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Entertainment Technology – Design and Execution of Theatrical Fog Effects

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Table of Contents

NOTICE and DISCLAIMER ii
Contact Information v
Acknowledgments vi
1 General 1
1.1 Scope 1
1.2 Purpose 1
1.3 Definitions 2
1.4 Other standards, regulations, and references 2
2 Personnel 3
2.1 Effect Designer 3
2.2 Effect Operator 3
3 Design and planning of the fog effect and equipment use 3
3.1 Selection of appropriate technology 3
3.1.1 Visual effect desired 3
3.1.2* Resources to use the technology safely and effectively 4
3.1.3 Restrictions in choices by local regulations or house rules 4
3.2 Storage of materials 4
3.2.1* Temperature 4
3.2.2* Avoidance of contamination 4
3.2.3* Ventilation 4
3.2.4 Access and egress 4
3.3 Siting of equipment 4
3.3.1* Access and egress 4
3.3.2* Protection from environmental hazards 4
3.3.3* Protection from unintended contact 4
3.3.4* Protection from heat and cold 5
3.4 Equipment 5
3.4.1* General 5
3.4.2 Commercially manufactured standard equipment 5
3.4.3 Custom equipment 5
3.5 Distribution of aerosol 5
3.5.1 General rules 5
3.5.2 Control of fluid residue build-up 6
3.5.3 Control of inhalation exposure to liquids and toxic gases 6
3.5.4* Oxygen enriched or deficient atmospheres 7
3.6 Maintenance 7
3.7* Fire detection systems 7
4 Operation of the effect 7
4.1 Cue operation 7
4.1.1 Cues shall be documented 7
4.1.2 Cues shall not be modified without approval 8
4.2 Monitoring distribution of the aerosol 8
4.2.1 Visual effect evaluation 8
4.2.2 Fluid residue build-up 8
4.3 Equipment maintenance 8
5 Documentation of effect 8
6 Approvals 9
Annex A 10

1 General

1.1 Scope

This Standard is intended to be applicable to the creation of theatrical effects using artificial fogs or mists in theatres, arenas, and other places of entertainment or public assembly.

The fogs and mists covered by this Standard are aerosols created using one or more of the following liquids:

Name	Chemical Abstracts Service (CAS) #
triethylene glycol	112-27-6
monopropylene glycol (propylene glycol; 1,2-propanediol)	57-55-6
diethylene glycol	111-46-6
dipropylene glycol	25265-71-8, 106-62-7, 110-98-5, 108-61-2
1,2-butylene glycol (1,2-butanediol)	584-03-2
1,3-butylene glycol (1,3-butanediol)	107-88-0
glycerin (glycerol; 1,2,3- propanetriol)	56-81-5
white mineral oil, medicinal or food grade	8042-47-5
water	07732-18-5
nitrogen, liquefied (LN2, L-N2))	7727-37-9
oxygen, liquefied (LOX)	80937-33-3
carbon dioxide, liquefied (LCO2, L-CO2)	124-38-9

The aerosols within the scope of this Standard are injected directly into the environment or are carried out of the fog generating equipment on a stream of ambient air, or a stream of nitrogen, argon, carbon dioxide, or a mixture of nitrogen and oxygen that approximates the composition of normal air. The Chemical Abstracts Service registry numbers for the gases that may be used as vehicles for the aerosols within the scope of this Standard are as follows:

Name	CAS #
oxygen	7782-44-7
nitrogen	7727-37-9
argon	7440-37-1
carbon dioxide	124-38-9

This Standard is not intended to be used for guidance in planning or executing any fog effect that uses a liquid or gas not listed above.

1.2 Purpose

The purpose of this Standard is to offer atmospheric effects creators and operators guidance in the planning and execution of theatrical fog effects so that the health and comfort of workers and spectators shall not be compromised by excessive exposure to chemicals and particulates that are the result of the use of such theatrical fog effects. The Standard is also intended to provide guidance related to the obscuration of hazards or paths of egress in the theatre, arena, place of entertainment or public assembly in which the fog effect is produced. In addition, the Standard is intended to help avoid

accidental triggering of fire detection and notification systems, while preserving the required functioning of the systems.

To help in offering guidance, Annex A contains explanatory text for some of the clauses in this Standard. Clauses for which explanatory text is available are marked with an asterisk. The relevant clause in Annex A has the same clause number as the text to which it refers, but the clause number is preceded by the letter A to show that it is part of the annex.

Annex A is informative only, and contains no mandatory requirements. If there is any apparent conflict between the requirements of this Standard and the advice offered in Annex A, the requirements of this Standard shall prevail.

1.3 Definitions

The meanings of all the words used in this Standard, other than those specifically defined below, can be found in a standard American English dictionary, such as *Merriam-Webster's Collegiate Dictionary*.

