SEMI S3-1211 (Reapproved 1017)[E]
SAFETY GUIDELINE FOR PROCESS LIQUID HEATING SYSTEMS

This Safety Guideline was technically approved by the Environmental, Health & Safety Global Technical Committee. This edition was approved for publication by the global Audits and Reviews Subcommittee on May 16, 2017. Available at www.semiviews.org and www.semi.org in October 2017; originally published in 1991; previously published December 2011.

[E] This Standard was editorially modified to make corrections that were approved outside of the normal reapproval process.

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

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

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

1 Purpose

1.1 The purpose of this Safety Guideline is to provide minimum general safety considerations for the design and documentation of heating systems used for changing or maintaining the temperatures of process liquids used in semiconductor and flat panel display manufacturing.

1.2 This Safety Guideline provides several means (see Table 1) of achieving a level of Risk no greater than Low (as defined by SEMI S10 and SEMI S14) for process liquid heating systems (PLHS). The choice of which means is used is not, however, a criterion for determining conformance with this Document.

1.2.1 For several common PLHS configurations, this Safety Guideline provides a prescriptive list of safety features to be incorporated in the PLHS. Design and performance criteria for those safety features are also provided. A PLHS that conforms to both the prescriptive list of safety features and the design and performance criteria for those safety features is presumed to achieve a risk level of no greater than Low (as defined by SEMI S10 and SEMI S14) and, thereby, conforms to this Safety Guideline.

1.2.2 Conformance with this Safety Guideline may also be achieved by designing a PLHS and incorporating safety features that are selected, designed, and perform such that the risk of the equipment is no greater than Low, as assessed using SEMI S10 and SEMI S14 and considering the hazards discussed within this Document.

NOTE 1: The second way of demonstrating conformance with this Safety Guideline is intended to provide a way to demonstrate conformance by PLHS configurations that are not among those for which prescriptive lists of safety features are provided and by PLHS configurations for which prescriptive lists are provided but for which alternative means of achieving a level of Risk no greater than Low (as defined by SEMI S10 and SEMI S14) are used.

Table 1 Means of Conformance to this Safety Guideline

	Selection of Safety Features by Use of Tables	*Selection of Alternative Sets of Safety Features to Achieve Risk No Greater than Low*
Design And Function Of Safety Features By Use Of Descriptions in This Document	See §§ 8.2, 9.1 through 9.16, and Appendix 2. Risk level of no greater than Low (as defined by SEMI S10 and SEMI S14) is presumed to be achieved and PLHS is found to conform.	See §§ 8.3, 9.1, and 9.3 through 9.16. Risk is to be assessed and whether the PLHS conforms to this Safety Guideline is to be determined as described in ¶ 1.2.2.

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	Selection of Safety Features by Use of Tables	*Selection of Alternative Sets of Safety Features to Achieve Risk No Greater than Low*
Design And Function Of Safety Features, Other Than As Described in This Document, To Achieve Risk No Greater Than Low	See §§ 8.2, 9.2 and Appendix 2. Risk is to be assessed and whether the PLHS conforms to this Safety Guideline is to be determined as described in ¶ 1.2.2.	See §§ 8.3 and 9.2. Risk is to be assessed and whether the PLHS conforms to this Safety Guideline is to be determined as described in ¶ 1.2.2.

NOTE 2: Cross references within this Document are presented as paragraph, figure, or table numbers, usually within parentheses. When this Document is viewed with Adobe Acrobat or Acrobat Reader, clicking on the number should cause the view of the Document to move to that paragraph, figure, or table.

2 Scope

2.1 The scope of this Safety Guideline is limited to heating systems designed to change or maintain the temperature of process liquids.

NOTE 3: Equipment, such as ovens and heated substrate supports (e.g., hotplates) intended to change or maintain the temperature of substrates are not 'PLHS,' even if heat is transferred to a process liquid.

2.1.1 *Deionized (DI) Water Heaters* — DI water heaters are included within the scope of this Safety Guideline when the heated DI water is used as a 'process liquid' as defined in § 5.

2.1.2 *Heat Transfer Fluids (HTFs)* — Where fluids are used to transfer heat between heating systems and process liquids, they are included within the scope of this Document. For the purpose of this Safety Guideline, HTFs are limited to liquids.

2.2 Although the scope of SEMI S3 is PLHS, this Safety Guideline may be used to evaluate subsystems to determine if integrating them into a PLHS will cause the PLHS not to conform to this Safety Guideline.

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

3 Limitations

3.1 This Safety Guideline does not address all safety concerns related to the design of PLHS. Refer to other SEMI Safety Guidelines for other safety provisions (e.g., SEMI S2 for electrical design and SEMI S14 for guidance in fire risk assessment and mitigation).

NOTE 4: The presence of some liquids (e.g., flammable liquids) may require, under the scope of other guidelines or standards such as NFPA 497 or ATEX 2014/34/EU, additional safety measures (e.g., purging) for components and systems that are not part of the PLHS.

3.2 This Safety Guideline is not intended to replace or supersede any provisions of local codes, national or international standards, or other regulatory requirements.

3.3 Existing PLHS should continue to meet the provisions of SEMI S2 and SEMI S3 that were in effect at the time of their design. Process liquid heating systems with redesigns that significantly affect the EHS aspects of the equipment should conform to the latest version of SEMI S3. This Safety Guideline is not intended to be applied retroactively.

3.4 In many cases, references to standards have been incorporated into this Safety Guideline. These references do not imply applicability of the entire standards, but only of the sections or topics referenced.

3.5 Heating systems for liquid materials for dry etch and deposition processes are outside the scope of this Safety Guideline.

3.6 Systems for the heating of process liquids by means of exothermic chemical reactions are outside the scope of this Safety Guideline.

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3.7 Systems intended to be used to heat liquids to above (autoignition temperature [AIT] − 50°C) or within a smaller margin of their AITs (as described in the Exception to ¶ 9.4.2.1) are outside the scope of this Safety Guideline. However, systems that are not intended to be used in that manner, but which have sufficient heater power to heat liquids to such temperatures, are within the scope of this Safety Guideline.

3.8 If the process fluid is a gas or plasma when it is in contact with the substrate, the heating systems that control the temperature of fluid delivery systems or process chambers are also not within the scope of this Safety Guideline.

