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NFPA 318 Protection of Cleanrooms 1992 Edition

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The Board of Directors reaffirms that the National Fire Protection Association recognizes that the toxicity of the products of combustion is an important factor in the loss of life from fire. NFPA has dealt with that subject in its technical committee documents for many years.

There is a concern that the growing use of synthetic materials may produce more or additional toxic products of combustion in a fire environment. The Board has, therefore, asked all NFPA technical committees to review the documents for which they are responsible to be sure that the documents respond to this current concern. To assist the committees in meeting this request, the Board has appointed an advisory committee to provide specific guidance to the technical committees on questions relating to assessing the hazards of the products of combustion.

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NFPA 318

Standard for the

Protection of Cleanrooms

1992 Edition

This edition of NFPA 318, *Standard for the Protection of Cleanrooms*, was prepared by the Technical Committee on Cleanrooms and acted on by the National Fire Protection Association, Inc. at its Fall Meeting held November 18-20, 1991 in Montréal, Québec, Canada. It was issued by the Standards Council on January 17, 1992, with an effective date of February 10, 1992.

The 1992 edition of this document has been approved by the American National Standards Institute.

Origin and Development of NFPA 318

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

The standard was submitted and adopted at the Fall Meeting in Montréal, Québec, Canada, November 18-20, 1991. The 1992 edition is the first edition of this standard.

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This list represents the membership at the time the Committee was balloted on the text of this edition. Since that time, changes in the membership may have occurred.

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.

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

Information on referenced publications can be found in Chapter 8 and Appendix C.

Chapter 1 General

1-1 Scope. This standard applies to all semiconductor facilities containing what is herein defined as a cleanroom or clean zone or both.

1-2* Purpose. This standard is intended to provide reasonable safeguards for the protection of facilities containing cleanrooms from fire and related hazards. These safeguards are intended to provide protection against injury, loss of life, and property damage.

1-3 Applicability. The provisions of this document are considered necessary to provide a reasonable level of protection from loss of life and property from fire and explosion. They reflect situations and the state of the art at the time the standard was issued.

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

1-4 Definitions.

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.

Approved. Acceptable to the "authority having jurisdiction."

NOTE: 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 or 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 concerned with product evaluations which is in a position to determine compliance with appropriate standards for the current production of listed items.

Authority Having Jurisdiction. The "authority having jurisdiction" is the organization, office or individual responsible for "approving" equipment, an installation or a procedure.

NOTE: The phrase "authority having jurisdiction" is used in NFPA documents in a broad manner since jurisdictions and "approval" agencies vary as do their responsibilities. Where public safety is primary, the "authority having jurisdiction" may be a federal, state, local or other regional department or individual such as a fire chief, fire marshal, chief of a fire prevention bureau, labor department, 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 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."

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

Cleanroom. A room in which the concentration of airborne particles is controlled to specified limits.

Compressed Gas. Any material or mixture having in the container an absolute pressure exceeding 40 psi (pounds per square inch) at 70°F (275.8 kPa at 21.1°C) or, regardless of the pressure at 70°F (21.1°C), having an absolute pressure exceeding 104 psi at 130°F (717 kPa at 54.4°C), or flammable liquid having a vapor pressure exceeding 40 psi absolute at 100°F (275.8 kPa at 37.8°C) as determined by ASTM test D323.

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

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

Hazardous Chemical. Any solid, liquid, or gas that has a degree-of-hazard rating in health, flammability, or reactivity of Class 3 or 4 as ranked by NFPA 704, *Identification of the Fire Hazards of Materials.*

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

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

Liquid. For the purpose of this code, any material that has a fluidity greater than that of 300 penetration asphalt when tested in accordance with ASTM D5, *Test for Penetration of Bituminous Materials.* When not otherwise identified, the term liquid shall mean both flammable and combustible liquids.

Combustible Liquid. A liquid having a flash point at or above 100°F (37.8°C).

Combustible liquids shall be subdivided as follows:

Class II liquids shall include those having flash points at or above 100°F (37.8°C) and below 140°F (60°C).

Class IIIA liquids shall include those having flash points at or above 140°F (60°C) and below 200°F (93°C).

Class IIIB liquids shall include those having flash points at or above 200°F (93°C).

Flammable Liquid. A liquid having a flash point below 100°F (37.8°C) and having a vapor pressure not exceeding 40 psia (2 068 mm Hg) at 100°F (37.8°C) shall be known as a Class I liquid.

Class I liquids shall be subdivided as follows:

Class IA liquids shall include those having flash points below 73°F (22.8°C) and having a boiling point below 100°F (37.8°C).

Class IB liquids shall include those having flash points below 73°F (22.8°C) and having a boiling point at or above 100°F (37.8°C).

Class IC liquids shall include those having flash points at or above 73°F (22.8°C) and below 100°F (37.8°C).

Noncombustible. A material that, in the form in which it is used and under the conditions anticipated, will not ignite, burn, support combustion, or release flammable vapors when subjected to fire or heat. Materials that are reported as passing ASTM E136, *Standard Test Method for Behavior of Materials in a Vertical Tube Furnace at 750 Degrees C* (formerly *Standard Method of Test for Noncombustibility of Elementary Materials*), shall be considered noncombustible. (*See NFPA 220, Standard on Types of Building Construction.*)

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

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

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

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

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.

Tool. Any device, storage container, work station, or process machine used in the cleanroom.

Work Station. A defined space or an independent principal piece of equipment using hazardous chemicals within a cleanroom or clean zone, where a specific function, a laboratory procedure, or a research activity occurs. The work station may include connected cabinets and contain ventilation equipment, fire protection devices, sensors for gas and other hazards, electrical devices, and other processing and scientific equipment.

Chapter 2 Fire Protection

2-1 Automatic Fire Extinguishing Systems.

2-1.1 General. Wet pipe automatic sprinkler protection shall be provided throughout facilities containing cleanrooms and clean zones.

2-1.2 Automatic Sprinkler Systems.

2-1.2.1* Automatic sprinklers for cleanrooms or clean zones shall be installed in accordance with NFPA 13, *Standard for the Installation of Sprinkler Systems*, and shall be hydraulically designed for a density of 0.20 gpm/sq ft [8.15 (L/min)/m^2] over a design area of 3000 sq ft (278.8 m^2).

2-1.2.2* Approved quick response sprinklers shall be utilized for sprinkler installations within downflow airstreams in cleanrooms and clean zones.

