# ANSI E1.23 – 2020
# Entertainment Technology—Design, Execution, and Maintenance of Atmospheric Effects

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|---|---|---|---|
| CP | Custom-market producer | DE | Designer |
| DR | Dealer or rental company | G | General interest |
| MP | Mass-market producer | U | User |

# Table of Contents

NOTICE and DISCLAIMER.....i
Investors in Innovation.....iii
Contact Information.....v
Acknowledgments.....vi
1 General.....1
1.1 Scope.....1
1.2 Purpose.....1
2 Definitions.....2
3 Other standards, regulations, and references.....2
4 Atmospheric Effect Design Requirements *.....3
4.1 Determination of the visual effect desired *.....3
4.2 Determination of the exposed population *.....3
4.2.1 Who is exposed?.....3
4.2.2 What is the exposure time?.....3
4.2.3 What is the risk to the exposed population.....3
4.3 Selection of equipment, fluids, and gases.....3
4.3.1 Selection of appropriate technology.....3
4.3.1.1 Resources to use the technology safely and effectively *.....3
4.3.1.2 Restrictions in choices by local regulations, contractual agreements, or house rules *.....3
4.3.2 Equipment shall be listed or approved *.....4
4.3.2.1 Commercially manufactured standard equipment.....4
4.3.2.2 Custom equipment.....4
5 Siting requirements for fog-making and distribution equipment.....4
5.1 Access and egress *.....4
5.2 Protection from environmental hazards *.....4
5.3 Protection from unintended contact *.....4
5.4 Protection from heat and cold *.....4
6 Distribution requirements for aerosols and gases.....4
6.1 Shall not hide hazards.....5
6.2 Distribute only where and when needed.....5
6.3 Verifying the distribution.....5
7 Control requirements for fluid accumulation.....5
7.1 Slip hazards *.....5
7.2 Blockage of distribution equipment.....5
7.3 Contamination of other equipment *.....5
8 Control requirements for inhalation exposure to fluids and toxic gases *.....5
8.1 Exposure limits *.....5
8.2 Monitoring fluid exposure *.....5
8.3 Oxygen-enriched or deficient atmospheres *.....6
8.4 Carbon dioxide-enriched atmospheres.....6
8.4.1 Control by ventilation.....6
8.4.2 Monitoring by meters.....6
9 Requirements for dealing with smoke detection devices as part of a fire protection system *.....6
9.1 Temporary interruption of smoke detection function.....7
9.2 Design for Atmospheric Effect operation within the limits of a smoke detection system.....7
9.3 Design of fire detection systems for permanently installed Atmospheric Effect operation.....7
10 Materials storage requirements.....7
10.1 Temperature *.....7
10.2 Avoidance of contamination *.....7
10.3 Ventilation *.....7
10.4 Access and egress *.....7

11 Equipment maintenance requirements....7
12 Atmospheric Effect maintenance and reevaluation requirements *....8
12.1 Scheduled periodic reevaluation....8
12.2 Identification of trigger-events....8
12.2.1 Fog or haze in new places *....8
12.2.2 Smoke detectors being triggered. *....8
12.2.3 Aerosol meters give changed readings *....8
12.2.4 Addition of a new fog or haze effect *....8
12.3 Affected population reporting mechanism *....8
13 Documentation of effect....8
14 Training Atmospheric Effect Operators....9
15 Operation of the effect....9
15.1 Cue operation....9
15.1.1 Cues shall be documented....9
15.1.2 Cues shall not be modified without approval....9
15.2 Monitoring distribution of the aerosol....9
15.2.1 Visual effect evaluation....9
15.2.2 Fluid residue build-up *....9
15.2.2.1 Slip hazards....9
15.2.2.2 Blockage of distribution equipment....9
15.2.3 Inhalation exposure....9
15.2.4 Oxygen enrichment or deficiency....10
15.2.5 Carbon dioxide enrichment....10
15.3 Documentation of any deviances....10
Annex A....11
A.4 Atmospheric Effect Design Requirements....11
A.4.1 Determination of the visual effect desired....11
A.4.2 Determination of the exposed population....11
A.4.3 Selection of equipment, fluids, and gases....12
A.4.3.1 Selection of appropriate technology....12
A.4.3.1.1 Resources to use the technology safely and effectively....12
A.4.3.1.2 Restrictions in choices by local regulations, contractual agreements, or house rules....12
A.4.3.2 Equipment shall be listed or approved....12
A.5 Siting requirements for fog-making and distribution equipment....13
A.5.1 Access and egress....13
A.5.2 Protection from environmental hazards....13
A.5.3 Protection from unintended contact....13
A.5.4 Protection from heat and cold....14
A.7 Control requirements for fluid accumulation....14
A.7.1 Slip hazards....14
A.7.3 Contamination of other equipment....14
A.8 Control requirements for inhalation exposure to fluids and toxic gases....14
A.8.1 Exposure limits....14
A.8.2 Monitoring fluid exposure *....15
A.8.3 Oxygen-enriched or deficient atmospheres....15
A.9 Requirements for dealing with smoke detection devices as part of a fire protection system....16
A.10 Materials storage requirements....17
A.10.1 Temperature....17
A.10.2 Avoidance of contamination....17
A.10.3 Ventilation....17
A.10.4 Access and egress....18
A.12 Atmospheric Effect maintenance and reevaluation requirements....18
A.12.2.1 Fog or haze in new places....18
A.12.2.2 Smoke detectors being triggered....18
A.12.2.3 Aerosol meters give changed readings....18

