylinders
Hazardous chemical flammables	Liquid	56.8 L (15 gal)[b, c]
	Solid	2.3 kg (5 lb)[b, c]
Corrosives[a]	Gas	3 cylinders
	Liquid	378.5 L (100 gal)[b, c]
	Solid	9.1 kg (20 lb)
Highly toxics	Liquid	56.8 L (15 gal)[b]
	Solid	2.3 kg (5 lb)[b]
Oxidizers[a]	Gas	3 cylinders
	Liquid	45.4 L (12 gal)[b, c]
	Solid	9.1 kg (20 lb)[b, c]
Pyrophorics	Liquid	1.9 L (0.5 gal)[d]
Toxics	Liquid	56.8 L (15 gal)[b, c]
	Solid	2.3 kg (5 lb)[b, c]
Unstable reactives Class 3	Liquid	1.9 L (0.5 gal)[b, c]
	Solid	2.3 kg (5 lb)[b, c]
Water reactives Class 3	Liquid	1.9 L (0.5 gal)[d]

[a] Combined aggregate volume of all cylinders at a workstation not to exceed an internal cylinder volume of 150 L (39.6 gal, or 5.29 ft^3).
[b] Allowable quantities increased 100 percent for use-closed systems operations. When note c also applies, the increase for both requirements are allowed.
[c] Allowable quantities are allowed to be increased 100 percent when tools are constructed of materials that are listed or approved for use without internal fire extinguishing or suppression or internally protected with an approved automatic fire-extinguishing or suppression system. When note b also applies, the increase for both notes are allowed.
[d] Only in tools that are internally protected with an approved automatic fire-extinguishing or fire protection system compatible with the reactivity of materials in use at the workstation.

7.2.8 Delivery pressure at the tool shall not exceed 103 kPa (15 psi).

7.2.9 Bulk Delivery Systems.

7.2.9.1 Bulk delivery systems shall be equipped with the following safeguards:

(1) Excess flow protection
(2) Secondary containment for spills
(3) Manual shutdown at point of use and dispensing
(4) Fill level monitors and automatic shutoff
(5) A preset meter for automated delivery systems

7.2.9.2 The preset meter shall be permitted to be installed at points of use.

7.3 Container Delivery.

7.3.1* In new buildings, a service corridor shall be provided when necessary to transport hazardous chemicals from a liquid storage room, hazardous chemical room, or gas room or from the outside of a building to the perimeter wall of a fabrication area.

7.3.1.1 In existing buildings, hazardous chemicals shall be transported in approved chemical carts.

7.3.2 Hazardous chemicals shall not be dispensed or stored in exit access corridors.

7.3.3* Chemical carts transporting or containing hazardous chemicals shall be designed so that the contents will be fully enclosed.

7.3.3.1 Chemical carts shall be capable of containing a spill from the largest single container transported, with a maximum individual container size of 19 L (5 gal) for liquids.

7.3.3.2 The capacity of carts used for transportation of hazardous chemicals shall not exceed the following:

(1) Liquids: 208 L (55 gal)
(2) Solids: 227 kg (500 lb)
(3) Compressed gases: 7 cylinders, up to 18 kg (40 lb) each

7.3.4 Incompatible chemicals shall not be transported simultaneously on the same hazardous chemical cart.

7.3.5 The minimum clear width of a service corridor shall be 1524 mm (5 ft) or 838 mm (33 in.) wider than the widest cart or truck used in the service corridor, whichever is greater.

7.3.6 Service corridors shall not be used as a required means of egress.

7.3.7 The maximum quantities of hazardous chemicals transported in a service corridor at one time shall not exceed two times that set forth in 7.3.3.

7.4 Liquid Waste Disposal.

7.4.1 Separate drainage systems shall be provided for incompatible materials.

7.4.2* Drainage systems shall be labeled in an approved manner to identify their intended contents.

7.4.3 Collection of chemicals shall be directed to containers compatible with the material being collected.

7.4.4 Flammable liquids shall be collected in approved containers.

7.4.5 During collection of flammable liquids, the waste container shall be within secondary containment.

7.4.6 Chemical containers shall be labeled as to their contents in an approved manner.

7.4.7 Incompatible chemicals shall not be transported simultaneously on the same hazardous chemical cart.

7.5 Spill Protection.

7.5.1 Spill protection for liquid hazardous chemicals shall be provided where leakage from a fitting or tool terminates in an unoccupied or belowgrade area.

7.5.2 Spill protection shall include secondary containment and a method of detecting a spill.

7.5.3 Workstations. Each workstation in a fabrication area using hazardous chemical liquids shall have the following:

(1) Drainage piping systems connected to a compatible system for disposition of such liquids
(2) Work surface provided with a slope or other means for directing spilled materials to the containment or drainage system
(3) Approved means of containing or directing spilled or leaked liquids to the drainage system

7.6 Supply Piping.

7.6.1 Supply piping for hazardous chemical liquids and gases shall be welded throughout, except for connections to the systems that are located within a ventilated enclosure if the material is a gas, or an approved method of drainage or containment shall be provided for connections if the material is a liquid.

7.6.2 Hazardous chemicals piping and tubing shall comply with ASME B31.3, *Process Piping*.

7.7* Welding.

7.7.1 Welders and pipefitters shall be trained and qualified for the specific function they are performing.

7.7.2* Thermoplastic welders for critical components shall be trained and qualified for the specific function they are performing.

7.8 Pyrophoric Liquids.

7.8.1 Pyrophoric liquids in containers greater than 2 L (0.5 gal) but not exceeding 20 L (5.3 gal) capacity shall be allowed at workstations when located inside cabinets.

7.8.2 The maximum amount per cabinet shall be limited to 20 L (5.3 gal).

7.8.3 Cabinet Construction. Cabinets shall be constructed according to the following:

(1) Cabinets shall be constructed of not less than 12 gauge steel.
(2) Cabinets shall be permitted to have self-closing, limited-access ports with noncombustible windows that provide access to cabinet controls.
(3) Cabinets shall be provided with self-closing doors or other means of ensuring that the tool will not be operated with the door in the open position.

7.8.4 Cabinet Exhaust Ventilation System. Cabinet exhaust shall comply with the following:

(1) The system shall be designed to maintain the cabinet at a negative pressure in relation to the surrounding area.
(2) The system shall be provided with monitoring equipment to ensure cabinet exhaust. The monitoring equipment shall transmit a signal to the on-site emergency control station in case of an exhaust system failure.

7.8.5 Cabinet Spill Containment. Spill containment shall be provided in each cabinet, with the spill containment capable of holding the contents of the aggregate amount of liquids in containers in each cabinet.

7.8.6 Valves. An automatic valve shall be provided between the product containers in the cabinet and the workstation served by the containers. Valve failure shall be in the closed position upon loss of power or actuation of the fire protection system.

7.8.7 Fire Detection System. Each cabinet shall be equipped with an automatic fire detection system that complies with the following conditions:

(1) Automatic detection system: A UV/IR, high-sensitivity smoke detection (HSSD) or other approved detection system shall be provided inside each cabinet.
(2) Automatic shutoff: Activation of the detection system shall automatically close the shutoff valve, or shutoff valves on the liquid supply.
(3) Alarms and signals: Activation of the detection system shall initiate a local alarm within the fabrication area and transmit a signal to the emergency control station. The alarm shall be both audible and visible.

7.8.8 Distribution. Following the initial installation or any modifications that compromise the piping integrity, the entire system shall be subjected to a pressure test at a minimum pressure of 50 percent over the maximum pressure available to the system, but not less than 552 kPa (gauge pressure of 80 psi) for 2 hours with no discernible pressure drop. Helium leak checking shall be permitted to be used as an alternate method at 1×10^{-6} atm·cc/sec (1.116×10^{-3}atm·cc·ft/yr).

7.8.9 Materials for tubing, piping, valves, and fittings used for the distribution shall be of noncombustible construction.

7.8.10 Electrical. Exhaust ventilation, detection, and shutdown systems shall be provided with an emergency source of backup power.

