

ESTA

ANSI E1.29 – 2009 (R2018)

**Product Safety Standard for Theatrical Fog
Generators That Create Aerosols of Water,
Aqueous Solutions of Glycol or Glycerin, or
Highly Refined Alkane Mineral Oil**

F&S/2007-3004r6

This document was approved as an American National Standard by the ANSI Board of Standards Review on 6 November 2018. It is a reaffirmation of the 2009 edition.

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The ESTA Technical Standards Program

The ESTA Technical Standards Program was created to serve the ESTA membership and the entertainment industry in technical standards related matters. The goal of the Program is to take a leading role regarding technology within the entertainment industry by creating recommended practices and standards, monitoring standards issues around the world on behalf of our members, and improving communications and safety within the industry. ESTA works closely with the technical standards efforts of other organizations within our industry, as well as representing the interests of ESTA members to ANSI, UL, and the NFPA. The Technical Standards Program is accredited by the American National Standards Institute.

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The Fog & Smoke Working Group, which authored this Standard, consists of a cross section of entertainment industry professionals representing a diversity of interests. ESTA is committed to developing consensus-based standards and recommended practices in an open setting.

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Foreword (non-mandatory, informative only)

This standard is intended to help guide product safety testing laboratory personnel in their evaluation of fog-making equipment for design or construction defects that might create unacceptable hazards to users of the equipment or the public. It is based on ANSI/UL 998 - 2006, Humidifiers, and adopts the requirements of that standard, but with modifications as noted in this Standard.

Many of the modifications listed in this standard are to allow the use of components sized in SI units. ANSI/UL 998 - 2006 uses SI units as the primary units, but they are hard conversions from the US customary units used historically and describe few or no real components. It is in the interests of the industry and the end-users of the products covered by this Standard to advance the development of products for a global market, so this Standard attempts to correct the regional bias in the component descriptions of the UL document without compromising safety.

Reaffirmation
public review copy

1 Introduction

1.1 Scope

The requirements of this Standard cover electrically powered theatrical fog generators rated 600 V or less, intended for use in professional live theatrical entertainment, professional film and video production, theme parks, and fire safety training, and to be used in accordance with the requirements of ANSI/NFPA 70, and the Canadian Electrical Code (CEC), Part 1, C22.1.

1.1.1 The theatrical fog generators that are the subject of this Standard use one or more of the following fluids.

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, liquified (LCO2, L-CO2)	124-38-9

Fog generators that use fog fluids not on this list are outside the scope of this Standard.

1.1.2 The aerosols created by the theatrical fog generators 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 are 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

Fog generators that use gases not on this list are outside the scope of this Standard.

1.2 Definitions

The following definitions apply in this Standard:

1.2.1 Alkane mineral oil, highly refined: water-clear white mineral oil, consisting almost entirely of saturated hydrocarbons (alkanes), lacking significant amounts of aromatic hydrocarbons, and suitable for use in medicines or food.

1.2.2 Class 2 Circuit: The portion of the wiring system between the load side of a Class 2 power source and the connected equipment. A Class 2 power source is limited to 0 to 20 volts at 100 watts or 5 amps; 21 to 30 volts at 100 watts or 3.3 amps; and 31 to 150 volts at 0.5 watts or 5 milliamps.

1.2.3 Current edition: The edition of a document that is current at the time the reader of this Standard is applying this Standard to the evaluation of a product.

1.2.4 Fog fluid: The liquid material that makes the droplets that are the aerosol called "fog."

1.2.5 Fog generator: A machine that is designed to create a liquid aerosol that simulates smoke, haze, or natural fog.

1.2.6 White mineral oil, medicinal or food grade: A highly purified oil consisting almost entirely of saturated alkanes and containing no significant amounts of aromatic hydrocarbons, suitable for use in medicines or food.

1.3 Referenced publications

When the following documents are referenced in the body of this Standard, these are the particular editions referenced. All are specific editions, except for the references to ANSI E1.5 and ANSI E1.14, which are to whatever editions of those standards are the current editions at the time the reader is using this Standard.

