NFPA 318

Standard for the Protection of Cleanrooms

2000 Edition

NFPA, 1 Batterymarch Park, PO Box 9101, Quincy, MA 02269-9101
An International Codes and Standards Organization

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NFPA 318

Standard for the

Protection of Cleanrooms

2000 Edition

This edition of NFPA 318, *Standard for the Protection of Cleanrooms*, was prepared by the Technical Committee on Cleanrooms and acted on by the National Fire Protection Association, Inc., at its World Fire Safety Congress and Exposition™ held May 14–17, 2000, in Denver, CO. It was issued by the Standards Council on July 20, 2000, with an effective date of August 18, 2000, and supersedes all previous editions.

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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 Montréal in 1991. The 1992 edition was the first edition of this standard.

The standard was revised in 1995. The 1998 edition was a partial revision of the standard. The 2000 edition is a partial revision of the standard.

Technical Committee on Cleanrooms

David A. Quadrini, *Chair*
Marsh Risk Consulting, TX [I]

Vincent A. DeGiorgio, *Secretary*
Technology Risk Consulting Services, LLC, MA [SE]

Roger B. Benson, FM Global, CA [I]
Aimee Bordeaux, Semiconductor Equipment & Materials Int'l (SEMI), CA [M]
Stephen P. Caley, Motorola, AZ [U]
Marvin Charney, Kidde-Fenwal Inc./Williams Holdings, CA [M]
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Dennis H. Collins, Intel Corp., OR [U]
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Gordon W. Greene, Cherry Semiconductor Corp., RI [M]
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Dennis Kirson, Angel Engr Consultants, Taiwan [SE]
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William R. MacDonald, Firelite Alarms Inc., Notifier, CT [M]
Rep. Nat'l Electrical Mfrs. Assn.
Mark S. McGreevey, DNS Electronics, TX [M]
Lawrence A. McKenna, Jr., Hughes Assoc. Inc., MD [SE]
Robert J. Pearce, Jr., HSB Industrial Risk Insurers, CA [I]
Frank M. Quinlan, Micron Technology, Inc., ID [U]
Rodney D. Randall, AON Risk Services, CA [I]
Lawrence E. Shea, Shea Technology, NV [M]
Richard A. Shiraishi, Kemper Insurance, CA [I]
Timothy J. Smith, Restoration Technologies Inc., IL [U]
John R. Weaver, Delphi Delco Electronics Systems, IN [U]
Rep. NFPA Industrial Fire Protection Section
William F. Wilke, The RJA Group, Inc., TX [SE]

Alternates

Steve C. Dryden, Marsh USA, Inc., MO [I]
(Alt. to D. A. Quadrini)
R. Bruce Fraser, Simplex Time Recorder Co., MA [M]
(Alt. to W. R. MacDonald)
Louis H. Greuling, Jr., HSB Industrial Risk Insurers, PA [I]
(Alt. to R. J. Pearce)
Michael W. Lynch, IBM, VT [U]
(Alt. to D. E. Libby)
Earl D. Neargarth, Fike Corp., MO [M]
(Alt. to M. Charney)
Heron Peterkin, FM Global, MA [I]
(Alt. to R. B. Benson)
Larry M. Romine, Carter & Burgess, Inc., TX [IM]
(Vot. Alt. to American Fire Sprinkler Assn. Rep.)
John G. Ronan, Micron Technology, Inc., ID [U]
(Alt. to F. M. Quinlan)
Derek A. White, Hughes Assoc. Inc., MD [SE]
(Alt. to L. A. McKenna)

David R. Hague, NFPA Staff Liaison

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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.

Contents

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

Changes other than editorial are indicated by a vertical rule in the margin of the pages on which they appear. These lines are included as an aid to the user in identifying changes from the previous edition. Where one or more complete paragraph(s) has been deleted, the deletion is indicated by a bullet between the paragraphs that remain.

Information on referenced publications can be found in Chapter 10 and Appendix C.

Chapter 1 General

1.1 Scope. This standard applies to all semiconductor facilities 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 Equivalency.

1.3.1 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. Technical documentation shall be submitted to the authority having jurisdiction to demonstrate equivalency. The system, method, or device shall be approved for the intended purpose by the authority having jurisdiction.

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

1.4 Applicability. The provisions of this document are considered necessary to provide a reasonable level of protection against loss of life and property from fire and explosion. They reflect situations and the state of the art at the time the standard was issued.

Unless otherwise noted, it is not intended that the provisions of this document be applied to facilities, equipment, structures, or installations that were existing or approved for construction or installation prior to the effective date of the document, except when it is determined by the authority having jurisdiction that the existing situation involves a distinct hazard to life or adjacent property.

1.5 Definitions.

1.5.1 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.

1.5.2* Approved. Acceptable to the authority having jurisdiction.

1.5.3* Authority Having Jurisdiction. The organization, office, or individual responsible for approving equipment, an installation, or a procedure.

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

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

1.5.6 Compressed Gas. Any material or mixture having in the container an absolute pressure exceeding 40 psi (pounds per square inch) at 70°F (275.8 kPa at 21.1°C) or, regardless of the pressure at 70°F (21.1°C), having an absolute pressure exceeding 104 psi at 130°F (717 kPa at 54.4°C), or flammable liquid having a vapor pressure exceeding 40 psi absolute at 100°F (275.8 kPa at 37.8°C) as determined by ASTM D 323, *Standard Test Method for Vapor Pressure of Petroleum Products.*

1.5.7 Explosion. An effect produced by the sudden, violent expansion of gases, which can be accompanied by a shockwave or disruption, or both, of enclosing materials or structures. An explosion might result from chemical changes such as rapid oxidation, deflagration, or detonation; decomposition of molecules; and runaway polymerization (usually detonations) or from physical changes (e.g., pressure tank ruptures).

1.5.8 Flammable Vapors. A concentration of flammable constituents in air that exceeds 10 percent of its lower flammable limit (LFL).

1.5.9* Hazardous Chemical. 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.*

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

1.5.11 Interlock. An arrangement in which the operation of one part or mechanism automatically brings about or prevents the operation of another.