A.12.2.4 Addition of a new fog or haze effect....18
A.12.3 Affected population reporting mechanism....18
A.15 Operation of the effect....19
A.15.2.2 Fluid residue build-up....19

# 1 General

## 1.1 Scope

This Standard is intended to be applicable to the creation of Atmospheric Effects using artificial fogs or mists in theatres, motion picture studios, arenas, and other places of entertainment, public assembly, or video production.

The Atmospheric Effects 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 |
| polyethylene glycol 200 to 400 | 25322-68-3 |
| 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 offered as guidance in planning or executing any Atmospheric 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, execution, and maintenance of theatrical Atmospheric 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 Atmospheric Effects. The Standard is also intended to provide guidance related to the obscuration of hazards or paths of egress in places where the Atmospheric Effect is used. 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.

The planning, execution, and maintenance of Atmospheric Effects outlined in this Standard is a reiterative process. The process is not finished until the Atmospheric Effect is removed from the production or event, or the production or event ceases to be performed.

Annex A contains information material with clause numbers keyed to the relevant main clauses. Main clauses for which there is a corresponding Annex A clause with substantive information are indicated with an asterisk “*****”.

## 2 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*.

**2.1 Atmospheric Effect:** a visual effect created by putting a liquid aerosol into the air of a theatre, motion picture studio, or entertainment venue.

**2.2 Atmospheric Effect Designer:** a Qualified Person responsible for designing the Fog or Haze effect, selecting the eqipment and fluids to be used, specifying how they shall be used, and implementing the requirements and recommendations of this Standard.

**2.3 Atmospheric Effect Operator:** a Competent Person responsible for the operation and maintenance of the Atmospheric Effect system as designed by the Atmospheric Effect Designer.

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

**2.5 Calibration factor:** An experimentally-created, unitless factor that is applied to a direct-reading instrument to adjust its sensor to the optical properties of a specific atmospheric fog.

**2.6 Competent Person:** One who is trained and skilled in the setup, operation and use of theatrical Atmospheric 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.

**2.7 Fog:** A mixture of liquid droplets in air that reduces visibility and reflects light, producing visible clouds or volutes in the air.

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

**2.9 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 Atmospheric Effects.

**2.10 Shall:** Indicates something that must be done to comply with this standard.

**2.11 Should:** Indicates something that is strongly recommended to be done.

**2.12 TWA:** Time Weighted Average. Exposure level averaged over period of time, generally an 8-hour period, a 40-hour work-week.

## 3 Other standards, regulations, and references

The following standards, regulations, and references shall be consulted when planning an Atmospheric 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,* 2018 edition, Chapter 9

# 4 Atmospheric Effect Design Requirements *

The Atmospheric Effect Designer shall design the Atmospheric Effect to achieve the desired effect, while keeping the risks to people within reasonable limits.

