NFPA® 318

Standard for the Protection of Semiconductor Fabrication Facilities

2015 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

2015 Edition

This edition of NFPA 318, *Standard for the Protection of Semiconductor Fabrication Facilities*, was prepared by the Technical Committee on Semiconductor and Related Facilities. It was issued by the Standards Council on April 29, 2014, with an effective date of May 19, 2014, and supersedes all previous editions.

This edition of NFPA 318 was approved as an American National Standard on May 19, 2014.

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 clarified the requirements for both Type 1 and Type 2 subatmospheric gas systems. Revisions also included the removal of seismic considerations, in order to focus the scope of the document.

The 2012 edition provided additional modifications to the requirements for subatmospheric gas systems (SAGS) based on the technical committee's review of necessary safeguards for these systems. Several reference standards were updated as part of this revision.

The 2015 edition has been completely reorganized in an effort to make the standard more user friendly. The term *subatmospheric gas system* has been revised to *subatmospheric gas source* throughout the standard to clarify its meaning. Various categories of hazardous materials have been identified, and the concept of "HPM risk assessment" has been introduced. New requirements have been added throughout the standard that encompass the following subject matter: hazardous materials, liquid chemical storage and handling, gas storage and handling, production and support equipment, waste treatment, and fire protection.

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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 the fire protection for fabrication facilities and comparable fabrication processes for semiconductor, display panel, photovoltaic, and related facilities. When bulk gas systems are involved the responsibility begins at a point downstream of the source valve.

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Standard for the

Protection of Semiconductor Fabrication Facilities

2015 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.

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 gpm = 3.785 L/min 1 ft^3/min = 28.3 L/min
liter/minute/ square meter	L/min·m^2	1 gpm/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
cubic meter/ minute/ square meter	m^3/min·m^2	1 ft^3/min·ft^2 = 0.31 m^3/min·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,* 2015 edition.

NFPA 12, *Standard on Carbon Dioxide Extinguishing Systems,* 2011 edition.

NFPA 13, *Standard for the Installation of Sprinkler Systems,* 2013 edition.

NFPA 30, *Flammable and Combustible Liquids Code,* 2015 edition.

NFPA 37, *Standard for the Installation and Use of Stationary Combustion Engines and Gas Turbines,* 2015 edition.

NFPA 55, *Compressed Gases and Cryogenic Fluids Code,* 2013 edition.

NFPA 70®, *National Electrical Code®*, 2014 edition.

NFPA 72®, National Fire Alarm and Signaling Code, 2013 edition.
NFPA 79, *Electrical Standard for Industrial Machinery,* 2015 edition.
NFPA 90A, *Standard for the Installation of Air-Conditioning and Ventilating Systems,* 2015 edition.
NFPA 92, *Standard for Smoke Control Systems,* 2012 edition.
NFPA *101®, Life Safety Code®,* 2015 edition.
NFPA 385, *Standard for Tank Vehicles for Flammable and Combustible Liquids,* 2012 edition.
NFPA 400, *Hazardous Materials Code,* 2013 edition.
NFPA 497, *Recommended Practice for the Classification of Flammable Liquids, Gases, or Vapors and of Hazardous (Classified) Locations for Electrical Installations in Chemical Process Areas,* 2012 edition.
NFPA 704, *Standard System for the Identification of the Hazards of Materials for Emergency Response,* 2012 edition.
NFPA 750, *Standard on Water Mist Fire Protection Systems,* 2014 edition.
NFPA 2001, *Standard on Clean Agent Fire Extinguishing Systems,* 2012 edition.
NFPA 5000®, Building Construction and Safety Code®, 2015 edition.

2.3 Other Publications.

2.3.1 ANSI/CGA Publications. Compressed Gas Association, 14501 George Carter Way, Suite 103, Chantilly, VA 20151-2923.

ANSI/CGA G-13, *Storage and Handling of Silane and Silane Mixtures*, 2006.

2.3.2 ANSI/FM Publications. ANSI/FM 4910, *Standard for Cleanroom Materials Flammability Test Protocol*, 2004.

2.3.3 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*, 2008, Revised 2010.

ANSI/UL 900, *Standard for Air Filter Units*, 2004, Revised 2010.

ANSI/UL 2360, *Standard Test Method for Determining the Combustibility Characteristics of Plastics Used in Semiconductor Tool Construction*, 2000.

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

ASME A.13.1, *Scheme for the Identifications of Piping Systems*, 2007.

ASME B31.3, *Process Piping*, 2012.

ASME Boiler and Pressure Vessel Code

2.3.5 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*, 2006 e1.

ASTM E 84, *Standard Test Method for Surface Burning Characteristics of Building Materials*, 2013.

ASTM E 136, *Standard Test Method for Behavior of Materials in a Vertical Tube Furnace at 750°C*, 2012.

2.3.6 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.

2.3.7 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.

SEMI S3-0306, *Safety Guidelines for Process Liquid Heating Systems*, 2006.

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

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

2.3.9 Other Publications.

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

2.4 References for Extracts in Mandatory Sections.
NFPA 1, *Fire Code,* 2015 edition.
NFPA 30, *Flammable and Combustible Liquids Code,* 2015 edition.
NFPA 55, *Compressed Gases and Cryogenic Fluids Code,* 2013 edition.
NFPA 69, *Standard on Explosion Prevention Systems,* 2014 edition.
NFPA *101®, Life Safety Code®,* 2015 edition.
NFPA 400, *Hazardous Materials Code,* 2013 edition.
NFPA 1670, *Standard on Operations and Training for Technical Search and Rescue Incidents,* 2014 edition.
NFPA 5000®, Building Construction and Safety Code®, 2015 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 are not to be considered a part of the requirements of a standard and shall be located in an appendix, annex, footnote, informational note, or other means as permitted in the *Manual of Style for NFPA Technical Committee Documents*.

3.3 General Definitions.

3.3.1 Bulk Gas System. A system in which compressed gas is delivered, stored, and discharged in the gaseous form to a piping system. The threshold quantity used to define a bulk gas system is determined based on material-specific requirements. The compressed gas system terminates at the point where compressed gas at service pressure first enters the distribution piping system.

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

3.3.3 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.

3.3.4 Compressed Gas. A material, or mixture of materials, that (1) is a gas at 68°F (20°C) or less at an absolute pressure of 14.7 psi (101.3 kPa) and (2) has a boiling point of 68°F (20°C) or less at an absolute pressure of 14.7 psi (101.3 kPa) and that is liquefied, nonliquefied, or in solution, except those gases that have no other health or physical hazard properties are not considered to be compressed gases until the pressure in the packaging exceeds an absolute pressure of 40.6 psi (280 kPa) at 68°F (20°C). [**55,** 2013]

3.3.5 Compressed Gas Container. A pressure vessel designed to hold compressed gas at an absolute pressure greater than 1 atmosphere at 68°F (20°C) that includes cylinders, containers, and tanks. [**5000,** 2015]

3.3.6* Corrosive Material. A chemical that causes visible destruction of, or irreversible alterations in, living tissue by chemical action at the point of contact. [**1,** 2015]

3.3.7 Dopant Gas. A dopant gas is a molecule that will insert a trace impurity element into a substance in order to alter the electrical properties or the optical properties of the substance.

3.3.8 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.

3.3.9 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.

3.3.10 Explosion. The bursting or rupture of an enclosure or a container due to the development of internal pressure from a deflagration. [**69,** 2014]

3.3.11 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.

3.3.12 Facility Sub-fab. A support area, used for facility equipment and services, located below the fabrication cleanroom level, but which is separated from the cleanroom air flow by a fire-rated barrier. Typically located one level below the Clean Sub-fab, which is directly below the fabrication cleanroom level, and is within the air return path. Sometimes referred to as the "Dirty Sub-fab."

3.3.13 Flammable Degradation Temperature (FDT). The temperature at which a liquid degrades producing a flammable byproduct. [SEMI S3-0306][Definition republished with permission from Semiconductor Equipment and Materials International, Inc. (SEMI) © 2012]

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

3.3.15 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.

3.3.16 Grade Plane. A reference plane upon which vertical measurements of a building are based.

3.3.17 Hazardous Production Material. 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*.

3.3.18 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,** 2014]

3.3.19 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.

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

3.3.21 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.

3.3.22 Limit.

3.3.22.1* *Permissible Exposure Limit (PEL).* The maximum permitted 8-hour, time-weighted average concentration of an airborne contaminant. [**5000,** 2015]

3.3.23 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.

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

3.3.23.2 *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).

3.3.24 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.

3.3.25 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,** 2015]

3.3.26 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.

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

3.3.28 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).

3.3.29 Room.

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

3.3.29.2 ***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.

3.3.30 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.

3.3.31 Service Corridor. A fully enclosed passage used for transporting HPM and for purposes other than required means of egress. [**5000,** 2015]

3.3.32 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.

3.3.33 Source Valve. A shutoff valve on the piping system serving a bulk gas supply system where the gas supply, at service pressure, first enters the supply line. [**55,** 2013]

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

3.3.35 System.

3.3.35.1 ***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.

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

3.3.35.3 ***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,** 2015]

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

3.3.35.5 ***Subatmospheric Gas Source (SAGS).***

3.3.35.5.1 ***Subatmospheric Gas Storage and Delivery Source (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 absolute pressure of 14.7 psi at NTP.

3.3.35.5.2 ***Subatmospheric Gas Delivery Source (Type 2 SAGS).*** A gas source package that stores compressed gas and delivers gas at subatmospheric pressure and includes a container (e.g., gas cylinder and outlet valve) that stores gas at a pressure greater than absolute presure of 14.7 psi at NTP and delivers gas at a pressure of less than absolute pressure of 14.7 psi at NTP.

3.3.36 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.