1.5.12 Liquid. For the purpose of this standard, any 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.* When not otherwise identified, the term *liquid* will mean both flammable and combustible liquids: (a) *Liquid, Combustible.* A liquid having a flash point at or above 100°F (37.8°C). Combustible liquids are subdivided as follows: (1) Class II liquids include those having flash points at or above 100°F (37.8°C) and below 140°F (60°C); (2) Class IIIA liquids include those having flash points at or above 140°F (60°C) and below 200°F (93°C); (3) Class IIIB liquids include those having flash points at or above 200°F (93°C); (b) *Liquid, Flammable.* A liquid having a flash point below 100°F (37.8°C) and having a vapor pressure not exceeding 40 psia (2068 mm Hg) at 100°F (37.8°C); known as a Class I liquid. Class I liquids are subdivided as follows: (1) Class IA liquids include those having flash points below 73°F (22.8°C) and having a boiling point below 100°F (37.8°C); (2) Class IB liquids include those having flash points below 73°F (22.8°C) and having a boiling point at or above 100°F (37.8°C); (3) Class IC liquids include those having flash points at or above 73°F (22.8°C) and below 100°F (37.8°C).

1.5.13* 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.

1.5.14 Noncombustible. 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 Degrees C,* are considered noncombustible. *(See NFPA 220, Standard on Types of Building Construction.)*

1.5.15 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.

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

1.5.17 Restricted-Flow Orifice. A device located in the gas cylinder valve body that restricts the maximum flow rate to 1.06 cfm (30 L/min).

1.5.18 Shall. Indicates a mandatory requirement.

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

1.5.20 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.

1.5.21 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, footnote, or fine-print note and are not to be considered a part of the requirements of a standard.

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

1.5.23 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.

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

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

Chapter 2 Fire Protection

2.1 Automatic Fire Extinguishing Systems.

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

2.1.2 Automatic Sprinkler Systems.

2.1.2.1* 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 0.20 gpm/ft^2 (8.15 L/min·m^2) over a design area of 3000 ft^2 (278.8 m^2).

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

2.1.2.3* Sprinklers shall be installed in gas cylinder cabinets that contain flammable gases.

2.1.2.4* Automatic quick-response sprinkler heads 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 6.4 and 6.5.

Exception: Where the open dispensing system is in accordance with Sections 6.4, 6.5, and Chapter 7, and designed to mitigate the effects of detonation, the automatic deluge water spray system shall not be required.

2.1.2.5* 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 0.20 gpm/ft^2 (8.15 L/min·m^2) over a design area of 3000 ft^2 (278.8 m^2).

Exception: Automatic sprinklers can be omitted if the construction and occupancy of these spaces are noncombustible.

2.1.2.6 All combustible exhaust ducts shall have interior automatic sprinklers where the largest interior cross-sectional diameter is equal to or greater than 10 in. (254 mm).

Exception: Ducts approved for use without internal automatic sprinklers.

2.1.2.6.1* Sprinklers installed in duct systems shall be hydraulically designed to provide 0.5 gpm (1.9 L/min) over an area derived by multiplying the distance between the sprinklers in a horizontal duct by the width of the duct. Minimum discharge shall be 20 gpm (76 L/min) per sprinkler from the five hydraulically most remote sprinklers. Sprinklers shall be spaced a maximum of 20 ft (6.1 m) apart horizontally and 12 ft (3.7 m) apart vertically.

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

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

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

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

2.1.2.6.6* 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.

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

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

2.2 Alarm Systems.

2.2.1 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.

2.2.2 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.

2.2.3 A manual notification system shall be provided to result in an audible alarm as described in 2.2.1.

2.3 Detection Systems.

2.3.1* A listed or approved smoke detection system shall be provided in the cleanroom return airstream at a point before dilution from makeup air occurs. The system shall have a minimum sensitivity of 0.03 percent per foot obscuration. The system shall be capable of monitoring particles to 10 microns or less. Where the system is of the light-scattering type, it shall have a minimum sensitivity of 0.03 percent per foot obscuration; where the system is of the cloud chamber type, it shall have a minimum sensitivity of 50,000 particles per millimeter.

2.3.2* 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.

2.3.3 Detection shall be provided at silane gas cylinders in the open dispensing systems described in Sections 6.4 and 6.5. Activation of detectors shall result in the closing of the cylinder automatic shutoff valves described in 6.1.2.

2.3.4* Where the potential exists for flammable gas concentrations to exceed 20 percent of the lower flammability limit (LFL), a continuous gas detection system shall be provided.

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

Chapter 3 Ventilation and Exhaust Systems

3.1 Air Supply and Recirculation Systems.

3.1.1 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.

3.1.2* High efficiency particulate air (HEPA) modules, ultra low 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 UL 900, *Standard for Air Filter Units.*

Exception: UL 900 Class II filters are acceptable in MAH/RAC (makeup airhandlers and recirculating airhandlers) provided the requirements of 2.3.5 are met.

3.1.3 Air supply and recirculation ducts shall have a flame spread index of not more than 25 and a smoke-developed rating of not more than 50 when tested in accordance with NFPA 255, *Standard Method of Test of Surface Burning Characteristics of Building Materials.*

3.2 Local Exhaust System.

3.2.1 Exhaust air discharged from cleanrooms shall not be recirculated. 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 reentry of hazardous chemicals.

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

3.2.3 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.

Exception: Downstream of fans, scrubbers, and treatment devices.

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

3.3 Local Exhaust System Construction.

3.3.1* Ribbed, flexible connections shall not be used in exhaust ductwork that is connected to combustible workstations or to workstations where combustible chemicals are used.

3.3.2 The entire exhaust duct system shall be self-contained. No portions of the building shall be used as an integral part of the system.

3.3.3 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.

3.3.4 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 6 ft (1.97 m) or a distance equivalent to two times the duct diameter, whichever is greater, on either side of the rated construction.

3.3.5 Fire dampers shall not be installed in exhaust ducts.

3.3.6* Exhaust duct systems shall be constructed of noncombustible materials or protected with sprinklers in accordance with 2.1.2.6.

Exception: Ducts approved for use without automatic sprinklers.

3.3.7 The interior and exterior surface of nonmetallic exhaust ducts shall have a flame spread rating of 25 or less, and the exterior surface of nonmetallic exhaust ducts shall have a smoke-developed rating of 25 or less when the interior or exterior of the duct is exposed to fire, when tested in accordance with NFPA 255, *Standard Method of Test of Surface Burning Characteristics of Building Materials.*

3.4 Duct Velocities. Airflow in cleanroom exhaust systems shall be designed to ensure dilution such that flammable vapors are not conveyed in the ducts. *(See definition 1.5.8, Flammable Vapors.)*

3.5 Controls.

3.5.1 The exhaust ventilation system shall have an automatic emergency source of power. The emergency power shall be designed and installed in accordance with NFPA 70, *National Electrical Code*®.