4 Referenced Standards and Documents

4.1 *SEMI Standards and Safety Guidelines*

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

SEMI S6 — EHS Guideline for Exhaust Ventilation of Semiconductor Manufacturing Equipment

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

SEMI S14 — Safety Guidelines for Fire Risk Assessment and Mitigation for Semiconductor Manufacturing Equipment

SEMI S22 — Safety Guideline for the Electrical Design of Semiconductor Manufacturing Equipment

4.2 *European Community Directive*[1]

2014/34/EC — Equipment and Protective Systems Intended for Use in Potentially Explosive Atmospheres (ATEX)

4.3 *NFPA Standards*[2]

NFPA 30 — Flammable and Combustible Liquids Code

NFPA 69 — Standard on Explosion Prevention Systems

NFPA 496 — Standard for Purged and Pressurized Enclosures for Electrical Equipment

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

4.4 *CEN/CENELEC Standards*[3]

EN 1127-1 — Explosive Atmospheres – Explosion Prevention and Protection Part 1: Basic Concepts and Methodology

4.5 *UL Standards*[4]

UL 943 — Standard for Ground-Fault Circuit-Interrupters

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

5 Terminology

5.1 *Abbreviations and Acronyms*

5.1.1 *AIT* — autoignition temperature

5.1.2 *ATL* — accredited testing laboratory

5.1.3 *FDT* — flammable degradation temperature

5.1.4 *FR* — flammable range

[1] http://europa.eu.int/smartapi/

[2] National Fire Protection Association, 1 Batterymarch Park, Quincy, MA 02269, USA; Telephone: +1.617.770.3000, Fax: +1.617.770.0700, http://www.nfpa.org

[3] European Committee for Standardization, Avenue Marnix 17, B-1000 Brussels; Telephone: +32.2.550.08.11, Fax: +32.2.550.08.19, http://www.cen.eu

[4] Underwriters Laboratory, 2600 N.W. Lake Road, Camas, WA 98607-8542, USA; Telephone: +1.877.854.3577, Fax: +1.360.817.6278, http://www.ul.com

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5.1.5 *GFCI* — ground fault circuit interrupter

5.1.6 *HDT* — hazardous degradation temperature

5.1.7 *HTF* — heat transfer fluid

5.1.8 *LFL* — lower flammable limit (See also the definition for flammable range.)

5.1.9 *PLHS* — process liquid heating system

5.1.10 *SME* — semiconductor manufacturing equipment

5.1.11 *UFL* — upper flammable limit (See also the definition for flammable range.)

5.2 *Definitions*

5.2.1 *accredited testing laboratory (ATL)* — an independent organization dedicated to the testing of components, devices, or systems; competent to perform evaluations based on established safety standards; and recognized by a governmental or regulatory body. [SEMI S2, SEMI S14, SEMI S22]

5.2.2 *autoignition temperature (AIT)* — the temperature at which a solid in contact with air, or a liquid or gas (including a vapor) mixed with air, ignites without contacting a surface of higher temperature or there being an explicit source of ignition, such as a spark or flame.

5.2.3 *boiling point* — the temperature at which the vapor pressure of a liquid equals 101.32 kPa (1 atmosphere, 14.7 psia)

5.2.4 *closed vessel* — an enclosed container, typically used for the heating, mixing, or application of process liquids, containing vapors and used in an application where unintended pressurization is possible. Some sealed processing chambers and DI water heaters are examples of closed vessels.

5.2.5 *combustible liquid* — a liquid that will burn and has a flash point at or above 37.8°C (100°F).

NOTE 5: For the purpose of this Safety Guideline (SEMI S3), a combustible liquid, when used by a system capable (under normal or single-fault conditions) of heating it above its flash point – 10°C, is treated as a flammable liquid. See § 8.1.

5.2.6 *external heater* — a heater applied to the outside of a vessel that heats the contents of the vessel through the vessel wall. (See Figure A1-8 and Figure A1-10 for examples of PLHS using external heaters.)

5.2.7 *fail-safe* — designed so that a failure does not result in an increased risk. [SEMI S2]

NOTE 6: For example, a fail-safe temperature limiting device would indicate an out-of-control temperature if it were to fail. This would cause the safety interlocks to remove power from the heaters. That might well interrupt a process, but would be preferable to the device indicating that the temperature is within the control limits, regardless of the actual temperature, in case of a failure.

5.2.8 *flammable degradation temperature (FDT)* — the temperature at which a liquid degrades producing a flammable byproduct.

5.2.9 *flammable liquid* — a liquid having a flash point below 37.8°C (100°F). [SEMI S2, SEMI S14]

5.2.10 *flammable range (FR)* — the range of concentrations of the dispersed chemical species in air through which a flame will propagate if a source of ignition is supplied. This range is bounded by the lower flammable limit (LFL) and the upper flammable limit (UFL).

NOTE 7: The following pairs of terms are commonly used interchangeably:

- ‘lower explosive limit (LEL)’ and ‘lower flammable limit (LFL)’;
- ‘upper explosive limit (UEL)’ and ‘upper flammable limit (UFL)’; and
- ‘explosive range’ and ‘flammable range’.

Some literature uses ‘LEL,’ ‘UEL,’ or ‘explosive range’ to designate concentrations to which a more specific criterion (e.g., a certain pressure rise or flame front speed) than the ability to propagate flame pertain. This Document uses the ‘flammable range’ terminology to avoid the ambiguity that accompanies the ‘explosive range’ terminology.

5.2.11 *flash point* — the minimum temperature at which a liquid gives off sufficient vapor to form an ignitable mixture with air near the surface of the liquid or within the test vessel used. [SEMI S2]

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NOTE 8: Flash point is determined by one of several standardized test methods at standard atmospheric temperature. The temperature at which the LFL will be reached does, however, depend on the pressure.

5.2.12 *fluid* — liquid or gas. [SEMI F78, SEMI F81]

5.2.13 *gas* — the fluid form of a substance in which it can expand indefinitely and completely fill its container; form that is neither liquid or solid. [SEMI S4, SEMI F78, SEMI F81]

5.2.14 *ground fault circuit interrupter (GFCI)* — a device intended for the protection of personnel that functions to de-energize a circuit or portion thereof within an established period of time when the current to ground exceeds a value in the range of 4 mA to 6 mA.

NOTE 9: Several standards, including UL 943, Standard for Ground-Fault Circuit-Interrupters, provide additional information on these devices.

5.2.15 *hazardous degradation temperature (HDT)* — the temperature at which a liquid degrades producing a hazardous (e.g., flammable, toxic, corrosive, or oxidizing) byproduct. For liquids that have flammable degradation byproducts, the HDT is no greater than the FDT. The HDT, however, is less than the FDT, if the liquid degrades to produce a byproduct with a hazardous characteristic other than flammability at a temperature below the FDT.

5.2.16 *headspace* — the volume above the liquid in a vessel.

5.2.17 *heat transfer fluid (HTF)* — a liquid used in a heat transfer system to convey heat from a heating source to the process liquid.

5.2.18 *heated area* — the portion of the heater surface intended for heat transfer. (See Figure A1-3, Figure A1-7, Figure A1-9, and Figure A1-12 for examples of heated areas.)

5.2.19 *heater* — an electrical device used to transfer heat energy to a liquid chemical. The heater consists of the heating element as well as any permanently attached wiring or other components.

5.2.20 *heating element* — the electrically conductive component in a heater where electrical energy is converted into heat energy. (See Figure A1-7, Figure A1-8, and Figure A1-12 for examples of heating elements.)

5.2.21 *inerting* — a technique by which a mixture of a flammable gas or vapor in air within its flammable range is rendered nonignitable by the addition of an inert gas.

NOTE 10: Inerting may be effective by the reduction of the fuel concentration or by reduction of the oxidizer concentration.

5.2.22 *interlock* — a mechanical, electrical or other type of device or system, the purpose of which is to prevent or interrupt the operation of specified machine elements under specified conditions. [SEMI S2]

5.2.23 *liquid* — the fluid form of a substance in which its molecules moving freely with respect to each other so as to flow readily, unlike a solid, but, because of cohesive forces, not expanding infinitely like a gas.