2-1.2.3* Sprinklers shall be installed in gas cylinder cabinets containing flammable gases.

2-1.2.4 Automatic sprinkler protection shall be designed and installed in the plenum and interstitial space above cleanrooms in accordance with NFPA 13, *Standard for the Installation of Sprinkler Systems*, for a density of 0.20 gpm/sq ft [8.15 (L/min)/m^2] over a design area of 3000 sq ft (278.8 m^2).

2-1.2.5 All combustible exhaust ducts shall have interior automatic sprinklers when the largest interior cross-sectional diameter is equal to or greater than 10 in. (254 mm).

Exception: Ducts approved for use without automatic sprinklers.

2-1.2.5.1* Sprinklers installed in duct systems shall be hydraulically designed to provide 0.5 gpm (1.9 L/min) over an area derived by multiplying the distance between the sprinklers in a horizontal duct by the width of the duct. Minimum discharge shall be 20 gpm (76 L/min) per sprinkler from the 5 hydraulically most remote sprinklers. Sprinklers shall be spaced a maximum of 20 ft (6.1 m) apart horizontally and 12 ft (3.7 m) apart vertically.

2-1.2.5.2 A separate indicating control valve shall be provided for sprinklers installed in ductwork.

2-1.2.5.3* Drainage shall be provided to remove all sprinkler water discharged in ductwork.

2-1.2.5.4 Where corrosive atmospheres exist, duct sprinklers and pipe fittings shall be manufactured of corrosion resistant materials or coated with approved materials.

2-1.2.5.5 The sprinklers shall be accessible for periodic inspection and maintenance.

2-1.2.6* Automatic sprinklers shall be provided in pass throughs used to convey combustible chemicals.

2-1.2.7* Combustible Tools.

2-1.2.7.1 When the horizontal surface of a combustible tool is obstructed from ceiling sprinkler discharge, automatic sprinkler protection shall be provided that will cover the horizontal surface of the tool.

Exception: An automatic gaseous fire suppression local surface application system shall be permitted as an alternative to sprinklers. Gaseous extinguishing systems shall be actuated by IR or UV/IR optical detectors. Detectors shall be tested monthly.

2-1.2.7.2 When the work station is of combustible construction, automatic sprinkler protection shall be provided in the exhaust transition piece.

Exception: An automatic gaseous fire suppression interior application system shall be permitted as an alternative to sprinklers.

2-1.2.7.3* When the branch exhaust ductwork is constructed of combustible material, automatic sprinkler protection shall be provided within the work station transition piece or the branch exhaust duct.

2-1.2.7.4 When the branch exhaust ductwork is subject to combustible residue build-up, regardless of the material of construction, automatic sprinkler protection shall be provided.

2-2 Alarm Systems.

2-2.1 The discharge of an automatic fire suppression system shall activate an audible fire alarm system on the premises and an audible or visual alarm at a constantly attended location.

2-2.2* Where a potential exists for flammable gas concentrations to exceed 20 percent of the LFL, a continuous gas detection system shall be provided.

2-2.3 Signal transmission for alarms designed to activate signals at more than one location shall be verified at each location during each test of the alarm system.

2-2.4 A manual notification system shall be provided to result in an audible alarm as in 2-2.1.

2-3 Smoke Detection.

2-3.1* An air sampling or particle counter-type smoke detection system shall be provided in the cleanroom return air stream to sample for smoke.

2-3.2* Smoke detection within a cleanroom air system shall result in an alarm transmission to a constantly attended location as well as a local alarm signal within the cleanroom that is distinctive from both the facility evacuation alarm signal and any process equipment alarm signals in the cleanroom.

Chapter 3 Ventilation and Exhaust Systems

3-1 Air Supply and Recirculation Systems.

3-1.1 The location of outside air intakes shall be chosen to avoid drawing in hazardous chemicals or products of combustion coming either from the building itself or from other structures and devices.

3-1.2 High Efficiency Particulate Air (HEPA) and Ultra Low Penetration Air (ULPA) filter modules shall meet the combustibility requirements outlined in UL 586, *High-Efficiency, Particulate, Air Filter Units.*

3-1.3 Air supply and recirculation ducts, connectors, and appurtenances shall be constructed of noncombustible material such as aluminum steel or of Class 0 or Class 1 materials as tested in accordance with UL 181, *Standard for Safety Factory-Made Air Ducts and Air Connectors.*

3-1.4 Supply air ducts shall have a flame spread index of not more than 25 and a smoke-developed rating of not more than 50 when tested in accordance with NFPA 255, *Standard Method of Test of Surface Burning Characteristics of Building Materials.*

3-2 Local Exhaust System.

3-2.1 Exhaust air discharged from cleanrooms shall not be recirculated. Ducts shall lead to the outside as directly as practical and shall discharge above the roof at a location, height, and velocity sufficient to prevent reentry of hazardous chemicals.

3-2.2 Energy conservation devices that create a risk of returning contaminants to the cleanroom air supply shall not be used in fume exhaust systems.

3-2.3 Air containing hazardous chemicals shall be conveyed through duct systems maintained at a negative pressure relative to the pressure of normally occupied areas of the building.

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

3-2.4 Work station exhaust ventilation shall be designed to capture and exhaust contaminants generated in the station.

3-3 Local Exhaust System Construction.

3-3.1* Ribbed flexible connectors or sections of duct in which hazardous chemicals may collect shall not be used in exhaust ductwork.

3-3.2 The entire exhaust duct system shall be self-contained. No portions of the building shall be used as an integral part of the system.

3-3.3 Two or more operations shall not be connected to the same exhaust system when the combination of the substances removed may create a fire, explosion, or chemical reaction hazard within the duct system.

3-3.4 Exhaust ducts penetrating fire resistance rated construction shall be contained in an enclosure of equivalent fire-resistive construction.

3-3.5 Fire dampers shall not be installed in exhaust ducts.

3-3.6* Exhaust duct systems shall be constructed of noncombustible materials or protected with sprinklers in accordance with 2-1.2.5.

Exception: Ducts approved for use without automatic sprinklers.

3-3.7 The exterior surface of nonmetallic exhaust ducts shall have a smoke developed rating of 25 or less when either the interior or exterior of the duct is exposed to fire, when tested in accordance with NFPA 255, *Standard Method of Test of Surface Burning Characteristics of Building Materials.*

3-4 Duct Velocities. Airflow in cleanroom exhaust systems shall be designed to ensure dilution such that flammable vapors are not conveyed in the ducts. (See definition of flammable vapors.)