3.5.2* 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.

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

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

3.5.5* The air-handling system shall be designed to provide smoke exhaust, or a dedicated smoke control system shall be provided.

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3.5.5.1* An operational acceptance test of dedicated smoke removal system detectors, actuation/control systems, dampers, and fan units shall be conducted during the initial start-up phase of cleanroom construction.

3.5.5.2* Annual maintenance tests of dedicated smoke removal systems shall include functional tests of detectors and actuation/control systems.

3.5.6 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).

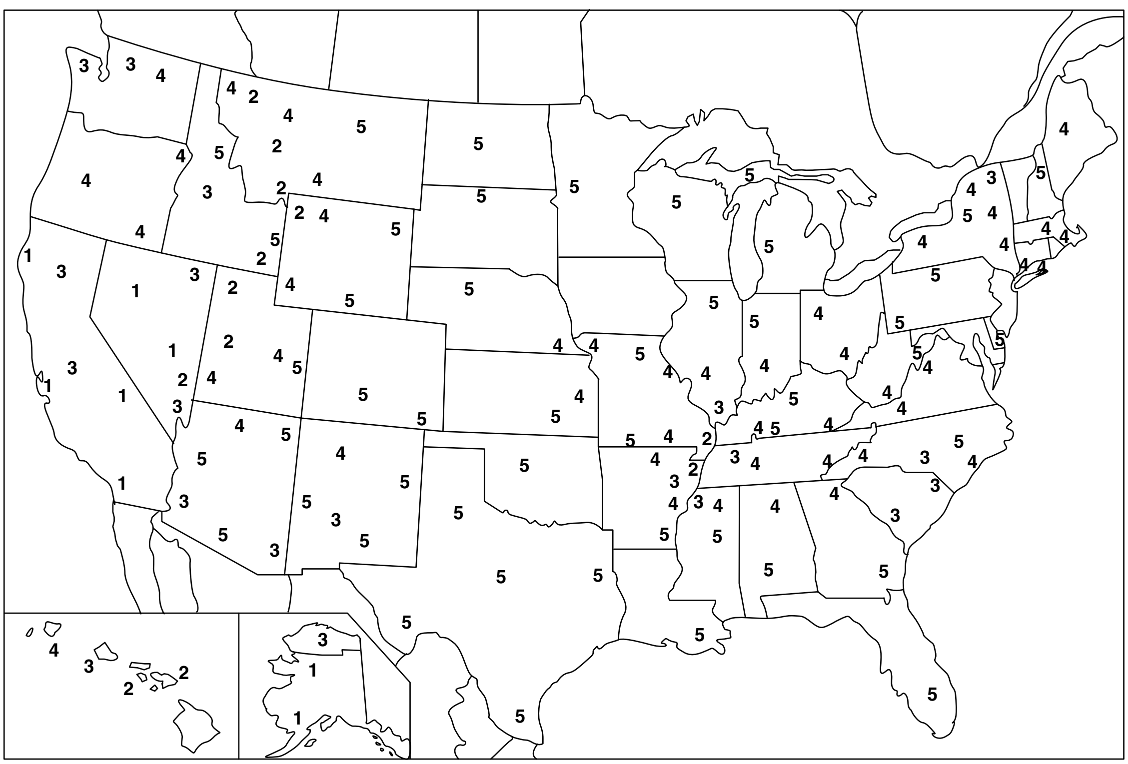
Chapter 4 Construction

4.1* Noncombustible Construction Components. Cleanrooms rated Class 100 or cleaner in accordance with Federal Standard 209 E, *Cleanroom and Work Station Requirements, Controlled Environment*, or cleanrooms having clean zones rated Class 100 or cleaner shall have approved, noncombustible components for walls, floors, ceilings, and partitions.

4.2 Fire Resistance Rating. Cleanrooms shall be separated from adjacent occupancies by 1-hour fire resistance–rated construction.

4.3 Access Floors. Cleanroom access floors shall be designed to resist a force of 0.5-G magnitude in seismic zones 1, 2, and 3, depicted in Figure 4.3.

FIGURE 4.3 Seismic map.



Earthquake Zones:
1 — Maximum potential for earthquake damage
2 — Reasonable potential
3 — Slight potential
4 and 5 — Earthquake protection not required

4.4* Electrical Classification. The cleanroom shall be considered unclassified electrically with respect to Article 500 of NFPA 70, *National Electrical Code*. Article 500 of NFPA 70, *National Electrical Code,* shall not apply to cleanrooms where chemical storage and handling meet the requirements of Chapter 5 of this standard.

Chapter 5 Chemical Storage and Handling

5.1* Hazardous Chemicals. Storage and handling of hazardous chemicals shall comply with applicable NFPA standards, including the following:

NFPA 30, *Flammable and Combustible Liquids Code*

NFPA 33, *Standard for Spray Application Using Flammable and Combustible Materials*

NFPA 70, *National Electrical Code*

NFPA 385, *Standard for Tank Vehicles for Flammable and Combustible Liquids*

NFPA 430, *Code for the Storage of Liquid and Solid Oxidizers*

NFPA 432, *Code for the Storage of Organic Peroxide Formulations*

5.1.1 Hazardous chemical storage and dispensing rooms shall be separated from the cleanroom by 1-hour fire resistance–rated construction.

5.1.2 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.

5.1.3 Hazardous chemicals in the cleanroom shall be limited to those needed for operations and maintenance. Quantities of hazardous chemicals shall be limited to those within the tool or the daily (24-hour) supply of chemicals needed.

5.1.4 Hazardous chemical storage and dispensing rooms shall have mechanical exhaust ventilation as follows.

5.1.4.1 Mechanical exhaust ventilation shall be at a minimum rate of 1 cfm/ft^2 (1 m^3/sec·m^2) of floor area.

5.1.4.2 Exhaust and inlet openings shall be arranged to prevent accumulation of vapors.

5.1.4.3 For dispensing rooms, the mechanical exhaust ventilation system shall be connected to an automatic emergency source of power.

5.1.5 Incompatible Storage.

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

Exception: Within hazardous materials storage or dispensing rooms.