5.2.24 *lower flammable limit (LFL)* — the minimum concentration of a flammable substance in air through which a flame will propagate. (See also the definition for flammable range.)

5.2.25 *maximum service temperature (for plastic materials)* — the highest temperature at which a plastic material has sufficient strength to perform the function for which it was intended. (Documentation and methods to determine the maximum service temperature are given in ¶ 7.3.2. The maximum service temperature of a plastic material depends on its use and loading in a structure.)

5.2.26 *noncombustible liquid* — a liquid that does not have a flash point. That is, there is no temperature to which it can be heated at which it produces flammable vapor in a concentration in air through which a flame will propagate. (The absence of a flash point on an MSDS [e.g., blank space or 'N/A'] does not mean that the liquid does not have a flash point.)

5.2.27 *open vessel* — a container, typically used for the heating, mixing, or application of process liquids, in which pressurization is not possible, because there is open communication between the vapor space and some region of near-atmospheric pressure. Open top immersion baths and ventilated storage containers are examples of open vessels.

5.2.28 *process liquid* — a substance that participates, while in the liquid state, in a chemical or physical reaction on the surface of a substrate as part of the manufacturing of semiconductor or flat panel devices.

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5.2.29 *process liquid heating system* (*PLHS)* — a heating system comprised of the heater, its power and control systems, the vessel in which the liquid chemical is heated, and, if applicable, the heat transfer liquid and its associated piping.

5.2.30 *process vessel* — a vessel in which substrates are processed by contact with a process liquid.

5.2.31 *purging* — the process of displacing gases (including vapors) from an enclosure to reduce the concentration of any flammable gases (including vapors) to no more than 25% of their LFL.

5.2.32 *radiant heat shield* — a component, opaque to the radiant energy, intended to keep the radiant heater from heating liquid overtemperature sensors or other components by radiant heating. For example, one could place a radiant energy shield between a radiant heater and a liquid overtemperature sensor so that the liquid overtemperature sensor could be activated by heat conducted by the liquid, but not by heat radiated through the liquid.

5.2.33 *radiant heater sheath* — a component, comprised of a material transparent to radiant heat, that contains a heating element and may contain other components. A radiant heater sheath separates the heating element and its other contents from the liquid in which it is immersed. (These sheaths are typically made of quartz and called 'quartz sheaths.')

5.2.34 *remote heater* — a vessel, separate from the process vessel, intended for heating liquid.

NOTE 11: In heat exchange systems, the system depicted in Figure A1-4 of Appendix 1 is considered a remote heater, while that depicted in Figure A1-3 is not.

5.2.35 *semiconductor manufacturing equipment (SME)* — equipment used to manufacture, measure, assemble, or test semiconductor products. It includes the equipment that processes substrates (e.g., silicon wafers, reticles), its component parts, and its auxiliary, support or peripheral equipment (e.g., chemical controllers, chemical delivery systems, vacuum pumps). SME also includes other items (e.g., structures, piping, ductwork, effluent treatment systems, valve manifold boxes, filtration, and heaters) specific to and provided with the aforementioned equipment, but does not include such an item if the item is part of a facility and can support more than one piece of SME.

5.2.36 *upper flammable limit (UFL)* — the maximum concentration of a flammable substance in air through which a flame will propagate. (See also the definition for flammable range.)

5.2.37 *vapor* — the gas phase of a substance that is usually considered to be a liquid.

5.2.38 *vessel* — a 'closed vessel' or an 'open vessel,' as defined above.

5.3 *Symbols*

5.3.1 § — a character used to identify a particular section or subsection of the Document. The identified portion includes the numbered paragraph or header identified by the number following the symbol and all subordinate headers and paragraphs, as well as the Exceptions and lists (bulleted or numbered) embedded therein. For example § 9.2 refers to paragraph 9.2, 9.21, 9.2.2, 9.2.3, and 9.2.4. When duplicated, as §§, it refers to more than one section or subsection.

5.3.2 ¶ — a character used to identify a particular paragraph of the Document. The identified portion includes the numbered paragraph identified by the number following the symbol and the Exceptions and lists (bulleted or numbered) embedded therein. It does not, however, include the subordinate headers and paragraphs. For example ¶ 9.2 refers to paragraph 9.2 only. It does not, however, include paragraph 9.2.1, 9.2.2, 9.2.3, and 9.2.4. When duplicated, as ¶¶, it refers to more than one paragraph.

6 Liquid Heating Method Classifications

6.1 This section provides classifications that later sections will use when providing considerations for specific types of process liquid heating systems (PLHS).

6.2 *Location of PLHS*

6.2.1 PLHS may either be incorporated in a process vessel or be located remotely.

NOTE 12: See Figure A1-3, Figure A1-5, Figure A1-6, Figure A1-8 and Figure A1-11 in Appendix 1 for examples of PLHS incorporated into process vessels and Figure A1-4, Figure A1-9, Figure A1-10 and Figure A1-13 in Appendix 1 for examples of remote PLHS.

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6.3 *Source of Heat Energy*

6.3.1 Heat energy is typically obtained from another liquid or an electric current.

6.3.2 *Heated Liquid Heat Exchange System* — This is a PLHS that uses a heater that may be located remotely from the heated vessel. The heater heats an HTF that in turn heats the process liquid by means of a heat exchanger (i.e., a device that allows heat energy to be transferred between the HTF and the process liquid, but prevents direct contact between them). There are three common configurations of such systems:

6.3.2.1 A remote heat exchange system may employ a dual-loop system and counterflow-type heat exchanger.

6.3.2.2 An external heater may be used in conjunction with a pump and a double-walled vessel where the heated transfer fluid is pumped from the external heater to the space between the inner and outer walls of the process vessel and heat exchange to the process liquid takes place through the vessel inner wall.

6.3.2.3 A third version uses a double- walled process vessel with a heater and the HTF in the space between the inner and outer walls of the vessel.

NOTE 13: Figure A1-3, Figure A1-4, and Figure A1-5 in Appendix 1 depict typical PLHS using heat exchangers. Table A2-1, Table A2-2, Table A2-3, Table A2-4, Table A2-5, and Table A2-6, in Appendix 2 contain design considerations for heated liquid heat exchangers.

6.3.3 *Electrical Resistive Element Heaters* — Heaters of this type use the energy generated by the resistance to the passage of electrical current through a conductor to heat a liquid.

6.3.3.1 *Configuration of Electrical Resistive Element Heaters*

6.3.3.1.1 The relationship of the heating element to the process liquid varies with system design.

6.3.3.1.2 *Thermally Conductive Heaters* — Thermally conductive heaters transfer energy by contact with the liquid being heated. They may either be immersion heaters, which are immersed directly in the liquid to be heated, or external heaters, which are normally bonded to the outside of a vessel. External heaters transfer energy by means of conduction from the heating element through the vessel wall to the liquid being heated. Common external heaters are manufactured from a thin metal material that results in a low-profile configuration.

NOTE 14: See Figure A1-3, Figure A1-4, Figure A1-5, Figure A1-6, and Figure A1-9 in Appendix 1 for examples of PLHS using immersion heaters (and Figure A1-7 for a detail of an immersion heater), and Figure A1-8 and Figure A1-10 in Appendix 1 for examples of PLHS using external heaters. Table A2-7, Table A2-8, and Table A2-9 in Appendix 2 contains design considerations for thermally conductive heaters; see also § 8.