3-5 Controls.

3-5.1 The exhaust ventilation system shall have an automatic emergency back-up source of power. The emergency power shall be designed and installed in accordance with NFPA 70, *National Electrical Code.*®

3-5.2* The emergency power shall operate the exhaust system at not less than 50 percent capacity when it is demonstrated that the level of exhaust will maintain a safe atmosphere.

3-5.3 Fire detection and alarm systems shall not be interlocked to shut down local exhaust fans automatically.

3-5.4 Dampers, where required for balancing or control of the exhaust system, shall be of a locking type.

3-5.5 The air handling system shall be designed to provide smoke exhaust, or a dedicated smoke control system shall be provided.

Exception No. 1: Where contamination within the cleanroom is limited and recirculation will not affect adjoining areas, the above shall not be required.

Exception No. 2: Where the cleanroom is not Class 1000 or cleaner as defined in Federal Standard 209D, Cleanroom and Work Station Requirements, Controlled Environment, the above shall not be required.

Exception No. 3: Where the fume exhaust system is capable of smoke removal or preventing smoke migration, the above shall not be required.

3-5.6 A manually operated remote switch(es) to shut off the affected areas of the cleanroom air recirculation system(s) shall be provided at an approved location(s).

Chapter 4 Construction

4-1* Cleanrooms rated Class 100 or cleaner in accordance with Federal Standard 209D, *Cleanroom and Work Station Requirements, Controlled Environment,* or cleanrooms having clean zones rated Class 100 or cleaner, shall have approved, noncombustible components for walls, floors, ceilings, and partitions.

4-2 Cleanrooms shall be separated from adjacent occupancies by 1-hr fire rated, noncombustible construction.

4-3 Cleanroom access floors shall be designed to resist a force of 0.5 G magnitude in seismic zones 1, 2, and 3, depicted in Figure 4-3.

Chapter 5 Chemical Storage and Handling

5-1 Hazardous Chemicals.

5-1.1* Storage and handling of hazardous chemicals shall comply with applicable NFPA standards, including the following:

NFPA 30, *Flammable and Combustible Liquids Code,* 1990 edition

NFPA 33, *Standard for Spray Application Using Flammable and Combustible Materials,* 1989 edition

NFPA 43A, *Code for the Storage of Liquid and Solid Oxidizers,* 1990 edition

NFPA 43B, *Code for the Storage of Organic Peroxide Formulations,* 1986 edition

NFPA 70, *National Electrical Code,* 1990 edition

NFPA 385, *Standard for Tank Vehicles for Flammable and Combustible Liquids,* 1990 edition

NFPA 386, *Standard for Portable Shipping Tanks for Flammable and Combustible Liquids,* 1990 edition.

5-1.1.1 Hazardous chemicals storage and dispensing shall be separated from the cleanroom by 1-hr fire resistance rating.

5-1.1.2 Hazardous chemicals 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 min.

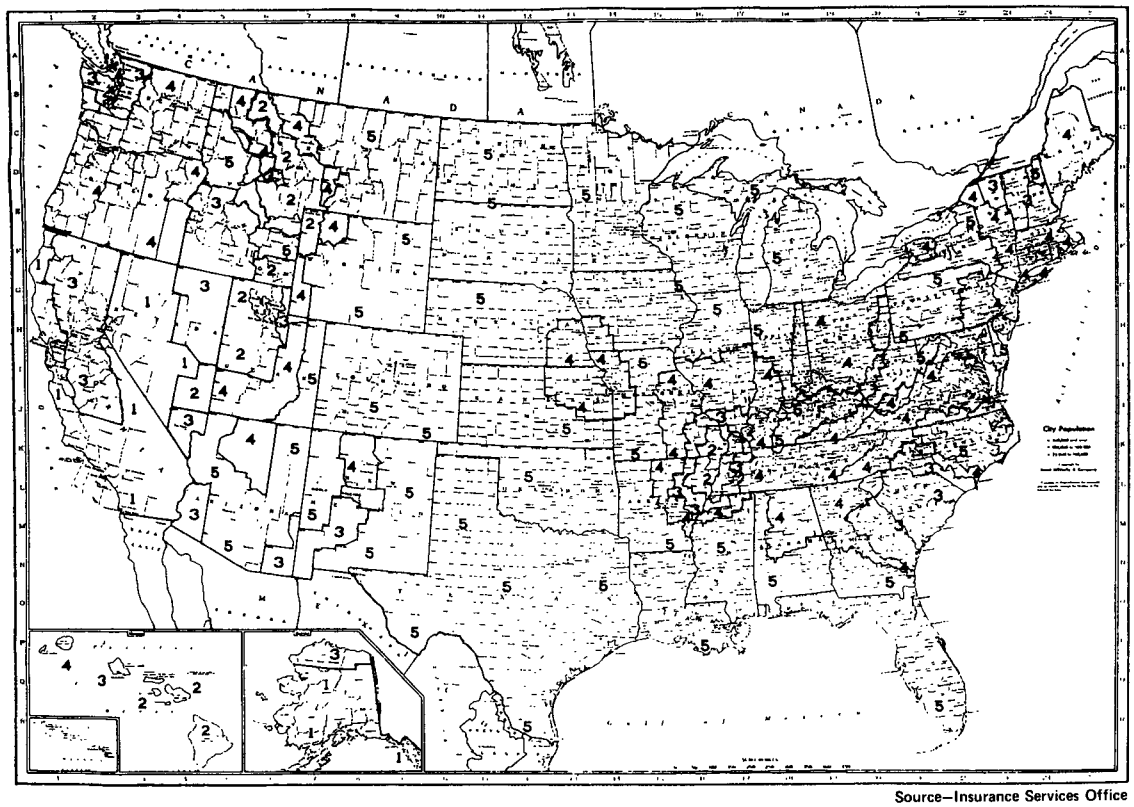
5-1.1.3 Hazardous chemicals stored in the cleanroom shall be limited to those needed for operations and maintenance. Quantities of hazardous chemicals shall be limited to those within the tool or the daily supply of chemicals needed.

5-1.1.4 Hazardous chemicals storage and dispensing rooms shall have mechanical exhaust ventilation as follows:

(a) Mechanical ventilation shall be at the rate of one cu ft per min (cfm) per sq ft of floor area.