Chapter 8 Hazardous Gas Cylinder Storage and Distribution

8.1 Packaging.

8.1.1 Container Data. The supplier shall accumulate and provide on request the following information:

(1) Cylinder contents with description of the components
(2) Cylinder serial number, material of construction, and standards used for construction and testing
(3) Cylinder valve with restricted orifice, when provided, and date of manufacture, material of construction, and flow curve for the orifice
(4) Description and date of last hydrostatic test

8.1.2* Cylinders. Cylinders containing pyrophoric gases shall be equipped with normally closed automatic shutoff valves that incorporate restricted flow orifices (RFOs).

8.2 Transport to the Semiconductor Facility. The operator of a vehicle transporting hazardous compressed and liquefied gases shall be trained in the handling of containers and the use of portable fire extinguishers. The operator shall be familiar with the site gas delivery procedures.

8.2.1 A leak check shall be performed on all gas cylinders prior to unloading from the transport vehicle.

8.2.2* An emergency response program shall be developed to handle accidents connected with the delivery of gases.

8.3 Distribution Systems.

8.3.1 Material for tubing, piping, and fittings used for distribution of compressed and liquefied gases shall be compatible with those gases.

8.3.1.1 The entire system shall be subjected to a pressure test at a minimum pressure of 20 percent over the maximum pressure available to the system but not less than 552 kPa (80 psi) for 2 hours with no discernible pressure drop.

8.3.2* Materials for tubing, piping, and fittings used for the distribution of compressed and liquefied gases shall be of noncombustible construction or of combustible construction contained in a noncombustible outer jacket.

8.3.2.1 Where double containment of highly corrosive gases is used, the use of combustible piping and a combustible outer jacket shall be permitted.

8.3.3 Tubing, piping, and fittings shall be welded.

8.3.3.1 Nonwelded connections and fittings shall be permitted to be used when housed in an exhausted enclosure or in an outside enclosure.

8.3.3.2 Hazardous gas piping and tubing shall comply with ASME B31.3, *Process Piping*.

8.3.4 Distribution piping shall be leak tested in accordance with SEMI F1, *Specification for Leak Integrity of High-Purity Gas Piping Systems and Components*.

8.3.5* Purge panels shall be provided at the cylinders on all compressed hazardous process gases when in use. *[See 8.4.3(H) for silane and silane mixes.]*

8.3.6 Gas cabinets or purge panels not located in gas cabinets shall be labeled with the process tools they serve, the type of gas, and the type of purge gas.

8.3.7* Purge panels shall be constructed of materials compatible with gases conveyed, minimize leakage potential, provide for control of excess flow, and be equipped with an appropriate emergency shutoff.

8.3.8 Purge panels shall be designed to prevent backflow and cross-contamination of purge gas or other process gases.

8.3.9 Check valves shall not be exposed to cylinder pressure if a cylinder has a pressure greater than 552 kPa (80 psi).

8.3.10 A manual isolation valve shall be provided on the process delivery line at the purge panel to permit removal of the purge panel for repair and maintenance.

8.3.11 Incompatible process gases shall not occupy the same gas cabinet.

8.3.12 Hazardous gas cylinder purge panels shall be provided with dedicated purge gas cylinders.

8.3.12.1 Only purge panels serving compatible gases shall be permitted to share a purge cylinder.

8.3.13 Bulk gas systems shall not be used as the purge source for hazardous gas cylinder purge panels.

8.4 Silane and Silane/Nontoxic Mixes Storage and Dispensing Areas.

8.4.1 Cylinders shall be stored in storage areas external to the building.

8.4.1.1 Cylinders not located in bunkers shall be provided with a security open chain-link fence.

8.4.1.1.1 The cylinders shall be separated from adjacent structures and the fence by a minimum distance of 2.7 m (9 ft).

8.4.1.2 The storage area shall be open on at least three sides with cylinders secured to steel frames.

8.4.1.2.1 Where a canopy is provided, the height shall be a minimum of 3.7 m (12 ft).

8.4.2 Gases shall be dispensed from open dispensing racks or adequately ventilated cabinets.

8.4.3 Dispensing areas shall be provided with the safeguards in 8.4.3(A) through 8.4.3(H). *(See Figure 8.4.3.)*

(A) Dispensing racks shall be located external to the building; however, where weather conditions do not permit, the dispensing racks shall be in an approved bunker or gas cabinet.

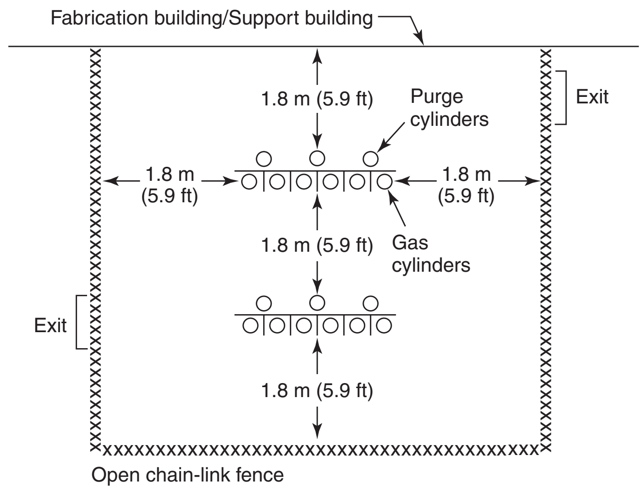


FIGURE 8.4.3 Silane Dispensing Area.

(B) Cylinders shall be separated from each other by a steel plate 6.3 mm (¼ in.) thick, extending 76 mm (3 in.) beyond the footprint of the cylinder. The steel plate shall extend from the top of the purge panel to 305 mm (12 in.) below the cylinder valve.

(C) Mechanical or natural ventilation at a minimum of 0.31 $m^3/min \cdot m^2$ (1 $ft^3/min \cdot ft^2$) of storage and dispensing area shall be provided.

(D) Cylinders shall be provided with protection and detection in accordance with 4.1.2.4 and 4.3.3.

(E) Remote manual shutdown of process gas flow shall be provided near each gas panel. The dispensing area shall have an emergency shutdown for all gases that can be operated at a minimum distance of 4.6 m (15 ft) from the dispensing area.

(F) Exterior dispensing areas shall be separated from structures in accordance with Figure 8.4.3. The dispensing area shall be open on at least three sides with cylinders secured to steel frames. Where a canopy is provided, the height shall be a minimum of 3.7 m (12 ft).

(G) Cylinders not located in bunkers shall be provided with a security open chain-link fence. The cylinders shall be separated from adjacent structures and the fence by a minimum distance of 1.8 m (5.9 ft).

(H) Silane and silane mixes shall be equipped with automated purge panels.

8.5* Silane/Toxic Mixes Storage and Dispensing Areas.

8.5.1 The storage area shall be located external to the building.

8.5.1.1 Cylinders not located in bunkers shall be provided with a security open chain-link fence.

8.5.1.1.1 The cylinders shall be separated from adjacent structures and the fence by a minimum distance of 1.8 m (5.9 ft).

8.5.1.2 The storage area shall be open on at least three sides with cylinders secured to steel frames.

8.5.1.2.1 Where a canopy is provided, the height shall be a minimum of 3.7 m (12 ft).

8.5.1.3 Where gas cabinets are used, only single-cylinder cabinets shall be used.

8.5.2 Silane/toxic mixes shall be dispensed from single-cylinder gas cabinets.

8.5.3 Dispensing areas shall be provided with the safeguards in 8.5.3(A) through 8.5.3(G). *(See Figure 8.5.3.)*

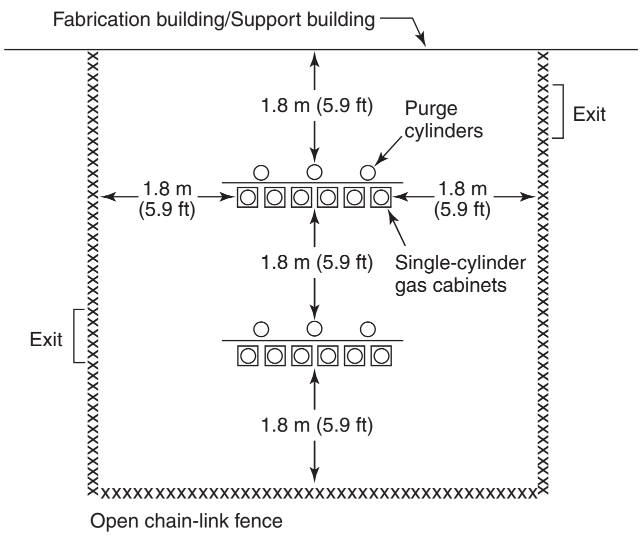


FIGURE 8.5.3 Silane/Toxic Mixes Dispensing Area.