6.3.3.1.3 *Radiant Heaters* — Radiant heaters (e.g., infrared heaters) use a glowing element that is separated from the liquid by nonconductive materials, usually air and quartz glass. Direct contact of liquid with the heater is not required for the transfer of heat energy. In some cases, infrared heaters may be located in wells within process vessels.

NOTE 15: Figure A1-12 in Appendix 1 depicts a detailed view of a typical radiant heater. Figure A1-11 and Figure A1-13 depict the use of radiant heaters in PLHS. Table A2-10, Table A2-11, and Table A2-12 in Appendix 2 contains design considerations for radiant heaters; see also § 8.

6.4 *Dependence on Flow of the Heated Process Liquid*

6.4.1 Systems vary in their dependence on flow of the heated process liquid to keep system elements and surroundings within intended temperature ranges. Surroundings include the process liquid chemical as well as the vessel and its supports.

6.4.1.1 *Flow-Independent Systems* — The heat transfer properties of these systems is such that free convection of the process liquid is sufficient for safe operation of the system. No means of flow or agitation is required to prevent overheating of the system or its surroundings.

6.4.1.1.1 Some systems (e.g., filtered recirculation baths) may use flow for other purposes but not for preventing overheating; these are considered flow-independent systems for the purpose of this Safety Guideline.

6.4.1.2 *Flow-Dependent Systems* — the heat transfer properties of these systems requires forced convection (e.g., flow or agitation of the liquid being heated) to prevent overheating of the system or its surroundings.

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7 General Safety Considerations

7.1 *Selection and Integration of Electrical Components, Devices and Assemblies Used in PLHS*

7.1.1 Within a PLHS, each electrical component or subsystem that has been certified by an accredited testing laboratory should be evaluated to determine whether its use is within the limits of its certification. If the use is within the limits of certification, no further evaluation of the component or subsystem is necessary. If the use is outside of the limits of the certification, the component or subsystem should be evaluated as if it were not certified.

7.1.2 Within a PLHS, each electrical component or subsystem operating in a safety circuit or within a hazardous voltage circuit that has not been certified by an accredited testing laboratory should be evaluated to applicable standard(s) or guideline(s), such as the appropriate portions of SEMI S2.

7.2 In no case should a PLHS achieve, under normal conditions, reasonably foreseeable single-point failures of the SME, and reasonably foreseeable misuse, temperatures or energy transfer rates that endanger the mechanical integrity of the PLHS or adjacent construction materials. This protection may be provided either through the use of PLHS that cannot attain damaging temperatures, or through the use of safety systems.

NOTE 16: A 'reasonably foreseeable single point failure' includes all of the consequences, including failure of other components or subsystems, that result from an initial failure. It does not, however, include cases where two or more independent failures occur.

7.3 *Construction Materials* — All portions of the PLHS that are heated or could come in contact with the chemicals should be constructed from appropriate materials. The maximum temperature and chemical exposure of each portion, during normal operation, maintenance, and under reasonably foreseeable, worst case single fault conditions should be considered. Chemical exposure includes exposure to the liquid (e.g., immersion, flow or spray) and to its vapors or aerosols.)

7.3.1 Testing to determine the properties of materials at reasonably foreseeable worst case temperature and exposure conditions may be performed in a suitable environmental test chamber, that is, the properties need not be determined by testing in a PLHS.

NOTE 17: Materials selection considerations include many factors, including compatibility of the material with the process liquid under operating conditions, that are outside the scope of this Document.

NOTE 18: It is recommended that designers of vessels obtain the physical strength characteristics at the maximum temperature under single point failure conditions and safety factors from the supplier of the material. It is also recommended that the vessel design be based on that information, the anticipated load, and an appropriate safety factor for the final design.

7.3.2 *Maximum Service Temperature for Plastic Materials*

7.3.2.1 Where temperature/strength limits for plastic components are available, the maximum service temperature is the temperature at which the plastic component's strength is equal to the maximum expected loading of the component.

7.3.2.2 Where these limits are not available, the equipment manufacturer should determine the maximum service temperature of components by engineering calculations or system testing at the maximum expected load.

7.3.3 *Electrical Wiring*

7.3.3.1 Insulation should be chemically resistant to the liquids to which it is expected to be exposed and their vapors.

7.3.3.2 Wiring materials (e.g., single conductors and multiple conductor cable) should be certified by an ATL as being capable of withstanding the temperatures expected. Where chemical compatibility or temperature concerns preclude the use of ATL certified wiring, the wiring should be used in accordance with the manufacturer's recommendations and be tested according to the dielectric strength test for conductors described in SEMI S22. This dielectric withstand testing should be conducted at the highest expected temperature under single-point failures.

NOTE 19: In the 1103 edition of SEMI S22, this test was described in ¶ 16.2.7.

8 Selection of Safety Features

NOTE 20: Several examples of the selection of safety features are provided in Related Information 2.

8.1 *Classification of HTF and Process Liquids*

8.1.1 The flowchart in Figure 1 should be used to classify each HTF (if one is to be used in the PLHS) and each process liquid as flammable, combustible, or noncombustible.

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8.1.2 If liquids are heated as a mixture, then the properties of the mixture should be used to determine the classification of the liquid.

8.1.2.1 If the properties of the mixture are not known, they should be obtained by testing.

8.1.2.2 As an alternative to testing, the lowest flash point of the flash points of the constituents of the mixture may be used as the flash point of the mixture for the purposes of classification and establishing interlock setpoints. The lowest of the constituents' autoignition temperatures and decompositions temperatures may be used in the same manner.

8.1.3 If the liquids are heated as separate components, then mixed, the properties for each component of the mixture should be used in determining the classification of that component.

8.1.4 If this Safety Guideline is being used to select safety features to be incorporated in a PLHS (rather than to assess whether appropriate safety features are included in a PLHS which has already been designed or constructed), the designer should determine whether adhering to the temperature limits relative to the HTF's or process liquid's flash point, flammable degradation temperature and autoignition temperature is consistent with the intended use of the equipment. If adhering to those limits is consistent with the intended use, then the safety features should be selected so as to adhere to those limits (e.g., a liquid overtemperature interlock set at no more than the liquid's flash point minus 10°C should be provided for a system intended to heat a combustible liquid to no more than its flash point minus 10°C.). If adhering to those limits is not consistent with the intended use, then the safety features should be selected to address the risks of the intended use (e.g., if the PLHS is intended to be used to heat a combustible liquid to or above its flash point minus 10°C, then the safety features should be selected using the criteria for a flammable liquid).