(b) Exhaust and inlet openings shall be arranged to prevent accumulation of vapors.

(c) For dispensing rooms, the mechanical ventilation system shall be connected to an automatic emergency back-up source of power.



Source—Insurance Services Office

Earthquake Zones

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

Figure 4-3 Seismic map.

5-1.1.5 Accidental Mixing.

5-1.1.5.1 Hazardous chemicals shall be stored within enclosed storage cabinets or work stations.

Exception: Within hazardous materials storage or dispensing rooms.

5-1.1.5.2 Incompatible chemicals shall not be stored in the same cabinet.

5-1.1.5.3 Storage cabinets shall be constructed of not less than 18 gauge steel. Doors shall be self-closing and shall be provided with a latching device.

5-1.1.6 Approved safety containers shall be used to store flammable liquids.

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

5-1.1.7 Chemical containers shall be labeled as to their contents.

5-2 Flammable and Combustible Liquid Delivery Systems.

5-2.1 Class I and II liquids shall not be piped to deliver by gravity from tanks, drums, barrels, or similar containers. Dispensing devices for flammable and combustible liquids shall be of an approved type.

5-2.2 When pressurized systems are utilized, all materials used in the system will be compatible with the chemicals being dispensed.

5-2.3 The pressurized system shall be equipped with the following safeguards.

(a) Automatic depressurization vents in the case of fire. Vent to a safe location.

(b) Manual vents to allow for the removal of canisters. Vent to a safe location.

(c) Manual shutoff valves at the point of use.

(d) Only inert gas shall be used.

5-2.4 For pressurized delivery systems of 10 gal (38.8 L) or less, inert gases shall be used at 15 psi (1 bar) or less.

5-2.4.1 Pressurized delivery systems for flammable or combustible liquids shall be hydrostatically tested to 150 percent of the working pressure for 2 hr with no visible leakage or loss of pressure.

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

5-2.5 Pressurized delivery systems for flammable and combustible liquids shall be constructed of a ferrous metal.

5-2.6 Delivery pressure shall not exceed 15 psi (103 kPa).

5-2.7 Bulk delivery systems shall be equipped with the following safeguards.

(a) Excess flow protection.

(b) Secondary containment for spills.

(c) Manual shutdown at point of use and dispensing.

(d) Fill level monitors and shutoff.

(e) Preset meter for automated delivery systems.

5-3 Chemical Carts.

5-3.1* In new buildings, hazardous chemicals shall not be permitted within an exit corridor. In existing buildings, hazardous chemicals shall be transported in approved chemical carts.

5-3.2* Chemical carts transporting or containing hazardous chemicals shall be designed so that the contents will be fully enclosed. They shall be capable of containing a spill from the largest single container transported, with a maximum individual container size of 5 gal (19 L). The capacity of carts used for transportation of hazardous chemicals shall not exceed 55 gal (208 L).

5-3.3 Incompatible chemicals shall not be transported simultaneously on the same hazardous chemical cart.

5-4 Waste Disposal.

5-4.1 Separate drainage systems shall be provided for incompatible materials.

5-4.2* Drainage systems shall be labeled as to their intended contents in an approved manner.

5-4.3 Collection of chemicals shall be directed to containers compatible with the material being collected.

5-4.4 Flammable liquids shall be collected in approved containers.

5-4.5 During collection of flammable liquids the waste container shall be within secondary containment.

5-4.6 Chemical containers shall be labeled as to their contents in an approved manner.

5-4.7 Incompatible chemicals shall not be transported simultaneously on the same hazardous chemical cart.

5-5 Spill Protection.

5-5.1 Spill protection for flammable liquids shall be provided where leakage from a fitting or tool will terminate in an unoccupied or below-grade area.

5-5.2 Spill protection shall include secondary containment and a method of detecting a spill.

Chapter 6 Hazardous Gas Cylinder Storage and Distribution

6-1 Packaging.

6-1.1 Container Data. The supplier shall accumulate and provide upon request the following information:

(a) Cylinder contents with description of the components.

(b) Cylinder serial number, material of construction, and standards used for construction and testing.

(c) Cylinder valve with restricted orifice, when provided. Date of manufacture, material of construction, and flow curve for the orifice.

(d) Description and date of last hydrostatic test.

6-1.2* Cylinders containing pyrophoric gases shall be equipped with normally closed automatic shutoff valves that incorporate restricted flow orifices.

6-2 Transport to the Semiconductor Facility. The operator of a vehicle transporting hazardous compressed and liquefied gases shall be trained in the handling of containers, use of portable fire extinguishers, and shall be familiar with the site gas delivery procedures.

6-2.1 A leak check shall be performed on all gas cylinders prior to unloading from the transport vehicle.

6-2.2* An emergency response program shall be developed to handle accidents connected with the delivery of gases.

6-3 Distribution Systems.

6-3.1 Material for tubing, piping, and fittings used for distribution of compressed and liquefied gases shall be compatible with those gases. The entire system shall be subjected to a pressure test at a minimum pressure of 20 percent over the maximum pressure available to the system but not less than 80 psi (552 kPa) for 2 hr with no discernible pressure drop.

6-3.2 Materials for tubing, piping, and fittings used for the distribution of compressed and liquefied gases shall be of noncombustible construction or contained in a noncombustible outer jacket.

6-3.2.1 Tubing, piping, and fittings shall be welded.

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

6-3.3 Distribution piping shall be leak tested in accordance with SEMI F1-90, *Specification for Leak Testing Toxic Gas Piping Systems.*

6-3.4* Welders and pipefitters shall be trained and qualified for the specific function they are performing.

6-3.5* Purge panels shall be provided at the cylinders on all compressed hazardous process gases when in use.

6-3.6* Purge panels shall be constructed of materials compatible with gases conveyed, minimize leakage potential, provide for control of excess flow, and be equipped with an appropriate emergency shutoff.

6-3.7 Purge panels shall be designed to prevent backflow and cross contamination of purge gas or other process gases.

6-3.8 Check valves shall not be exposed to cylinder pressure if a cylinder has a pressure greater than 80 psi (552 kPa).

6-3.9 A manual isolation valve shall be provided on the process delivery line to permit removal of the purge panel for repair and maintenance.

6-3.10 Incompatible process gases shall not occupy the same gas cabinet.