(A) The dispensing areas shall be located external to the building; however, where weather conditions do not permit, the dispensing racks shall be in an approved bunker.

(B) If cabinets are used, ventilation shall be as follows:

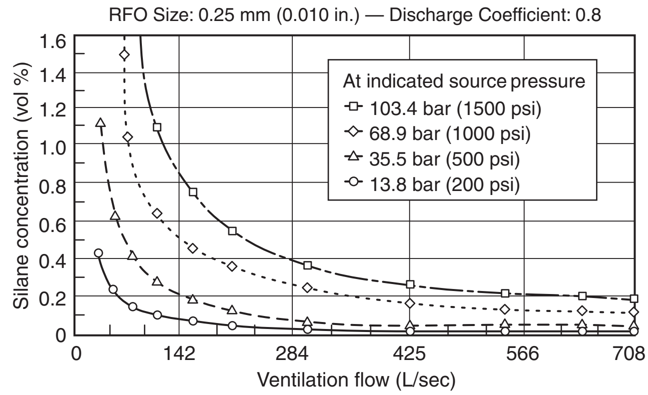
(1) Continuous internal ventilation shall be provided inside the enclosure. The ventilation system shall be arranged to prevent the formation of dead zones near likely leakage sites. This will avoid the possibility of local accumulation of silane at higher concentrations.
(2) The ventilation system shall be sized to limit the maximum concentration of silane inside the enclosure to 0.4 percent by volume. The maximum concentration of silane inside the enclosure shall be based on the continuous release of SiH_4 at a standard volumetric flow rate given by the size of the restricted flow orifice (RFO) in the discharge line and the maximum SiH_4 gas cylinder storage pressure.

(C) For a 0.4 percent concentration, the required ventilation airflow rate can be estimated from Figure 8.5.3(C). To satisfy the minimum concentration requirement, the airflow rate shall equal at least 250 times the estimated SiH_4 gas release rate at the standard volume flow rate. The estimated SiH_4 gas release rate can be taken from Table 8.5.3(C) for a given RFO size and maximum gas cylinder storage pressure.

(D) The ventilation system shall be provided with an automatic emergency source of power to operate at full capacity.

(E) Remote manual shutdown of process gas flow shall be provided outside each gas cabinet.

(F) Exterior dispensing areas shall be separated from structures in accordance with Figure 8.4.3 and Figure 8.5.3. The dispensing area shall be open on at least three sides with cylin-



Notes:
1. If RFO = 0.36 mm (0.014 in.), multiply silane concentration by 2.0.
2. If RFO = 0.51 mm (0.020 in.), multiply silane concentration by 4.0.
3. If RFO = 0.15 mm (0.006 in.), multiply silane concentration by 0.36.

FIGURE 8.5.3(C) Average Silane Concentration in a Ventilated Enclosure.

ders in single-cylinder cabinets. Where a canopy is provided, the height shall be a minimum of 1.8 m (5.9 ft).

(G) Gas cabinets not located in bunkers shall be provided with a security open chain-link fence. Cabinets shall be separated from adjacent structures and the fence by a minimum of 1.8 m (5.9 ft).

8.6 Flammable or Toxic Gases.

8.6.1* Toxic or flammable gases in use shall be contained in cabinets provided with exhaust ventilation.

8.6.1.1 Cabinets shall be provided with gas detection and automatic shutdown of the gas supply.

8.6.1.2 Exhaust ventilation shall be continuous or activated automatically by gas detection.

8.6.1.3 Lecture cylinders in ion implanters shall be in gas cabinets, or exhausted enclosures with gas detection and automatic shutdown of the gas supply.

8.6.2* Subatmospheric Gas Systems (SAGS).

8.6.2.1 General.

8.6.2.1.1 SAGS cylinders with incompatible gases shall be permitted to occupy the same gas cabinet or exhausted enclosure.

8.6.2.1.2 Ventilation in the enclosure or gas cabinets shall be sufficient to maintain vapors below 25 percent of LFL and below IDLH.

8.6.2.1.3 Purge gas shall be allowed to be supplied from a house system or from dedicated cylinders.

8.6.2.1.4 The requirements for automatic shutoff valves under 8.1.2 shall not be required for Type 1 or Type 2 SAGS containing pyrophoric gases.

8.6.2.1.5 Treatment systems for SAGS containers containing highly toxic or toxic gases as specified by Section 8.9 shall not be required.

8.6.2.1.6* The gas distribution system to which SAGS are connected shall be equipped with a method to protect system

Table 8.5.3(C) Silane Flow Rates Through Restricted Flow Orifices (RFOs) Based on the Predictions from the FMRC Model

RFO Diameter		Source Pressure, bar (psi)								
mm	in.	103.4 (1500)	82.7 (1200)	68.9 (1000)	55.1 (800)	41.3 (600)	27.6 (400)	13.8 (200)	6.9 (100)	3.5 (50)
0.51	0.020	4.72 (10.00)	3.72 (7.88)	2.85 (6.04)	2.05 (4.34)	1.43 (3.020)	0.91 (1.920)	0.45 (0.949)	0.23 (0.497)	0.136 (0.288)
0.36	0.014	2.32 (4.91)	1.82 (3.86)	1.40 (2.96)	1.01 (2.13)	0.70 (1.480)	0.44 (0.941)	0.22 (0.465)	0.11 (0.243)	0.064 (0.136)
0.25	0.010	1.18 (2.50)	0.93 (1.97)	0.71 (1.51)	0.51 (1.08)	0.356 (0.755)	0.23 (0.480)	0.11 (0.237)	0.059 (0.124)	0.033 (0.069)

Notes:
(1) The flows through the 0.36 mm (0.014 in.) and 0.25 mm (0.010 in.) RFOs are equal to 49 and 25 percent, respectively, of the flow through the 0.5 mm (0.020 in.) diameter RFO.
(2) Source temperature: 25°C (77°F); downstream pressure: 0 bar (0 psig); discharge coefficient: 0.8.

components from pressures exceeding their rating in the event of a failure in a SAGS.

8.6.2.2 SAGS Type 1.

8.6.2.2.1 Type 1 SAGS cylinders shall meet all of the requirements for compressed gases and gases, except as provided for in 8.6.2.1 and 8.6.2.2.

8.6.2.2.2 The requirements for an RFO under 8.1.2 shall not apply to SAGS Type 1 cylinders containing pyrophoric gases.

8.6.2.2.3 Gas distribution systems for SAGS Type 1 cylinders shall be subject to a pressure test at a minimum pressure of 20 percent over the maximum pressure available to the system but not less than 173 kPa (25 psi) for 2 hours with no discernible pressure drop.

8.6.3 Welding and other activities that produce ignition shall be minimized in areas where there is potential flammable gas release.

8.6.3.1 Welding or other activities that produce a spark shall be allowed only through a special internal permit procedure that calls for monitoring in the area for 25 percent of the LFL and a fire watch and ventilation to reduce the potential of explosive concentrations.

8.6.4 "No Smoking" signs shall be provided in the flammable gas storage area, in areas with a potential for flammable gas release, and within 7.6 m (25 ft) of those areas.

8.6.5 Open flames shall not be used in the flammable gas storage or dispensing areas. All sources of electrical heat shall comply with *NFPA 70*, *National Electrical Code*.

8.6.5.1 Compressed and liquefied gases in storage or dispensing shall be protected from uncontrolled heat sources.

8.7 Vent Headers.

8.7.1 Purge panel vent line headers, where used, shall be designed to prevent the mixing of incompatible gases and silane with air.

8.7.1.1 Vent header inert gas purge shall be monitored and provided with a local alarm when flow falls below a required set point.

8.7.2 Silane vent headers or individual purge panel vent lines shall have a continuous flow of nitrogen.

8.7.2.1 To prevent back diffusion of air into the vent line, a nitrogen flow shall be introduced.

8.7.2.2 The nitrogen shall be introduced upstream of the first exhaust connection to the header.

8.7.3 Vents shall terminate at a safe location or in treatment systems.

8.7.4 Process delivery lines used for hazardous gases shall be dedicated to those gases.

8.8* Training.