ANSI E1.5 - (current edition), Entertainment Technology - Theatrical Fog Made with Aqueous Solutions of Di- and Trihydric Alcohols

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

ANSI/NFPA 70 - 2008, National Electrical Code

ANSI/UL 998 - 2006, Humidifiers, the fourth edition with revisions through May 12, 2006

C22.1-06, Canadian Electrical Code, Part I

IEC 60228 Ed. 3.0 b:2004, Conductors of insulated cables

2 Requirements

2.1 General

The requirements for humidifiers specified in the referenced edition of ANSI/UL 998, Humidifiers, shall be used to evaluate the theatrical fog generators covered by this Standard, except as those requirements in the referenced edition of ANSI/UL 998 are modified by the clauses and subclauses in 2.2 of this Standard.

2.2 Modifications

2.2.1 Flexible power cords

2.2.1.1 Flexible power cords used on fog generators that are within the scope of this Standard shall be rated "Hard usage" or "Extra hard usage" per Table 400.4 of ANSI/NFPA 70.

2.2.1.2 All requirements in ANSI/UL 998 that pertain to SP, SPT, and SVT type flexible power cords are void.

2.2.1.3 A knot shall not be permitted as a strain relief for flexible power cords. Therefore, clause 22.4 of ANSI/UL 998 is void.

2.2.2 Conductor gauges

Conductor sizes in ANSI/UL 998 are given by specifying the cross sectional area equivalents in square millimeters of standard American Wire Gauge sizes. Common conductors per IEC 60228 are not available in sizes that exactly match the cross sectional areas listed in ANSI/UL 998. Therefore, the following common metric conductor sizes shall be considered equivalent to the conductor sizes specified in ANSI/UL 998 when evaluating fog generators that are within the scope of this Standard. Equivalents for gauges other than those shown or outside the scope of IEC 60228 shall be left to the discretion of the testing laboratory engineers.

UL 998 specified wire size	Acceptable common metric size if used in a Class 2 Circuit	Acceptable common metric size if not used in a Class 2 Circuit
No. 30 AWG (0.05 mm ²)	Outside the scope of IEC 60228	
No. 24 AWG (0.21 mm ²).		
No. 20 AWG	0.5 mm ²	0.75 mm ²
0.82 mm ² (18 AWG)	0.75 mm ²	1.0 mm ²
1.3 mm ² (16 AWG)	1.0 mm ²	1.5 mm ²
2.1 mm ² (14 AWG)	1.5 mm ²	2.5 mm ²
3.3 mm ² (12 AWG)	2.5 mm ²	4.0 mm ²
5.3 mm ² (10 AWG)	4.0 mm ²	6.0 mm ²
8.4 mm ² (8 AWG)	6.0 mm ²	10 mm ²
13.2 mm ² (6 AWG)	10 mm ²	16 mm ²
26.7 mm ² (4 AWG)	25 mm ²	25 mm ²
33.6 mm ² (3 AWG)	25 mm ²	35 mm ²
42.4 mm ² (0 AWG)	35 mm ²	50 mm ²
53.5 mm ² (1/0 AWG)	50 mm ²	50 mm ²
67.4 mm ² (2/0 AWG)	50 mm ²	70 mm ²
85.0 mm ² (3/0 AWG)	70 mm ²	95 mm ²
107.2 mm ² (4/0 AWG)	95 mm ²	120 mm ²

2.2.3 Screw fastener sizes

Some machine screw sizes in ANSI/UL 998 are often given in numerical gauges with no metric equivalent. The following standard metric fastener sizes shall be considered equivalent to the fastener sizes shown, when evaluating fog generators that are within the scope of this Standard and using the requirements of ANSI/UL 998. Equivalents for fastener sizes other than those shown shall be left to the discretion of the testing laboratory engineers.

American screw size	Metric size
No. 6	M3.5
No. 8	M4
No. 10	M5

2.2.4 Consideration of the effects of fog fluid on components

2.2.4.1 At every instance in which ANSI/UL 998 requires the evaluation of the effect of oil or grease on components, the components in a fog generator shall be evaluated for the effect of fog fluid on the components in addition to the effects of oil and grease.