1.3.1 Authority Having Jurisdiction: An organization or individual responsible for enforcing the requirements of a code or standard, or for approving equipment, materials, installations, or procedures.

1.3.2 competent person: One who is trained and skilled in the setup, operation and use of theatrical fog effects and is capable of identifying existing or predictable hazards in the surroundings or working conditions that are unsanitary, hazardous, or dangerous to employees or other persons, and who has authorization to take prompt corrective action to eliminate these hazardous conditions.

1.3.3 fog: A mixture of liquid droplets in air that reduces visibility and reflects light.

1.3.4 haze: An accumulation in the atmosphere of very fine, widely dispersed, solid or liquid particles giving the air an opalescent appearance.

1.3.5 qualified person: A person who, by possession of a recognized degree, certificate or professional standing, or who by extensive knowledge, training and experience, has successfully demonstrated his or her ability to solve or resolve problems relating to theatrical fog effects.

1.4 Other standards, regulations, and references

The following standards, regulations, and references also shall be consulted when planning a fog effect. If no year is specified, the most recent edition shall be used.

29 CFR 1910.146, *Permit-required confined spaces*

29 CFR 1910.1000, *Air contaminants*

ANSI E1.5, *Entertainment Technology — Theatrical Fog Made With Aqueous Solutions Of Di- And Trihydric Alcohols* (current edition)

ANSI E1.14, *Entertainment Technology — Recommendations for Inclusions in Fog Equipment Manuals* (current edition)

NFPA 55, *Standard for the Storage, Use and Handling of Compressed and Liquefied Gases in Portable Cylinders* (current edition)

NFPA 72, *National Fire Alarm Code* (current edition)

NFPA 101, *Life Safety Code* (current edition)

International Fire Code, 2003 edition, Chapters 30 (except section 3006) and Chapter 32

2 Personnel

2.1 Effect Designer

2.1.1 The fog effect covered by this Standard shall have a person who is designated as the Effect Designer and who is responsible for selecting the appropriate fog technology and equipment and for designing its installation and use to meet the theatrical production or event's fog requirements. The Effect Designer shall be responsible for creating the documentation of the fog effect, as described in Clause 5.

2.1.2 The Effect Designer shall be qualified in evaluating the health and safety effects of the selected fog technology, and shall specify the location and operational aspects of the fog equipment used to insure the safety of workers and the public.

2.1.3 The Effect Designer shall be responsible for the satisfaction of the requirements of this Standard.

2.1.4 The Effect Designer shall be of such age as to be legally responsible.

2.1.5 The Effect Designer shall be permitted to delegate tasks to assistants under his or her direction, but shall maintain responsibility for their proper execution. The assistants shall be competent.

2.2 Effect Operator

2.2.1 There shall be a person (or persons) designated as the Effect Operator (or Effect Operators). The Effect Designer shall be permitted to be the Effect Operator.

2.2.2 The Effect Operator shall be responsible for the operation and maintenance of the effect system as designed by the Effect Designer.

2.2.3 The Effect Operator shall be trained and experienced in the use of theatrical fog effects and shall be a competent person.

2.2.4 The Effect Operator may have assistants under his or her direction. The assistants shall be competent.

3 Design and planning of the fog effect and equipment use

3.1 Selection of appropriate technology

The Effect Designer shall specify the appropriate fog effect equipment, and shall specify its installation and operation to achieve the following:

3.1.1 Visual effect desired

The fog effect materials and devices chosen shall be appropriate to achieve the effect desired by the Director of the event.

3.1.2* Resources to use the technology safely and effectively

The fog effect materials and devices chosen shall be appropriate to the number of persons available to operate it, the skills of these persons, and the environment in which the fog materials and devices are stored and used. Fog-making technologies that are beyond the competency of the operators to use and maintain safely shall not be selected and shall not be used.

3.1.3 Restrictions in choices by local regulations or house rules

Fog effect materials and devices that are prohibited by local governmental regulations or the proprietary rules of the entertainment venue shall not be used.

3.2 Storage of materials

Fog-making materials shall be stored in accordance with the following clauses 3.2.1 through 3.2.4.

3.2.1* Temperature

The storage temperature shall be controlled so that there is no degradation of the fog-making materials that results in unhealthful fog aerosols. The fluid manufacturer's documentation or scientific literature on the fluid components shall be consulted to determine the acceptable range of storage temperatures.

3.2.2* Avoidance of contamination

Fog-making materials shall be stored so that there is no contamination of the materials.

3.2.3* Ventilation

Fog-making materials shall be stored where there is adequate ventilation. Personnel shall be able to enter the storage area and not be endangered by excessive exposure to fog-making materials, toxic gases, oxygen deficient atmospheres, or oxygen enriched atmospheres.

3.2.4 Access and egress

Fog-making materials shall be stored where the fog effect personnel can safely access the material. The materials shall not be stored in places that would block emergency egress from the work site or place of public assembly.