8.8.1 Operators working with hazardous gases and handling hazardous compressed and liquefied gas containers shall be trained for that function.

8.8.2 Training shall be provided annually.

8.9 Treatment Systems. Treatment systems shall be provided for highly toxic or toxic compressed gases in accordance with NFPA 1, *Fire Code*.

8.9.1 Monitoring Stack Discharge. When gas monitoring is provided in individual gas cabinets, valve manifold boxes (VMBs), or tool gas box exhaust ducts, stack monitoring is not required.

Chapter 9 Bulk Silane Systems

9.1 Tube Trailer Systems.

9.1.1* Tube trailers shall be located remotely from important fabrication buildings.

9.1.2 Automatic fixed water spray protection shall be provided to the tube trailer storage.

9.1.2.1 The system shall be designed to provide a density of 12 mm/min (0.30 gal/min·ft^2) over the external surface area of the trailers for a 2-hour duration.

9.1.2.2 Regular systems and control panel areas shall also be protected by this system.

9.1.2.3 The water spray system shall be activated by approved optical flame detectors.

9.1.3 Activation of the water spray system shall close emergency shutoff valves (ESOVs).

9.1.3.1 Tube trailers should be provided with pneumatically held open, normally closed valves on the discharge line from each tube and at least one pneumatically operated ESOV on the line between the babes and the diameter index safety (DIS) connection.

9.1.3.2 The ESOV shall be operated by a signal from the cleanroom gas detection system to initiate ESOV closure if a gas leak is detected in the valve manifold box (VMB).

9.1.3.3 Upon detection of a leak, the closest upstream valve to the VMB or the ESOV shall be shut automatically.

9.1.4 A 2-hour–rated fire wall shall separate the tube trailers from each other and from the regulator station.

9.1.5 The arrangement of piping, valving controls, and VMBs shall be as recommended for silane cylinder systems.

9.1.6 The RFO size used in the bulk systems shall be as small as possible to meet process needs and on each tube and located as close to each tube as possible.

9.1.7 Pressure relief valves (PRVs) of the combination fusible plug and burst disk type (U.S. Compressed Gas Association fitting type CG-4) shall be provided for each tube in a tube trailer.

9.1.7.1 The release from these devices shall be arranged in short stacks discharging above the trailer, or manifolded to a main release stack away from the tube trailer, such that a gas flare resulting from a PRV release will not impinge on adjacent tubes, piping, or control systems.

9.1.7.2 Stacks shall be provided with blow-off caps or other means of preventing rain and other foreign material from entering the stacks.

9.2 Cylinder Pack Systems and 450 L (119 gal) Cylinders.

9.2.1 The general arrangement of piping, valving, and controls shall be as recommended for single-cylinder systems.

9.2.2 Approved optical flame detectors that will respond to the flame signature of silane shall be provided to close ESOVs and to actuate deluge water spray systems, if provided, upon alarm.

9.2.3 Gas Detection.

9.2.3.1 A gas-detection system shall be provided to close all cylinder ESOVs upon activation.

9.2.3.2 Gas detection requirements shall not apply to outdoor systems.

9.2.4 Cylinder pack and 450 L (119 gal) systems shall be treated as bulk silane systems and shall be located outdoors.

Chapter 10 Production and Support Equipment

10.1 General.

10.1.1 Production and support equipment shall be designed and installed in accordance with Sections 10.2 through 10.8. *(See Annex C.)*

10.1.2 Vessels containing hazardous chemicals located in or connected to a workstation shall be protected from physical damage.

10.1.3 Chemicals or gas vessels shall be protected from seismic forces.

10.1.4 Workstations containing hazardous materials shall be provided with horizontal clearances of not less than 914 mm (3 ft) where servicing is required, such as cylinder change or hand pouring of chemicals.

10.2* Interlocks.

10.2.1* Interlocks that automatically bring the tool to standby mode shall be interfaced with the tool's operating system.

10.2.2 A local visual and audible alarm shall be provided to indicate activation of any interlock.

10.2.2.1 Panel interlocks shall not require a local visual and audible alarm.

10.2.3 Each interlock and its operation shall be described in both the operations manual and the maintenance manual for the tool.

10.2.4 Tools utilizing hazardous chemicals shall be designed to accept inputs from monitoring equipment.

10.2.4.1 An alarm signal from the monitoring equipment shall automatically stop the flow of hazardous chemicals to the tool.

10.2.5 Interlocks shall be designed to require manual reset and to permit restart only after fault correction.

10.3 Electrical Design.

10.3.1 The tool or associated equipment shall be approved as a complete system.

10.3.1.1 Process tools and associated equipment shall meet the requirements of Section 90.7 of *NFPA 70, National Electrical Code*.

10.3.1.2 Electrical components and wiring shall be in accordance with *NFPA 70, National Electrical Code*, and NFPA 79, *Electrical Standard for Industrial Machinery*.

10.3.1.3 All electrical components and wiring shall be listed.

10.3.1.4 Where the air space below a raised floor or above a suspended ceiling is used to recirculate cleanroom environmental air, plenum-rated cable shall not be required.

10.3.2 Electrical equipment and devices within 1.5 m (5 ft) of workstations in which flammable liquids or gases are used shall comply with the requirements of *NFPA 70, National Electrical Code*, for Class I, Division 2 locations.

10.3.2.1 The requirements for Class I, Division 2 locations shall not apply when the air removal from the workstation or dilution will ensure nonflammable atmospheres on a continuous basis.

10.3.3 Workstations where flammable chemicals are used shall be provided with interlocks to prevent the workstations from being energized without adequate ventilation.

10.3.3.1 Workstations consisting of no more than a sink with drain and exhaust shall have the exhaust monitored and be provided with an alarm in accordance with 10.2.2.

10.4 Process Liquid Heating Equipment.

10.4.1* All process liquid heating systems shall be listed or approved for the proposed use and a risk assessment shall be performed to ensure that safety features have been incorporated in the design.

10.4.2 Electrically heated chemical baths shall have the safeguards in 10.4.2.1 through 10.4.2.5.

10.4.2.1 The electrical supply shall include a ground-fault interrupt circuit breaker with appropriately sized overcurrent protection.

10.4.2.2 An automatic temperature control system shall be included.

10.4.2.3 A power interrupt circuit with manual reset that removes all power to the heating elements when activated shall be included.

10.4.2.3.1 Upon activation of this circuit, a system warning alarm shall be provided to the operator.

10.4.2.4 A liquid-level detection system shall remove power from the heating element if liquid level falls to a point where any portion of the element is exposed.

10.4.2.4.1 This system shall activate the power interrupt circuit required in 10.4.2.3.

10.4.2.5 A process liquid over-temperature detection system shall remove power from the heating element if the temperature of the liquid rises to a point where it is clear that a failure of the automatic temperature control system has occurred. It shall activate the power interrupt circuit required in 10.4.2.3.

10.4.3* Those baths heating flammable or combustible liquids shall have high-temperature limit switches.

10.4.4* Liquid-level sensors shall be tested at intervals specified by the manufacturer.

10.4.5* Where combustible liquids are heated and the heating system is intended to heat or is capable of heating the liquid above its flash point, the liquid shall be treated as a flammable liquid.

10.4.6 Where a combustible liquid is heated and the combination of process controls and safety interlocks prevent the liquid from reaching its flash point, then no concentrations of ignitible vapors will exist and the liquid shall be permitted to be treated as a combustible liquid.

10.5 Materials of Construction.

10.5.1 Tools shall be constructed of noncombustible materials.

10.5.1.1 Small parts within the tool such as knobs, buttons, electrical contacts, and terminal strips shall not be required to be of noncombustible materials.

10.5.1.2* Materials listed for use without internal fire detection and suppression shall be an acceptable alternative to noncombustible materials.

10.5.1.3 Fire sprinklers, approved gaseous agent fire suppression systems, or other approved engineering controls designed to prevent or limit fire damage shall be an acceptable alternative to the use of noncombustible materials or of materials that comply with 10.5.1.2.

10.6 Vacuum Pumps.

10.6.1* Vacuum pumps using combustible oils shall use a control device to remove oils prior to their discharge into the exhaust duct system.

10.6.2 Exhaust Conditioning.

10.6.2.1* Vacuum pumps that handle flammable gases in excess of 25 percent of the LFL shall discharge into a control device that treats the flammable gases from the airstream prior to discharge into exhaust system ductwork.