## 4.1 Determination of the visual effect desired *

The Atmospheric Effect Designer shall determine the visual effect to be created by the Atmospheric Effect. This determination should be done in consultation with the other members of the design team for the specific theatrical production, special event, or motion picture shoot in which the Atmospheric Effect will be used.

## 4.2 Determination of the exposed population *

### 4.2.1 Who is exposed?

The Atmospheric Effect Designer shall determine the population to be exposed to the Atmospheric Effect, e.g., performers, stagehands, audience members, musicians, camera operators, and so on.

### 4.2.2 What is the exposure time?

The amount of exposure time for members of the affected population shall be considered. Exposures longer than eight hours a day or more than 40 hours a week require exposure controls beyond those required for exposures of fewer hours in a day or week.

### 4.2.3 What is the risk to the exposed population

Identify who is most likely to be adversely affected by the Atmospheric Effect, given the probability of exposure and duration of frequency of the exposure. Consider their activities while exposed to the Atmospheric Effect. Use this information in appropriately addressing the requirements of all the subsequent clauses of this Standard.

## 4.3 Selection of equipment, fluids, and gases

### 4.3.1 Selection of appropriate technology

The Atmospheric Effect Designer shall specify the appropriate Atmospheric Effect equipment, fluids, and gases to achieve the visual effect desired.

#### 4.3.1.1 Resources to use the technology safely and effectively *

The Atmospheric 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 Atmospheric Effect Operators to use and maintain safely shall not be selected and shall not be used.

#### 4.3.1.2 Restrictions in choices by local regulations, contractual agreements, or house rules *

Atmospheric Effect materials and devices that are prohibited by local governmental regulations, contractual agreements, or the proprietary rules of the venue shall not be chosen for use.

#### 4.3.2 Equipment shall be listed or approved *

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

#### 4.3.2.1 Commercially manufactured standard equipment

Commercially manufactured standard equipment shall be used according to this section's subclauses. 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.

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

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

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

#### 4.3.2.2 Custom equipment

Custom-made equipment shall be permitted to be used if the requirements of this section's subclauses are met.

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

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

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

## 5 Siting requirements for fog-making and distribution equipment

The Atmospheric Effect Designer shall plan the siting fog-making devices and distribution equipment in accordance with this section's subclauses.

### 5.1 Access and egress *

Fog-making devices and devices for controlling the distribution of fog materials shall be sited where the Atmospheric 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.

### 5.2 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.

### 5.3 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.

### 5.4 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.

## 6 Distribution requirements for aerosols and gases

The Atmospheric Effect Designer shall plan the distribution of the aerosols to achieve the desired Atmospheric Effect while not over-exposing any person to the aerosols or gases.

### 6.1 Shall not hide hazards

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.

### 6.2 Distribute only where and when needed

Aerosols should be distributed only where and when needed. Measures shall be taken to minimize the movement of aerosols into areas where they are not needed. Measures shall be taken to avoid unnecessarily long exposures such as having people work in fog an entire day when the fog is only needed for a short scene.

### 6.3 Verifying the distribution

Testing shall be done before the event using the Atmospheric 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.

## 7 Control requirements for fluid accumulation

The Atmospheric Effect Designer shall plan methods to control undesirable or unsafe fluid accumulation.

### 7.1 Slip hazards *

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

### 7.2 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.

### 7.3 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 Atmospheric Effects.

## 8 Control requirements for inhalation exposure to fluids and toxic gases *

The Atmospheric Effect Designer shall plan methods to control undesirable or unsafe exposure of people to liquids and toxic gases.

### 8.1 Exposure limits *

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.

TWA limits shall be adjusted for exposures that are longer than 8 hours a day or more than 40 hours a week.

### 8.2 Monitoring fluid exposure *

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

**8.2.1** 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 Atmospheric Effect haze machine.

**8.2.2** 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 Atmospheric Effect shall be permitted to be adopted as an exposure control means.

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

**8.2.4** 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.

### 8.3 Oxygen-enriched or deficient atmospheres *

When Atmospheric 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.

Corrective measures that might need to be taken to address problems with oxygen-enriched or oxygen-deficient atmospheres shall be planned in advance of any possible event needing them. The people who might need to take part in these corrective measures shall be trained in advance.