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

5.1.5.3 Storage cabinets shall be constructed of not less than 18-gauge steel. Doors shall be self-closing and shall be provided with a latching device.

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

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

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

5.2 Flammable and Combustible Liquid Delivery Systems.

5.2.1 Class I and Class II liquids shall not be piped to deliver by gravity from tanks, drums, barrels, or similar containers. Dispensing devices for flammable and combustible liquids shall be of an approved type.

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

5.2.3 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

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

5.2.5 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.

Exception: 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.

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

Exception: 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 2000°F (1093.3°C).

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

5.2.8 Bulk Delivery Systems.

5.2.8.1 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

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

5.3 Container Delivery.

5.3.1* In new buildings, hazardous chemicals shall not be permitted within an exit corridor. In existing buildings, hazardous chemicals shall be transported in approved chemical carts.

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

5.3.3* Chemical carts transporting or containing hazardous chemicals shall be designed so that the contents will be fully enclosed. They shall be capable of containing a spill from the largest single container transported, with a maximum individual container size of 5 gal (19 L). The capacity of carts used for transportation of hazardous chemicals shall not exceed 55 gal (208 L).

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

5.4 Liquid Waste Disposal.

5.4.1 Separate drainage systems shall be provided for incompatible materials.

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

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

5.4.4 Flammable liquids shall be collected in approved containers.

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

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

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

5.5 Spill Protection.

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

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

Chapter 6 Hazardous Gas Cylinder Storage and Distribution

6.1 Packaging.

6.1.1 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

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

6.2 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.

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

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

6.3 Distribution Systems.

6.3.1 Material for tubing, piping, and fittings used for distribution of compressed and liquefied gases shall be compatible with those gases. 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 80 psi (552 kPa) for 2 hours with no discernible pressure drop.

6.3.2* 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.

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

6.3.3 Tubing, piping, and fittings shall be welded.

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

6.3.4 Distribution piping shall be leak tested in accordance with SEMI F1, *Specification for Leak Testing Toxic Gas Piping Systems.*

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

6.3.6* Purge panels shall be provided at the cylinders on all compressed hazardous process gases when in use. *[See 6.4.3(j) for silane and silane mixes.]*

6.3.7 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.

6.3.8* 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.

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

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

6.3.11 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.

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

6.3.13 Hazardous gas cylinder purge panels shall be provided with dedicated purge gas cylinders. Only purge panels serving compatible gases shall be permitted to share a purge cylinder.

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

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

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

6.4.1.1 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 9 ft (2.7 m).

6.4.1.2 The storage 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 12 ft (3.7 m).

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

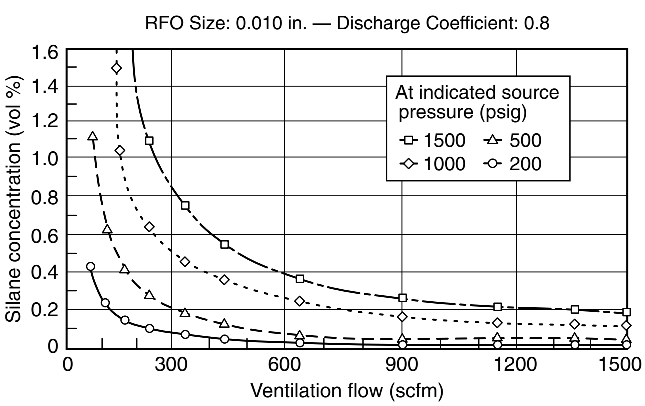
6.4.2.1 If cabinets are used, ventilation shall be as follows:

(a) 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.

(b) 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.

For a 0.4 percent concentration, the required ventilation airflow rate can be estimated from Figure 6.4.2.1. To satisfy the minimum concentration requirement, the airflow rate needs to 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 6.4.2.1 for a given RFO size and maximum gas cylinder storage pressure.

FIGURE 6.4.2.1 Average silane concentration in a ventilated enclosure.



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

6.4.3 Dispensing areas shall be provided with the following safeguards.

(a) Dispensing racks shall be located external to the building.

Exception: Where weather conditions do not permit, the dispensing racks shall be in an approved bunker.

(b) Cylinders shall be separated from each other by a steel plate $^1/_4$ in. (6.3 mm) thick, extending 3 in. (76 mm) beyond the footprint of the cylinder. The steel plate shall extend from the top of the purge panel to 12 in. (305 mm) below the cylinder valve.

(c) Mechanical or natural ventilation at a minimum of 1 cfm/ft^2 (0.00047 m^3/sec · 0.09 m^2) of storage and dispensing area shall be provided.

(d) Cylinders shall be provided with protection and detection in accordance with 2.1.2.4 and 2.3.3.

(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 15 ft (4.6 m) from the dispensing area.

(f) Exterior dispensing areas shall be separated from structures in accordance with Figure 6.4.3. 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 12 ft (3.7 m).

(g) Gas vent headers or individual purge panel vent lines shall have a continuous flow of nitrogen. To prevent back diffusion of air into the vent line, a nitrogen flow shall be introduced. The nitrogen shall be introduced upstream of the first vent or exhaust connection to the header.

(h) 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 9 ft (2.7 m).

(i) If mechanical ventilation is provided, the ventilation system shall be provided with an automatic emergency source of power to operate at full capacity.

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

Table 6.4.2.1 Silane flow rates through restricted flow orifices based on the predictions from the FMRC model

		Silane Flow (scfm)								
RFO Dia.		Source Pressure (psig)								
in.	mm	1500	1200	1000	800	600	400	200	100	50
0.020	0.51	10.0	7.88	6.04	4.34	3.02	1.92	0.949	0.497	0.288
0.014	0.36	4.91	3.86	2.96	2.13	1.48	0.941	0.465	0.243	0.136
0.010	0.25	2.50	1.97	1.51	1.08	0.755	0.480	0.237	0.124	0.069

Notes:
1. The flows through the 0.014 in. (0.36 mm) and 0.010 in. (0.25 mm) RFOs are equal to 49 and 25 percent of the flow through the 0.020 in. (0.5 mm) diameter RFO.
2. To convert (scfm) to [slpm], multiply by 28.32.
3. To convert from psig to bar, divide by 14.5.
4. Source temperature: 77°F; Downstream pressure: 0 psig; Discharge coefficient: 0.8.