10.6.2.2 Vacuum pumps handling flammable or pyrophoric chemicals or high-concentration oxygen shall not use combustible pump oils.

10.6.2.3 Vacuum pumps that handle flammable or pyrophoric gases shall be equipped with a nitrogen purge and interlocked with the process tool operating system.

10.6.2.4 Interlocks that shut down gas flow at the tool in the event of the following shall be provided with a control device:

(1) The exhaust conditioning alarm signals, for example, when an over-temperature condition occurs.
(2) Airflow/exhaust through the exhaust conditioning system falls below prescribed set point.

10.7 Hazardous Gas Delivery Systems. Mass flow controller bypass valves shall be designed to prevent excess flow of silane and to prevent their being left in the open position.

10.8* Tools Using Flammable or Combustible Chemicals. All tools using flammable or combustible chemicals shall be provided with exhaust to reduce the concentration of flammable gases and vapors to less than 25 percent of the LFL.

10.9 Gas-Detection Systems.

10.9.1 General. A gas-detection system shall be provided for hazardous chemical gases when the physiological warning properties of the gas are at a higher level than the accepted permissible exposure limit (PEL) for the gas, for flammable gases, and for pyrophoric gases.

10.9.2 Where Required.

10.9.2.1 Fabrication Areas. A gas-detection system shall be provided in fabrication areas at locations in the fabrication area where gas is used or stored.

10.9.2.2 Hazardous Chemical Rooms. A gas-detection system shall be provided in hazardous chemical storage and dispensing rooms when hazardous gas is in use in the room.

10.9.2.3 Gas Cabinets, Exhausted Enclosures, and Gas Rooms.

10.9.2.3.1 A gas-detection system shall be provided in gas cabinets and exhausted enclosures.

10.9.2.3.2 A gas-detection system shall be provided in gas rooms when gases are not located in gas cabinets or exhausted enclosures.

10.9.2.4 Exit Access Corridors.

10.9.2.4.1 When gases are transported in piping placed within an exit access corridor or in proximity to the corridor in such a way as to pose a threat to occupants, should a leak occur, gas detection shall be provided to warn occupants and signal an emergency response.

10.9.2.4.2 A gas-detection system shall not be required for occasional transverse crossings of the corridors by supply piping that is enclosed in a ferrous pipe or tube for the width of the corridor.

10.9.3 Gas-Detection System Operation.

10.9.3.1 Monitoring. Gas-monitoring equipment, when required by this standard to warn of the presence of leaked gas, shall be capable of detection and alarm initiation at or below the following gas concentrations:

(1) Immediately dangerous to life or health (IDLH) values when the monitoring point is within an exhausted enclosure
(2) PEL levels when the monitoring point is in an area outside an exhausted enclosure
(3) Twenty-five percent of LFL when the monitoring point is within or outside an exhausted enclosure

10.9.3.2 Shutoff of Gas Supply.

10.9.3.2.1 Gas-monitoring systems shall automatically close the nearest isolation valve upon high-level (IDLH, PEL, and LFL) detection alarms:

(1) At local gas boxes near the tool or in the tool gas jungle
(2) At VMBs, shut down individual sticks
(3) At the gas source
(4) At the bulk source

10.9.3.2.2 Shutoff of flammable gas systems shall be initiated at 50 percent of LFL.

10.10 Emergency Alarm System.

10.10.1 General.

10.10.1.1 Emergency alarm systems shall be provided in accordance with this section.

10.10.1.2 The exempt provisions of NFPA 1, *Fire Code*, shall not apply to emergency alarm systems required for hazardous chemicals.

10.10.2 Where Required.

10.10.2.1 Emergency Alarm. When hazardous chemicals are transported through service corridors, exit access corridors, or exit enclosures, there shall be an emergency telephone system, a local manual alarm station, or approved alarm-initiating device, at intervals no greater than 45.7 m (150 ft) and at each exit and exit-access doorway throughout the transport route.

10.10.2.1.1 The signal shall be relayed to the emergency control station and shall initiate a local alarm.

10.10.2.2 Exit access corridors and exit enclosures shall be in accordance with NFPA 1, *Fire Code*.

10.10.2.3 Storage rooms and gas rooms shall be in accordance with NFPA 1, *Fire Code*.

10.10.3 Alarm-Initiating Devices. An approved emergency telephone system, local alarm manual pull stations, or other approved alarm initiating devices shall be permitted to be used as emergency alarm-initiating devices.

10.10.4 Alarm Signals. Activation of the emergency alarm system shall sound a local alarm and transmit a signal to the emergency control station.

Chapter 11 Emergency Control Station

11.1* Emergency Control Station.

11.1.1 An emergency control station shall be provided at an approved location, outside of the fabrication area and shall be continuously staffed by trained personnel.

11.1.2 The emergency control station shall receive signals from emergency equipment and alarm and detection systems.

11.1.3 Such emergency equipment and alarm and detection systems shall include, but not necessarily be limited to, the following when such equipment or systems are required to be provided either by this chapter or elsewhere in this standard:

(1) Automatic fire sprinkler system alarm and monitoring systems
(2) Manual fire alarm systems
(3) Emergency alarm systems
(4) Continuous gas-detection systems
(5) Smoke-detection systems
(6) Emergency power system

Chapter 12 General Safety Precautions

12.1 Emergency Plan.

12.1.1 Plans and Diagrams. Plans and diagrams shall be maintained in approved locations indicating architectural features, use, and the approximate equipment placement for each area; the amount and type of hazardous chemicals stored, handled, and used; locations of shutoff valves for hazardous chemicals supply piping; emergency telephone locations; and locations of exits.

12.1.2 Plan Updating.

12.1.2.1 Plans and diagrams shall be maintained up-to-date.

12.1.2.2 The fire department shall be informed of architectural changes affecting access and egress, use, materials, occupancy, warning and controls, or other functions that could affect their emergency response.

12.2 Emergency Response Team.

12.2.1 Responsible persons shall be designated to an on-site emergency response team and trained to be liaison personnel for the fire department.

12.2.2 These persons shall aid the fire department in preplanning emergency responses; identifying locations where hazardous chemicals are stored, handled, and used; and shall be familiar with the chemical nature of hazardous chemicals.

12.2.3 An approved number of personnel for each work shift shall be designated.

12.3 Emergency Drills.

12.3.1 Emergency drills of the on-site emergency response team shall be conducted on a frequency that ensures proficiency.

12.3.2 Records of drills conducted shall be maintained at the emergency control station for a period of one year.

Chapter 13 Means of Egress

13.1 Means of Egress. Means of egress shall be designed in accordance with Chapters 7 and 40 of NFPA *101, Life Safety Code*.

13.1.1 Travel distance, measured in accordance with Section 7.6 of NFPA *101, Life Safety Code*, shall not exceed 60 m (200 ft).

13.1.2 Travel Distance to Exits. Travel distance shall not exceed that provided by Table 13.1.2 for buildings protected throughout by an approved, supervised automatic sprinkler system.

Table 13.1.2 Maximum Travel Distance to Exits

Level of Protection	General Industrial Occupancy		Special-Purpose Industrial Occupancy		High Hazard Industrial Occupancy	
	ft	m	ft	m	ft	m
Protected throughout by an approved, supervised automatic sprinkler system in accordance with 9.7.1.1(1) of NFPA ***101***	250	76*	400	122	75	23
Not protected throughout by an approved, supervised automatic sprinkler system in accordance with 9.7.1.1(1) of NFPA ***101***	200	61	300	91	NP	NP

NP: Not permitted.

*In single-story buildings, a travel distance of 400 ft (122 m) is permitted, provided that a performance-based analysis demonstrates that safe egress can be accomplished.

[***101***:40.2.6]

13.2 Service Corridors.

13.2.1 Service corridors shall be provided with two or more exits, and not more than one-half of the required number of exits shall lead to the fabrication area.

13.2.2 The travel distance within a service corridor to an exit or to a door into a fabrication area shall not exceed 23 m (75 ft). Dead ends shall not exceed 1.22 m (4 ft).

13.2.3 Doors from service corridors shall swing in the direction of exit travel and shall be self-closing.

Annex A Explanatory Material

Annex A is not a part of the requirements of this NFPA document but is included for informational purposes only. This annex contains explanatory material, numbered to correspond with the applicable text paragraphs.