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

3.3.38* Toxic Material. A material that produces a lethal dose or a lethal concentration within any of the following categories: (1) a chemical or substance that has a median lethal dose (LD_{50}) of more than 50 mg/kg but not more than 500 mg/kg of body weight when administered orally to albino rats weighing between 200 g and 300 g each; (2) a chemical or substance that has a median lethal dose (LD_{50}) of more than 200 mg/kg but not more than 1000 mg/kg of body weight when administered by continuous contact for 24 hours, or less if death occurs within 24 hours, with the bare skin of albino rabbits weighing between 2 kg and 3 kg each; (3) a chemical or substance that has a median lethal concentration (LC_{50}) in air of more than 200 parts per million but not more than 2000 parts per million by volume of gas or vapor, or more than 2 mg/L but not more than 20 mg/L, of mist, fume, or dust when administered by continuous inhalation for 1 hour, or less if death occurs within 1 hour, to albino rats weighing between 200 g and 300 g each. [**1**, 2015]

3.3.38.1* ***Highly Toxic Material.*** A material that produces a lethal dose or lethal concentration that falls within any of following categories: (1) a chemical that has a median lethal dose (LD_{50}) of 50 mg/kg or less of body weight when administered orally to albino rats weighing between 200 g and 300 g each; (2) a chemical that has a median lethal dose (LD_{50}) of 200 mg/kg or less of body weight when administered by continuous contact for 24 hours, or less if death occurs within 24 hours, with the bare skin of albino rabbits weighing between 2 kg and 3 kg each or albino rats weighing 200 g to 300 g each; (3) a chemical that has a median lethal concentration (LC_{50}) in air of 200 parts per million by volume or less of gas or vapor, or 2 mg/L or less of mist, fume, or dust, when administered by continuous inhalation for 1 hour, or less if death occurs within 1 hour, to albino rats weighing between 200 g and 300 g each. [**1**, 2015]

3.3.39* Water-Reactive Material. A material that explodes, violently reacts; produces flammable, toxic, or other hazardous gases; or evolves enough heat to cause self-ignition or ignition of nearby combustibles upon exposure to water or moisture. [**1,** 2015]

3.3.40* 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 Building Construction and Related Services

4.1 General.

4.1.1 Occupied Levels of Fabrication Areas. Normally, occupied levels of fabrication areas handling HPM shall be located at or above grade.

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

4.2 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*.

4.3* 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.

4.4 Fire Resistance Rating.

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

4.4.2 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*.

4.5 Pass-Throughs in Existing Exit Access Corridors.

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

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

4.6 Vertical Openings.

4.6.1 Openings through floors of fabrication areas shall be permitted to be unprotected, in accordance with 4.5.2, where the interconnected levels are used solely for mechanical equipment directly related to the fabrication areas. [**5000**:34.3.7.2.1.5]

4.6.1.1 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)]

4.6.1.2 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)]

4.6.1.3 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)]

4.6.2 Unenclosed vertical openings not contained within fire-rated 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 be separated from other fire or smoke compartments on the same floor.
(5) In new construction, the convenience opening shall be separated from the corridor referenced in 8.12.5.1(3) of *NFPA 5000* by a smoke partition, unless Chapters 15 through 31 and 33 through 34 of *NFPA 5000* require the corridor to have a fire resistance rating.
(6)*Such openings shall not serve as a required means of egress.

4.7 Air Supply and Recirculation Systems.

4.7.1 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.

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

4.7.3 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*.

4.7.4 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).

4.7.5 Testing.

4.7.5.1 Testing of automatic detection devices shall be conducted in accordance with the requirements of Chapter 12.

4.8* Electrical Classification.

4.8.1 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 Chapters 5, 6, and 7 of this standard.
(2) Ventilation and exhaust systems meet the requirements of this chapter, and Chapter 9 of this standard.
(3) The average ventilation flow rate is not less than 0.176 L/sec·m^2 (4 ft^3/min·ft^2) of floor area, and the ventilation flow rate 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.

4.8.2 Workstations. Workstations shall be in accordance with 8.4.2.

4.9 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

4.9.1 Diesel generators shall be installed in accordance with the requirements of NFPA 37, *Standard for the Installation and Use of Stationary Combustion Engines and Gas Turbines*.

4.10 Means of Egress.

4.10.1 Means of egress shall be provided in accordance with NFPA *101*, *Life Safety Code*.

4.10.2 Service Corridors.

4.10.2.1 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.

4.10.2.2 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).

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

Chapter 5 Hazardous Materials — General Provisions

5.1* Hazardous Chemicals.

5.1.1 Materials Classification. Hazardous Production Materials (HPM) shall be defined by the following classes of chemicals or substances.

5.1.1.1 Physical Hazards. The following material categories shall be classified as physical hazards, and a material with a primary classification as a physical hazard can pose a health hazard:

(1) Flammable and combustible liquids
(2) Flammable solids and gases
(3) Oxidizer materials
(4) Pyrophoric liquids, gases, and solids
(5) Unstable (reactive) materials
(6) Water-reactive solids and liquids
(7) Cryogenic fluids
(8) Compressed gases

5.1.1.2 Health Hazards. The following material categories shall be classified as health hazards, and a material with a primary classification as a health hazard can pose a physical hazard:

(1) Highly toxic and toxic materials
(2) Corrosive materials

5.2 HPM Risk Assesment.

5.2.1 This section shall apply to the management methodology used to identify, evaluate, and control the hazards involved in the processing and handling of flammable and combustible liquids. These hazards include, but are not limited to, preparation; separation; purification; and change of state, energy content, or composition.

5.2.2 Operations involving flammable and combustible liquids shall be reviewed to ensure that fire and explosion hazards are addressed by fire prevention, fire control, and emergency action plans. [**30:**6.4.1]

Exception No. 1: Operations where liquids are used solely for on-site consumption as fuels.

Exception No. 2: Operations where Class II or Class III liquids are stored in atmospheric tanks or transferred at temperatures below their flash points.

5.2.3 The fire hazards management review shall be repeated whenever the hazards leading to a fire or explosion change significantly. Conditions that shall require repeating a review shall include, but are not limited to, the following:

(1) When changes occur in the materials in process
(2) When changes occur in process equipment
(3) When changes occur in process control
(4) When changes occur in operating procedures or assignments

5.2.4 A written emergency action plan that is consistent with available equipment and personnel shall be established to respond to fires and related emergencies. This plan shall include the components contained in 6.8.1 of NFPA 30, *Flammable and Combustible Liquids Code*.

5.3 Container Delivery.

5.3.1* 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.

5.3.1.1 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.

5.3.3.1 Chemical carts shall be capable of containing a spill from the largest single container transported, with a maximum individual container size of 20 L (5.3 gal) for liquids.

5.3.3.2 The capacity of carts used for the 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
(4) SAGS: 7 cylinders, up to 18 kg (40 lb) each

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

5.3.5 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.

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

5.3.7 The maximum quantities of hazardous chemicals transported in a service corridor at one time shall not exceed two times that set forth in 6.3.3.

5.4 Storage and Handling of Hazardous Chemicals. 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 55, *Compressed Gases and Cryogenic Fluids Code*
(3) *NFPA 70, National Electrical Code*
(4) NFPA 385, *Standard for Tank Vehicles for Flammable and Combustible Liquids*
(5) NFPA 400, *Hazardous Materials Code*

5.5* Separation of Hazardous Chemicals. Hazardous chemicals stored in hazardous chemical rooms shall be separated from incompatible materials in accordance with Table 5.5.

5.5.1 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.

5.5.2 Hazardous chemicals in the fabrication area shall be limited to those needed for operations and maintenance and as required by 5.5.2.1 and 5.5.2.2, with quantities not exceeding the limitations specified in Table 5.5.2. The limits of Table 5.5.2 shall be permitted to be exceeded, provided a submittal using alternative methods and materials is approved by the authority having jurisdiction (AHJ).

5.5.2.1 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 5.5.2.1 unless a risk assessment determines that a significant fire is unlikely to take place.

5.5.2.1.1* The amounts in Table 5.5.2.1 shall be permitted to be exceeded if a risk assessment is performed and approved by the AHJ.

5.5.2.2 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.

Table 5.5 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 457 mm (18 in.) 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 5.5, or are required to be kept in approved gas cabinets.
*Separation by not less than 6 m (20 ft) is permitted in lieu of a noncombustible partition.

Table 5.5.2 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 [b]	Note [b]
Oxidizing					0.76	2.5
Flammable gas						
Gaseous					Note [b]	Note [b]
Liquefied					Note [b]	Note [b]
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				
Organic peroxide						
Unclassified detonable	Note [a]	Note [a]	Note [a]	Note [a]		
Class I	Note [a]	Note [a]	Note [a]	Note [a]		
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 [a]	Note [a]	Note [a]	Note [a]		
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 [a]	Note [a]	0.1	0.0025	Notes [b] and [c]	Notes [b] and [c]
Unstable reactive						
Class 4	Note [a]	Note [a]	Note [a]	Note [a]	Note [a]	Note [a]
Class 3	0.8	0.05	0.2	0.005	Note [a]	Note [a]
Class 2	3.2	0.2	0.8	0.02	Note [a]	Note [a]
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 [b]	Note [b]
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 [b]	Note [b]

Note: Hazardous materials within piping not to be included in the calculated quantities.

[a]Quantity of hazardous materials in a single fabrication not to exceed exempt amounts in NFPA 1, *Fire Code.*

[b]The aggregate quantity of flammable, pyrophoric, toxic, and highly toxic gases not to exceed a density limit of 0.2 ft^3 per ft^2 at NTP.