6-3.11 Hazardous gas cylinder purge panels shall be provided with dedicated purge gas cylinders. Only purge panels serving compatible gases shall be permitted to share a purge cylinder.

6-3.12 Low pressure bulk gas systems shall not be used as the purge source for hazardous gas cylinder purge panels.

6-4 Pyrophoric Storage and Dispensing Areas.

6-4.1 Pyrophoric gas cylinders in storage or dispensing shall be provided with the following safeguards:

(a) Pyrophoric storage and dispensing areas shall be located exterior to the building.

Exception: Where the weather conditions do not permit, the storage shall be in an approved shelter.

(b) When used in a manifold or dispensing rack system, pyrophoric gas cylinders shall be separated from each other by a steel plate 1/4 in. (6 mm) thick, extending 3 in. (76 mm) beyond the footprint of the cylinder. The steel plate shall extend from the top of the purge panel to 12 in. (305 mm) below the cylinder valve.

(c) Mechanical or natural ventilation at a minimum of 1 cfm/sq ft (.00047 m^3/s per .09 m^2) of storage and dispensing area shall be provided.

(d)* Cylinders located in cabinets shall be provided with mechanical ventilation at a minimum of 200 ft per min (fpm) (.762 m/s) across the cylinder neck and the purge panel. The ventilation system shall be provided with an automatic emergency back-up source of power to operate at full capacity.

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

(f) Gas cabinets and cylinders not located in shelters or bunkers containing silane or silane mixes shall be provided with a security chain link fence to prevent unauthorized entry and to reduce the impact of an explosion at the perimeter. The area shall also be separated from structures in accordance with the following table:

Distance from Fence and Walls

	Distance to Fence in Ft	Distance to Wall in Ft
Unconfined Cylinders	6	9
Single Cylinder Cabinets	12	12

Gas cabinets and cylinders located in shelters containing silane or silane mixes shall comply with the table without regard to shelter walls.

(g) When gas cabinets are used, only single cylinder cabinets shall be used for pyrophorics and pyrophoric mixes.

6-4.2 Flammable or Toxic Concentrations.

6-4.2.1* Toxic or nonpyrophoric-flammable gases in use shall be contained in cabinets provided with exhaust ventilation. Cabinets shall be provided with gas detection and automatic shutdown of the gas supply. Exhaust ventilation shall be continuous or activated automatically by gas detection.

Exception: Lecture cylinders in ion implanters.

6-4.2.2 Exhaust ventilation shall be provided where there is potential for gas release and for the area containing valves, fittings or connections, transfer stations, or vacuum pumps. Detection of toxic or flammable gases shall activate a local alarm and shut down the gas supply. Alarms shall be continuously monitored.

6-4.2.3 Exhaust ventilation, detection, and shutdown systems shall be provided with an automatic emergency source of back-up power.

6-4.2.4 Welding and other activities that may produce ignition shall be minimized in areas where there is potential flammable gas release. It shall be allowed only through a special internal permit procedure that calls for monitoring in the area for 20 percent of the lower explosive limit and a fire watch and ventilation to reduce the potential of explosive concentrations.

6-4.3 "No Smoking" signs shall be provided in the flammable gas storage area, in areas where there is a potential for flammable gas release, and within 25 ft (7.6 m) of those areas.

6-4.4 Open flames shall not be used in the flammable gas storage or dispensing areas. All sources of electrical heat shall comply with NFPA 70, *National Electrical Code.* Compressed and liquefied gases in storage or dispensing shall be protected from uncontrolled heat sources.

6-4.5 Low pressure bulk gas systems shall not be used as a purge source for hazardous gases.

6-4.6 Vent Headers.

6-4.6.1 Purge panel vent line headers, when used, shall be designed to prevent the mixing of incompatible gases and silane with air.

6-4.6.2 Silane vent headers or individual purge panel vent lines shall have a continuous flow of nitrogen.

6-4.6.3 Vents shall terminate at a safe location or in treatment systems.

6-4.7 Process delivery lines used for hazardous gases shall be dedicated to those gases.

6-5* Training. Operators working with hazardous gases and handling hazardous compressed and liquefied gas containers shall be trained for that function. Training shall be provided annually.

Chapter 7 Production and Support Equipment

7-1* General. Production and support equipment shall be designed and installed in accordance with Sections 7-2 through 7-8.

7-2 Interlocks.

7-2.1* Hardware interlocks that will automatically bring the tool to standby mode shall be interfaced with the tool's operating system.

7-2.2 A local visual and audible alarm shall be provided to indicate activation of any interlock.

Exception: Panel interlocks.

7-2.3 Each interlock and its operation shall be described in both the operations and maintenance manuals for the tool.

7-2.4 Tools utilizing hazardous chemicals shall be designed to accept inputs from monitoring equipment. An alarm signal from the monitoring equipment shall automatically stop the flow of hazardous chemicals to the tool.

7-2.5 Interlocks shall be designed to require manual reset and to permit restart only after fault correction.

7-3 Electrical Design.

7-3.1 Electrical components and wiring shall be in accordance with NFPA 70, *National Electrical Code*, and NFPA 79, *Electrical Standard for Industrial Machinery*.

7-3.2 Electrical equipment and devices within 5 ft (1.5 m) of work stations in which flammable liquids or gases are used shall comply with the requirements of NFPA 70, *National Electrical Code*, for Class I, Division 2 locations.

Exception: The requirements for Class I, Division 2 locations shall not apply when the air removal from the work station or dilution will assure nonflammable atmospheres on a continuous basis.

7-3.2.1 Work stations using flammable chemicals shall not be capable of being energized without adequate exhaust ventilation.

7-4 Process Liquid Heating Equipment. Electric immersion heaters and hot plates shall not be used in combustible tools or tools using combustible or flammable liquids.

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

7-4.1 Where stand-alone electric water heaters are used, they shall include:

(a) Ground fault interrupters
(b) Overcurrent protection
(c) Power interrupts
(d) Manual resets
(e) Temperature controllers
(f) Redundant liquid level sensors
(g) Redundant over-temperature protection.

7-4.2 Electrically heated baths shall have the following interlocks to activate both shutdown and alarms:

(a) Ground fault interrupters
(b) Overcurrent protection
(c) Power interrupts
(d) Manual resets
(e) Temperature controllers
(f) Redundant liquid level sensors
(g) Redundant over-temperature protection.