A.1.2 A systems approach to risk management was attempted throughout this standard. These fire safety objectives are achieved through the proper management of fire prevention and fire response activities.

A.1.4.3 An equivalent method of protection is one that provides an equal or greater level of protection. It is not a waiver or deletion of a standard requirement.

A.1.5 For additional conversions and information, see IEEE/ASTM SI 10, *Standard for Use of the International System of Units (SI): The Modern Metric System.*

A.3.2.1 Approved. The National Fire Protection Association does not approve, inspect, or certify any installations, procedures, equipment, or materials; nor does it approve or evaluate testing laboratories. In determining the acceptability of installations, procedures, equipment, or materials, the authority having jurisdiction may base acceptance on compliance with NFPA or other appropriate standards. In the absence of such standards, said authority may require evidence of proper installation, procedure, or use. The authority having jurisdiction may also refer to the listings or labeling practices of an organization that is concerned with product evaluations and is thus in a position to determine compliance with appropriate standards for the current production of listed items.

A.3.2.2 Authority Having Jurisdiction (AHJ). The phrase "authority having jurisdiction," or its acronym AHJ, is used in NFPA documents in a broad manner, since jurisdictions and approval agencies vary, as do their responsibilities. Where public safety is primary, the authority having jurisdiction may be a federal, state, local, or other regional department or individual such as a fire chief; fire marshal; chief of a fire prevention bureau, labor department, or health department; building official; electrical inspector; or others having statutory authority. For insurance purposes, an insurance inspection department, rating bureau, or other insurance company representative may be the authority having jurisdiction. In many circumstances, the property owner or his or her designated agent assumes the role of the authority having jurisdiction; at government installations, the commanding officer or departmental official may be the authority having jurisdiction.

A.3.2.3 Listed. The means for identifying listed equipment may vary for each organization concerned with product evaluation; some organizations do not recognize equipment as listed unless it is also labeled. The authority having jurisdiction should utilize the system employed by the listing organization to identify a listed product.

A.3.3.11 Hazardous Chemical. The terms *hazardous materials*, *hazardous chemicals*, and *hazardous wastes* are often used interchangeably, and, in most contexts, it is properly understood that they have the same meaning. In the United States, however, these terms actually have quite different definitions under the Code of Federal Regulations (CFR).

(1) *Hazardous Materials.* Hazardous materials are raw materials in transit to the user and are governed by the U.S. Department of Transportation (DOT) under 49 CFR, "Transportation."
(2) *Hazardous Chemicals.* By definition, a hazardous material becomes a hazardous chemical once it arrives at a plant and is used in the workplace, at which time its use is governed by the Occupational Safety and Health Administration (OSHA) under 29 CFR, "Labor."
(3) *Hazardous Wastes.* Waste is generated by a process. A chemical becomes waste once it completes its useful life in-plant, and its disposal is classified as ignitible, corrosive, reactive, or toxic. Where it is considered hazardous waste, it is regulated by the Environmental Protection Agency (EPA) under 40 CFR, "Protection of the Environment."

Although ignitible wastes are of particular interest to NFPA, all hazardous waste should be protected to avoid adverse impact to the environment.

A.3.3.16.2 Permissible Exposure Limit (PEL). The maximum permitted time-weighted average exposures to be utilized are those published in 29 CFR 1910.1000, "Air Contaminants." [**5000,** 2009]

A.3.3.31 Workstation. The terms *workstation, tool, process tool, process equipment,* and *semiconductor manufacturing equipment* are often used interchangeably. In the United States, the term *workstation* has connotation and definition under other recognized codes and standards. In this document, the term *workstation* is used to specifically designate the point where a single process step, function, or procedure is performed. Equipment used in the manufacture of semiconductor devices can contain one or more process steps and accordingly one or more workstations.

It should be noted that all workstations are tools, but not all tools are workstations.

The workstation can include connected cabinets and contain ventilation equipment, fire protection devices, sensors for gas and other hazards, electrical devices, and other processing and scientific equipment.

A.4.1.1 Automatic sprinkler systems and their water supplies should be designed for maximum reliability. In the event of any impairments of the yard main system, sprinkler system lead-in(s) connections should be capable of being isolated and protection promptly restored through valving or interconnection of automatic sprinkler systems, or both, inside the building.

A.4.1.2.1 Typical configurations of cleanrooms and their chases and plenums create numerous areas that might be sheltered from sprinkler protection. These areas can include air-mixing boxes, catwalks, hoods, protruding lighting, open waffle slabs, equipment, piping, ductwork, and cable trays. Care should be taken to relocate or supplement sprinkler protection to ensure that sprinkler discharge covers all parts of the occupancy. Care should also be taken to ensure that sprinklers are located where heat will be satisfactorily collected for reliable operation of the sprinkler.

Gaseous fire suppression systems are not substitutes for automatic sprinkler protection. The large number of air changes in cleanrooms can cause dilution or stratification of the gaseous agent.

It is recommended that sprinkler systems be inspected at least semiannually by a qualified inspection service. *(See NFPA 25, Standard for the Inspection, Testing, and Maintenance of Water-Based Fire Protection Systems.) The length of time between such inspections can be decreased due to ambient atmosphere, water supply, or local requirements of the authority having jurisdiction.*

Prior to taking a sprinkler system out of service, one should be certain to receive permission from all authorities having jurisdiction and to notify all personnel who might be affected during system shutdown. A fire watch during maintenance periods is a recommended precaution. Any sprinkler system taken out of service for any reason should be returned to service as promptly as possible.

A sprinkler system that has been activated should be thoroughly inspected for damage and its components replaced or repaired promptly. Sprinklers that did not operate but were subjected to corrosive elements of combustion or elevated temperatures should be inspected and replaced if necessary, in accordance with the minimum replacement requirements of the authority having jurisdiction. Such sprinklers should be destroyed to prevent their reuse.

A.4.1.2.2 The use of quick-response sprinklers, while still delayed in opening by the downward airflow, would respond to a smaller-size fire more quickly than would conventional sprinklers. (Glass bulb–type quick-response sprinklers might be preferable to other types of quick-response sprinklers.)

A.4.1.2.3 It is recommended that a listed 57°C (135°F), 9.5 mm (3⁄8 in.) orifice sprinkler be used. It is recommended that a sprinkler be installed in all gas cylinder cabinets.

A.4.1.2.4 The purpose of the water spray deluge system is to cool the cylinders. The water spray nozzle should be located to maximize cylinder cooling and minimize damage to electrical control systems. Optical detectors could also serve the function required in 4.3.3.

A.4.1.2.5.1 Examples of combustible materials that might be found in these spaces are as follows:

(1) Roof, floor, wall construction materials
(2) Unapproved HEPA or ULPA filter modules
(3) Supply air or exhaust ducts
(4) Air handler unit enclosures or air plenum boxes
(5) Exposed electrical cable or pipe insulation
(6) Plastic piping
(7) Flammable or combustible liquid piping

A.4.1.2.6(1)(a) Equivalent to 10 in. (254 mm) diameter duct.

A.4.1.2.6.2.1 Small-orifice sprinklers, 9.5 mm (3⁄8 in.) or larger, can be used.

A.4.1.2.6.4 Drainage for, and placement of, sprinklers should be designed to prevent water from flowing back into process equipment, to prevent ductwork from collapsing under the weight of the water, or both. Because water discharged into exhaust ductwork will most likely be contaminated, outflow from the drain lines should be piped in accordance with local environmental regulations.

A.4.1.2.6.7 To minimize the effect of automatic sprinkler water discharge on airflow in exhaust ducts, it is preferable to locate the sprinkler head in the workstation transition piece. It is also acceptable to use a 9.5 mm (3⁄8 in.) orifice sprinkler.

A.4.1.2.7 It is recommended that an approved 9.5 mm (3⁄8 in.) orifice sprinkler be used. Drainage should be provided to remove all sprinkler water discharged in the pass-through.

A.4.3.1 The detectors can also be used to shut down the recirculating fans, to activate a dedicated smoke control system, or both. See NFPA 90A, *Standard for the Installation of Air-Conditioning and Ventilating Systems.*

When using air-sampling smoke detection systems in a ballroom cleanroom with a pressurized supply plenum, detection should be installed in one or more of the following places:

(1) Below the waffle slab
(2) Before the entry to the air return fans
(3) In the air return ducts after the air return fans
(4) In the air supply plenum above the cleanroom

The system should be capable of monitoring particles to 10 microns or less.