3.3 Siting of equipment

The fog-making devices and devices for controlling the distribution of fog shall be sited in accordance with the following clauses 3.3.1 through 3.3.4.

3.3.1* Access and egress

Fog-making devices and devices for controlling the distribution of fog materials shall be sited where the fog effect personnel can safely access the equipment to operate or service it. The equipment shall not be sited in places that would block emergency egress from the work site or place of public assembly.

3.3.2* Protection from environmental hazards

Fog-making devices and devices for controlling the distribution of fog materials shall be protected from environmental hazards that might cause the equipment to malfunction and endanger workers or the public.

3.3.3* Protection from unintended contact

Fog-making devices and devices for controlling the distribution of fog materials shall be guarded from unintended contact that might damage the equipment or endanger the person making the contact.

3.3.4* Protection from heat and cold

Fog-making devices and devices for controlling the distribution of fog materials shall be located so that the heat generated or absorbed by the fog equipment does not damage or adversely affect people or equipment in the vicinity of the equipment. The equipment shall be located so that heat or cold from the surrounding environment or equipment does not adversely affect the fog equipment.

3.4 Equipment

3.4.1* General

The equipment shall meet the regulatory safety requirements for appliances of its type in the nation where the fog effect shall be executed.

3.4.2 Commercially manufactured standard equipment

Commercially manufactured standard equipment shall be used according to the following clauses 3.4.2.1 through 3.4.2.3. Any commercially manufactured standard equipment not used according to these clauses shall be considered custom equipment, and the party making the modification to the equipment or to the operating procedure shall be considered the manufacturer of the custom equipment.

3.4.2.1 The equipment shall be used according to the manufacturer's instructions.

3.4.2.2 Only fluids and gases specified by the equipment manufacturer shall be used in the equipment.

3.4.2.3 The equipment shall not be modified, unless the modification is approved by the manufacturer.

3.4.3 Custom equipment

Custom-made equipment shall be permitted to be used if the stipulations of clauses 3.4.3.1 through 3.4.3.3 are met.

3.4.3.1 The manufacturer of the custom-made equipment gives written assurance of the safety of the equipment and its suitability for making theatrical fog.

3.4.3.2 The manufacturer of the custom-made equipment provides written instructions per ANSI E1.14 on how to use the equipment.

3.4.3.3 The equipment is used according to the manufacturer's instructions.

3.5 Distribution of aerosol

3.5.1 General rules

3.5.1.1 Aerosols shall not be distributed in such a way as to hide hazards, egress paths, or warning signs. Procedures shall be adopted and implemented to allow prompt remedial action to be taken if excessive obscuration occurs.

3.5.1.2 Aerosols should be distributed only where needed. Measures shall be taken to minimize the movement of aerosols into areas where they are not needed.

3.5.1.3 Testing shall be done before the event using the fog effect to ensure that critical visibility is not lost and that the aerosol does not drift into unintended areas or that the levels in these areas is acceptable. This testing shall be done with conditions that approximate as closely as possible the

conditions of the actual event. Those conditions of concern would include the lighting; heating, cooling, and ventilation air flow; and placement of scenery or personnel that would affect fog distribution. With haze effects, monitoring of the obscuration caused by the effect shall be permitted to be done during the event in lieu of pre-event testing.

3.5.2 Control of fluid residue build-up

3.5.2.1* Slip hazards
Measures shall be adopted to monitor and control residue build-up from aerosol settling on walking surfaces.

3.5.2.2 Blockage of distribution equipment
Measures shall be adopted to monitor and control fluid build-up that blocks or otherwise negatively affects the operation of fog distribution equipment.

3.5.2.3* Contamination of other equipment
Measures shall be adopted to monitor and control fluid build-up that may negatively affect other types of equipment located in the vicinity of fog effects.

3.5.3 Control of inhalation exposure to liquids and toxic gases

3.5.3.1* The permissible amount of human exposure to the fog materials (both liquid and gas) shall be determined. ANSI E1.5 (current edition) and 29 CFR 1910.1000 shall be consulted by users of this Standard in the United States of America and its territories for citations relevant to the materials being used. Users outside United States jurisdiction may consult these references but shall consult the relevant exposure standards published by the governmental occupational health and safety authority in their jurisdiction. Consulting non-governmental and non-standards guidance documents shall be permitted and the exposure guidelines given in them used, as long as the exposure levels are lower than those stated in any relevant governmental or nationally recognized standards document.

3.5.3.2 Measures shall be adopted to monitor and control the exposure of workers and the public to the fog materials. The monitoring method chosen shall be appropriate to the exposure limit of concern. The following monitoring methods shall be permitted to be adopted:

3.5.3.2.1 Monitoring by means of calculating time-weighted average exposure levels from the quantity of fluid used over an interval of time and the volume of the venue shall be permitted to be adopted as an exposure control means in cases of haze effects in which the effect is evenly distributed and no person is ever present in the visible plume from the fog effect machine.