### 8.4 Carbon dioxide-enriched atmospheres

When Atmospheric Effects are used that may cause a carbon dioxide-enriched atmosphere, measures shall be taken to assure that people are not exposed to levels that are immediately hazardous or that may impare their ability to avoid other hazards in the venue.

#### 8.4.1 Control by ventilation

Control by means of ventilation to limit exposure shall be considered as a possible reasonable control method. Planning for control by ventilation shall consider:

- the rate at which the carbon dioxide is to be introduced into the space;
- the volume of the space;
- the rate of air exchange to dilute or to flush the atmosphere in the space; and
- the probability of stratification of the atmosphere in the space, including consideration of any measures taken to reduce or to obviate stratification.

#### 8.4.2 Monitoring by meters

Monitoring peak and time-weighted average exposure levels by the use of meters shall be permitted to be adopted as an exposure control means. Meter reading action-trigger points shall be established. Any corrective measures that might need to be taken in response to the action-triggers shall be planned in advance of any possible event needing them. The people who might need to take part in these corrective measures shall be trained in advance.

## 9 Requirements for dealing with smoke detection devices as part of a fire protection system *

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

### 9.1 Temporary interruption of smoke detection function

Portions of smoke detection systems shall be permitted to be interrupted during the operation of a temporarily installed Atmospheric 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.

(d) 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 Atmospheric Effect has passed.

### 9.2 Design for Atmospheric Effect operation within the limits of a smoke detection system

If no adjustment of the fire detection system can be made per 9.1, the temporarily installed Atmospheric Effect shall be designed to operate with amounts of fog below the amount that will trigger the smoke detection system.

### 9.3 Design of fire detection systems for permanently installed Atmospheric Effect operation

In the case of a permanently installed Atmospheric Effect, the fire detection systems should be designed to work without issuing false alarms and initiating unneeded fire protection measures.

## 10 Materials storage requirements

The Atmospheric Effect Designer shall plan the storage of the atmospheric effect-making materials to meet the requirements of this section's subclauses.

### 10.1 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.

### 10.2 Avoidance of contamination *

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

### 10.3 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.

If adequate ventilation cannot be assured, the fog-making materials storage space shall be considered a "Permit-required confined space" per 29 CFR 1910.46, and the requirements of 29 CFR 1910.46 shall come into force.

### 10.4 Access and egress *

Storage of fog-making materials shall be planned so the Atmospheric 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.

## 11 Equipment maintenance requirements

The Atmospheric Effect Designer shall plan for maintaining the Atmospheric Effect equipment. Documentation provided by the equipment manufacturer shall be consulted for guidance in developing a suitable maintenance plan.

 

## 12 Atmospheric Effect maintenance and reevaluation requirements *

The Atmospheric Effect Designer shall plan for the maintenance of the Atmospheric Effect to avoid the diminution of its effectiveness or the creation of an unhealthy Atmospheric Effect over time.

### 12.1 Scheduled periodic reevaluation

Periodic reevaluation of the effect at reasonable set intervals shall be planned and carried out to assure that it is continues to be visually effective, that it does not over-expose any member of the planned exposed population, and that it does not create a hazard for any persons who were not originally considered in the plan.

**Note:** If the expected period during which the Atmospheric Effect is to be used is so short that a reevaluation is unlikely to be useful, this shall be noted and no periodic reevaluation planned. However, clauses 12.2 and 12.3 shall apply.

### 12.2 Identification of trigger-events

Events that would trigger a reevaluation of the Atmospheric Effect sooner than the scheduled reevaluation shall be identified. Events may include, but are not limited to:

#### 12.2.1 Fog or haze in new places *

If fog or haze is visible where it hadn't been before, something has changed, and the effect needs to be reevaluated.

#### 12.2.2 Smoke detectors being triggered. *

If smoke detectors that had not been triggered before are now issuing alarms, something has changed, and reevaluation is needed.

#### 12.2.3 Aerosol meters give changed readings *

Aerosol meters in the performance environment showing changes in ambient fog levels can indicate that reevaluation is needed.

#### 12.2.4 Addition of a new fog or haze effect *

If a new fog or haze effect is added to an existing scene or effect, this should trigger a reevaluation. The environment is no longer what it was during the original evaluation.

### 12.3 Affected population reporting mechanism *

A method shall be devised for members of the exposed population to report their concerns or observations of changes in the Atmospheric Effect and thus trigger a reevaluation of the Atmospheric Effect and its operation.