FIGURE 6.4.3 Silane dispensing area.

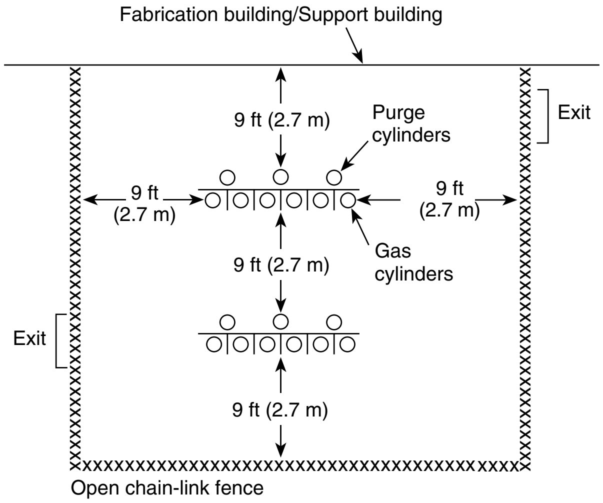
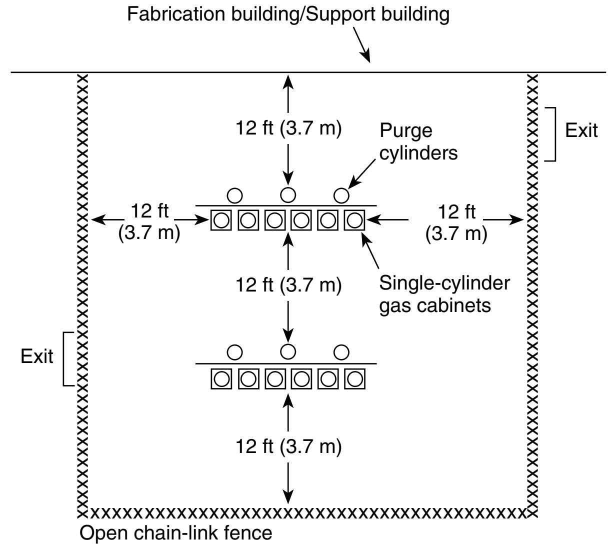


FIGURE 6.5.3 Silane/toxic mixes dispensing area.



6.5* Silane/Toxic Mixes Storage and Dispensing Areas.

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

6.5.1.1 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 9 ft (2.7 m).

6.5.1.2 The storage 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 12 ft (3.7 m).

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

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

6.5.3 Dispensing areas shall be provided with the following safeguards.

(a) The dispensing areas shall be located external to the building.

Exception: Where the weather conditions do not permit, the dispensing area shall be in an approved bunker.

(b) *Silane/toxic mixes located in cabinets shall be provided with mechanical ventilation at a minimum of 200 ft/min (fpm) (0.762 m/sec) across the cylinder neck and the purge panel. The ventilation system shall be provided with an automatic emergency source of power to operate at full capacity.

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

(d) Gas vent headers or individual purge panel vent lines shall have a continuous flow of nitrogen. To prevent back diffusion of air into the vent line, a nitrogen flow shall be introduced. The nitrogen shall be introduced upstream of the first exhaust connection to the header.

(e) Exterior dispensing areas shall be separated from structures in accordance with Figure 6.5.3. The dispensing area shall be open on at least three sides with cylinders in single-cylinder cabinets. Where a canopy is provided, the height shall be a minimum of 12 ft (3.7 m).

(f) 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 12 ft (3.7 m).

6.6 Flammable or Toxic Gases.

6.6.1* Toxic or flammable gases in use shall be contained in cabinets provided with exhaust ventilation. Cabinets shall be provided with gas detection and automatic shutdown of the gas supply. Exhaust ventilation shall be continuous or activated automatically by gas detection.

Exception: Lecture cylinders in ion implanters need not be in gas cabinets. They shall be located in exhausted enclosures with gas detection and automatic shutdown of the gas supply.

6.6.2* Subatmospheric flammable dopant gas sources shall be used instead of high-pressure cylinder flammable gas sources whenever process compatibility will allow.

6.6.3 Exhaust ventilation shall be provided where there is potential for gas release and for the area containing valves, fittings or connections, transfer stations, or vacuum pumps. Detection of toxic or flammable gases shall activate a local alarm and shut down the gas supply. Alarms shall be monitored continuously.

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

6.6.5 Welding and other activities that might produce ignition shall be minimized in areas where there is potential flammable gas release. Welding or other activities that might produce a spark shall be allowed only through a special internal permit procedure that calls for monitoring in the area for 20 percent of the lower explosive limit (LEL) and a fire watch and ventilation to reduce the potential of explosive concentrations.

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

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

6.7 Vent Headers.

6.7.1 Purge panel vent line headers, where used, shall be designed to prevent the mixing of incompatible gases and silane with air. Vent header inert gas purge shall be monitored and provided with a local alarm when flow falls below a required set point.

6.7.2 Silane vent headers or individual purge panel vent lines shall have a continuous flow of nitrogen. To prevent back diffusion of air into the vent line, a nitrogen flow shall be introduced. The nitrogen shall be introduced upstream of the first exhaust connection to the header.

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

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

6.8* Training. Operators working with hazardous gases and handling hazardous compressed and liquefied gas containers shall be trained for that function. Training shall be provided annually.

Chapter 7 Bulk Silane Systems

7.1 Tube Trailer Systems.

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

7.1.2 Automatic fixed water spray protection shall be provided to the tube trailer storage. The system shall be designed to provide a density of 0.30 gpm/ft^2 (12 mm/m^2) over the external surface area of the trailers for a 2-hour duration. Regular systems and control panel areas shall also be protected by this system. The water spray system shall be activated by approved optical flame detectors.

7.1.3 Activation of the water spray system shall close emergency shutoff valves (ESOVs). ESOVs shall be located as close to the piping connection to the tube trailer as possible.

7.1.4 Tube trailers shall be separated from each other and from the regulator station by 2-hour-rated fire walls.

7.1.5 The arrangement of piping, valving controls, and valve manifold boxes shall be as recommended for silane cylinder systems.

7.1.6 The restricted flow orifice (RFO) size used in the bulk systems shall be as small as possible to meet process needs. An RFO shall be provided for each tube and located as close to each tube as possible.