3.5.3.2.2* Monitoring peak exposures by means of time/distance aerosol concentration tables developed by a Certified Industrial Hygienist or other qualified professional for the particular fluid and machine combination being used in the fog effect shall be permitted to be adopted as an exposure control means.

3.5.3.2.3* Monitoring peak and time-weighted average exposure levels by the use of meters shall be permitted to be adopted as an exposure control means.

3.5.3.2.4 Monitoring time-weighted average exposure levels by the use of calibrated sampling pumps and sampling tubes, with the sampling tubes being sent to an accredited laboratory for analysis, shall be permitted to be adopted as an exposure control means.

3.5.4* Oxygen enriched or deficient atmospheres

When fog effects are used that may cause an oxygen enriched or oxygen deficient atmosphere to develop in the venue, measures shall be adopted to monitor the amount of oxygen in the atmosphere of the venue and to take corrective measures immediately, if needed. The use of calibrated meters that give real-time readings shall be a permissible method of monitoring.

3.6 Maintenance

Plans for maintaining the fog effect equipment shall be included as part of the effect design. Documentation provided by the equipment manufacturer shall be consulted for guidance in developing a suitable maintenance plan.

3.7* Fire detection systems

The Effect Designer shall determine if the entertainment venue's fire alarm system includes a fire detection means that may be inappropriately triggered by the fog effect.

3.7.1* In the case of a temporarily installed fog effect, the fire detection systems shall not be permitted to be interrupted during the operation of the fog effect, with the following exception: Portions of fire detection systems shall be permitted to be interrupted during the operation of a temporarily installed fog effect when all the following conditions are met:

(a) Approval of the Authority Having Jurisdiction is received.

(b) Approval of the venue owner or owner’s agent is received.

(c) An approved fire watch capable of directing the operation of all fire detection and life safety systems installed in the building is present.

The individual responsible for the life safety systems of the building shall return the systems to normal operating conditions as soon as the likelihood of false alarms from the fog effect has passed.

3.7.2* If no adjustment of the fire detection system can be made per the exceptions in clause 3.7.1, the fog effect shall be designed to operate with amounts of fog below the amount that will trigger the fire detection system.

3.7.3 In the case of a permanently installed fog effect, the fire detection systems shall be designed to work without issuing false alarms and initiating unneeded fire protection measures.

4 Operation of the effect

4.1 Cue operation

The specifics of cue operation, including timing and duration, shall be set by the Effect Designer. The cue shall be operated by the Effect Operator.

4.1.1 Cues shall be documented

All cues will be documented as required in Clause 5 in regards to cue timing, output volumes, and duration.

4.1.2 Cues shall not be modified without approval

Cue timing, output volumes, and duration shall not be modified without the approval of the Effect Designer, unless the Effect Operator considers the changes necessary for health and safety reasons or is instructed to do so for health and safety reasons by an Authority Having Jurisdiction. Any repeated modification of an effect shall be reported by the Effect Operator to the Effect Designer.

4.2 Monitoring distribution of the aerosol

4.2.1 Visual effect evaluation

The visual effect produced by the fog effect shall be evaluated by the Effect Operator to ensure that it conforms to the designed effect. Persistent variations in the effect from the initially designed effect shall be reported to the Effect Designer. The Effect Operator shall determine what conditions have changed to cause the change in the effect.

4.2.2 Fluid residue build-up

4.2.2.1* Slip hazards

Walking surfaces where residue from the fog fluids may collect shall be monitored. Any slip hazards noted shall be cleaned up immediately by the Effect Operator or his assistants.

4.2.2.2 Blockage of distribution equipment

The Effect Operator shall inspect the distribution at intervals frequent enough to detect the accumulation of fluid in quantities that blocks or impairs the operation of the distribution equipment. Blockages shall be removed as soon as practical.

4.2.3 Inhalation exposure

Inhalation exposure shall be monitored and controlled by the Effect Operator or his assistants per the method or methods determined by the Effect Designer in accordance with clause 3.5.3 of this Standard and its subclauses.

4.2.4 Oxygen enrichment or deficiency

When fog effects are used that might cause abnormal levels of oxygen in the air, the oxygen content of the air shall be monitored and controlled by the Effect Operator or his assistants per the method or methods determined by the Effect Designer in accordance with clause 3.5.4 of this Standard.

4.3 Equipment maintenance

The equipment shall be maintained by the Effect Operator or his assistants according to the maintenance plan developed per clause 3.6.

5 Documentation of effect

The fog effects shall be documented by the Effect Designer in a written plan that shall be used as a reference by the Effect Operator or his assistants for the execution of the effect and that shall be kept current and made available on request to the Authority Having Jurisdiction.