[c]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.*

Table 5.5.2.1 Maximum Quantities of Hazardous Chemicals at a Workstation

Hazardous Chemical	State	Maximum Amount
Flammables, highly toxics, and pyrophorics and toxics combined[a]	Gas	Combined aggregate volume of all cylinders at a work station shall not exceed an internal cylinder volume of 150 L (39.6 gal, or 5.29 ft^3).
Hazardous chemical flammables	Liquid	56.8 L (15 gal)[a, b]
	Solid	2.3 kg (5 lb)[a, b,]
Corrosives[a]	Gas	Combined aggregate volume of all cylinders at a work station shall not exceed an internal cylinder volume of 150 L (39.6 gal, or 5.29 ft^3).
	Liquid	378.5 L (100 gal)[a, b]
	Solid	9.1 kg (20 lb)
Highly toxics	Liquid	56.8 L (15 gal)[a]
	Solid	2.3 kg (5 lb)[a]
Oxidizers[a]	Gas	Combined aggregate volume of all cylinders at a work station shall not exceed an internal cylinder volume of 150 L (39.6 gal, or 5.29 ft^3).
	Liquid	45.4 L (12 gal)[a, b]
	Solid	9.1 kg (20 lb)[a, b]
Pyrophorics	Liquid	20 L (5.3 gal)[c, d]
Toxics	Liquid	56.8 L (15 gal)[a, b]
	Solid	2.3 kg (5 lb)[a, b]
Unstable reactives Class 3	Liquid	20 L (5.3 gal)[a, b, d]
	Solid	2.3 kg (5 lb)[a, b]
Water reactives Class 3	Liquid	1.9 L (0.5 gal)[c]

[a]Allowable quantities increased 100 percent for use-closed systems operations. When note b also applies, the increase for both requirements is allowed.

[b]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 a also applies, the increase for both notes is allowed.

[c]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.

[d]20 L is acceptable, it is more reflective of current practices for volumes of materials used at individual tools.

5.5.3 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.

5.5.4 Incompatible Storage.

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

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

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

5.6 Systems, Equipment, and Processes. Systems, equipment, and processes utilized for storage, dispensing, use, or handling of hazardous materials shall be in accordance with 5.6.1 through 5.6.2.

5.6.1 Design and Construction of Containers, Cylinders, and Tanks.

5.6.1.1 Containers, cylinders, and tanks shall be designed and constructed in accordance with approved standards.

5.6.1.2 Containers, cylinders, tanks, and other means used for containment of hazardous materials shall be of an approved type.

5.6.2 Piping, tubing, valves, and fittings conveying hazardous materials shall be designed and installed in accordance with approved standards and shall be in accordance with 5.6.2.1.

5.6.2.1* Design and Construction. Piping, tubing, valves, fittings, and related components used for hazardous materials shall be in accordance with the following:

(1) Piping, tubing, valves, fittings, and related components shall be designed and fabricated from materials that are compatible with the material to be contained and shall be of adequate strength and durability to withstand the pressure, structural, and seismic stress and exposure to which they are subject.
(2) Piping and tubing shall be identified in accordance with ASME A13.1, *Scheme for the Identification of Piping Systems,* to indicate the material conveyed.
(3) Readily accessible manual valves or automatic remotely activated fail-safe emergency shutoff valves shall be installed on supply piping and tubing at the following locations:
    (a) The point of use
    (b) The tank, cylinder, or bulk source
(4) Manual emergency shutoff valves and controls for remotely activated emergency shutoff valves shall be identified and the location shall be clearly visible, accessible, and indicated by means of a sign.
(5) Backflow prevention or check valves shall be provided when the backflow of hazardous materials could create a hazardous condition or cause the unauthorized discharge of hazardous materials.
(6) Where gases or liquids have a hazard ranking of health hazard Class 3 or 4, flammability Class 4, reactivity Class 3 or 4, in accordance with NFPA 704, *Standard System for the Identification of the Hazards of Materials for Emergency Response,* and are carried in pressurized piping above gauge pressure of 103 kPa (15 psi), an approved means of leak detection and emergency shutoff or excess flow control shall be provided. Where the piping originates from within a hazardous material storage room or area, the excess flow control shall be located within the storage room or area.

5.6.3 Hazard Chemical Storage Cabinets. Hazardous chemicals shall be stored within enclosed storage cabinets or workstations.

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

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

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

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

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

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

5.7 Supply Piping.

5.7.1 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.

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

5.7.3 Supply piping for all liquids shall be hydrostatically tested to 150 percent of the maximum allowable working pressure for 2 hours with no visible leakage or loss of pressure.

5.8 Welding.

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

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

Chapter 6 Liquid Chemical Storage and Handling

6.1 General. Liquid chemical hazards are identified in Sections 6.2 through 6.8.

6.2* Flammable and Combustible Liquid Delivery Systems.

6.2.1 The design, fabrication, assembly, test, and inspection of dispensing systems shall comply with the provisions of Section 27.3 of NFPA 30, *Flammable and Combustible Liquids Code*.

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

6.2.3 Dispensing systems for flammable and combustible liquids shall contain devices of an approved type.

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

6.2.5 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) Each canister venting device shall be marked per Section 22.7.3.10 of NFPA 30, *Flammable and Combustible Liquids Code,* with the start-to-open pressure, pressure at which the vent reaches the full open position, and the flow capacity at the relieving pressure.
(6) Piping to or from approved emergency vent devices for pressurized canisters shall be sized in accordance with the *ASME Boiler and Pressure Vessel Code*.

6.2.6 Transfer of liquids among vessels, containers, tanks, and piping systems by means of air or inert gas pressure shall be permitted only under all of the following conditions:

(1) The vessels, containers, tanks, and piping systems shall be designed for such pressurized transfer and shall be capable of withstanding the anticipated operating pressure.
(2) Safety and operating controls, including pressure-relief devices, shall be provided to prevent overpressure of any part of the system.
(3) Only inert gas shall be used to transfer Class I liquids. Only inert gas shall be used to transfer Class II and Class III liquids that are heated above their flash points.

[**30:**18.4.4]

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

6.2.7.1 Systems acceptance testing shall be documented in accordance with recognized engineering standards.

6.2.7.2 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.

6.2.8 All wetted parts in pressurized delivery systems for flammable liquids shall be metallic construction with a melting point above 1093.3°C (2000°F).

6.2.8.1 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).

6.2.8.2 Nonmetallic tubing and associated secondary containment shall be designed and built in accordance with recognized standards of design or approved equivalents and shall be installed in accordance with the provisions of 27.4.4 of NFPA 30, *Flammable and Combustible Liquids Code*.

6.2.9 Bulk Delivery Systems.

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

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

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

6.2.9.3 Hazardous production material (HPM) liquid 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.

6.2.10 Processing and handling of Class II and Class III liquids heated at or above their flash point shall follow the requirements for Class I liquids, unless an engineering evaluation conducted in accordance with Chapter 6 of NFPA 30 justifies following the requirements for some other liquid class. [**30:**18.3]

6.2.10.1 When a process requires heating a liquid to a temperature at or above its flashpoint, the following shall apply:

(1) The process vessel shall be closed to the room in which it is located.
(2) Process heating controls shall be interlocked with the exhaust ventilation, such that the process heat will shut down if the ventilation fails or is turned off.
(3) The process vessel shall be equipped with an excess temperature control set to limit excessive heating of the liquid and the subsequent release of vapors.
(4) If a heat transfer medium is used to heat the liquid and the heat transfer fluid can heat the liquid to its boiling point on failure of the process and excess temperature heat controls, a redundant excess temperature control shall be provided.

6.2.11 Where Class I liquids are handled or used above grade within buildings with basements or closed pits, into which flammable vapors can travel, such belowgrade areas shall be provided with mechanical ventilation designed to prevent the accumulation of flammable vapors. [**30:**17.6.9.1]

6.2.12 Ventilation for Dispensing Areas.

6.2.12.1 Ventilation for flammable and combustible liquid dispensing areas shall comply with the provisions of Section 18.6 of NFPA 30, *Flammable and Combustible Liquids Code.*

6.3 Spill Protection.

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

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

6.3.3 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

6.4 Pyrophoric Liquids.

6.4.1* 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.

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

6.4.3 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 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.
(4) The cabinet shall be designed to provide real-time feedback to the operator and/or chemical handling technician so they remain aware of valve positioning and material flow.

6.4.4* 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.

6.4.5 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.

6.4.5.1 Each cabinet shall be equipped with a liquid leak detector interlocked to shutdown the cabinet and corresponding liquid flow upon detection of a leak.

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

6.4.7 Fire Detection System. Fire detection systems shall comply with the requirements of Chapter 11.

6.4.8 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).

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

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

6.5 Corrosive Liquids.

6.5.1 Indoor Storage.

6.5.1.1 Liquid-Tight Floor. Floors in storage areas for *corrosive* liquids shall be of liquid-tight, noncombustible construction.

6.5.2 Use.

6.5.2.1 Liquids having a hazard ranking of 3 when exceeding 20 L (5.3 gal), or liquids having a hazard ranking of 4 when exceeding 4 L (1.1 gal), shall be transferred by one of the following methods:

(1) From safety cans
(2) Through an approved closed-piping system

(3) From containers or tanks by an approved pump taking suction through an opening in the top of the container or tank
(4) For other than highly toxic liquids, from containers or tanks by gravity through an approved self-closing or automatic-closing valve where the container or tank and dispensing operations are provided with spill control and secondary containment complying with 6.3.1.4.1 through 6.3.1.4.2.10
(5) By the use of approved engineered liquid transfer systems

[**400:**6.3.1.7.2]

6.5.2.2 Ventilation. Where corrosive liquids having a hazard ranking of 3 or 4 in accordance with NFPA 704, *Standard System for the Identification of the Hazards of Materials for Emergency Response,* are dispensed or used, mechanical exhaust ventilation shall be provided to capture mists or vapors at the point of generation.

6.6 Toxic and Highly Toxic Materials. Toxic and highly toxic materials shall be arranged and protected per the requirements of NFPA 400, *Hazard Materials Code.*

6.7* Water Reactive Chemistries.

6.7.1* Water-based heating baths used for heating ampoules or cylinders shall be thoroughly inspected to assure leak tightness to prevent entry of water into the water reactive material.