7.1.7 Pressure relief devices (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. 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. Stacks shall be provided with blow-off caps or other means of preventing rain and other foreign material from entering the stacks.

7.2 Cylinder Pack Systems.

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

7.2.2 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.

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

Chapter 8 Production and Support Equipment

8.1* General.

8.1.1 Production and support equipment shall be designed and installed in accordance with Sections 8.2 through 8.8.

8.1.2* Maximum quantities of chemicals at individual workstations shall not be limited where the tool is designed and built in accordance with this chapter.

Workstations or defined spaces shall be limited to the following amounts of chemicals in use or staging at any one time:

(1) Corrosives: 100 gallons
(2) Flammable/Toxic: 75 gallons
(3) Oxidizers: 50 gallons
(4) Pyrophorics: 10 gallons

8.2 Interlocks.

8.2.1* Hardware interlocks that automatically bring the tool to standby mode shall be interfaced with the tool's operating system.

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

Exception: Panel interlocks.

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

8.2.4 Tools utilizing hazardous chemicals shall be designed to accept inputs from monitoring equipment. An alarm signal from the monitoring equipment shall automatically stop the flow of hazardous chemicals to the tool.

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

8.3 Electrical Design.

8.3.1 Electrical components and wiring shall be in accordance with NFPA 70, *National Electrical Code*, and NFPA 79, *Electrical Standard for Industrial Machinery*. The tool or associated equipment shall be approved as a complete system.

8.3.1.1 Process tools and associated equipment shall meet the requirements of Article 90-7 of NFPA 70, *National Electrical Code*.

8.3.1.2 All electrical components and wiring shall be listed.

8.3.1.3 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.

8.3.2 Electrical equipment and devices within 5 ft (1.5 m) 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.

Exception: 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.

8.3.3 Workstations where flammable chemicals are used shall be provided with interlocks to prevent the workstations from being energized without adequate ventilation. 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 8.2.2.

8.4 Process Liquid Heating Equipment. Electric immersion heaters and hot plates shall not be used in combustible tools or tools using combustible or flammable liquids.

Exception: Stand-alone electric water heaters, external to combustible wet stations, or bonded heaters shall be permitted.

8.4.1 Where used, stand-alone electric water heaters shall include the following safeguards.

(a) The electrical supply connection shall include a ground fault interrupt circuit breaker with appropriately sized over-current protection.

(b) An automatic temperature control system shall be included.

(c) A power interrupt circuit with manual reset that removes all power to the heating elements when activated shall be included. Upon activation of this circuit a system warning alarm shall be provided to the operator.

(d) 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. This circuit shall include at least two independent liquid level sensing devices. It shall activate the power interrupt circuit required in (c).

(e) An 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. This circuit shall include at least two independent temperature-sensing devices. It shall activate the power interrupt circuit required in (c).

8.4.2 Electrically heated chemical baths shall have the following safeguards.

(a) The electrical supply connection shall include a ground fault interrupt circuit breaker with appropriately sized over-current protection.

(b) An automatic temperature control system shall be included.

(c) A power interrupt circuit with manual reset that removes all power to the heating elements when activated shall be included. Upon activation of this circuit a system warning alarm shall be provided to the operator.

(d) 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. This circuit shall include at least two independent liquid level sensing devices. It shall activate the power interrupt circuit required in (c).

(e) An 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. For baths containing flammable or combustible liquids, this circuit shall remove power from the heating element prior to temperature of the fluid reaching its flash point. This circuit shall include at least two independent temperature-sensing devices. It shall activate the power interrupt circuit required in (c).

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

8.4.4* Liquid level sensors shall be tested after every maintenance but at least monthly.

8.5 Materials of Construction. Tools shall be of noncombustible construction.

Exception No. 1: Small parts within the tool such as knobs, buttons, electrical contacts, and terminal strips.

Exception No. 2: Materials listed for use without internal fire detection and suppression.*

Exception No. 3: Fire sprinklers, approved gaseous agent fire suppression systems, or other approved engineering controls designed to prevent or limit fire damage.

8.6 Vacuum Pumps.

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

8.6.2 Exhaust Conditioning.

8.6.2.1* Vacuum pumps that handle flammable gases in excess of 20 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.

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

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

8.6.2.4 Interlocks that shut down gas flow at the tool in the event of the following shall be provided with the 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

8.7 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.

8.8* 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 20 percent of the LFL.

Chapter 9 Means of Egress

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

Chapter 10 Referenced Publications

10.1 The following documents or portions thereof are referenced within this standard as mandatory requirements and shall be considered part of the requirements of this standard. The edition indicated for each referenced mandatory document is the current edition as of the date of the NFPA issuance of this standard. Some of these mandatory documents might also be referenced in this standard for specific informational purposes and, therefore, are also listed in Appendix C.

10.1.1 NFPA Publications. National Fire Protection Association, 1 Batterymarch Park, P.O. Box 9101, Quincy, MA 02269-9101.

NFPA 13, *Standard for the Installation of Sprinkler Systems*, 1999 edition.

NFPA 30, *Flammable and Combustible Liquids Code*, 2000 edition.

NFPA 33, *Standard for Spray Application Using Flammable or Combustible Materials*, 2000 edition.

NFPA 70, *National Electrical Code*®, 1999 edition.

NFPA 79, *Electrical Standard for Industrial Machinery*, 1997 edition.

NFPA *101*®, *Life Safety Code*®, 2000 edition.

NFPA 220, *Standard on Types of Building Construction*, 1999 edition.

NFPA 255, *Standard Method of Test of Surface Burning Characteristics of Building Materials*, 2000 edition.

NFPA 385, *Standard for Tank Vehicles for Flammable and Combustible Liquids*, 2000 edition.

NFPA 430, *Code for the Storage of Liquid and Solid Oxidizers*, 2000 edition.

NFPA 432, *Code for the Storage of Organic Peroxide Formulations*, 1997 edition.

NFPA 704, *Standard System for the Identification of the Hazards of Materials for Emergency Response*, 1996 edition.

10.1.2 Other Publications.

10.1.2.1 ASTM Publications. American Society for Testing and Materials, 100 Barr Harbor Drive, West Conshohocken, PA 19428-2959.

ASTM D 5, *Standard Test Method for Penetration of Bituminous Materials,*1986.

ASTM D 323, *Standard Test Method for Vapor Pressure of Petroleum Products,* 1990.