The plan for the fog effect shall be in writing and shall provide the following:

5.1 Name of the person, group, or organization sponsoring the production.

5.2 Date and time of day of the production.

5.3 Exact location of the production.

5.4 Name of the Effect Operator or Operators and Assistants

5.5 Names of all assistants who are to be present.

5.6 Qualifications of the Effect Designer.

5.7 Number and types of fog effect devices and materials to be used, the Operator's experience with those devices and effects, and a definition of the general responsibilities of Assistants.

5.8 A diagram of the grounds or facilities where the production using the fog effect or effects is to be held. This diagram shall show the point at which the fog effect devices are to be situated and the paths of egress that might be affected by the fog effect.

5.9 Manner and place of storage of the fog effect materials and devices.

5.10 Material safety data sheet (MSDS) for the fog effect materials to be used.

5.11 A narrative description of the risks identified by section 3 and the remedies used to abate them.

5.12 A narrative description of operating procedures as determined by section 4.

5.13 A statement of who is responsible for the effect and contact information for this person.

5.14 Name and signature of the Effect Designer.

6 Approvals

Any approvals required by the Authority Having Jurisdiction shall be obtained in advance of the execution of the effect.

Annex A
(Informational only. Contains no requirements.)

This annex is informational only, and is not part of the requirements of this Standard. If there is any apparent disagreement between the information in this annex and the requirements stated in this Standard, the requirements of this Standard shall prevail.

A.3.1.2 Generally, it is better to use a simple technology that can be used consistently in a controlled manner than it is to use a complex technology that, while it may offer a better effect or use materials of lower toxicity, the technology may not be used consistently because its proper use is beyond the abilities of the technicians or the equipment available.

A.3.2.1 Some fog-making materials, such as glycols, change with heat and time. It is generally wise to store all fog fluids out of sunlight and at temperatures that most people would find comfortable. The notable exceptions to the temperature rule are cryogenics, such as liquid nitrogen, liquid carbon dioxide, and dry ice. In any case, the documentation supplied by the manufacturer for any proprietary fog fluid should be consulted, as should the scientific literature or information from your supplier for any bulk chemical.

A.3.2.2 Fluids commonly become contaminated by
a) being left in open containers so that dirt falls into the fluid.
b) being stored or transported in unlabeled containers so that other materials are poured into the container and mixed by accident. Please note that storing hazardous materials in an unlabeled container is a violation of the OSHA hazard communication regulation 29 CFR 1910.1200.
c) being stored or transferred in containers that contain remnants of previous contents.
d) being poured into fog equipment that contains remnants of previously used fluids.
e) being stored in partially filled containers for extended lengths of time so the fluid is subject to oxidation by contact with the air.

Fluid contamination almost always results in fluids of unknown content. It is impossible to predict the effect on the machine or the fog of using an unknown fluid. Using unknown fluids must be avoided.

A.3.2.3 Dry ice, liquid carbon dioxide in dewars, liquid nitrogen, and liquid synthetic air should not be stored in confined areas, particularly confined areas with poor ventilation. The solid dry ice will slowly turn to gas and add CO_2 to the air around it. Dewars holding liquid CO_2 or liquid nitrogen have vents that release pressure as the liquids gain heat from the surroundings, evaporate, and build pressure inside the dewars. If dry ice or liquid CO_2 in a dewar is stored in a place with poor ventilation, high levels of CO_2 may result in the air in the storage area. A similar problem can result if liquid nitrogen is stored in a space with poor ventilation, although the risk in this case is caused by the nitrogen driving out air and creating low oxygen levels.

Liquid synthetic air also has risks in storage that should be considered. Liquid synthetic air is a mixture of liquid nitrogen and liquid oxygen that produces an oxygen/nitrogen gas mix in low-lying fog effects that is close to that found in natural air. Liquid nitrogen and liquid oxygen have different evaporation temperatures (-196 degrees C and -183 degrees C respectively) however, so a separation of the elements occurs as the mixture in the storage dewar gains heat. First the liquid nitrogen turns to gas and is vented, which produces a risk of low oxygen levels in the storage area. Later, as the nitrogen in the mixture is depleted and the contents of the dewar rise in temperature, oxygen is vented, which can create an oxygen enriched atmosphere in the storage area. Also, the fog effect produced with the

enriched oxygen mixture will contain abnormally high levels of oxygen. High oxygen levels greatly increase the risks of fires. Any oxygen level above 23.5% is considered high, but any level above normal levels will accelerate a fire.

Adequate ventilation is a simple way to control all these risks from venting gases. Meters that read carbon dioxide and oxygen levels can be used to verify that the ventilation is adequate and that levels of these gases in storage areas are within safe ranges. Liquid synthetic air mixtures must be monitored to ensure that the mixtures do not become too oxygen-enriched to be used for creating fog effects safely.