6.8 Oxidizers.

6.8.1 The use and handling of oxidizer liquids shall be in accordance with Sections 15.5 and 15.6 of NFPA 400, *Hazard Materials Code.*

Chapter 7 Gas Storage and Handling

7.1* General. The storage, use, and handling of hazardous gases shall be in accordance with the provisions of this chapter, Chapter 5, and NFPA 55, *Compressed Gases and Cryogenic Fluids Code.*

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

7.1.1.1* 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.

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

7.1.3 Distribution Systems.

7.1.3.1 Piping, tubing, fittings, and related components shall be designed, fabricated, and tested in accordance with the requirements of ANSI/ASME B31.3, *Process Piping,* or other approved standards. [**55:**7.3.1.3]

7.1.3.1.1 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.

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

7.1.3.2 Material for tubing, piping, and fittings used for distribution of compressed gases or hazardous production material gases shall be compatible with those gases.

7.1.3.3* Materials for tubing, piping, and fittings used for the distribution of compressed gas or hazardous production material gases shall be of noncombustible construction or of combustible construction contained in a noncombustible outer jacket.

7.1.3.4 Tubing, piping, and fittings shall be welded.

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

7.1.4 Purge Panels.

7.1.4.1* Purge panels shall be provided at the cylinders for all hazardous production material gases when in use. *(See 7.6.2 for silane and silane mixes.)*

7.1.4.2 Purge panels shall be labeled with the type of gas, and the type of purge gas.

7.1.4.3* 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.

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

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

7.1.4.6 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.

7.1.4.7 Hazardous production material gas cylinder purge panels shall be provided with dedicated purge gas cylinders.

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

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

7.1.5 Vent Headers.

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

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

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

7.1.5.2.1 To prevent back diffusion of air into the vent line, an inert gas flow shall be introduced.

7.1.5.2.2 The inert gas shall be introduced upstream of the first exhaust connection to the header.

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

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

7.1.6* Gas-Detection Systems.

7.1.6.1 General. A gas-detection system shall be provided for hazardous production material 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.

7.1.6.2 Where Required.

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

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

7.1.6.2.3 Gas Cabinets, Exhausted Enclosures, and Gas Rooms.

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

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

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

7.1.6.2.4 Exit Access Corridors.

7.1.6.2.4.1 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.

7.1.6.2.4.2 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.

7.1.6.3 Gas-Detection System Operation.

7.1.6.3.1 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

7.1.6.3.2 Shutoff of Gas Supply.

7.1.6.3.2.1 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

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

7.1.7 Fire Protection. Automatic fixed fire protection and fire detection systems for hazardous gases shall be in accordance with Chapter 11.

7.1.8 Fire Protection. Automatic fixed fire protection and fire detection systems for hazardous gases shall be in accordance with Chapter 11.

7.1.9 Indoor Gas Cabinets.

7.1.9.1* HPM gases in cylinders used indoors, including gas rooms, shall be contained in cabinets provided with exhaust ventilation in accordance with NFPA 1, *Fire Code*, for silane and silane mixes. *(See Section 7.6.)*

7.1.9.1.1 Where nonbulk indoor silane cylinders are located in rooms meeting the construction, ventilation, and safeguard requirements within CGA G-13 to minimize the effects of detonation, gas cabinets shall not be required.

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

7.1.9.3 Exhaust ventilation shall be continuous.

7.2 Corrosive Gases. The storage, use, and handling of corrosive gases shall be in accordance with Section 7.5 of NFPA 55, *Compressed Gases and Cryogenic Fluids Code.*

7.3 Flammable Gases. The storage, use, and handling of flammable gases shall be in accordance with Section 7.6 of NFPA 55.

7.4 Oxidizing Gases. The storage, use, and handling of oxidizing gases shall be in accordance with Section 7.7 of NFPA 55.

7.5 Pyrophoric Gases. The storage, use, and handling of pyrophoric gases shall be in accordance with Section 7.8 of NFPA 55.

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

7.5.1.1 Information on the date of manufacture, material of construction, and orifice flow curve shall be available and provided upon request for the restricted flow orifices.

7.6* Silane Systems. Silane and silane mixtures shall be stored, used, and handled in accordance with the provisions of ANSI/CGA G-13, *Storage and Handling of Silane and Silane Mixtures.* [**55:**7.8.2]

7.6.1* A normally closed automatic shutoff valve shall be installed on all silane and silane mixture cylinders and bulk sources.

7.6.2* Dispensing systems for silane and silane mixes shall employ automated purge panels.

7.6.3 Mass flow controller bypass valves shall be designed to prevent excess flow of silane and to prevent their being left in the open position.

7.6.4 Optical flame detection for silane delivery systems shall be provided as described in 11.2.5.1.

7.7 Toxic and Highly Toxic Gases. The storage, use, and handling of toxic and highly toxic gases shall be in accordance with Section 7.9 of NFPA 55, *Compressed Gases and Cryogenic Fluids Code*.

7.7.1 Cylinders and bulk sources containing pyrophoric gases shall be equipped with normally closed automatic shutoff valves that incorporate restricted flow orifices (RFOs).

7.7.1.1 The size of RFO shall be calculated based on the capacity of the abatement device.

7.8 Unstable Reactive Gases. The storage, use, and handling of unstable reactive gases shall be in accordance with Section 7.10 of NFPA 55, *Compressed Gases and Cryogenic Fluids Code*.

7.9 Cryogenic Fluids. The storage, use, and handling of cryogenic fluids shall be in accordance with Chapter 8 of NFPA 55.

7.10 Bulk Oxygen Systems. The storage, use, and handling of bulk oxygen systems shall be in accordance with Chapter 9 of NFPA 55.

7.11 Gaseous Hydrogen Systems. The storage, use, and handling of gaseous hydrogen systems shall be in accordance with Chapter 10 of NFPA 55.

7.12 Liquefied Hydrogen Systems. The storage, use, and handling of liquefied hydrogen systems shall be in accordance with Chapter 11 of NFPA 55.

7.13 Gas Generation Systems. The storage, use, and handling of gas generation systems shall be in accordance with Chapter 12 of NFPA 55.

7.13.1 Fluorine Gas Generators. (Reserved)

7.13.2 Ozone Gas Generators. (Reserved)

7.14 Dopant Gas Sources.

7.14.1 Dopant gas cylinders shall be in gas cabinets, or exhausted enclosures with gas detection and automatic shutdown of the gas supply.

7.14.2* Subatmospheric Gas Sources (SAGS). All (both Type 1 and Type 2) SAGS shall meet all requirements for gases found in this standard, except as provided for in 7.14.2.1 through 7.14.2.6.

7.14.2.1* SAGS cylinders with incompatible gases shall be permitted to occupy the same gas cart, gas cabinet, or exhausted enclosure.

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

7.14.2.3 Purge gas supply, referenced in 7.1.4.7, shall be permitted from a house system.

7.14.2.4 Shared purge panels for incompatible gases shall be permitted for SAGS sources.

7.14.2.5* The requirements for automatic shutoff valves under 7.5.1 shall not be required for SAGS containing pyrophoric gases.

7.14.2.6* The requirements for an RFO shall not apply to SAGS Type 1 cylinders containing hazardous production material gases.

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 8.3 through 8.4. *(See Annex C.)*

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

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

8.1.4 Workstations containing hazardous materials shall be provided with horizontal clearances of not less than 0.914 m (3 ft) where servicing is required, such as cylinder changes or hand pouring of chemicals.

8.1.5 Tools shall be designed to contain a release of HPM liquids as follows:

(1) The containment system shall have the capacity to contain 110% volume of the largest container or anticipated leak or spill, whichever is greater.
(2) The containment system shall provide leak detection arranged to alarm at a constantly attended location.

8.2 Materials of Construction.

8.2.1 Tools shall be constructed of noncombustible materials.

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

8.2.1.2* Materials listed for use without internal fire detection and suppression shall be an acceptable alternative to noncombustible materials, where process concerns or process chemicals require alternatives.

8.2.2 Tools not meeting the requirements of 8.2.1 shall be provided with internal tool fire detection and suppression (fire sprinklers, approved gaseous agent fire suppression systems, or watermist) unless a risk assessment approved by the authority having jurisdiction concludes otherwise. The risk assessment shall include evaluation of approved engineering controls designed to prevent or limit fire damage and fire detection and suppression options.

8.3* Equipment Safety Systems and Interlocks.

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

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

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

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

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

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

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

8.4 Electrical Design.

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

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

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

8.4.1.3 All electrical components and wiring shall be listed.

8.4.1.4 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.

8.4.2 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.

8.4.2.1 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.

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

8.4.3.1 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 8.3.2.

8.5 Process Liquid Heating Equipment.

8.5.1* 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 into the design.

8.5.2 Electrically heated process liquid heating systems (PLHS) shall have the safeguards in 8.5.3 through 8.5.5.9 where applicable.

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

8.5.4 An automatic temperature process control system shall be included.

8.5.5 A power interrupt circuit with manual reset that removes all power to the heating elements when activated shall be included to limit the effects of the conditions described in 8.5.5.1 to 8.5.5.9 where risk assessment determines that the conditions can result in unacceptable damage to equipment and/or an unacceptable risk of injury to personnel.

8.5.5.1* Liquid Overtemperature Protection. Process liquid overtemperature protection shall be provided and set at a temperature that prevents the hazardous degradation of the process liquid.

8.5.5.2* The interlock shall prevent process liquids from reaching a point where the properties of the liquid create a potentially dangerous situation (e.g., boiling, autoignition, flammable degradation temperatures, or expansion volume).

8.5.5.2.1 The liquid overtemperature setpoint shall be determined based on both the chemicals being heated and the properties of the materials of construction in contact with the liquid and shall be set as high as is consistent with safety considerations, with reference to Table 8.5.5.3.

8.5.5.3 Liquid overtemperature protection shall be provided to prevent process liquids from reaching a point where the properties of the liquid create a potentially dangerous situation as shown in Table 8.5.5.3.