7-4.3* Those baths heating flammable or combustible liquids shall have high-temperature limit switches.

7-4.4* Liquid level sensors shall be tested after maintenance but at least monthly.

7-5 Materials of Construction. Tools shall be of noncombustible construction.

Exception: That part of the work station that comes into contact with corrosive materials.

7-6 Vacuum Pumps.

7-6.1* Vacuum pumps using combustible oils shall use a control device to remove oils prior to their discharge into the exhaust duct system.

7-6.2 Exhaust Conditioning.

7-6.2.1* Vacuum pumps that handle flammable gases in excess of 20 percent of LFL shall discharge into a control device to treat the flammable gases from the airstream prior to discharge into exhaust system ductwork.

7-6.2.2 Vacuum pumps handling flammable or pyrophoric chemicals or high concentration oxygen shall not use combustible pump oils.

7-6.2.3 Vacuum pumps that handle flammable or pyrophoric gases shall be equipped with a nitrogen purge and interlocked with the process tool operating system.

7-7 Hazardous Gas Delivery Systems. Hazardous gas piping, controls, and valves that are internal to tools using hazardous gases shall be contained within a noncombustible enclosure that is exhausted at a minimum airflow of 100 cfm per sq ft (.047 m^3/s per .09 m^2) of average transverse cross-sectional area of the enclosure.

7-8* All tools using flammable or combustible chemicals shall be provided with exhaust to reduce the concentration of flammable gases and vapors to less than 20 percent of the LFL.

Chapter 8 Referenced Publications

8-1 The following documents or portions thereof are referenced within this standard and shall be considered part of the requirements of this document. The edition indicated for each reference is the current edition as of the date of the NFPA issuance of this document.

8-1.1 NFPA Publications. National Fire Protection Association, 1 Batterymarch Park, P.O. Box 9101, Quincy, MA 02269-9101.

NFPA 13, *Standard for the Installation of Sprinkler Systems*, 1991 edition

NFPA 30, *Flammable and Combustible Liquids Code*, 1990 edition

NFPA 33, *Standard for Spray Application Using Flammable and Combustible Materials*, 1989 edition

NFPA 43A, *Code for the Storage of Liquid and Solid Oxidizers*, 1990 edition

NFPA 43B, *Code for the Storage of Organic Peroxide Formulations*, 1986 edition

NFPA 70, *National Electrical Code*,® 1990 edition

NFPA 79, *Electrical Standard for Industrial Machinery*, 1991 edition

NFPA 220, *Standard on Types of Building Construction*, 1992 edition

NFPA 255, *Standard Method of Test of Surface Burning Characteristics of Building Materials*, 1990 edition

NFPA 385, *Standard for Tank Vehicles for Flammable and Combustible Liquids*, 1990 edition

NFPA 386, *Standard for Portable Shipping Tanks for Flammable and Combustible Liquids*, 1990 edition

NFPA 704, *Standard System for the Identification of the Fire Hazards of Materials*, 1990 edition.

8-1.2 Other Publications.

8-1.2.1 ASTM Publications. American Society for Testing and Materials, 1916 Race Street, Philadelphia, PA 19103.

ASTM D5-1986, *Standard Test Method for Penetration of Bituminous Materials*

ASTM D323-1990, *Standard Test Method for Vapor Pressure of Petroleum Products*

ASTM E136-1982, *Standard Test Method for Behavior of Materials in a Vertical Tube Furnace at 750 Degrees C* (formerly *Standard Method of Test for Noncombustibility of Elementary Materials*).

8-1.2.2 FED STD Publication. Superintendent of Documents, U.S. Government Printing Office, Washington, DC 20402.

FED STD 209D, 1988, *Cleanroom and Work Station Requirements, Controlled Environment.*

8-1.2.3 SEMI Publication. Semiconductor Equipment and Materials International, 805 East Middlefield Road, Mountain View, CA 94043-4080.

SEMI F1-90, *Specification for Leak Testing Toxic Gas Piping Systems.*

8-1.2.4 UL Publications. Underwriters Laboratories Inc., 333 Pfingsten Rd., Northbrook, IL 60062.

UL 181-1990, *Standard for Safety Factory-Made Air Ducts and Air Connectors*

UL 586-1990, *High-Efficiency, Particulate, Air Filter Units.*

Appendix A

This Appendix is not a part of the requirements of this NFPA document, but is included for information purposes only.

A-1-2 A systems approach to risk management was attempted throughout this standard. These firesafety objectives are achieved through the proper management of fire prevention and fire response activities.

A-2-1.2.1 Typical configurations of cleanrooms and their chases and plenums create numerous areas that may be sheltered from sprinkler protection. These areas may include air-mixing boxes, catwalks, hoods, protruding lighting, open waffle slabs, equipment, piping, ducting, and cable trays. Care should be taken to relocate or supplement sprinkler protection to ensure sprinkler discharge will cover all parts of the occupancy. Care should also be taken to ensure 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 may 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 13A, *Recommended Practice for the Inspection, Testing and Maintenance of Sprinkler Systems.*) The length of time between such inspections may 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 notify all personnel who may 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 components replaced or repaired promptly. Sprinklers that did not operate but were subjected to corrosive elements of combustion or elevated temperatures should be inspected, and replaced if necessary, in accordance with the minimum replacement requirements of the authority having jurisdiction. Such sprinklers should be destroyed to prevent their reuse.

A-2-1.2.2 The use of quick response sprinklers, while still delayed in opening by the downward airflow, would respond to a smaller size fire quicker than conventional sprinklers. (Glass bulb-type quick response sprinklers may be preferable to other types of quick response sprinklers.)

A-2-1.2.3 It is recommended that an approved 135°F (57°C) 3/8-in. (9.5-mm) orifice sprinkler be used. It is recommended that a sprinkler be installed in all gas cylinder cabinets.

A-2-1.2.5.1 Small orifice sprinklers, 3/8 in. (9.5 mm) or larger may be used.

A-2-1.2.5.3 Drainage and placement of sprinklers should be designed to prevent water from flowing back into process equipment or the ductwork collapsing under the weight of the water or both. Since water discharged into exhaust ductwork will most likely be contaminated, outflow from the drain lines should be piped in accordance with local environmental regulations.

A-2-1.2.6 It is recommended that an approved 3/8-in. (9.5-mm) orifice sprinkler be used. Drainage should be provided to remove all sprinkler water discharged in the pass through.