The atmosphere is normally about 21% oxygen (O_2). Nitrogen or other biologically inert gases can be added to the atmosphere until the oxygen level falls to 19.5%, according to OSHA regulations in the U.S., or to 18% according to HSE guidelines in the U.K. HSE also notes that the Mines and Quarries Act of 1954 requires that oxygen levels never be allowed to fall below 19% by volume. This is obviously a more conservative level than that imposed on general industry, but is not so conservative as the levels set by OSHA. Breathing air with reduced levels of oxygen causes impaired coordination and judgment, so these minimum levels are set to avoid accidents in their respective industries. Lower levels of oxygen, besides increasing the risk of accident, can lead to unconsciousness. Extremely low oxygen levels can cause death. Be particularly careful if there are people present with impaired lung function. Lower oxygen levels may affect them more severely.

A.3.3.1 Frequently fog-making equipment is installed in restricted spaces on catwalks, within scenery, and under stages. Remember that the technicians need to be able access it to service it, but also that the technicians need to be able to get out of the area quickly in an emergency. The demands of a fog effect do not trump the safe egress requirements in OSHA regulations, NFPA 101, or other applicable standards and laws.

Many of the places where fog-making equipment is placed are defined as confined spaces by the federal Occupational Safety and Health Administration in the United States. OSHA defines a confined space as a space that:

(1) is large enough and so configured that an employee can bodily enter and perform assigned work; and

(2) has limited or restricted means for entry or exit (for example, tanks, vessels, silos, storage bins, hoppers, vaults, and pits are spaces that may have limited means of entry.); and

(3) is not designed for continuous employee occupancy.

OSHA requires all employers to evaluate their workplaces to determine if any spaces are permit-required confined spaces. The addition of fog-making equipment in a small space might require that a space be defined as a permit-required confined space. OSHA defines a permit-required confined space as a confined space that has one or more of the following characteristics:

(1) Contains or has a potential to contain a hazardous atmosphere;

(2) Contains a material that has the potential for engulfing an entrant;

(3) Has an internal configuration such that an entrant could be trapped or asphyxiated by inwardly converging walls or by a floor which slopes downward and tapers to a smaller cross-section; or

(4) Contains any other recognized serious safety or health hazard.

If fog-making machinery is placed in a space meeting this definition the requirements of 29 CFR 1910.146 *Permit-required confined spaces* must be met as a legal requirement in the United States. Other nations may have similar regulations. The health and safety concerns associated with confined spaces apply everywhere.

A.3.3.2 While there are many possible environmental hazards that could damage theatrical fog equipment so as to make it hazardous, protecting it from exposure to weather and water and from damage by moving scenery is usually sufficient. Most fog equipment is electrical and rain on the equipment could create a shock hazard. Unless the equipment is designed for outdoor use or wet locations, it needs to be protected from rain and moisture. Moving scenery could hit the equipment and break it, causing it to release fluid or become an electrical shock hazard. Fog equipment needs to be placed so that it is not hit by moving scenery or guards need to be put around it to protect it from collisions. Rain and moving scenery are not the only hazards to fog equipment; the effect designer should evaluate the environment where the equipment is going to be installed, look for any hazards that are likely to damage the equipment, and take steps to guard against this damage.

A.3.3.3 Particular care needs to be paid to fog effects equipment that uses cryogenic materials or hot vapors. Insulation or guards should be installed to protect workers and the public from direct contact with surfaces that might burn or freeze flesh.

A.3.3.4 Many fog-producing machines use heat to vaporize the fog fluids. They should not be built into scenery or other confined spaces where the heat they produce will be trapped and damage the fog equipment or other materials nearby. Machines that use cryogenic materials also may make things around them too cold. Conversely, extremes of heat (too hot or too cold) in the environment might affect the fog equipment. This is less likely than heat from the fog machine making things around the machine too hot, but it is a possibility. All machines that are listed by a nationally recognized testing laboratory have some ambient temperature range in which they are designed to operate and in which they have been tested and found to operate safely. Siting a machine so that it operates outside its design temperature range should be avoided.

A.3.4.1 In the United States, OSHA regulations require almost all electrical apparatus used by employees to be Listed. 29 CFR 1910.303 (a), which deals with electrical devices, says, "The conductors and equipment required or permitted by this subpart shall be acceptable only if approved." Section 1910.399 gives the definitions for the section, and says something is "approved" if it is "acceptable." The definition for "acceptable" says something is acceptable if:

"(i) If it is accepted, or certified, or listed, or labeled, or otherwise determined to be safe by a nationally recognized testing laboratory; or

"(ii) With respect to an installation or equipment of a kind which no nationally recognized testing laboratory accepts, certifies, lists, labels, or determines to be safe, if it is inspected or tested by another Federal agency, or by a State, municipal, or other local authority responsible for enforcing occupational safety provisions of the National Electrical Code, and found in compliance with the provisions of the National Electrical Code as applied in this subpart; or

"(iii) With respect to custom-made equipment or related installations which are designed, fabricated for, and intended for use by a particular customer, if it is determined to be safe for its intended use by its manufacturer on the basis of test data which the employer keeps and makes available for inspection to the Assistant Secretary and his authorized representatives."