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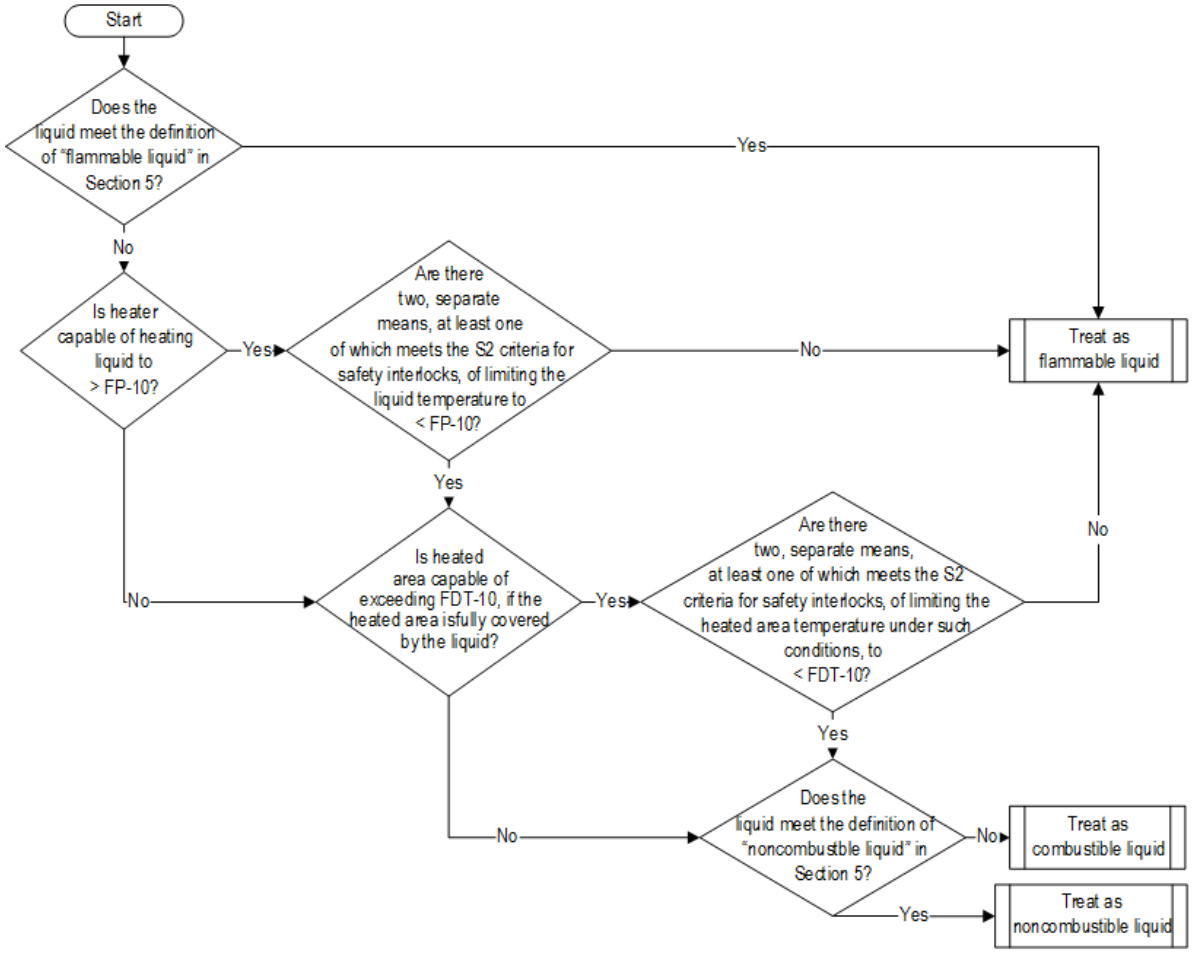

#1 'FP-10' means 10°C less than the liquid's flash point. If the liquid is noncombustible, then the heater is not capable of heating the liquid to FP-10. If the liquid is combustible and the heater is capable of boiling the liquid, then the heater is capable of heating the liquid to FP-10.

#2 'FDT-10' means 10°C less than the temperature at which the liquid yields flammable degradation products. If degradation of the liquid does not produce flammable products, then the heated area is not capable of exceeding FDT-10. If FDT is unknown, but the thermal degradation of the liquid is known to have flammable byproducts, assume heated area can achieve FDT-10.

#3 The phrases 'Is heater capable' and 'Is heated area capable' refer to the power of the heater, operated continuously at the available voltage and current, considered in the context of the liquid's properties and the configuration of the PLHS.

#4 'Liquid' refers to the process liquid or HTF, depending on for which you are trying to determine if it is to be considered 'combustible' or 'flammable.'

Figure 1
Means of Determining Whether a Liquid is to be Treated as Flammable, Combustible, or Noncombustible

8.2 *Selection of Safety Features using the Tables in Appendix 2*

EXCEPTION: Instead of conformance to the provisions of § 8.2, alternative means of achieving a level of Risk no greater than Low (as defined by SEMI S10 and SEMI S14) may be used in accordance with the criteria of § 8.3.

8.2.1 The heating method and the classification (flammable, combustible, or noncombustible) of the liquid should be used with Table 2 to select the appropriate table(s) in Appendix 2.

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Table 2 Selection of Safety Features

Heated Liquid	*Heating Method*	*Liquid*	*Safety Feature Table*
Heat Transfer Fluid	Any	Flammable HTF	Table A2-1
		Combustible HTF	Table A2-2
		Noncombustible HTF	Table A2-3
Process Liquid	Heat Transfer System	Flammable process liquid	Table A2-4
		Combustible process liquid	Table A2-5
		Noncombustible process liquid	Table A2-6
	Thermally- Conductive Heaters – Immersion Heaters or External Heaters	Flammable process liquid	Table A2-7
		Combustible process liquid	Table A2-8
		Noncombustible process liquid	Table A2-9
	Radiant Heaters	Flammable process liquid	Table A2-10
		Combustible process liquid	Table A2-11
		Noncombustible process liquid	Table A2-12

8.2.2 The tables in Appendix 2 list process liquid properties and heating system characteristics that may pertain to a PLHS and the corresponding safety features. The appropriate table(s) in Appendix 2 should be used to select the safety features for each PLHS.

8.2.3 The PLHS should incorporate the safety features identified by the tables in Appendix 2.

8.2.4 If a PLHS uses an HTF, the safety features identified by Tables A2-1, A2-2, and A2-3 should be incorporated in the portion of the PLHS that heats the HTF and the safety features identified by Tables A2-4, A2-5, and A2-6 should be incorporated in the portion of the PLHS that heats the process liquid.

8.3 *Selection of Safety Features Based on Risk*

8.3.1 ¶ 8.3 should be used if the PLHS is not described by one or more of the tables in Appendix 2 or if the equipment supplier chooses to use alternative means of achieving a level of Risk no greater than Low (as defined by SEMI S10 and SEMI S14).

8.3.2 The risks of the PLHS should be assessed in accordance with SEMI S10 and SEMI S14. The hazards and risks considered should include those described in SEMI S2 and this Safety Guideline.

8.3.3 Safety features (e.g., interlocks) and practices should be included in the system to ensure that the residual risk is no greater than Low (as defined by SEMI S10 and SEMI S14).

8.3.4 If the safety features are selected based on risk, rather than on the tables in Appendix 2, then the statement of conformance to SEMI S3 should include the information that the risk method, rather than the tables, was used.

9 Design and Performance of Safety Features

9.1 Safety features should be designed and should perform as described in §§ 9.3 through 9.16.

EXCEPTION: Alternative designs of safety features may be used, in accordance with the criteria of § 9.2 and its subparagraphs.

9.1.1 Not every PLHS needs all of the safety features described in the following sections. The safety features for each PLHS should be selected in accordance with § 8. The design and performance of the safety features should be as described in the following sections.