A-2-1-2.7 Figure A-2-1.2.7 from FM Loss Prevention Data Sheet 7-7 "Semiconductor Fabrication Facilities" August 1991 illustrates various arrangements of a wet bench work station, the associated fume exhaust ductwork, and possible locations of fire protection devices. (*See Figure A-2-1.2.7 on the following page.*)

A-2-1.2.7.3 To minimize the effect of automatic sprinkler water discharge on airflow in exhaust ducts, it is preferable to locate the sprinkler head in the work station transition piece. It is also acceptable to use a 3/8-in. (9.5-mm) orifice sprinkler.

A-2-2.2 Cleanroom hydrogen monitoring should use parts per million detectors to provide alarm and detection for hydrogen leaks.

A-2-3.1 The detectors may also be used to shut down the recirculating fans or activate a dedicated smoke control system, or both. See NFPA 90A, *Standard for the Installation of Air Conditioning and Ventilating Systems.*

A-2-3.2 Smoke detection need not result in an automatic facility evacuation alarm signal.

A-3-3.1 Ribbed flex duct is frequently used to connect a piece of equipment to the exhaust duct system. Trapped sections occur where ducts are routed under structural members or other mechanical ducts or piping. Transport velocities that are adequate in straight sections of ductwork may not be adequate in the above sections due to turbulence, and as a result, hazardous chemicals may deposit in the ductwork.

Ribbed flex duct also has the undesirable property of very rapid burn through or collapse in the event of internal fire exposure.

A-3-3.6 Considering fire protection issues only, duct materials listed in descending order of preference are:

(a) Metallic.

(b) Approved coated metallic or nonmetallic not requiring fire sprinklers, fire dampers, or interrupters of any kind.

(c) Combustible with internal automatic sprinkler protection.

A-3-5.2 Emergency power systems are not intended to keep production equipment operating except in limited cases. When electrical utility power in a facility fails, most production equipment will shut down, thereby reducing the hazardous fumes transported in the fume exhaust duct system.

A-4-1 Buildings housing these cleanrooms should be of noncombustible or fire resistive construction.

A-5-1.1 The following documents should be consulted for storage and handling of hazardous chemicals.

NFPA 68, *Guide for Venting of Deflagrations,* 1988 edition

NFPA 329, *Recommended Practice for Handling Underground Leakage of Flammable and Combustible Liquids,* 1987 edition.

A-5-3.1 New buildings are designed to provide chemical handling corridors.

A-5-3.2 Breakable individual chemical containers should be separated to avoid breakage.

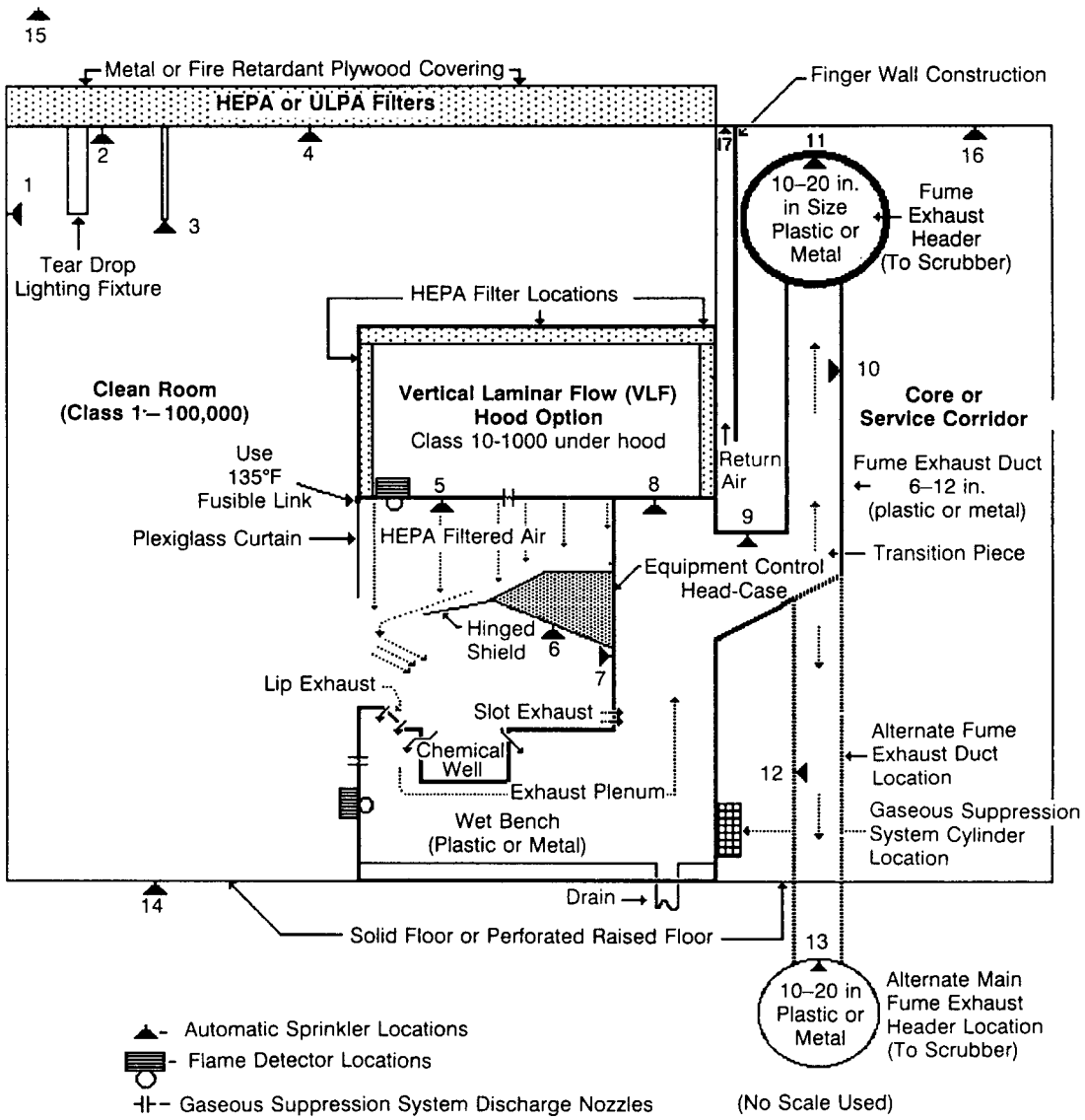


Figure A-2-1.2.7 Example of sprinkler locations for combustible tools.