Other nations have other ways of ensuring electrical appliance safety that does not involve listing.

A.3.5.2.1 All fog technologies have the potential for putting slippery liquids on walking surfaces. Some fluids, effects, and types of equipment are more likely to create slip and fall hazards than others, but all have this potential.

A.3.5.2.3 Steps should be taken to minimize the accumulation of fog fluids on the optics of fire alarm sensors, theatrical lighting and projection equipment along with electrical and electronics equipment throughout the venue. Reasonable steps would include minimizing the levels of fog around the equipment, installing filters on air intakes while ensuring that adequate cooling air flow is maintained, or using a stepped up maintenance schedule to clean the affected equipment more frequently.

A.3.5.3.1 The U.S. references provide limits for the liquids cited in the first table in section 1.1 and for carbon dioxide, which is listed in the second table. The materials are generally used in glycol, glycerin, mineral oil, and dry ice fog effects. The use of argon, nitrogen, and oxygen have risks associated with elevated or depressed levels of oxygen in the environment, and controlling the risks from abnormal oxygen levels is required in clause 3.5.4. Nitrogen is used in liquid nitrogen fog effects and as part of fog effects created using liquid synthetic air. Oxygen is used in liquid synthetic air fog effects. Argon is used infrequently for low-lying fog effects with motion picture miniature settings.

A.3.5.3.2.2 Monitoring peak exposures by the use of time/distance aerosol concentration tables is the method described in the *Equipment-Based Guidelines for the Use of Theatrical Smoke and Haze*, prepared for the Equity-League Pension and Health Trust Funds by ENVIRON International Corporation. This guidelines document is available at the time of the writing of this Standard on the Actors' Equity website at http://www.actorsequity.org/library/library.asp?cat=33 and on the Equity-League Pension, Health, and 401(k) Trust Funds website at http://www.equityleague.org/PDF/smokehaze/guidelines.pdf. The protocol developed by ENVIRON International for creating the time-distance tables in the Guidelines is posted on the Equity-League Fund's website at http://www.equityleague.org/PDF/smokehaze/protocol.pdf.

Please note that *Equipment-Based Guidelines for the Use of Theatrical Smoke and Haze* states that its procedures are designed to avoid the use of air sampling monitoring methods (e.g. those methods described in 3.5.3.2.3 and 3.5.3.2.4 of this Standard) but that "these Equipment-Based Guidelines may not be appropriate for all productions." The Effect Designer must determine whether this monitoring method is appropriate for any particular fog effect and performance situation or whether another method would serve better.

A.3.5.3.2.3 PLASA's "A Test Is Worth a Thousand Words" fog testing program offers protocols for controlling exposure by the use of meters for all the major fog-making technologies. At the time of this writing, information about the protocols is accessible on the PLASA website at http://tsp.plasa.org/tsp/safety/fog.html. It is also available by contacting the PLASA office or emailing a request to foginfo@esta.org.

A.3.5.4 Liquid synthetic air is a mixture of liquid nitrogen and liquid oxygen that produces an oxygen/nitrogen gas mix in low-lying fog effects that is close to that found in natural air. Liquid nitrogen and liquid oxygen have different evaporation temperatures (-196 degrees C and -183 degrees C respectively) however, so a separation of the elements occurs as the mixture in the storage dewar gains heat. First the liquid nitrogen turns to gas and is vented, which leaves an oxygen-enriched mixture in the dewar. A fog effect produced with this oxygen-enriched mixture will contain abnormally

high levels of oxygen. High oxygen levels greatly increase the risks of fires. Any oxygen level above 23.5% is considered high, but any level above normal levels will accelerate a fire.

Cold gases and gases that are heavier than air may collect in low-lying areas and create concentrations there that are significantly different from the concentrations in the general atmosphere of a venue. Particular attention should be given to monitoring and controlling the oxygen concentrations in low-lying areas such as trap rooms, orchestra pits, and basements.

The atmosphere is normally about 21% oxygen (O_2). Nitrogen or other biologically inert gases can be added to the atmosphere until the oxygen level falls to 19.5%, according to OSHA regulations in the U.S., or to 18% according to HSE guidelines in the U.K. HSE also notes that the Mines and Quarries Act of 1954 requires that oxygen levels never be allowed to fall below 19% by volume. This is obviously a more conservative level than that imposed on general industry, but is not so conservative as the levels set by OSHA. Breathing air with reduced levels of oxygen causes impaired coordination and judgment, so these minimum levels are set to avoid accidents in their respective industries. Lower levels of oxygen, besides increasing the risk of accident, can lead to unconsciousness. Extremely low oxygen levels can cause death. Be particularly careful if there are people present with impaired lung function. Lower oxygen levels may affect them more severely.