ASTM E 136, *Standard Test Method for Behavior of Materials in a Vertical Tube Furnace at 750 Degrees C,* 1993.

10.1.2.2 SEMI Publication. Semiconductor Equipment and Materials International, 805 East Middlefield Road, Mountain View, CA 94043-4080.

SEMI F1, *Specification for Leak Testing Toxic Gas Piping Systems,* 1990.

10.1.2.3 UL Publication. Underwriters Laboratories Inc., 333 Pfingsten Road, Northbrook, IL 60062.

UL 900, *Standard for Air Filter Units.*

10.1.2.4 U.S. Government Publication. Superintendent of Documents, U.S. Government Printing Office, Washington, DC 20402.

FED STD 209 E, *Cleanroom and Work Station Requirements, Controlled Environment,* 1992.

Appendix A Explanatory Material

Appendix A is not a part of the requirements of this NFPA document but is included for informational purposes only. This appendix 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.1.3.2 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.1.5.2 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.1.5.3 Authority Having Jurisdiction. The phrase "authority having jurisdiction" 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.1.5.9 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).*

(a) *Hazardous Materials.* Hazardous materials are raw materials in transit to the user and are governed by the U.S. Department of Transportation (DOT) under *CFR*, Title 49, "Transportation."

(b) *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 *CFR*, Title 29, "Labor."

(c) *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 *CFR*, Title 40, "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.1.5.13 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.1.5.25 Workstation. The terms *workstation, tool, process tool, process equipment,* or *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.

A.2.1.1 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.2.1.2.1 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.2.1.2.2 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.2.1.2.3 It is recommended that an approved 135°F (57°C), $^3/_8$-in. (9.5-mm) orifice sprinkler be used. It is recommended that a sprinkler be installed in all gas cylinder cabinets.

A.2.1.2.4 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 2.3.3.

A.2.1.2.5 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.2.1.2.6.1 Small-orifice sprinklers, $^3/_8$ in. (9.5 mm) or larger, can be used.

A.2.1.2.6.3 Drainage for, and placement of, sprinklers should be designed to prevent water from flowing back into process equipment, 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.2.1.2.6.6 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 $^3/_8$-in. (9.5-mm) orifice sprinkler.

A.2.1.2.7 It is recommended that an approved $^3/_8$-in. (9.5-mm) orifice sprinkler be used. Drainage should be provided to remove all sprinkler water discharged in the pass-through.

A.2.3.1 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.*

A.2.3.2 Smoke detection need not result in an automatic facility evacuation alarm signal.

A.2.3.4 Cleanroom hydrogen monitoring should use parts-per-million detectors to provide alarm and detection for hydrogen leaks.

A.3.1.2 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 2 can be up to 8 ft (2.6 m).

A.3.3.1 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.

A.3.3.6 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.3.5.2 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.3.5.5 Semiconductor cleanrooms are operationally sensitive to fire products of combustion. A fire will result in smoke and corrosive particle contamination to the cleanroom, process equipment, and work in process. A properly designed, installed, and maintained smoke control system can reduce contaminant migration. A smoke control system will not prevent contamination, but will limit the spread and concentration of the contaminate. The basis of the smoke control system design should be aligned with the organization's risk management financial objectives.

Automatic actuation of dedicated smoke control systems is preferable; however, many facilities prefer manual activation. If the system is manually activated, the following should be done.

(a) The smoke detection system should be monitored by qualified personnel 24 hours per day.

(b) Emergency response teams (ERR) or other personnel authorized to actuate the manual smoke control system should be capable of prompt notification.

(c) Detailed smoke control emergency procedures should be documented and practiced. These procedures can include hazardous gas shutdowns and shutdowns of appropriate air recirculation fans as well as activating the smoke control exhaust fans.

Smoke removal system capacity requirements are dependent on the design fire size and materials involved. Subjectively lesser hazards should be protected with a system designed to provide a minimum of 3 cfm/ft^2 (0.007 cmm/m^2). Higher hazard areas (i.e., where combustible wet benches are located) should be protected with a system designed to provide a minimum of 5 cfm/ft^2 (0.004 cmm/m^2).

The smoke control system capacity is directly related to the design fire size. In order to achieve a system that is economically feasible, the maximum design fire size should be limited to the fire size at sprinkler operation. For a typical cleanroom configuration, the fire size at sprinkler operation is in the range of 600 to 800 kilowatts.

Smoke removal system capacity can be designed based on an integrated system approach. The total capacity can include the fume exhaust system capacity and dedicated smoke removal system capacity.

When the fume exhaust system is used for smoke removal, the following design parameters should be followed.

(a) The fume exhaust system ductwork should be of noncombustible construction or should be listed/approved for smoke removal and not incorporate the use of fire dampers or interrupters.

(b) It should be confirmed that sufficient fume exhaust system intake points exist throughout the clean room. If not, additional intake points should be provided and incorporate the use of normally closed dampers. These dampers should be opened either automatically by activation of the smoke detection system and/or by manual means.

(c) When the fume exhaust system is used for smoke removal, it can incorporate the use of variable speed fan(s). During the smoke removal mode, fire dampers on supplemental intake points will open and the fan speed will be increased. The design capture velocity at the tool(s) could be affected, and this should be reviewed. Necessary balancing changes should be made to ensure the design capture velocity is maintained.

The ventilation system make-up air fans should be sized such that under full smoke and process exhaust the fabrication area maintains a positive pressure relative to adjacent areas.

Smoke removal system intake locations are dependent on the fabrication area design. Design alternatives should be addressed with a competent fire protection engineering design firm.

For open manufacturing areas, smoke removal system intake sequencing should be designed such that individual zones can be activated to prevent contaminant migration to clean areas of the fab.

A.3.5.5.1 Testing methods should not cause an unacceptable decrease in cleanroom air quality.

A.3.5.5.2 Smoke removal systems should be designed to facilitate the maintenance testing of components. If possible, design should allow annual tests of dampers and fan units.

A.4.1 Buildings housing these cleanrooms should be of noncombustible or fire-resistive construction.

A.4.4 The hand delivery and pouring of combustible and flammable chemicals has 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.5.1 The following documents should be consulted for storage and handling of hazardous chemicals:

NFPA 68, *Guide for Venting of Deflagrations*

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

A.5.3.1 New buildings are designed to provide chemical-handling corridors.