2.2.4.2 At every instance in which ANSI/UL 998 requires the evaluation of the effect of water or moisture on components, the components in a fog generator shall be evaluated for the effect of fog fluid on the components in addition to the effects of water and moisture.

2.2.4.3 At every instance in which ANSI/UL 998 requires the evaluation of the effect of a fluid or the functioning of a fluid in a product, fog fluid shall be considered as a fluid the effect or functioning of which needs to be evaluated.

2.2.5 Fans shall be guarded regardless of mass and rotational speed

Fog generators that conform to this Standard shall have fans guarded against accidental contact by persons and guarded against the ejection of foreign objects that might fall into a fan, regardless of the fan mass and rotational speed. Clause 8.6 of ANSI/UL 998, which allows a fan to be considered to not need a guard if the mass and rotational speed are low enough, is void. Clause 8.6 is incompatible with the requirement of clause 8.4 of ANSI/UL 998, which requires a fan to be guarded to retain foreign objects that might fall into the fan and would otherwise be forcibly ejected. Low fan mass by itself is not protection against foreign object ejection.

2.2.6 Aerosol hygiene

2.2.6.1 Fog generators that use glycol, glycerin, or white mineral oil

The hygiene of the aerosols produced by fog generators that produce aerosols of glycol, glycerin, or white mineral oil (highly refined alkane oil), or any combination of these chemicals, with or without water, shall be evaluated by the tests described in clauses 2.2.6.1.1 through 2.2.6.1.3.

2.2.6.1.1 The fog generator and fluid shall be evaluated as a possible vector for harmful micro-organisms. Forty covered Petri dishes with sterile nutrient agar shall be distributed in 20 sampling pairs about a testing room. One of each of the pairs shall be uncovered and exposed to the air in the room for 20 minutes and then covered. Immediately following this, the fog generator being evaluated shall be used according to its user operating instructions to fog the same room to a concentration of twice the glycol and glycerin peak exposure limits stated in the current edition of ANSI E1.5, or to 50 mg/m³ for highly refined alkane mineral oil, as appropriate for the fog fluid used with the machine. The fog level shall be maintained for 20 minutes while the un-exposed Petri dishes of each of the pairs are uncovered and exposed to the fog for 20 minutes and then covered. All 40 Petri dishes shall be allowed to incubate at 20 degrees C for three days and then the Petri dishes shall be evaluated for bacteria and fungus growth. The Petri dishes exposed to the fog shall not have significantly larger fungus or bacterial colonies than the Petri dishes not exposed to the fog. The null hypothesis shall be that there is no significant difference between the two means of the two sets of samples. The null hypothesis shall not be rejected if the mean for the fog exposed samples is below the mean for the non-fog exposed samples, or if the mean is higher but the probability of the difference being attributable to chance is above 0.9. The fog generator produces an aerosol that is acceptable if the null hypothesis is not rejected. The fog generator and fog fluid combination shall be considered unlikely to be a vector of harmful micro-organisms if the null hypothesis is not rejected.

2.2.6.1.2 The fog generator shall be evaluated for the risk of producing harmful fog fluid decomposition products. The fog generator being investigated shall be used to fill a testing room according to its user operating instructions with fog to a concentration of twice the glycol and glycerin peak exposure limits in the current edition of ANSI E1.5, or to 50 mg/m³ for highly refined alkane mineral oil, as appropriate for the fog fluid used with the machine. The concentration of fog shall be kept at that level or above for 15 minutes, and during this time the air shall be sampled to determine the time-weighted average concentration levels of formaldehyde, acrolein, acetaldehyde and other possible hazardous products of thermal degradation. The fog produced shall be judged reasonably free from harmful decomposition products if these compounds are present at concentrations below the maximum permissible exposure levels for an eight-hour work day set by governing occupational health and safety authority for the nation or state where the product is intended to be used.