A.3.7 The simplest way to see if a fog effect will trigger a smoke detection system is to run the effect, perhaps at a higher level than planned, and see if the fire detection system is triggered. Of course, it is necessary to make sure that no alarm sounds to start a building evacuation and that no call signal is issued to the fire department. All fire detection systems have some way of aborting the alarm, either as part of the normal operating procedure or as part of a test and maintenance procedure. Either way, you will have to work with whomever is in charge of the alarm system at a venue to silence the alarm part of the system. It may also be necessary to notify the Authority Having Jurisdiction that the alarm is bypassed while you are testing the system.

Keep in mind that air conditioning and heating equipment may move the fog from where it does not trip smoke detectors to other areas of the building where it does. Ensure that any tests for interaction between the fog and the fire detectors are done with the air handling equipment in performance conditions, or take steps to determine that the air handling equipment will have no effect on the probability of fog triggering a fire detection system. The smoke detectors may not trip immediately, so wait at least 20 minutes after your test is over for any delayed effects.

A.3.7.1 When considering how to negotiate an acceptable solution to controlling false alarms with the Authority Having Jurisdiction and the venue's owner or his agent, it is useful to be aware of what the basic requirements are for fire detection systems in assembly occupancies. NFPA 101-2009 covers this in section 12.3.4 for new assembly occupancies and in section 13.3.4 for existing assembly occupancies. Briefly summarized, these sections require manual pull-boxes and waterflow sensors on automatic sprinkler systems, when these are provided, to be the basic fire alarm initiation devices. Manual pull-boxes and waterflow sensors, of course, are not susceptible to false alarms from fog. Automatic fire detectors may be used as initiation devices, but whatever initiation devices are used, the signal is to go to a station that is constantly attended by a person while the assembly occupancy is occupied. That person, on receipt of the alarm signal, is to take appropriate action, such as notifying the occupants and calling for help from the fire department. A permitted alternative is a positive alarm sequence (sections 12.3.4.3.1 and 13.3.4.3.1), which is described in section 1-5.4.11 of NFPA 72-1999 and section 6.8.1.3 of the newer version, NFPA 72-2002. A positive alarm sequence automatically sounds an alarm on detection of conditions that suggest a fire, but allows a trained person a certain amount of time between the time the condition is detected and the time the alarm sounds to abort the alarm signal. Unfortunately, for the purposes of avoiding false alarms, if two or more smoke sensors are

triggered in quick succession, all the normal building and remote signals are activated immediately and automatically, so some false alarms can be avoided with a positive alarm sequence, but not all. Nevertheless, the above referenced sections describe fire detection and alarm systems that can be run in such a way that, when fog is used, it is unlikely that alarms will be issued and the fire department dispatched. Conditions (a) through (c) in clause 3.7.1 of this Standard are broadly consistent with the requirements of NFPA 101-2003.

Systems in which the automatic fire detectors automatically start an alarm sequence without human intervention are permitted in sections 12.3.4.3.5 and 13.3.4.3.5 of NFPA 101-2003. It is these types of systems that are most likely to issue false alarms when theatrical fog effects are used.

A.3.7.2 Small amounts of fog do not necessarily mean weak fog effects. How the fog is illuminated and how it is distributed make a big difference on how it looks. Depending on the angle of illumination, a little bit of fog can look like a lot or it can look like none at all. A little fog placed just where it is needed will create a better effect and be less likely to trip fire detection systems than will a lot of fog indiscriminately distributed. See the *Introduction to Modern Atmospheric Effects*, published by PLASA, for some advice on using fog frugally and effectively. Certainly other books on fog effects can be consulted for advice on maximizing an effect with a minimum amount of fog.

A.4.2.2.1 All glycol, glycerin, and mineral oil fogs deposit fog fluid on building surfaces. Some fluids, effects, and types of equipment create a build-up that is objectionable faster than others, but, given enough time, all fogs made with these fluids will leave noticeable deposits. Cleaning at some interval will be needed to avoid slippery build-ups of fog fluids on all walking surfaces reached by the fog.

Dry ice, liquid nitrogen, and liquid synthetic air are used to create low-lying fog effects in which the droplets are only water. The water eventually evaporates and does not build up on building surfaces as glycol, glycerin, and mineral oil will, but the water can collect on the floor in the short term, particularly near the discharge port of the fog machine. Ducting between the fog machine and the performance space can be used to give the heavier droplets a chance to fall out of the fog before it is expelled. Please note that this technique will result in water in the ducting, and some provision will be needed to drain it to avoid eventual duct blockage, to avoid the development of mold, and to keep it from leaking and creating a mess.

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