A.5.3.3 Individual breakable, chemical containers should be separated to avoid breakage.

A.5.4.2 Labeling of contents should be in accordance with ANSI B31.3, *Chemical Plant and Petroleum Refinery Piping*.

A.6.1.2 If a flow-restricted orifice is placed in a system with an excess flow device, the excess flow device might not shut off.

A.6.2.2 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.6.3.2 If the distribution piping is of noncombustible construction, a combustible outer jacket can be used for secondary containment.

A.6.3.5 Training should be as outlined in SEMI F3, *Guideline for Welding Stainless Steel Tubing for Semiconductor Manufacturing Applications*.

A.6.3.6 Automated purge panels are recommended because they reduce the potential for human error.

A.6.3.8 The basic components of purge panels should incorporate the following features.

(a) Tied diaphragm regulators should be used.

(b) 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.

(c) Burst pressure components should be rated to at least 50 percent above the maximum pressure available to all components.

(d) All components should have a helium leak rate no greater than 0.00001 cc/hour.

(e) 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.

(f) No check valves should be used as a primary control of potential cross contamination and backflow.

(g) Electrical components on purge panels should be intrinsically safe.

(h) Excess flow control (valve or switch) should be provided on the high-pressure side of the purge panel.

(i) 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.

(j) All systems should be equipped with an emergency shutoff.

A.6.5 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.6.5.3(b) Exhaust airflow should be calculated by multiplying 200 ft/min (61 m/min) by the cross-sectional area of the cabinet.

A.6.6.1 Alternative substances should be considered for replacement of hazardous gases.

A.6.6.2 Traditionally high-pressure cylinders have been used to contain flammable dopant gases such as arsine, and phospine used, for example, in chemical vapor deposition (CVD) and ion implantation operations. In ion implanters, it is common to have small dopant gas cylinders in a gas cabinet located within the implanter enclosure. A recent innovation dopant source that is an alternative to the high-pressure gas cylinder is called the subatmospheric dopant gas source. This gas source looks like a high-pressure cylinder except that it is filled with a microporous material that adsorbs the dopant gas. During normal operation, the gas cylinder pressure is reduced and the gas is withdrawn.

Under leak scenarios, the gas release from these new subatmospheric systems is decreased by a factor of 30 to 60 thousands as compared to a high-pressure cylinder source. These systems offer a considerable reduction in fire hazard. There are also process advantages since the gas in the new system is at 100 percent concentration rather than at 10 to 15 percent concentration typical in high-pressure systems because of safety reasons. In addition, the systems are located at or within the ion implanter or CVD tool, eliminating long runs of costly co-axial tubing from the gas vault.

A.6.8 A certification program should be used to ensure adequate training.

A.7.1.1 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 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 1 psig (gauge pressure of 6.9 kPa) is acceptable and we assume a release through a $^1/_2$-in. (12.7 mm) orifice pressure relief valve (PRV) venting a tube trailer pressurized to 1400 psig (gauge pressure of 9653 kPa), then the separation distance should be approximately 130 ft (39.6 m). If the tube trailer pressure is only 1000 psig (gauge pressure of 6895 kPa) the distance drops to approximately 100 ft (30.5 m).
(2) If the PRV orifice diameter is 1 in. (25.4 mm), however, with the tube trailer pressure at 1000 psig (gauge pressure of 6895 kPa) a distance of approximately 180 ft (54.8 m) will be needed to achieve only a 1 psig (gauge pressure of 6.9 kPa) overpressure.

A.8.1 *Introduction.* Chapter 8 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.

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 8. 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 specifically addressed in the tool's operation and maintenance manuals or in a notice accompanying the tool.

Plans and specifications for tools, prior to their fabrication or use, or both, should be reviewed and signed by a trained employee or independent third party using the requirements of Chapter 8.

The maintenance and operation manuals should provide guidance for the posting of appropriate signs on tools to indicate that maintenance is in process.

Administration. Owners should designate a responsible individual in their employ to review drawings of tool and system designs and to ensure that tools will be in conformance with these requirements.

Owners should perform physical inspection of tools on their receipt to ensure they are in conformance with their design and review documents.

Owners should ensure that tools are accompanied with adequate installation, maintenance, and operating instructions, including appropriate wiring details and facilitation of the tool.

Owners should ensure that a proper hands-on training program in the safe operation of a tool is instituted and that standardized examinations are given to test knowledge and ability.

Owners should institute an appropriate maintenance program to ensure that all safety controls will work in a proper manner and when required. Qualified personnel should inspect and conduct maintenance against a checklist on a sufficiently frequent basis to ensure continued safe operation of the tool. The name of the inspector and the date of last inspection should be posted on or close to each tool.

Production and support equipment can be designed to comply with SEMI S2, *Product Safety Guidelines*, and designed and installed in accordance with Sections 8.2 through 8.8.

A.8.1.2 Quantities can be doubled in closed loop systems (no hand pouring).

A.8.2.1 Interlock systems should be designed to prevent override during normal operation.

A.8.4.3 Wet benches that use combustible chemicals, heated above their flash points, or flammable chemicals should be provided with devices to detect fire.

A.8.4.4 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.8.5 Exception No. 2. Factory Mutual Research Corporation has developed Test Standard 4910 "Cleanroom Material Flammability Test Protocol" 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.

The protocol utilizes three small scale tests and a large scale validation test if needed. 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:

(a) *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.

(b) *Smoke Damage 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 damage 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 will not propagate a fire beyond the ignition zone. Smoke and corrosive products generated from the combustion of these materials is reduced, minimizing nonthermal damages.

Another test standard is UL 2360, *Standard Test Method for Determining the Combustibility Characteristics of Plastics Used in Semiconductor Tool Construction.* Testing is based on the cone calorimeter test established in ASTM E 1354, *Standard Test Method for Heat and Visible Smoke Release Rates for Materials and Products Using an Oxygen Consumption Calorimeter.* Tests can be correlated with the parallel panel test.

A.8.6.1 Such devices can be traps, condensers, demisters, or coalescing filters. As an alternative, noncombustible oils or dry-type pumps not requiring lubricant should be used.

A.8.6.2.1 Vacuum pumps whose construction is susceptible to backstreaming oil into tools should have foreline traps on their inlets.

A.8.8 Exhaust flow should be monitored and controlled by a sensor set at a negative static pressure to provide the minimum airflow specified in Chapter 5.

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