Table 8.5.5.3 Maximum Overtemperature Setpoint

Liquid Property	Maximum Overtemperature Setpoint
Noncombustible	Boiling point (bp)
Combustible	Lesser of boiling point (bp) or auto ignition temperature (AIT) less 50°C
Flammable	Flashpoint (fp) less 10°C

8.5.5.4* Heater overtemperature protection shall be provided that prevents degradation of the structural integrity of the heater or its surrounding materials.

8.5.5.5 Heat Exchanger Overtemperature. Where a heat exchanger and heat transfer fluid are employed, sensors shall be located where required and set at a temperature that prevents degradation of the structural integrity of the heat exchanger, the vessel containing the process liquid, or their surrounding materials at any process liquid level, including the absence of liquid. This interlock shall perform its intended function up to the maximum heated temperature of the transfer fluid, taking into account the power of the heater and any interlocks incorporated in the heated liquid heat exchange system.

8.5.5.6 Low Liquid Level. A sensor shall be located such that the interlock shall protect against loss of heat absorption capacity of the liquid being heated and ensure that liquid remains present to absorb residual heat energy to assure that a hazardous temperature is not reached when the process liquid is at the setpoint of the liquid overtemperature interlock.

8.5.5.7 Liquid Flow. In a flow-dependent system, a sensor to monitor for liquid flow shall be installed that allows for the PLHS to be energized only when a safe rate of flow is present.

8.5.5.8 Overpressure. The PLHS shall be provided with a means of preventing the rupture of the vessel due to excessive pressure or vapor generation.

8.5.5.9 Where purging or inerting is used to control a flammable atmosphere associated with the operation of the PLHS, interlocks to assure that purging or inerting is operational prior to power being applied to the heater shall be installed.

8.6 General Requirements for Tools Using Flammable or Combustible Liquids.

8.6.1 Tools shall be constructed of noncombustible materials.

8.6.2 Materials listed for use without internal fire detection and suppression shall be an acceptable alternative to noncombustible materials, where process concerns or process chemicals require alternatives.

8.6.3* Tools handling flammable or heated combustible liquids shall be provided with internal tool fire detection and suppression (fire sprinklers, approved gaseous agent fire suppression systems, or watermist) unless a risk assessment approved by the authority having jurisdiction concludes otherwise. The risk assessment shall include evaluation of approved engineering controls designed to prevent or limit fire damage and fire detection and suppression options.

8.6.4 Bulk delivery systems shall be arranged in accordance with 6.2.10.1.

8.7 Photolithography Tools.

8.7.1 Noncombustible or approved or listed air handling ductwork shall be used within photolithography equipment air handling systems.

8.7.2 Approved or listed materials shall be used to insulate the stepper/scanner air handling ductwork when required.

8.7.3 The handling of HPM liquids at the wafer tracks shall be in accordance with NFPA 30, *Flammable and Combustible Liquids Code*.

8.8 Ion Implanters.

8.8.1 Ion implanters shall be directly connected to fume ductwork that is noncombustible, approved, or listed for use without sprinklers.

8.8.2 Subatmospheric gas source (SAGS) shall be employed unless the process considerations prevent its use.

8.8.2.1 The installation of SAGS shall be in accordance with Section 7.14.

8.8.3 Dry-type isolation transformers shall be used in ion implanters.

8.8.3.1 Where oil-filled isolation transformers are used they shall be protected with protective devices (circuit breakers, fuses, etc.) in accordance with *NFPA 70, National Electrical Code*.

8.9 Wet Process and Wet Etch Tools.

8.9.1 Materials selection shall be in accordance with Section 8.1.

8.9.2 Duct connections of wet process and wet etch tools shall be in accordance with Chapter 9.

8.9.3 Process liquid heating systems for wet process equipment shall be protected in accordance with Section 8.5.

8.10 CVD and Furnace Tools.

8.10.1 Effluent shall be evaluated to ensure that risks of fire, explosion, and rapid chemical decomposition are identified.

8.10.1.1 Where the risks of 8.10.1 exist they shall be mitigated through engineering design, and/or the use of point-of-use effluent treatment systems.

8.10.1.2 Paragraph 8.10.1.1 shall not be required where the risks will not expose personal and/or equipment to harm.

8.10.2 Furnace quartzware shall be provided with seismic restraint in accordance with manufacturers' requirements when installed in high-hazard seismic areas.

8.10.3 Duct connections of CVD and furnace tools shall be in accordance with Chapter 9.

8.11 Automated Materials Handling Systems (AMHS).

8.11.1 Ceiling-mounted tracks supporting AMHS shall be installed to avoid obstruction of sprinkler protection.

8.11.2* Stockers constructed of combustible materials, or noncombustible stockers used to store masks, reticles, wafers, or substrates in combustible containers shall be provided with internal tool fire detection and suppression (fire sprinklers, approved gaseous agent fire suppression systems, or watermist) unless a risk assessment approved by the authority having jurisdiction concludes otherwise. The risk assessment shall include evaluation of approved engineering controls designed to prevent or limit fire damage and fire detection and suppression options.

8.11.2.1 Where front opening unified pods (FOUPs) or other containers constructed of listed or approved materials are employed, fire detection and suppression shall be permitted to be omitted inside of the stocker.

8.12 Support Equipment.

8.12.1 Vacuum pumps handling flammable or pyrophoric chemicals or high-concentration oxygen shall be of the dry type or use noncombustible pump oils.

8.12.1.1* Vacuum pumps that handle flammable gases in excess of 25 percent of the LFL shall discharge into a control device, in accordance with Chapter 10, that treats the flammable gases from the airstream prior to discharge into exhaust system ductwork.

8.12.1.2* Vacuum pumps using combustible oils shall use a point-of-use scrubber protected in accordance with 10.6 to remove oils prior to their discharge into the exhaust duct system.

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

8.13 Production Equipment Fire Protection. Where fire protection is required it shall be installed in accordance with the requirements of Chapter 11.

8.14 Exposures.

8.14.1 To avoid damage to process equipment liquid services, including cooling water, process liquid chemicals and waste water systems shall not be routed above cleanroom ceilings or cleanroom equipment.

8.14.2* When a facility is located in a high-hazard seismic area, process equipment and facilities equipment shall be designed to minimize the effects of seismic activity.

Chapter 9 Exhaust Systems

9.1 General Exhaust Conditions.

9.1.1 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.

9.1.2 Workstations. Workstations shall be in accordance with Sections 9.2 and 9.3.

9.1.3 Hazardous Production Materials. Exhaust ventilation shall be provided in hazardous production materials in accordance with NFPA 1, *Fire Code*.

9.1.4 Gas Cabinets. Exhaust ventilation shall be provided for gas cabinets in accordance with Chapter 7.

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

9.1.6 General Exhaust Ducts. General exhaust ducts conveying nonhazardous materials shall be noncombustible or in accordance with the requirements of 9.3.8.

9.2 Local Hazardous Chemical Exhaust System.

9.2.1 Exhaust air discharged from cleanrooms shall not be recirculated.

9.2.1.1 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.

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

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

9.2.3 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.

9.2.3.1 The requirements of 9.2.3 shall not apply to ducts downstream of fans, scrubbers, and treatment devices.

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

9.3 Local Hazardous Chemical Exhaust System Construction.

9.3.1* 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.

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

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

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

9.3.4 Exhaust ducts penetrating fire resistance–rated construction shall be contained in an enclosure of equivalent fire-resistive construction. Fire resistance construction and enclosures 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.

9.3.5 Fire dampers shall not be installed in exhaust ducts.

9.3.6* Exhaust duct systems shall be constructed of noncombustible materials, an approved or listed duct system for use without internal sprinklers, or protected with sprinklers in accordance with Chapter 11.

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

9.3.7 Ductwork directly connected to equipment shall be in accordance with 9.3.6 for equipment processing flammable or combustible liquids or flammable gases.

9.3.7.1 Ductwork directly connected to equipment that does not process flammable or combustible liquids or flammable gases, and where the equipment is constructed of noncombustible materials or materials listed as meeting the requirements of ANSI/UL 2360 or ANSI/FM 4910, shall be permitted to be completed using ductwork that is constructed of materials listed as meeting the requirements of ANSI/UL 2360 or ANSI/FM 4910, provided the hook-up duct does not exceed 16.4 ft (5 m) and is connected directly to a duct that complies with 9.3.6.

9.3.7.1.1 Ductwork meeting the requirements of 9.3.7.1 shall not require internal sprinklers.

9.3.8 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*.

9.4 Hazardous Chemical Exhaust Duct Airflow and Dilution.

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

9.4.1.1* To determine the presence of a flammable concentration 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 $in.^2$).

9.5 Exhaust Ducts. Automatic sprinkler protection shall be provided in accordance with Chapter 11.

9.6 Hazardous Chemical Exhaust Controls.

9.6.1* 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.

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

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

Chapter 10 Waste Treatment

10.1 Waste Recovery and Handling Systems. Waste treatment facilities shall be designed with dual waste treatment lines or alternative built-in redundancy, to assure the continuity of waste treatment in the event of maintenance or unplanned outages.

10.2 Acid Waste Treatment Facility Safeguards. Acid waste treatment facilities shall be provided with the following safeguards.

10.2.1* Automatic pH monitoring shall be provided in neutralization tanks using redundant probes with automatic cleaning facilities to minimize corrosion of probes. The operation of the waste treatment facility shall be interlocked to prevent the transfer of liquids from neutralizing tanks until the pH measurement is within acceptable limits for subsequent processing.

10.2.2 The design of acid waste treatment facilities handling ammonium salts and ammonia containing compounds shall prevent the addition of NaOCl to acidic waste streams prior to the adjustment of waste stream pH to acceptable levels.

10.3 Organic Waste Treatment Facilities. Organic waste treatment facilities that are capable of generating ignitable concentrations of flammable gases or vapors during normal operation or upset condition shall be zoned in accordance with NFPA 497, *Recommended Practice for the Classification of Flammable Liquids, Gases, or Vapors and of Hazardous (Classified) Locations for Electrical Installations in Chemical Process Areas,* or be provided with adequate ventilation (natural or mechanical) to prevent an ignitable concentration of flammable gases or vapors.