9.2 If the safety features are not as described in §§ 9.3 through 9.16, the safety features should conform to ¶¶ 9.2.1 through 9.2.4.

9.2.1 The risks of reliance on each safety feature that does not conform to §§ 9.3 through 9.16. should be assessed in accordance with SEMI S10 and SEMI S14. The hazards and risks considered should include those described in SEMI S2 and this Safety Guideline.

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9.2.2 The design and performance of safety features (e.g., interlocks) should ensure that the residual risk is no greater than Low (as defined by SEMI S10 and SEMI S14).

9.2.3 If the safety features are found to be acceptable based on risk, rather than on §§ 9.3 through 9.16, then the statement of conformance to SEMI S3 should include the information that the risk method, rather than §§ 9.3 through 9.16, was used.

9.2.4 The use of risk assessment, rather than conformance to §§ 9.3 through 9.16 to find the design and performance of a safety feature selected in accordance with Appendix 2 to result in a level of Risk no greater than Low (as defined by SEMI S10 and SEMI S14) does not, itself, impose a criterion that the risk of the entire PLHS be assessed. That is, a PLHS may be found to conform to SEMI S3 if the safety features are selected in accordance with Appendix 2 but one or more of the safety features are found acceptable on the basis of resulting in a level of Risk no greater than Low (as defined by SEMI S10 and SEMI S14), rather than on the basis of conformance with §§ 9.3 through 9.16.

9.3 *Characteristics Common to All Safety Interlocks*

9.3.1 Safety interlock systems should comply with the safety interlock systems provisions of SEMI S2.

9.3.2 A reset should be incorporated into safety interlock systems so that when the safety interlock system interrupts the PLHS, an informed and deliberate human intervention is necessary to re-energize the PLHS.

NOTE 21: An interlock is defined in § 5 as 'a mechanical, electrical or other type of device or system, the purpose of which is to prevent or interrupt the operation of specified machine elements under specified conditions.' Although the same devices and circuitry may be used for the 'prevent' and 'interrupt' functions, the inclusion of a requirement for informed and deliberate resetting pertains only to the 'interrupt' function. For example: A low level sensor in a vessel may be the input to an interlock for heater power. That interlock serves both functions:

1. it prevents (as a backup to the control program) the application of heater power during the vessel's programmed empty and refill cycle and
2. it interrupts the heater power if the liquid level in the vessel reaches the low level while heater power is being applied.

The intent of the preceding paragraph is that the system requires an informed and deliberate human intervention to re-energize the heater in the second case, but not the first. This is because the first case (the low level with heater off) is a 'normal' condition, while the second case (the low level with the heater on) is an 'abnormal' condition.

9.3.3 Safety interlock system sensors and their associated circuitry and wiring should be separate from those used for process control. 'Separate from' means that the interlock has no components (e.g., sensors, control circuits, or actuators) in common with the process control.

EXCEPTION: There may be common elements if the safety interlock system is fail-safe.

NOTE 22: This differs from SEMI S2-0703 in that the criterion in this Safety Guideline is 'fail-safe,' not 'fault tolerant.' 'Fault tolerant' is defined as 'designed so that a reasonably-foreseeable single point failure does not result in an unsafe condition.' As 'unsafe condition' is not defined, some have argued that an interlock that merely ceases to function meets this criterion, as long as the interlock itself does not, by failing, introduce some hazard. For example, if two thermocouples are used to measure a temperature of an object and one of the thermocouples becomes separated from the object and now measures a lower temperature, one might argue that the system is 'fault tolerant,' because the detachment of the thermocouple does not raise the temperature of the object. However, a fail-safe system would be, for example, one in which the thermocouple temperatures were compared and, if they were substantially different, a fail-safe (defined as 'designed so that a failure does not result in increased risk') system would remove power from the heaters if it detected a significant discrepancy between the thermocouple temperatures.

9.3.4 *Single-Point Failure* — Safety interlocks should be used to back up process controls in the event of their failure, not be used as *de facto* process controllers. For one example, low-liquid level safety interlocks (§ 9.6) and liquid flow safety interlocks (§ 9.7) should not be used as the primary means of de-energizing heaters when process vessels are drained. Instead the drain sequence should de-energize heaters as part of the drain sequence. (Related Information 1 contains a discussion of example design practices.) The low-liquid level safety interlock (§ 9.6) should be used as protection only if this sequence fails to occur. For another example, process temperature controllers should not be set to temperatures higher than the setpoint temperature for the liquid overtemperature safety interlock. If the process temperature controller were set to a temperature higher than that of the overtemperature interlock, the overtemperature interlock would become the *de facto* controller and the system would be unprotected should the interlock fail.

NOTE 23: For a process controller in which the process temperature is set in software, the limit on the temperature to which the process controller may be set may also be set in software, provided that a higher level of software access is necessary to set the limit than is necessary to set the process temperature.

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9.4 *Liquid Overtemperature Safety Interlock* — The liquid overtemperature safety interlock should prevent process liquids from reaching a point where the properties of the liquid change to create a potentially dangerous situation (e.g., reach boiling, autoignition or flammable degradation temperatures).

9.4.1 Liquid overtemperature protection may be provided either by a separate safety interlock or by using a process temperature controller approved by an accredited testing laboratory for use as both a process temperature controller and for overtemperature protection. If such an approved device is used for both process control and the safety interlock, it should be fail-safe.

NOTE 24: Not all devices approved by accredited testing laboratories are fail safe.

9.4.2 A liquid overtemperature setpoint should be determined based on both the chemicals being heated and the properties of the materials of construction in contact with the liquid. In general, the liquid overtemperature setpoint may be set as high as is consistent with safety considerations.

9.4.2.1 For liquids, the maximum overtemperature setpoint should be selected by using Table 3. The liquid overtemperature setpoint for combustible liquids may be set higher than the liquid's flash point minus 10°C, however, the liquid should then be considered a flammable.

Table 3 Selection of Maximum Overtemperature Interlock Setpoint

Liquid Treated As	*Maximum Overtemperature Setpoint*
Noncombustible	Boiling Point
Flammable	Lesser of (Autoignition Temperature − 50°C) or Boiling Point
Combustible	Flash point − 10°C

EXCEPTION: Small margins (i.e., temperatures within 50°C of the autoignition temperature or within 10°C of the flash point) may be used if the interlock performance is found, through testing or analysis, to preclude reaching the autoignition or flash point. If a smaller margin is used, the rationale for its acceptance should be documented in the SEMI S3 conformance assessment report.

NOTE 25: The limitations in this table preclude the use of PLHS that heat liquids in closed vessels at pressures above atmospheric pressure and to temperatures above the liquid's boiling point, but without boiling the liquid. Such PLHS may, however, be found to be in conformance with this document based on the assessment of the risk of the pressure and temperature control features.

9.4.2.2 A risk assessment should be conducted to determine that all components are at or below their maximum service temperature for the liquid overtemperature setpoint chosen. The risk assessment should include all liquid containment, piping, and support structures associated with the PLHS.

9.4.3 The liquid overtemperature sensor should be located so that it will accurately reflect the highest temperature of the liquid.

NOTE 26: See Appendix 1 for examples of placement of liquid overtemperature safety interlock sensors for various PLHS.