A-5-4.2 Labeling of contents should be in accordance with ANSI B 31.3.

A-6-1.2 If a flow restricted orifice is placed in a system with an excess flow device, the excess flow device may not shut off.

A-6-2.2 This program should be coordinated with the fire department, the plant emergency response team, and the gas supply organization. A response time for all parties concerned should be a part of the procedure. Periodic drills should be performed with all parties involved to handle simulated accidents.

A-6-3.4 Training should be as outlined in SEMI F3-90, *Guideline for Welding Stainless Steel Tubing for Semiconductor Manufacturing Applications.*

A-6-3.5 Automated purge panels are recommended because they reduce the potential for human error.

A-6-3.6 The basic components of purge panels should incorporate the following features:

(a) Tied diaphragm regulators should be used.

(b) All piping/tubing connections should be welded or of a metal gasket face seal fitting with zero clearance, except valve connection to cylinder.

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

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

(e) Regulators should be of the hand loaded type. Dome loaded regulators should not be used on hazardous gases. Remotely operated gas delivery systems may use dome loaded regulators.

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

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

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

(i) Emergency high pressure shutoff valves should be provided and should operate upon the activation of an emergency off button, gas monitoring alarm (high alarm), or electronically monitored excess flow control switch.

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

A-6-4.1(d) Exhaust airflow should be calculated by multiplying 200 fpm by the cross-sectional volume of the cabinet.

A-6-4.2.1 Alternate substances should be considered for replacement of hazardous gases.

A-6-5 A certification program should be used to ensure adequate training.

A-7-1 Introduction. This chapter may 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 design, use, and maintainability of all tools.

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

General Recommendations. Tools should be designed to achieve fire prevention, or in the event of fire, to provide early detection and suppression adequate to prevent fire spread, explosion, or threat to life safety.

The completed system should have third party review based on the requirements of this chapter.

Where available, components and subassemblies used should be listed.

Listed below is a guideline setting 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:

(a) Materials of constructions (flammability, combustibility, and compatibility)

(b) Electrical components, their mounting, and enclosures

(c) Electrical circuit protection

(d) Access to components within equipment

(e) Minimization and control of pyrophoric chemicals

(f) A review of process piping, connectors, and materials

(g) Methods of preventing excess flow of gases

(h) Earthquake stability where and when applicable

(i) Redundant controls of electrical heaters

(j) 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, when 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 may constitute firesafety hazards that could exist in their products.

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

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

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

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

Owners should perform physical inspection of tools on receipt to ensure that the tool is in conformance with their design/review documents.

Owners should ensure that the tool is accompanied with adequate installation, maintenance, and operating instructions, which will include appropriate wiring details and facilitizing of the tool.

Owners should ensure that a proper hands-on training program is instituted in the safe operation of the tool 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 when required. Inspection and maintenance should be done on a sufficiently frequent basis

against a checklist by qualified personnel to ensure continued safe operation of the tool. The name of the inspector should be posted on or close to the tool, as well as the date of last inspection.

Production and Support Equipment may be designed to comply with SEMI S2-91, *Product Safety Guidelines*, and designed and installed in accordance with Sections 7-2 through 7-8.

A-7-2.1 Interlock systems should be designed to prevent override during normal operation.

A-7-4.3 Wet benches that use combustible chemicals, heated above their flash points, or flammable chemicals should be provided with devices to detect fire.

A-7-4.4 A convenient way in which to test low liquid level sensors is to use them at least weekly to shut down the process by removing them from the bath; if they fail to shut off equipment, they prove they are not operating properly.

A-7-6.1 Such devices may be traps, condensers, demisters, or coalescing filters. As an alternative, noncombustible oils should be used, or dry-type pumps not requiring lubricant should be used.

A-7-6.2.1 Vacuum pumps whose construction is susceptible to backstreaming oil into tools should have foreline traps on their inlets.

A-7-8 Exhaust flow should be monitored and controlled by a sensor set at a negative static pressure to provide the minimum airflow specified in Chapter 5.

As an alternative to the above, the minimum airflow may 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.

Appendix B

This Appendix is not a part of the requirements of this NFPA document, but is included for information purposes only.

B-1 The following appendix contains useful and explanatory information about subjects related to the installation of fire protection systems but not covered in the text.

B-2 Seismic Protection.

B-2.1 In seismic zones, where required by the authority having jurisdiction, approved seismic warning and control systems should be installed to mitigate the damage of an earthquake.

B-2.2 An approved seismically activated valve should be provided to automatically shut off piping systems conveying hazardous chemicals during significant seismic events. It 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-2.3 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-2.4 The optimal seismic warning and control system should react only to a ground acceleration of 0.05G–0.25G at the specific frequencies inherent to earthquakes (0.5 Hz–15 Hz).

B-2.5 Electrically operated seismic warning systems should be powered by an uninterruptible power supply.

Appendix C Referenced Publications

C-1 The following documents or portions thereof are referenced within this standard for informational purposes only and thus are not considered part of the requirements of this document. The edition indicated for each reference is the current edition as of the date of the NFPA issuance of this document.

C-1.1 NFPA Publications. National Fire Protection Association, 1 Batterymarch Park, P.O. Box 9101, Quincy, MA 02269-9101.

NFPA 13A, *Recommended Practice for the Inspection, Testing, and Maintenance of Sprinkler Systems*, 1987 edition

NFPA 68, *Guide for Venting of Deflagrations*, 1988 edition

NFPA 90A, *Standard for the Installation of Air Conditioning and Ventilating Systems*, 1989 edition

NFPA 329, *Recommended Practice for Handling Underground Leakage of Flammable and Combustible Liquids*, 1987 edition.

C-1.2 Other Publications.

C-1-2.1 ANSI Publication. American National Standards Institute, Inc., 1430 Broadway, New York, NY 10018.

ANSI B31.3-1988, Chemical Plant and Petroleum Refinery Piping.

C-1-2.2 SEMI Publications. Semiconductor Equipment and Materials International, 805 East Middlefield Road, Mountain View, CA 94043-4080.

SEMI F3-90, *Guideline for Welding Stainless Steel Tubing for Semiconductor Manufacturing Applications*

SEMI S2-91, *Product Safety Guidelines.*

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