10.4 Waste Liquid Handling.

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

10.4.2 Separate drainage systems shall be provided for incompatible materials.

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

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

10.4.5 Flammable liquid waste shall be collected in approved containers.

10.4.5.1 Flammable liquid waste containers shall be equipped with local exhaust or be fully enclosed to prevent the liberation of vapors to the fab or sub-fab room environment during transfer operations.

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

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

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

10.4.9 Class I liquid wastes shall not be handled or used in basements.

10.4.9.1 Collection of Class I wastes collected in vessels in belowgrade sub-fabs shall be permitted if the criteria in 10.4.9.1.1 through 10.4.9.1.6 are met.

10.4.9.1.1 The collection vessel shall be located inside an approved waste collection system.

10.4.9.1.2 The storage cabinet shall be equipped with exhaust ventilation.

10.4.9.1.3 The exhaust ventilation shall be equipped with a static pressure monitoring device that is interlocked to shut down the process upon loss of ventilation.

10.4.9.1.4 The cabinet shall be equipped with an automatic sprinkler head.

10.4.9.1.5 A level sensing device shall be provided to monitor the level of the collection vessel.

10.4.9.1.6 A second collection vessel shall be provided for automatic transfer from one collection vessel to another when a collection vessel level reaches its maximum permissible amount.

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

10.6 Scrubbers.

10.6.1 Thermal processing units (TPUs) comprised of gas-fired and wet scrubbing sections shall be provided with automatic sprinkler protection or installed in an area that is isolated from cleanroom air recirculation systems by a minimum 1-hour fire-rated construction, either in a cut-off room or in the facility sub-fab.

10.6.2 TPUs shall be provided with the interlocks designed in accordance with 8.3 and listed in 10.6.2.1 through 10.6.2.7.

10.6.2.1 Exhaust Over Temperature. The interlock shall detect an increase in exhaust temperature above the setpoint and shall prevent degradation of materials in the TPU exhaust stream and facility exhaust system.

10.6.2.2 Exhaust Flow. The exhaust flow shall be designed to operate continually and an interlock shall be provided to detect a reduction in exhaust flow of 50 percent.

10.6.2.3 Flame Failure. A sensor shall be installed and located to detect flame failure in the reaction chamber.

10.6.2.4 Low Fuel Pressure. The interlock shall detect excess fuel pressure for gas-fired burners.

10.6.2.5 High Reaction Chamber Temperature. A sensor shall be located and set at a temperature that prevents degradation of the structural integrity of the reaction chamber or its surrounding materials.

10.6.2.6 Cooling Water. A sensor shall be installed to monitor cooling water flow and set at a flow rate that prevents degradation of the structural integrity of the reaction chamber or its surrounding materials.

10.6.2.7 High Fuel Pressure Alarm. A sensor and alarm shall detect excess fuel pressure for gas-fired burners and operate a local visual and audible alarm.

10.6.2.8 Low Reaction Chamber Temperature Alarm. A sensor shall be located and set to detect low reaction chamber temperature and operate a local visual and audible alarm.

10.6.3 Facility fume exhaust scrubbers shall be located external to the fabrication building or external to the cleanroom in a cut-off room separated by 1-hour fire-rated construction.

10.6.4 Where facility fume exhaust scrubbers of combustible construction are located on a roof and supplied by combustible ductwork that is not protected by automatic sprinklers, individual scrubbers shall be separated by at least 6.56 ft (2 m) to prevent fire spread and facilitate manual intervention by fire fighters.

10.6.5 Automatic fixed fire protection systems for scrubbers shall be in accordance with Chapter 11.

10.7 Vapor Recovery and Vapor Processing Systems. Flammable and combustible vapor recovery and vapor processing systems, including abatement systems, shall comply with the provisions of Section 19.5 of NFPA 30, *Flammable and Combustible Liquids Code.*

Chapter 11 Fire Protection

11.1 Facility-Wide Systems

11.1.1* Emergency Control Station.

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

11.1.1.2 The fire system shall transmit all alarms, trouble, and supervisory conditions to the emergency control station.

11.1.1.3 The emergency control station shall be permitted to serve as the supervising station when it complies with *NFPA 72, National Fire Alarm and Signaling Code,* for supervising stations.

11.1.1.4 All emergency safety conditions shall be transmitted to the emergency control station, including emergency alarm systems, gas detection systems, and emergency power systems.

11.1.2 Alarm and Communication Systems.

11.1.2.1 General. A fire alarm system shall be provided throughout buildings containing fabrication areas; the system shall be designed and installed in accordance with *NFPA 72, National Fire Alarm and Signaling Code.*

11.1.2.1.1 Initiation. Initiation of the required fire alarm system shall be by manual means and by means of any required fire suppression system waterflow alarms, detection devices, or detection system.

11.1.2.1.2 Notification. Notification in the form of audible alarm signals shall be provided throughout the building to alert occupants of a fire or other emergency.

11.1.2.1.3 Emergency Forces. Activation of the fire alarm system shall transmit the appropriate signal to the supervising station in accordance with *NFPA 72, National Fire Alarm and Signaling Code.*

11.1.3 Detection Systems.

11.1.3.1* Smoke Detection System. A listed or approved smoke detection system capable of detection to a minimum sensitivity of 0.2 percent/foot shall be provided in the cleanroom return airstream at a point before dilution from makeup air occurs.

11.1.3.2* Smoke detection within a cleanroom air system shall result in an alarm transmission to a supervising station as well as a local alarm signal within the cleanroom that is distinctive from both the facility audible alarm signal and any process equipment alarm signals in the cleanroom.

11.1.3.3 Testing of Ventilation System Detection Systems.

11.1.3.3.1* The frequency of testing for automatic smoke detection devices to shut down ventilation systems and/or control smoke shall be permitted to be increased from the requirements of *NFPA 72, National Fire Alarm and Signaling Code;* NFPA 90A, *Standard for the Installation of Air-Conditioning and Ventilating Systems*; and NFPA 92, *Standard for Smoke Control Systems*, up to testing the detection devices once every five years.

11.1.3.3.2 To avoid contamination of the cleanroom, the detection and control components shall be permitted to be tested independent of shutdown of the ventilation systems and/or control smoke.

11.1.3.3.2.1* The actual ventilation system shall not be required to be shut down during the testing.

11.1.4 Building Automatic Sprinkler Systems.

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

11.1.4.2* 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).

11.1.4.3 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).

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

11.2 Protection of Specific Facility Elements.

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

(1) Interior automatic sprinklers shall be provided in metallic and noncombustible, nonmetallic exhaust ducts when both 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 conveying flammable vapors or fumes at concentrations greater than 25 percent of the lower flammable limit (LFL).
(2) Interior 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}).

11.2.1.1 Interior automatic sprinklers shall not be required where ducts are approved for use without internal automatic sprinklers.

11.2.1.2 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.

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

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

11.2.1.2.3 Sprinklers shall be installed within 1 m (3.2 ft) downstream of a connection to a larger duct.

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

11.2.1.4* Drainage shall be provided to remove the anticipated sprinkler water discharged in ductwork.

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

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

11.2.1.7* 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.

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

11.2.2* Pass-Through Cabinets. Automatic sprinklers shall be provided in pass-throughs used to convey combustible chemicals.

11.2.3 Scrubbers. An automatic sprinkler shall be installed in the inlet and outlet of combustible scrubbers.

11.2.3.1 Local fire hydrants or standpipes shall be provided within 98.4 ft (30 m) of all roof-mounted scrubbers.

11.2.4* Gas Cabinets and Exhausted Enclosures.

11.2.4.1 Sprinklers shall be installed in gas cabinets that contain flammable, toxic and highly toxic, and pyrophoric gases (including silane).

11.2.4.1.1 Exhausted enclosures as defined by this standard shall not require sprinklers.

11.2.4.1.2 Automatic sprinklers are not required in gas cabinets containing water-reactive gases.

11.2.4.1.3 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.

11.2.5 Silane Gas Systems.

11.2.5.1 Optical flame detectors that will respond to the flame signature of silane shall be provided to detect a fire at potential leak points on the silane delivery system. Coverage shall be provided to address container connections, process gas and purge gas panels, and other potential leak points where unwelded fittings or connections are used.

11.2.5.1.1 An optical flame detection system shall be provided inside of VMBs to detect a fire within the VMB.

11.2.5.1.2 Activation of a detection system shall result in the closing of the following nearest isolation valve:

(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 cylinder source
(4) At the bulk source

11.2.5.1.3 Flame detection shall result in an alarm transmission to the supervising station as well as a local alarm signal that is distinctive from the facility's audible alarm signal and any process equipment alarm signals.

11.2.5.2 Automatic Sprinkler Systems.

11.2.5.2.1* Open Rack Cylinder Dispensing Systems. Automatic quick-response sprinklers or a deluge system shall be provided in the proximity of and directed at individual silane cylinders in open rack dispensing areas.

11.2.5.2.1.1 Where the open rack dispensing system is in accordance with CGA-G-13: *Storage and Handling of Silane and Silane Mixtures*, and designed to mitigate the effects of detonation, an automatic deluge water spray system shall not be required.

11.2.5.2.2 Bulk Silane Systems.

11.2.5.2.2.1 Automatic fixed deluge water spray protection shall be provided to bulk silane delivery systems.

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

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

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

11.2.6 Pyrophoric Liquids Cabinets.

11.2.6.1 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(s) on the liquid supply.

11.2.7 Production Equipment.

11.2.7.1 Production Equipment Detection System Options.

11.2.7.1.1* System Options. Where provided, detection systems shall be designed, installed, and maintained in accordance with *NFPA 72*, *National Fire Alarm and Signaling Code*, or manufacturer's specifications.

11.2.7.2 Production Equipment Suppression System Options.

11.2.7.2.1 Carbon Dioxide Agent Suppression Systems.

11.2.7.2.1.1 Where provided, carbon dioxide agent suppression systems shall be designed, installed, and maintained in accordance with NFPA 12, *Standard on Carbon Dioxide Extinguishing Systems*.