9.5 *Heater Overtemperature Safety Interlock* — A sensor should be located and set at a temperature that prevents degradation of the structural integrity of the heater or its surrounding materials.

9.5.1 If there is a low liquid level safety interlock, the heater overtemperature safety interlock should prevent degradation at any liquid level above the level at which the low liquid level safety interlock removes power from the heater.

9.5.2 If there is no low liquid level safety interlock, the heater overtemperature safety interlock should prevent degradation at any liquid level, including the absence of liquid.

9.5.3 Overtemperature conditions may occur at different locations, and multiple sensors may be required to monitor those locations.

NOTE 27: Refer to Appendix 1 for places where heater overtemperature safety interlock sensors may be located for various PLHS.

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9.5.4 A single safety interlock may be used as both the heater overtemperature and heated area overtemperature safety interlocks, as long as the setpoint is no more than the lower of the setpoint temperatures determined to be appropriate for the individual interlocks.

9.6 *Low-Liquid-Level Safety Interlock* — This interlock should protect from failure due to loss of the heat absorption capacity of the liquid.

9.6.1 The low-liquid level safety interlock should be located such that it allows a sufficient volume of process liquid to remain present to absorb residual heat energy to assure that a hazardous temperature is not reached by either the process liquid or the PLHS when the process liquid is at the setpoint temperature of the liquid overtemperature safety interlock.

NOTE 28: Refer to Appendix 1 for places where low-liquid level safety interlock sensors may be located for various PLHS.

9.6.2 The selection of a suitable sensor should take into account the physical properties of the liquids being heated, the environmental conditions to which the sensor will be subjected, and the failure mode(s) of the sensor.

9.6.3 Where a liquid overtemperature safety interlock is used, the sensor for the *low-liquid level* safety interlock should be located so that the sensor for the *liquid overtemperature* safety interlock is immersed in liquid below the level where the low-liquid level safety interlock allows energization of the PLHS.

9.7 *Liquid Flow Safety Interlock* — In a flow dependent system, a sensor to monitor for liquid flow should be provided that allows the PLHS to be energized only when a safe rate of flow is present.

NOTE 29: Flow switches are not the only means of monitoring adequacy of flow.

NOTE 30: Providing a common source of power for both the liquid pump and the PLHS may not be sufficient to assure liquid flow, because pump failure might not be detected by such a design.

NOTE 31: Refer to Appendix 1 for places where liquid flow safety interlock sensors may be located for various PLHS.

9.7.1 The configuration of the vessel containing the flow dependent heater should be such that a hazardous temperature is not reached by either the process liquid or the liquid chemical heating system when the process liquid flow is interrupted and the heater is at the setpoint temperature of the liquid overtemperature safety interlock. This criterion may be met by ensuring a sufficient volume of process liquid remains present upon interruption of flow to absorb residual heat energy to assure that hazardous temperatures are not reached.

9.8 *Overpressure Protection*

9.8.1 A means, such as adequate venting capability, should be sufficient to prevent rupturing of the vessel due to excessive pressure or vapor generation.

NOTE 32: An equation that can be used to estimate needed vent capacity is given in Related Information 1.

9.9 *Inerting* — Inerting of the vapor space of a vessel is effective as a risk control measure when the vessel is substantially sealed and there is no introduction of air or other oxidizer that can cause the vapor concentrations to pass through the flammable range. Inerting is also effective as a risk control measure for the space between the heating filament and the sheath in radiant heaters.

9.9.1 Where an inert atmosphere is used, it should be confirmed, by measurement of the oxygen concentration in a representative sample of the design, that the inerting system is effective in reducing oxygen to a level where combustion will not be supported unless air or oxygen is introduced.

NOTE 33: Extreme caution should be taken following inerting of a vessel as opening the enclosure may cause the mixture to pass through the flammable range if fresh air is admitted.

9.9.2 *Inerting Safety Interlock*

9.9.2.1 When inerting is used, an appropriate safety interlock should be provided to monitor the inert gas flow and prevent the heater from operating unless there is adequate performance of the inerting system.

9.9.2.2 Energization of the PLHS should be prevented until a sufficient volume of inerting gas has been introduced to reduce the oxidizer concentration to an acceptable level.

NOTE 34: Information on the minimum concentration of oxygen to support combustion of various fuels can be found in published literature and standards, such as NFPA 53, Recommended Practice on Materials, Equipment, and Systems Used in Oxygen-Enriched Atmospheres.

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9.9.2.2.1 It is acceptable to ensure that a sufficient delay is provided between detection of inert gas flow and energization of the heater to assure that the oxidizer concentration has been reduced to an acceptable level. Direct measurement of oxidizer concentration is not required.

NOTE 35: This time delay may be determined from measurement of oxygen concentration in a representative sample of the design, or by engineering calculations.

9.9.2.3 If flow is required to maintain an inert atmosphere, energy to the heaters should be interrupted if an insufficient flow is detected.

NOTE 36: A flow monitor on the inert gas inlet is not sufficient to ensure adequate performance of the inerting system. Outlet flow, or inlet flow combined with pressure monitoring within the inerted vessel, is the preferred means of detecting adequate flow.

9.9.3 Nitrogen or other inert gases, when used as carriers for flammable vapors (e.g., in alcohol vapor driers), may be considered in determining whether of the PLHS conforms to § 9.9.

9.9.4 Purging with an inert gas, designed and tested in accordance with an appropriate standard (e.g., NFPA 496 or EN 1127-1) may be presumed to conform to the criteria of § 9.9, as it reduces the fuel concentration.

NOTE 37: Inerting the radiant heaters can be such a suitable means of preventing ignition at the heater element surface, because the exclusion of oxidizers from the heater elements prevents the elements being in contact with a mixture of flammable vapor and an oxidizer. However, purging the radiant heaters with air does not provide this protection, as a mixture of flammable vapor and air is, in some range of concentrations, ignitable. A description of purging is provided below.

9.10 *Purging* — Purging of the vapor space of a vessel may be effective as a risk control measure.

NOTE 38: Both the loss of the process liquids into the exhausted air and the need to treat the air containing them properly should be considered when considering this method.

9.10.1 Where purging is used, it should be confirmed, by measurement of the flammable vapor concentration in a representative sample of the design, that the purging system is effective in reducing the concentration of the flammable vapor to no more than 25% of the LFL within the vessel when the liquid is at the maximum single-fault temperature.

9.10.2 *Purging Safety Interlock* — When purging is used, an appropriate safety interlock should be provided to ensure that a sufficient flow is present to remove flammable vapors to below 25% of LFL. Energy to the heaters should be interrupted if an insufficient flow is detected.

9.10.3 Purging designed and tested in accordance with an appropriate standard (e.g., NFPA 496 or EN 1127-1) may be presumed to conform to the criteria of § 9.10.

NOTE 39: Purging is a means of protection applicable to headspaces over liquids. It is not, however, applicable to protecting a heater that could be flooded if a barrier failed. Inerting is applicable both to heaters and headspaces.

NOTE 40: A flow monitor on the purge inlet port(s) is not sufficient to assure adequate performance of the purge system. Monitoring of outlet port flow is the preferred means of detecting if adequate flow is present. If no defined outlet is available, then inlet flow and pressure monitoring within the purged vessel or enclosure is acceptable.