## 13 Documentation of effect

The Atmospheric Effect 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 Atmospheric Effect shall be in writing and shall provide the following in addition to the plans outlined in clauses 4 through 12

**13.1** Identification of the event or production using the Atmospheric Effect.

**13.2** Name of the Atmospheric Effect Designer.

**13.3** Name of the Atmospheric Effect Operator or Operators and assistants.

**13.4** Safety data sheet (SDS) for the Atmospheric Effect materials to be used.

**13.5** A narrative description of the Atmospheric Effect or Effects, the risks identified and the measures used to control them.

**13.6** Contact information for a person to be contacted if there is a problem.

## 14 Training Atmospheric Effect Operators

The Atmospheric Effect Designer shall train the Atmospheric Effect Operator or Operators in the operation of the Atmospheric Effect. The Atmospheric Effect Designer shall ensure that the Effect Operators are aware of the risks, the measures taken for controlling the risks, and that they are capable of carrying out these measures.

**Note:** The Atmospheric Effect Designer may also serve as an Atmospheric Effect Operator, obviating the need for extensive training.

## 15 Operation of the effect

### 15.1 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 per the instructions from the Effect Designer.

#### 15.1.1 Cues shall be documented

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

#### 15.1.2 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.

### 15.2 Monitoring distribution of the aerosol

#### 15.2.1 Visual effect evaluation

The visual effect produced by the Atmospheric 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. Conditions that could change and thus change the effect include outside temperature, humidity, seasonal weather change, and changes in the heating/air conditioning operating mode to account for the weather changes.

#### 15.2.2 Fluid residue build-up *

##### 15.2.2.1 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.

##### 15.2.2.2 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.

#### 15.2.3 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 this Standard.

#### 15.2.4 Oxygen enrichment or deficiency

When Atmospheric 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 this Standard.

#### 15.2.5 Carbon dioxide enrichment

When Atmospheric Effects are used that might cause abnormal levels of carbon dioxide in the air, the carbon dioxide 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 this Standard.

### 15.3 Documentation of any deviances

The Effect Operator shall document any deviances from the plan, anomolies in the performance, particularly those that would be considered “trigger events” noted per clause 12.2.

# 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.

Not all clauses in the main body of the standard have a corresponding Annex note.

## A.4 Atmospheric Effect Design Requirements

The Design Requirements Section may be more easily implemented by using a checklist. A possible checklist of things to consider might be:

1. What type of fog effect do you want to use?
   a. How long of an effect is required (e.g., 12-hour continuous or short-lived)? This will determine whether you will be concerned about ceiling exposure limits or TWA limits or both.
   b. Where is the effect required (e.g. localized or homogeneous on-set/stage)?
   c. What are the options for achieving such effect?
      i. Is there a way to substitute something else (e.g., lighting, digital editing) for the fog effect?
      ii. Is there a fog with a lower calibration factor that can achieve the same effect? Lower calibration factors mean more light-scattering with less fog material in the air.
2. Where do you want to use the fog?
   a. Is it in a localized area? Can the effect be contained to the desired area? If it is not contained, will people be exposed who don't need to be?
   b. Is it going to be throughout the studio/theatre?
   c. Is there ventilation? Is it localized or general dilution?
3. Who will be exposed?
   a. Only those in the scene?
   b. All workers?
   c. Are there any children, seniors, other vulnerable populations?
4. Do we know what the levels of fog will be?
   a. Is there any previous exposure data?
   b. Do you have access to a direct-reading instrument for which there are established calibration factors?
   c. Are you able measure the fog level while establishing the look of the effect?

### A.4.1 Determination of the visual effect desired

The first step is deciding what kind of Atmospheric Effect will be needed for the theatrical performance or event That will then guide all the rest of the planning.

### A.4.2 Determination of the exposed population

A risk assessment approach would be useful here. The exact level of risk can't be determined until the Atmospheric Effect materials are selected, but it is possible to determine who is likely to be adversely affected, if there is an adverse effect. Performers working in a hazy atmosphere would obviously be part of "the exposed population," but also consider technicians who are in the same space. Furthermore, consider people in places where the Atmospheric Effect is not intended to be, but where it might go. For example, air handling systems that recirculate a studio or theatre's air into offices will expose workers in those offices to the Effect. Do not think, "This is where we need fog," and ignore surrounding spaces and the people in them. If you ignore them, even though their exposure might be low, it can lead to unpleasant workplace discussions.