11.2.7.2.2 Clean Agent Suppression Systems.

11.2.7.2.2.1 Where provided, clean agent suppression systems shall be designed, installed, and maintained in accordance with NFPA 2001, *Standard on Clean Agent Fire Extinguishing Systems*.

11.2.7.2.3 Water Mist Agent Suppression Systems.

11.2.7.2.3.1 Where provided, water mist agent suppression systems shall be designed, installed, and maintained in accordance with NFPA 750, *Standard on Water Mist Fire Protection Systems*.

11.2.7.2.4 Automatic Sprinkler Systems.

11.2.7.2.4.1 Where provided, automatic sprinkler systems shall be designed, installed, and maintained in accordance with NFPA 13, *Standard for the Installation of Sprinkler Systems*.

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.

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.1.1 The primary semiconductor and related industries include, but are not limited to, the following:

(1) *Silicon Integrated Circuits.* Traditional semiconductor process for memory, logic, microprocessors, and similar integrated circuits on silicon wafers. Process includes epitaxial layer formation, oxidation, chemical vapor deposition, sputtering, photolithography, etching, and ion implantation. Processing can involve the use of over 30 electronic specialty materials—primarily in gas and liquid form. Current technologies focus on 7.9 in. (200 mm) and 11.8 in. (300 mm) wafer sizes while 17.7 in. (450 mm) wafer technology is under development.
(2) *III–V MOCVD (Metalorganic Chemical Vapor Deposition).* Process using the III–V family of semiconductors for power transistors, logic chips, LED, and some photovoltaic products on typically gallium arsenide wafers. Process is similar to silicon wafers, but primary materials are different and/or used in different quantities (processes require large volumes of arsine, phosphine, ammonia, and metal organics). Current technologies focus on 5.9 in. (150 mm) wafers.
(3) *TFT-LCD (Thin film transistor liquid crystal displays).* Process utilizing large glass substrates to manufacture flat-panel displays for use in televisions, computer screens, mobile device screens, and other applications. Primary process includes PECVD (plasma-enhanced chemical vapor deposition), photolithography, sputtering, and etching (dry and wet). The number of hazardous materials used is less than silicon processes, but the volumes are much larger; usually involving bulk supplies. The latest Generation 8 process utilizes 86.6 in. (2200 mm) x 98.4 in. (2500 mm) glass substrates.
(4) *Crystalline Silicon Photovoltaic.* Silicon-based process for creating solar cells on wafers, square ingots, or ribbons. Process does not require stringent cleanliness, and is located in nonclean room environments for doping silicon layers and growing antireflection layers. The use of PECVD process is prevalent, with new ion implantation technology introduced in 2011.
(5) *Thin Film Photovoltaic.* This industry is much more fragmented with many different types of technologies on a variety of substrates (glass, stainless steel, silicon ribbon). The traditional amorphous silicon process uses silane, ammonia, nitrogen trifluoride, and trimethylboron mixtures in bulk supply. Other technologies use different materials and techniques.

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.3.3.6 Corrosive Material. A chemical is considered to be corrosive if it destroys or irreversibly changes the structure of the tissue at the site of contact within a specified period of time using one of the in vivo or in vitro OECD test methods authorized in 49 CFR Part 173.137. For purposes of this code, this term does not refer to action on inanimate surfaces (e.g., steel or aluminum). Available testing data produced prior to September 30, 1995 from the test method in Appendix A to 49 CFR Part 173 in effect on October 1, 1994 can also be used to determine the corrosivity of a material. [**1,** 2015]

A.3.3.22.1 Permissible Exposure Limit (PEL). The maximum permitted time-weighted average exposures to be utilized are those published in 29 CFR 1910.1000. [**5000,** 2015]

A.3.3.38 Toxic Material. While categorization is basically simple in application, the degree of hazard depends on many variables that should be carefully considered individually and in combination. Some examples include the following:

(1) Materials wherein the toxic component or mixtures thereof are inextricably bound and cannot be released so there is little or no potential for exposure
(2) Nonfriable solid hazardous materials existing in product forms and in the demonstrated absence of inhalable particles that might not present the same inhalation hazard as the chemical components existing in a friable state
(3) Mixtures of toxic materials with ordinary materials, such as water, that might not warrant classification as toxic

[**1,** 2015]

Any hazard evaluation that is required for the precise categorization of toxic material is required to be performed by experienced, technically competent persons. [**1**, 2015]

A.3.3.38.1 Highly Toxic Material. While categorization is basically simple in application, the degree of hazard depends on many variables that should be carefully considered individually and in combination. Some examples include the following:

(1) Materials wherein the highly toxic component or mixtures thereof are inextricably bound and cannot be released so there is little or no potential for exposure
(2) Nonfriable solid hazardous materials existing in product forms and in the demonstrated absence of inhalable particles that might not present the same inhalation hazard as the chemical components existing in a friable state
(3) Mixtures of highly toxic materials with ordinary materials, such as water, that might not warrant classification as highly toxic

[**1**, 2015]

Any hazard evaluation that is required for the precise categorization of highly toxic material is required to be performed by experienced, technically competent persons. [**1**, 2015]

A.3.3.39 Water-Reactive Material. There are three classes of water-based material. Class 1 water-reactive materials are those whose heat of mixing is at or above 30 cal/g and less than 100 cal/g. Class 2 water-reactive materials are those whose heat of mixing is at or above 100 cal/g and less than 600 cal/g. And Class 3 water-reactive materials are those whose heat of mixing is greater or equal to 600 cal/g.

A.3.3.40 Workstation. The terms *workstation, tool, process tool, process equipment,* and *semiconductor manufacturing equipment* are often used interchangeably. In the U.S., 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.4.3 Buildings housing these cleanrooms should be of noncombustible or fire-resistive construction.

A.4.6.2(4) The intent of this requirement is to prohibit a communication of two compartments on the same floor via two convenience openings. This is represented in Figure A.4.6.2(4).

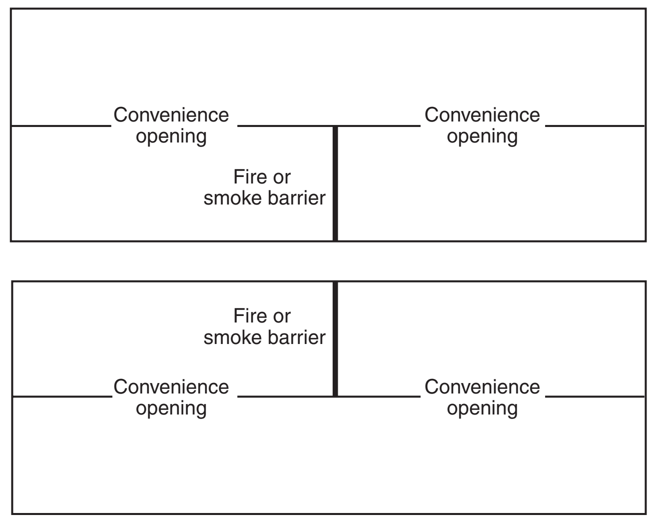

FIGURE A.4.6.2(4) Convenience Opening Arrangement.

A.4.6.2(6) This requirement prohibits means of egress down or up the convenience opening. It does not prohibit means of escape from running down or up the convenience opening within residential dwelling units.

A.4.8 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.5.1 The following documents should be consulted for storage and handling of hazardous chemicals:

(1) NFPA 68, *Standard on Explosion Protection by Deflagration Venting*
(2) NFPA 329, *Recommended Practice for Handling Releases of Flammable and Combustible Liquids and Gases*

A.5.3.1 Model building codes in the U.S. call for special protection requirements for corridors where hazardous materials are transported. These codes do not necessarily apply to jurisdictions outside the United States.

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

A.5.5 For Table 5.5, 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.5.5.2.1.1 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.5.6.2.1 Canister fabricators should treat the design of the canister as a pressure vessel. It is strongly recommended all new canisters are subjected to radiographic (X-ray) analysis of all welds.

A.5.8.2 Thermoplastic welders should be qualified under DVS welding standards. (DVS = Deutscher Verband für Schweissen und verwandte Verfahren e.V.)

A.6.2 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.6.4.1 There is no way to practically suppress a fire involving pyrophoric liquids. Nonetheless, a fire control methodology should be designed to protect the cabinet and surrounding areas. Acceptable fire control media include, but are not limited to, nitrogen inerting and vermiculite.

A.6.4.2 Careful consideration should be given to the amount of liquid pyrophoric material needed for operations. Many times the 20 L quantity is not needed to sustain production.

A.6.4.4 Cabinet internal pressure should remain negative or neutral relative to surrounding areas upon discharge of a fire control medium, such as nitrogen inerting.

A.6.7 See definitions and empirical tests required to classify water reactive materials in Annex E of NFPA 704, *Standard System for the Identification of the Hazards of Materials for Emergency Response.*

A.6.7.1 If water is introduced into the cylinders containing the water reactive chemistries it can lead to explosive rupture of the cylinder. Non-water-based heater baths should be used or alternate temperature control methods employed.

A.7.1 NFPA 55, *Compressed Gases and Cryogenic Fluids Code,* is a material-specific code that addresses the storage, transfer, and use of industrial gases. The requirements within NFPA 55 are applicable for semiconductor and related facilities. The NFPA 318 standard leverages the requirements within NFPA 55 by referencing relevant chapters. Within Chapter 7, NFPA 318 provides additional use and industry-specific gas-related requirements pertaining to semiconductor and related facilities.