9.11 *High Temperature Metal Construction*

9.11.1 Vessels used to contain flammable liquids should be constructed of metals that have sufficient strength at 1100°C (2012°F) to contain the liquids, unless such materials are not suitable due to process compatibility concerns. The reasonably foreseeable weight and pressure of the liquid should not result in stresses greater than the room temperature ultimate tensile strength divided by 3.5.

NOTE 41: The factor of 3.5 was obtained from the ASME Boiler and Pressure Vessel Code.

NOTE 42: Various codes, regulations and standards specify either the types of metal (e.g., ferrous metal) or the melting points of metals used to contain flammable liquids. Conformance with the criterion in this document does not necessarily comprise compliance with the relevant codes, regulations and standards applicable to the location in which the PLHS is to be used.

EXCEPTION: Alternate materials, such as plastics, may be used only if it can be confirmed, by means of a risk assessment, that the method of containment and the materials used provide a level of Risk no greater than Low (as defined by SEMI S10 and SEMI S14) in the following situations:

- During normal process temperature ranges controlled by the process temperature control.
- During abnormal temperature conditions up to the value limited by the overtemperature safety interlock.

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- During a fire involving the chemicals contained within the vessel or liquid chemical heating system (e.g., within a process vessel).
- During a fire elsewhere within the equipment (e.g., within the wet bench subsurface area).

NOTE 43: The intent is that the Exception criteria and discussion of plastic materials in § 7 encourage the designer to consider issues such as the suitability of the plastics for normal and abnormal process temperatures and the associated mechanical, thermal and chemical stresses that would be experienced.

NOTE 44: It may be possible to address the fire risk and process compatibility concerns by using:

- a vessel of a suitable (to manage the fire risk) metal lined with a process-compatible plastic,
- a process-compatible plastic vessel inside a suitable metal vessel, or
- a process-compatible plastic vessel with secondary containment constructed of a suitable metal.

9.12 *Protection of Personnel from Electrical Shock* — Personnel should be protected from electric shock by at least one of the following means:

9.12.1 Ground fault circuit interrupter (GFCI) certified by an ATL as complying with an appropriate standard for the protection of personnel.

9.12.2 Inclusion of a grounded conductive barrier between the heating element and the HTF or process liquid.

9.13 *Shielding from Radiant Heating*

9.13.1 A shield, opaque to the radiant energy, should be provided to protect those components and surrounding materials the temperatures of which can be raised by radiant heating to above their maximum service temperatures.

9.13.2 A shield, opaque to the radiant energy, should be provided to protect overtemperature sensors (other than those intended to sense the temperature of the radiant heating element) from radiant heating.

9.14 *Heated Area Overtemperature Safety Interlock* — A sensor should be located and set at a temperature that prevents the heated area's reaching the FDT-10 if the heated area is submerged in the liquid.

9.14.1 Overtemperature conditions may occur at different locations, and multiple sensors may be required to monitor those locations.

9.14.2 A single safety interlock may be used as both the heater overtemperature and heated area overtemperature safety interlocks, as long as the setpoint is no more than the lower of the setpoint temperatures determined to be appropriate for the individual interlocks.

9.15 *Certification for Use in Hazardous Locations* — Electrical PLHS components and equipment for use in locations that have been classified as hazardous (i.e., from an 'explosive' or flammable standpoint) should be specifically certified or otherwise evaluated to the applicable standards for that use.

NOTE 45: UL 823, UL 1604 and the IEC 60079 series are among the documents that provide methods for making this evaluation.

NOTE 46: NFPA 497 and EN 1127-1 are among the documents that provide methods for determining hazardous locations.

9.16 *Heat Exchanger Overtemperature Safety Interlock* — A sensor should be located 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 process liquid.

NOTE 47: Refer to Appendix 1 for places where heater overtemperature safety interlock sensors may be located for various PLHS.

9.16.1 Overtemperature conditions may occur at different locations, and multiple sensors may be required to monitor those locations.

9.16.2 This interlock should perform its intended function at the maximum temperature to which the HTF may be heated, considering the power of the heater and any interlocks incorporated in the heated liquid heat exchange system.

10 Documentation

10.1 Documentation supplied with the system should describe the tests that should be performed periodically on the process temperature controllers and safety interlocks of PLHS. These tests should not be destructive in nature. Tested devices should include temperature controls and their sensors, liquid overtemperature interlocks, heater

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overtemperature interlocks, level controls, low-liquid level safety interlocks, liquid flow safety interlocks, flow and pressure sensors for purging or inerting gasses and flammable vapor detectors.

EXCEPTION: Process temperature controllers, or parts of process temperature controllers, that either do not provide safety functions or are automatically monitored are excluded from the above periodic testing provision.

10.2 Documentation should include the test procedures to be used and the intervals for testing.

NOTE 48: Refer to SEMI S2 and SEMI S13 for other information that should be included in documentation.

11 Related Documents

11.1 *ASME Document*[5]

Boiler and Pressure Vessel Code

11.2 *ASTM Standards*[6]

ASTM C1147 — Practice for Determining the Short Term Tensile Weld Strength of Chemical-Resistant Thermoplastics

ASTM D150 — Dielectric Constant, Dissipation Factor

ASTM D621 — Deformation under Load

ASTM D638 — Tensile Strength and Ultimate Elongation

ASTM D648 — Heat Deflection Temperature/Heat Deflection Temperature Under Load

ASTM D790 — Flex Modulus

ASTM D792 — Specific Gravity

ASTM D1238 — Melt Flow Rate

ASTM D2240 — Hardness

ASTM D2990 — Creep Resistance

ASTM D4591 — Melting Point

11.3 *DVS Guideline*[7]

DVS 2205-1 — Design Calculations for Containers and Apparatus Made of Thermoplastics – Characteristic Values

11.4 *IEC Standard*[8]

IEC 60079-0 — Electrical Apparatus for Explosive Gas Atmospheres

11.5 *NFPA Documents*[2]

NFPA 1 — Uniform Fire Code

NFPA 53 — Recommended Practice on Materials, Equipment, and Systems Used in Oxygen-Enriched Atmospheres

NFPA 70 — National Electrical Code

NFPA 77 — Recommended Practice on Static Electricity

NFPA 318 — Standard for the Protection of Semiconductor Fabrication Facilities

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[5] American Society of Mechanical Engineers, Three Park Avenue, New York, NY 10016-5990, USA; Telephone: +1.973.882.1170, Fax: +1.973.882.1717, https://www.asme.org

[6] American Society for Testing and Materials, 100 Barr Harbor Drive, West Conshohocken, PA 19428-2959, USA; Telephone: +1.610.832.9585, Fax: +1.610.832.9555, http://www.astm.org

[7] DVS-Verlag GmbH, Aachener Str. 172, D-40223 Duesseldorf, Germany. Telephone: +49.211.1591.161; Fax: +49.211.1591.150; http://www.dvs-verlag.de

[8] International Electrotechnical Commission, 3 rue de Varembé, Case Postale 131, CH-1211 Geneva 20, Switzerland; Telephone: +41.22.919.02.11, Fax: +41.22.919.03.00, http://www.iec.ch

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11.6 *UL Standards*[4]

UL 746B — Maximum Continuous In-Use Temperature

UL 843 — Standard for Electric Heaters for Use in Hazardous Locations

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