Exposure time also must be considered. The performers for a motion picture production may only be in a hazy studio for a few minutes a day, but the gaffers and grips might be there for many hours. Different controls will be needed for the performers and technicians due to their different exposure times.

Motion picture production often has long workdays, but long workdays and long exposures also can be experienced by people working on live productions. During a day of tech or dress rehearsals on stage, the lighting team will often turn on the haze at the start of the day and leave it running for 12 hours. Normal exposure during the production run might be for fewer than eight hours during a day, but much longer during this tech and dress rehearsal period.

Enlist the help of others in determining who might be exposed and for how long. You are less likely to overlook someone, and involving others can make it clear to other people in the workplace that their health and comfort are important.

## A.4.3 Selection of equipment, fluids, and gases

### A.4.3.1 Selection of appropriate technology

#### A.4.3.1.1 Resources to use the technology safely and effectively

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 have the potential to offer a better effect or to use materials of lower toxicity, is likely to be used inconsistently or improperly.

#### A.4.3.1.2 Restrictions in choices by local regulations, contractual agreements, or house rules

It's rarely worth the effort to argue with venue owners or AHJs (e.g., fire marshals or other public safety officials) about bans on some fog-making technology. It is worth asking if you want to use something that is banned, but if the initial discussion doesn't reveal a willingness to allow the banned material or technology, arguing further is likely to create more resistance. There are many technologies that can be used for almost the same effect; pick another.

Different rules can arise because different criteria are used. For example, this standard lists diethylene glycol as an acceptable fog-making chemical. It is useful for creating a quick-dissipating fog effect, and it should cause no health problems if exposures are kept below the limits in ANSI E1.5. However, it is more toxic than others on the list, so if a rule is created to limit the fog-making chemicals to the least toxic, it would be left out.

### A.4.3.2 Equipment shall be listed or approved

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.5 Siting requirements for fog-making and distribution equipment

### A.5.1 Access and egress

Frequently fog-making equipment is installed on catwalks, within scenery, and under stages. Remember that the technicians need to be able to 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 an Atmospheric 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.5.2 Protection from environmental hazards

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.5.3 Protection from unintended contact

Particular care needs to be paid to Atmospheric 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.5.4 Protection from heat and cold

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.7 Control requirements for fluid accumulation

### A.7.1 Slip hazards

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.7.3 Contamination of other equipment

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.8 Control requirements for inhalation exposure to fluids and toxic gases

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 Atmospheric 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. Nitrogen is used in liquid nitrogen Atmospheric Effects and as part of Atmospheric Effects created using liquid synthetic air. Oxygen is used in liquid synthetic air Atmospheric Effects. Argon is used infrequently for low-lying Atmospheric Effects with motion picture miniature settings.

### A.8.1 Exposure limits

ANSI E1.5 (current edition) and 29 CFR 1910.1000 are the base-line exposure limit documents for this Standard, but other entertainment industry documents and labor contracts may prohibit some atmospheric effect materials or may set lower exposure limits. Those prohibitions and lower limits should be respected.

TWA limits are normally set for people exposed for no more than eight hours a day or 40 hours a week. Longer exposures require adjusting the limits lower. Commonly used formulas for calculating the modified TWA limits are as follows.

For longer work-days:

RF = 8/T x ((24-T)/16)

Where:

RF = Reduction Factor

T = time in hours worked per shift

For longer work-weeks:

RF = 40/T x ((168-T)/128)

Where:

RF = Reduction Factor

T = time in hours worked per week

A simpler method for longer workdays is to use this table:

| Reduction factor | Length of work period in hours |
|---|---|
| 0.7 | More than 8, but not more than 10 |
| 0.5 | More than 10, but not more than 12 |
| 0.25 | More than 12, but not more than 16 |
| 0.1 | More than 16 |

### A.8.2 Monitoring fluid exposure *

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 https://www.actorsequity.org/resources/Producers/safe-and-sanitary/smoke-and-haze/.