The use and industry-related requirements in NFPA 318 were developed by comparing the following primary gas-specific safeguards contained within NFPA 55 and NFPA 318:

(1) Gas detection systems and source shutdown arrangements
(2) Restricted Flow Orifices (RFOs)
(3) Emergency shutoff valves
(4) Pressure relief devices for sources
(5) Ventilation rates for various arrangements
(6) Fire detection and fire protection for various arrangements
(7) Treatment systems
(8) Excess flow control

A.7.1.1.1 For information on safety in cutting and welding, see NFPA 51B, *Standard for Fire Prevention During Welding, Cutting, and Other Hot Work.*

A.7.1.3.3 If the distribution piping is of noncombustible construction, a combustible outer jacket can be used for secondary containment.

A.7.1.4.1 Automated purge panels are recommended because they reduce the potential for human error. *[See 7.6.2 for silane and silane mixes.]*

A.7.1.4.3 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.7.1.6 Chapter 7 of NFPA 55, *Compressed Gases and Cryogenic Fluids Code,* addresses gas detection in material-specific sections within, with the only direct requirement listed for toxic and highly toxic gases. Gas detection for other hazardous gases is warranted.

A.7.1.9.1 Alternative substances should be considered for replacement of hazardous gases.

A.7.1.9.2 The use of normally closed, pneumatic-operated cylinder valves located directly on HPM cylinders is preferred as it provides the ability to isolate the cylinder and stop gas flow in the event of a leak. Emergency shutoff valves located downstream or adjacent to the active cylinder might not be effective in preventing leaks caused at the point of connection of the cylinder to the gas delivery system, where the majority of leaks are involved.

A.7.5.1 If an RFO is placed in a system with an excess flow device, the excess flow device might not shut off.

A.7.6 CGA-13 contains extensive requirements for the storage, use, and handling of silane gas. With some exceptions, these requirements are aligned with the historical approach within NFPA 318. Exceptions are included within NFPA 318 requirements in various sections.

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. Due to the extremely hazardous nature of silane, storage and dispensing areas would benefit from video cameras for remote monitoring and security purposes.

A.7.6.1 The use of a cylinder-mounted automatic pneumatic cylinder valve is the preferred shutoff valve. Pneumatic valves that employ a knife edge seat design reduce cross-port leaks and silane "poppers."

A.7.6.2 The use of two single-stage regulators in series will help reduce liquefaction during pressure reduction. Replaceable metal gaskets in DISS connections are preferred over PTFE gaskets that can cold flow and leak at pressures higher than 500 psi. The use of solid stainless steel pigtail lines is preferred over flexible steel lines. The use of a Venturi eductor to evacuate the gas panel during system purge is strongly recommended. The dome of the pressure regulator should also be vented to a safe location.

A.7.14.2 A subatmospheric gas source (SAGS) reduces the risk and magnitude of gas releases. In a SAGS, a vacuum (subatmospheric) condition is required to induce gas flow from the cylinder. An accidental opening of the valve under atmospheric conditions will result in little or no gas release. In a Type 1 SAGS, gas is adsorbed on a medium and is released under a vacuum condition. In a Type 2 SAGS, the pressure driver is mitigated via a normally closed internal valve that requires a vacuum condition to release the gas. Because of its improved built-in safety features, a SAGS should be used instead of standard high-pressure cylinder gas wherever process compatibility allows.

A.7.14.2.1 Release rates from SAGS will be small relative to a conventional compressed gas. When combined with ventilation, this results in a low risk of mixing incompatible gases.

A.7.14.2.2 Subsections 9.1.4 and 9.1.5 provide reference requirements in NFPA 1, *Fire Code*, for minimum external face velocities of 200 fpm (1 m/s) at openings. Maintaining conditions below IDLH within the gas box represents a higher standard of control. Also, per NFPA 1, treatment systems for corrosive, toxic, or highly toxic gases can include nontreated ventilation systems that dilute the accidental release to less than ½ IDHL. Ventilation system design for SAGS meets these dilution thresholds and therefore meets the requirement for treatment systems.

A.7.14.2.5 The automatic shutoff valve requirement is effectively met in both SAGS sources. SAGS sources are designed to flow gas under vacuum conditions and, coupled with ventilation requirements, ensure that concentrations in gas cabinets or exhausted enclosures will be less than IDLH.

A.7.14.2.6 A Type 1 SAGS has an inherent flow restriction because the cylinder's internal gas pressure is subatmospheric.

A.8.2.1.2 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 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.8.3 See Section 11 of SEMI S2-0703a, *Environmental, Health, and Safety Guideline for Semiconductor Manufacturing Equipment*, or ANSI/ISA S84.01, *Application of Safety Instrumented Systems for the Process Industries*.

A.8.3.1 Interlock systems should be designed to prevent override during normal operation.

A.8.5.1 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.8.5.5.1 Some organometallic liquids or solids can undergo violent decomposition if overheated, in some cases heating for an extended period below the initiation temperature can also cause the decomposition reaction to occur. These include trimethylaluminum, dimethylzinc, diethylzinc, trimethylindium, and trimethylgallium. Maximum temperatures of 100°C–120°C are recommended.

A.8.5.5.2 A sensor should be located and set at a temperature that prevents degradation of the structural integrity of the heater or its surrounding materials. Where a low liquid level interlock is installed, the heater overtemperature interlock should prevent degradation at any liquid level above the level at which the low liquid level interlock removes power from the heater. Where a liquid level interlock is not installed, the heater overtemperature interlock should prevent degradation at any liquid level—including the absence of liquid.

A.8.5.5.4 Heater overtemperature interlocks are usually installed to prevent the heater from damaging itself or its surroundings and, depending on the type of heating system, can be required in addition to the liquid overtemperature interlock. The type of sensor, its location, and the method of interlocking is specific to each style of heating system.

A.8.6.3 The risk assessment for process equipment handling flammable or heated combustible liquids should take account of the following:

(1) When the presence and quantity of flammable liquid is so limited that in the event of a fire it would already be consumed before any suppression systems was discharged.
(2) Whether combustible liquids are heated, or capable of being heated, above their flashpoints
(3) Combustible liquids at risk of ignition due to the method of handling (e.g., spraying, atomizing)
(4) The influence of ventilation, purging, or inerting to prevent ignition
(5) The ability of engineering controls and safety interlocks to prevent overheating, ignition, or fire development

The extent of damage that would occur following ignition is a key factor in the risk assessment, as is the volume and type of smoke and by-products of combustion that are generated.

A.8.11.2 The typical wafer stocker consists of plastic containers holding noncombustible wafers, reticles, or masks, which are stored within a structure that is usually noncombustible apart from vision panels, which are often polycarbonate. The transport system and lighting provide the only ignition sources within the stockers, however, these are generally separated from the combustible plastics. It is recognized that stockers are often installed in such a manner that can obstruct ceiling sprinklers, and if a fire were to occur, then the smoke and heat would cause extensive damage in the cleanroom.

Similarly, stockers in LCD fabs holding glass substrates are often surrounded by polycarbonate vision panels.

The need for protection and the level of protection needed is subject to detailed evaluation and risk assessment, taking account of risk management objectives, the quantity and type of combustible materials present, the power rating of electrical equipment, and the type of electrical protection provided. Protection schemes can include fire suppression systems, which include sprinklers, fine water mists, and smoke detection (possibly interlocked to shut down power to the stocker).

A.8.12.1.1 Vacuum pumps whose construction is susceptible to backstreaming oil into tools should have foreline traps on their inlets.

A.8.12.1.2 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.8.14.2 SEMI S2-0703a, *Environmental, Health, and Safety Guideline for Semiconductor Manufacturing Equipment,* provides guidance on protecting equipment from seismic risks including risk of injury to personnel, adverse environmental impact, damage due to movement or overturning, failure due to fragile parts, or leakage of chemicals.

A.9.3.1 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.9.3.6 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.9.4.1 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 should also be provided. The sensor and alarm should be of the manual reset type.

A.9.4.1.1 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.9.6.1 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.10.2.1 Risk of reaction of ammonia salts with strong acids where there is inadequate neutralization can be prevented through correct monitoring and system design. Not previously recognized in NFPA 318 as a risk, but relevant to semiconductor and LCD industries where TMAH is present in acid waste streams processed in waste water treatment plants by neutralization.

The mixing of ammonia salts, such as in the residue from TMAH and acids, can lead to the formation of nitrogen trichloride. This can then decompose explosively. There has been at least one incident within the industry that has been put down to this cause. This resulted in physical damage to the neutralization equipment.

A.10.4.3 Labeling of contents should be in accordance with ANSI B31.3, *Chemical Plant and Petroleum Refinery Piping*.

A.11.1.1 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.

A.11.1.3.1 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.11.1.3.2 Smoke detection need not result in an automatic facility evacuation alarm signal.

A.11.1.3.3.1 The frequency of testing should be determined by the owner, based on a risk-based approach.

A.11.1.3.3.2.1 Cleanroom ventilation systems are critical to maintaining product quality control. Shutting down the ventilation system during testing would be detrimental to the protection of the cleanroom. Variation from the testing frequency and functional testing is allowed due to the high level of maintenance on the ventilation system, due to their critical nature.

A.11.1.4.1 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.11.1.4.2 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.11.1.4.4 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.11.2.1(1)(a) Equivalent to 10 in. (254 mm) diameter duct.

A.11.2.1.2.1 Small-orifice sprinklers, 9.5 mm (3⁄8 in.) or larger, can be used.

A.11.2.1.4 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.11.2.1.7 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.11.2.2 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.11.2.4 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.11.2.5.2.1 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 11.2.5.1.2.

A.11.2.7.1.1 Detection systems to consider include linear heat detection, multiple types of smoke detection, optical flame detection, and video technology detection. The preferred optical flame detection systems are combination ultraviolet/infrared (UV/IR) flame detection devices that sense radiation from both the ultraviolet and infrared spectrums and use the combined technologies to indicate a fire shall be installed internal to the tool at locations as specified by the limits of the detection system detailed by the manufacturer to provide for a complete field of view of all affected compartments.

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 a 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 addressed specifically 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.

C.3 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 S2-0703a, *Environmental, Health, and Safety Guideline for Semiconductor Manufacturing Equipment*, and designed and installed in accordance with Sections 8.1 through 8.14.