When using air-sampling smoke detection systems in a ballroom cleanroom with fan filter units, detection should be installed in one or more of the following places:

(1) Below the waffle slab
(2) Before the entry to the air return ducts
(3) In the air supply plenum above the cleanroom

When using an air-sampling system for a bay and chase cleanroom, detection should be installed in one or more of the following places:

(1) At ceiling level in the service chase air return path
(2) Before the entry to the recirculating air handling system

A.4.3.2 Smoke detection need not result in an automatic facility evacuation alarm signal.

A.4.3.4 Cleanroom hydrogen monitoring should use parts-per-million detectors to provide alarm and detection for hydrogen leaks.

A.5.1.2 ANSI/UL 900 Class I–rated filters are preferable because of their lower combustibility and smoke generation. These qualities are very desirable for filters in air-handling units serving cleanroom occupancies. Although a Class I filter cannot have any flame extension, the extension from a Class II can be up to 2.4 m (8 ft).

A.5.1.5.1 Air-handling systems should be designed to facilitate the maintenance testing of components. Design should allow periodic tests of dampers and fan units.

A.5.3.1 Ribbed flex duct is frequently used to connect a piece of equipment to the exhaust duct system. Trapped sections can occur where these ducts are routed under structural members or other mechanical ducts or piping. Furthermore, transport velocities that are adequate in straight sections of ductwork might not be adequate in the aforementioned sections due to turbulence, and as a result, hazardous chemicals can deposit in the ductwork. Ribbed flex duct has the undesirable property of very rapid burn-through or collapse in the event of internal fire exposure.

The duct system should be designed and constructed to minimize the collection of hazardous chemicals.

FM 4922, *Fume Exhaust Ducts or Fume and Smoke Exhaust Ducts,* is an appropriate test method for evaluating flexible fume exhaust duct.

A.5.3.6 Considering fire protection issues only, the following are duct materials listed in descending order of preference:

(1) Metallic
(2) Approved coated metallic or nonmetallic not requiring fire sprinklers, fire dampers, or interrupters of any kind
(3) Combustible with internal automatic sprinkler protection

A.5.5.1 The concentration of vapors should be estimated by calculation at the design stage or verified by measurement when installed.

A.5.5.2 The estimated concentration should be based on normal operating conditions and take into account a realistic and foreseeable scenario involving a single point failure. This can include a spillage, a leak from a mechanical joint or seal in a ventilated enclosure, or a failure resulting in a maximum flow condition from one source, combined with normal process flows from all other equipment and process served by the ductwork.

A.5.6.1 Emergency power systems are not intended to keep production equipment operating except in limited cases. When electrical utility power in a facility fails, most production equipment will shut down, thereby reducing the hazardous fumes transported in the fume exhaust duct system.

A.6.2 Buildings housing these cleanrooms should be of noncombustible or fire-resistive construction.

A.6.4 The hand delivery and pouring of combustible and flammable chemicals have been reduced to a minimum in large state-of-the-art factories. Storage, located in storage rooms, is remote from the cleanroom. The majority of chemicals are dispensed automatically by way of bulk delivery systems. The hazards associated with spills in the cleanroom are minimal, considering the amount of air being recirculated.

A.7.1 The following documents should be consulted for storage and handling of hazardous chemicals:

NFPA 68, *Standard on Explosion Protection by Deflagration Venting*

NFPA 329, *Recommended Practice for Handling Releases of Flammable and Combustible Liquids and Gases*

A.7.1.1.2 For Table 7.1.1.2, the containment system design can consist of a separate basin for each chemical, a series of drainage trenches that drain incompatible chemicals to independent collection basins, drains, or any configuration that maintains separation of incompatibles.

A.7.1.3.1.1 SEMI S2-0703a, *Environmental, Health, and Safety Guideline for Semiconductor Manufacturing Equipment*, and SEMI S14, *Safety Guidelines for Fire Risk Assessment and Mitigation for Semiconductor Manufacturing Equipment*, are examples of acceptable guidelines for risk assessment.

A.7.2 It is the committee's intent that this section does not apply to piping within tool enclosures. Tool enclosures should be evaluated using SEMI S14, *Safety Guidelines for Fire Risk Assessment and Mitigation for Semiconductor Manufacturing Equipment*, to ensure acceptable risk based analysis. *(See Annex C).*

A.7.3.1 New buildings are designed to provide chemical-handling corridors.

A.7.3.3 Individual, breakable chemical containers should be separated to avoid breakage.

A.7.4.2 Labeling of contents should be in accordance with ANSI B31.3, *Chemical Plant and Petroleum Refinery Piping*.

A.7.7 Training should be as outlined in SEMI F3, *Guideline for Welding Stainless Steel Tubing for Semiconductor Manufacturing Applications*.

A.7.7.2 Thermoplastic welders should be qualified under DVS welding standards. (DVS = Deutscher Verband für Schweissen und verwandte Verfahren e.V.)

A.8.1.2 If an RFO is placed in a system with an excess flow device, the excess flow device might not shut off.

A.8.2.2 The emergency response program should be coordinated with the fire department, the plant emergency response team, and the gas supply organization. A response time for all parties concerned should be a part of the procedure. Periodic drills in handling simulated accidents should be performed with all parties involved.

A.8.3.2 If the distribution piping is of noncombustible construction, a combustible outer jacket can be used for secondary containment.

A.8.3.5 Automated purge panels are recommended because they reduce the potential for human error. *[See 8.4.3(H) for silane and silane mixes.]*

A.8.3.7 The basic components of purge panels should incorporate the following features:

(1) Tied diaphragm regulators should be used.
(2) All piping or tubing connections, except the valve connection to a cylinder, should be welded or have a metal gasket face seal fitting with zero clearance.
(3) Burst pressure components should be rated to at least 50 percent above the maximum pressure available to all components.
(4) All components should have a helium leak rate no greater than 0.00001 cc/hr.

(5) Regulators should be of the hand-loaded type. Dome-loaded regulators should not be used on hazardous gases. Remotely operated gas-delivery systems can use dome-loaded regulators.
(6) No check valves should be used as a primary control of potential cross-contamination and backflow.
(7) Electrical components on purge panels should be intrinsically safe.
(8) Excess flow control (valve or switch) should be provided on the high-pressure side of the purge panel.
(9) Emergency high-pressure shutoff valves should be provided and should operate on the activation of an emergency off button, gas monitoring alarm (high alarm), or electronically monitored excess flow control switch.
(10) All systems should be equipped with an emergency shutoff.

A.8.5 The use of silane/toxic mixes is discouraged because of the dangers inherent in these materials. Alternative methods should be sought to eliminate the use of these chemicals.

A.8.6.1 Alternative substances should be considered for replacement of hazardous gases.

A.8.6.2 Subatmospheric Gas Systems (SAGS) Type 1 and Type 2 sources should be used instead of high-pressure cylinder gas, whenever process compatibility will allow.

A.8.6.2.1.6 Emergency high-pressure shutoff valves should be provided between the SAGS cylinder and the gas distribution system and should operate on the activation of a pressure switch in order to protect system components from excessive pressure.

A.8.8 A certification program should be used to ensure adequate training.

A.9.1.1 The separation distance between tube trailers and important buildings is a function of the acceptable allowable overpressure from an assumed explosion. According to the Compressed Gas Association (CGA)/Arthur D. Little (ADL) report, *Large Scale Silane Release Tests,* on large-scale silane releases, the estimated safe separation distance would be as follows for these two example scenario explosions:

(1) If an overpressure of gauge pressure of 6.9 kPa (1 psi) is acceptable and we assume a release through a 12.7 mm (½ in.) orifice pressure relief valve (PRV) venting a tube trailer pressurized to gauge pressure of 9653 kPa (1400 psi), then the separation distance should be approximately 39.6 m (130 ft). If the tube trailer pressure is only gauge pressure of 6895 kPa (1000 psi), the distance drops to approximately 30.5 m (100 ft).
(2) If the PRV orifice diameter is 25.4 mm (1 in.), however, with the tube trailer pressure at gauge pressure of 6895 kPa (1000 psi), a distance of approximately 54.8 m (180 ft) will be needed to achieve only a gauge pressure of 6.9 kPa (1 psi) overpressure.