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, 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 Atmospheric Effect and performance situation or whether another method would serve better.

Protocols for controlling exposure by the use of meters is accessible on the ESTA website at https://tsp.esta.org/tsp/working_groups/FS/fogtesting.html. It is also available by contacting the ESTA office or emailing a request to foginfo@esta.org. Additional calibration factors for different meters, and additional information, can be found in the “calibration factor” documents at https://tsp.esta.org/tsp/working_groups/FS/fogdocs.html.

### A.8.3 Oxygen-enriched or deficient atmospheres

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.

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.

Liquid synthetic air is a mixture of liquid nitrogen and liquid oxygen that produces an oxygen/nitrogen gas mix in low-lying Atmospheric 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. an Atmospheric 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.

## A.9 Requirements for dealing with smoke detection devices as part of a fire protection system

The simplest way to see if an Atmospheric 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.

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 101-2018 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, section 6.8.1.3 of NFPA 72-2002, and 23.8.1.2 of NFPA 72-2019. 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 Atmospheric Effects are used.

Small amounts of fog do not necessarily mean weak Atmospheric 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 ESTA, for some advice on using fog frugally and effectively. Certainly other books on Atmospheric Effects can be consulted for advice on maximizing an effect with a minimum amount of fog.

 

## A.10 Materials storage requirements

### A.10.1 Temperature

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.10.2 Avoidance of contamination

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.10.3 Ventilation

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 Atmospheric 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 Atmospheric 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 Atmospheric 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.

If there is any credible possibility of an oxygen-deficient or toxic atmosphere (e.g., too much carbon dioxide), a rescue plan should be developed, personnel trained to use it, and the rescue plan practiced. Multiple deaths often happen when there is no plan and no training, so a worker collapses, another worker without protective gear or training goes in to rescue the first, and that worker collapses, too. See 29 CFR 1910.146 for a good outline of how to deal with potentially hazardous workplace atmospheres.

### A.10.4 Access and egress

Storage of fog-making materials shall be planned so the Atmospheric 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.

## A.12 Atmospheric Effect maintenance and reevaluation requirements

#### A.12.2.1 Fog or haze in new places

If fog or haze is visible where it hadn't been before, something has changed, and the effect needs to be reevaluated. The air currents in the venue may have changed due to changing heating or air conditioning, a door that was planned to be closed is now open, the atmospheric effect machine is being run longer or at higher setting, or something else has changed. What has changed needs to be investigated.

**I**n any production, changing the sets constitutes a change in the environment, The fog/haze exposures should be reevaluated when moving/changing to a new set.

#### A.12.2.2 Smoke detectors being triggered.

Problems with smoke detection systems should have been worked out in advance, but if smoke detectors that had not been triggered before are now issuing alarms, something has change. The change might be a change in the HVAC system so it now is carrying fog or haze into areas where it had not been before. In any case, this needs to be addressed, if for no other reason than that smoke alarms going off can interrupt a show or motion picture shoot.

#### A.12.2.3 Aerosol meters give changed readings

Installing aerosol meters in the performance environment and noting any changes is a reasonable method for monitoring for changes. The fog effect concentration of concern for health is the concentration in the breathing zone of performers, technicians, and other exposed people, but an aerosol meter elsewhere in the performance or studio space can be used as a measure to see if anything has changed. That is, if the aerosol level at a location usually shows a level, for example, of 2.0 mg/m$^3$, and it starts consistently showing 4.0 mg/m$^3$, the atmospheric effect in the environment has changed, and should be reevaluated. It may be that the aerosol exposure to people is not higher or not enough higher to be a problem, but the change in the environmental meter can show that attention needs to be paid to the possibly changed situation.

#### A.12.2.4 Addition of a new fog or haze effect

“Can we have a little haze added on top of this fog effect?” is a reasonable request, but it changes the combined effect. The new effect needs to be evalutated. The different fog-making materials may have different calibration factors. Use the the calibration factor for the fog or haze with the highest calibration factor, not the lowest.

### A.12.3 Affected population reporting mechanism

Don't wait for grumbling in the green room to get loud before it is heard. Figure out a way to solicit comments and concerns before they become problems.

## A.15 Operation of the effect

### A.15.2.2 Fluid residue build-up

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 Atmospheric 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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