A.10.2 See SEMI S2-0703a, *Environmental, Health, and Safety Guideline for Semiconductor Manufacturing Equipment,* Section 11, or ANSI/ISA-S84.01, *Application of Safety Instrumented Systems for the Process Industries.*

A.10.2.1 Interlock systems should be designed to prevent override during normal operation.

A.10.4.1 Electric immersion heaters and hot plates used in combustible tools or tools using combustible or flammable liquids are examples of process liquid heating systems that need careful review to assure that the proper safety features have been incorporated in the design.

A.10.4.3 Wet benches that use combustible chemicals, heated above their flash points, or flammable chemicals should be provided with devices to detect fire.

A.10.4.4 A convenient way of testing low liquid-level sensors is to use them at least weekly to shut down the process by removing them from the bath; if they fail to shut off equipment, they are not operating properly.

A.10.4.5 A system that incorporates a process liquid overtemperature interlock that is capable of being set at or above the flash point of the liquid results in a liquid that can be heated above its flash point in the event of a failure of the process control system. Where a liquid is flammable or is required to be treated, a flammable and an ignitible atmosphere is likely to be present, and the area should be electrically classified as a hazardous location.

A.10.5.1.2 NFPA has developed NFPA 287, *Standard Test Methods for Measurement of Flammability of Materials in Cleanrooms Using a Fire Propagation Apparatus (FPA),* to provide guidance for the assessment of the fire hazard expected of materials used in environments highly sensitive to thermal and nonthermal damage, such as within cleanrooms in the semiconductor industry. ASTM has also developed ASTM E 2058, *Standard Test Methods for Measurement of Synthetic Polymer Material Flammability Using a Fire Propagation Apparatus (FPA),* as a generic version of the same test method. The initial work on this issue was performed at FM Global and published as FM 4910, *Clean Room Materials Flammability Test Protocol.*

The protocol utilizes three small-scale tests. The small-scale tests are performed in a flammability apparatus that includes a fire products collector and data evaluation equipment.

The tests are as follows:

(1) Ignition tests
(2) Fire propagation tests
(3) Combustion tests

Based on results of the three small-scale tests, the following indexes are determined for each material tested:

(1) *Fire Propagation Index (FPI).* This index is determined based on the fire propagation tests conducted and represents the ease/difficulty of fire propagation on the surface of the material beyond the ignition zone, under simulated flame heating conditions expected in large-scale fires. Nonpropagating materials have FPI values at or below 6.0.
(2) *Smoke Development Index (SDI).* This index is defined as the product of the FPI index and the yield of smoke for a given material and represents the rate at which smoke is expected to be released during fire propagation. Materials expected to restrict smoke development have an SDI of 0.4 or less.

Materials that meet the flammability protocol criteria require high heat fluxes to be ignited; once ignited, these materials can burn locally in the ignition area, but they are likely not to propagate a fire beyond the ignition zone. Smoke and corrosive products generated from the combustion of these materials are reduced, minimizing nonthermal damages. Research at FM Global suggests that materials with a low fire propagation index in NFPA 287, *Standard Test Methods for Measurement of Flammability of Materials in Cleanrooms Using a Fire*

Propagation Apparatus (FPA), are likely to perform well in a larger-scale flammability test known as the parallel panel test.

Another test standard intended for the same use is ANSI/UL 2360, *Standard Test Method for Determining the Combustibility Characteristics of Plastics Used in Semiconductor Tool Construction*. Testing with ANSI/UL 2360 is conducted using a cone calorimeter fire test apparatus, as described in NFPA 271, *Standard Method of Test for Heat and Visible Smoke Release Rates for Materials and Products Using an Oxygen Consumption Calorimeter*, or in ASTM E 1354, *Standard Test Method for Heat and Visible Smoke Release Rates for Materials and Products Using an Oxygen Consumption Calorimeter*. Results of tests using ANSI/UL 2360 have also been shown to correlate with those from the parallel panel test.

A.10.6.1 Such devices can be traps, condensers, de-misters, or coalescing filters. As an alternative, noncombustible oils or dry-type pumps not requiring lubricant should be used.

A.10.6.2.1 Vacuum pumps whose construction is susceptible to backstreaming oil into tools should have foreline traps on their inlets.

A.10.8 Exhaust flow should be monitored and controlled by a sensor set at a negative static pressure to provide the minimum airflow specified in Chapter 7.

As an alternative to the foregoing, the minimum airflow can be monitored by periodic inspection to preclude changes caused by modifications to the exhaust duct system.

In the event a low airflow condition results, a local audible and visual alarm should provide a signal at the tool. The sensor and alarm should be of the manual reset type.

Exhaust static pressure or flow monitoring should be provided on all exhausted tools. Local visual and audible alarms should also be provided. The sensor and alarm should be of the manual reset type.

A.11.1 Semiconductor facilities can be considered to be special-purpose industrial occupancies containing ordinary hazard manufacturing operations. Chapter 19, Section 13 of the NFPA *Fire Protection Handbook* points out that high-hazard occupancies are limited to those industrial facilities that house extremely hazardous operations and do not include those buildings in which there is incidental or restricted use of chemicals and gases, such as semiconductor cleanrooms designed in accordance with this standard.

Annex B Seismic Protection

This annex is not a part of the requirements of this NFPA document but is included for informational purposes only.

B.1 General. This annex contains useful and explanatory information about the installation of seismic protection for fire protection systems.

B.1.1 In seismic zones, where required by the authority having jurisdiction, approved seismic warning and control systems should be installed to mitigate earthquake damage.

B.1.2 An approved seismically activated valve should be provided for automatic shutoff of piping systems that convey hazardous chemicals during significant seismic events. This valve should generate a signal to activate emergency shutoff valves on gas cabinets, hazardous gas supply lines, and appropriate utility services, such as natural or LP-Gas.

B.1.3 Seismic warning and control systems should be able to discriminate actual seismic activity from background industrial interference, such as a forklift operating in the area of the seismic sensors.

B.1.4 The optimal seismic warning and control system should react only to a ground acceleration of 0.05 G–0.25 G at the specific frequencies inherent in earthquakes (0.5 Hz–15 Hz).

B.1.5 Electrically operated seismic warning systems should be powered by an uninterruptible power supply.

Annex C Production and Support Equipment

This annex is not a part of the requirements of this NFPA document but is included for informational purposes only.

C.1 Introduction. Chapter 10 can be used to minimize known fire hazards inherent in the construction and operation of cleanroom tools. Proper materials, regulatory requirements, and good practices should be considered in the design, use, and maintenance of all tools.

Where hazards cannot be eliminated, no single failure should result in an exposure situation that places people in jeopardy. All fire prevention or protection systems used internal to, or with, equipment should be fail-safe.

C.2 General Recommendations. Tools should be designed to achieve fire prevention or, in the event of fire, to provide early detection and suppression adequate to prevent fire spread, explosion, or threat to life safety. The completed system should have third-party review based on the requirements of Chapter 10. Where available, components and subassemblies used should be listed.

The following guideline sets forth areas of consideration when tool design drawings are being reviewed. This list includes only recommendations — design review should not be limited by, or to, these items:

(1) Materials of construction (flammability, combustibility, and compatibility)
(2) Electrical components, their mounting, and enclosures
(3) Electrical circuit protection
(4) Access to components within equipment
(5) Minimization and control of pyrophoric chemicals
(6) A review of process piping, connectors, and materials
(7) Methods of preventing excess flow of gases
(8) Earthquake stability where and when applicable
(9) Redundant controls of electrical heaters
(10) Software interlocks

Tools should bear a nameplate identifying the manufacturer by name and address and the model and serial number of the tool.

Tool manufacturers should notify owners of inherent defects that affect fire and safety as soon as they become known. Likewise, users should notify tool manufacturers of potential fire and safety considerations.

Tool manufacturers should conduct ongoing programs of quality assurance, safety research, and investigation to identify, correct, and inform users of any potential operating malfunctions that might constitute fire safety hazards that could exist in their products.

All known hazards that cannot be engineered out of a tool should be clearly identified and controlled. These conditions should be addressed specifically in the tool's operation and maintenance manuals or in a notice accompanying the tool.