2.2.6.1.3 The tests described in 2.2.6.1.1 and 2.2.6.1.2 may be carried out at the same time in the same room.

2.2.6.1.4 The test described in 2.2.6.1.1 shall be judged to be unnecessary and the aerosol reasonably unlikely to be a vector for viable micro-organisms if the fog fluid is heated to 80 degrees C or above and held at that temperature for 5 minutes or longer before it is possible to generate fog, or if the fog fluid is heated to 70 degrees C or above and held at that temperature for 30 minutes or more before it is possible to generate fog. The fluid shall not decompose as a result of this heating; the fog generator must be tested per 2.2.6.1.2.

2.2.6.2 Fog generators that use heated water and no glycol, glycerin, or mineral oil

The hygiene of the aerosols produced by fog generators that produce fogs of water by processes that heat the water and store it in a tank and then create a fog by bringing the hot water or the water vapor above the hot water into contact with a cryogen shall be evaluated per clauses 2.2.6.2.1 and 2.2.6.2.2.

2.2.6.2.1 Forty covered Petri dishes with sterile nutrient agar shall be distributed in 20 sampling pairs on the floor of a testing room. One of each of the pairs shall be uncovered and exposed to the air in the room for five minutes and then covered. Immediately following this, the un-exposed Petri dishes of each of the pairs shall be uncovered and then exposed to a blanket of fog from the generator being tested and used according to its user operating instructions that covers the floor of the room for 5 minutes. The fog shall be dense enough that some of the Petri dishes are obscured from view when viewed by a person at two meters distance with standard room illumination from above at a level of 300 to 400 lux. The dishes shall then be covered. All 40 Petri dishes shall be allowed to incubate at 20 degrees C for three days and then the Petri dishes shall be evaluated for bacteria and fungus growth. The Petri dishes exposed to the fog shall not have significantly larger fungus or bacterial colonies than the Petri dishes not exposed to the fog. The null hypothesis shall be that there is no significant difference between the two means of the two sets of samples. The null hypothesis shall not be rejected if the mean for the fog exposed samples is below the mean for the non-fog exposed samples, or if the mean is higher but the probability of the difference being attributable to chance is above 0.9. The fog generator produces an aerosol that is acceptable if the null hypothesis is not rejected.

2.2.6.2.2 The test described in 2.2.6.2.1 shall be judged to be unnecessary and it shall be permissible to judge the aerosol reasonably free from being a vector for viable micro-organisms if

- (a) the water is heated to 80 degrees C or above and held at that temperature for at least 5 minutes or if it is heated to 70 degrees C or above and held for at least 30 minutes before fog is generated;
- (b) the user operating instructions cite the importance of this temperature and holding period and caution the user not to attempt to generate fog with water at a lower temperature or water that has not been held for the full length of time for that temperature; and
- (c) the fog generator's user operating instructions state that only potable water shall be used in the fog generator.

2.2.6.3 Fog generators that use unheated water and no glycol, glycerin, or mineral oil

The hygiene of the aerosols produced by fog generators that produce fogs of water without heating the water shall be evaluated per clauses 2.2.6.3.1 and 2.2.6.3.2.

2.2.6.3.1 Forty covered Petri dishes with sterile nutrient agar shall be distributed in 20 sampling pairs on the floor of a testing room. One of each of the pairs shall be uncovered and exposed to the air in the room for five minutes and then covered. Immediately following this, the un-exposed Petri dishes of each of the pairs shall be uncovered and then exposed to a blanket of fog from the generator being tested and used according to its user operating instructions that covers the floor of the room for 5 minutes. The fog shall be dense enough that it can be seen to be wafting over the Petri dishes when viewed by a person at two meters distance with standard room illumination from above at a level of 300 to 400 lux. The dishes shall then be covered. All 40 Petri dishes shall be allowed to incubate at 20 degrees C for three days and then the Petri dishes shall be evaluated for bacteria and fungus growth. The Petri dishes exposed to the

fog shall not have significantly larger fungus or bacterial colonies than the Petri dishes not exposed to the fog. The null hypothesis shall be that there is no significant difference between the two means of the two sets of samples. The null hypothesis shall not be rejected if the mean for the fog exposed samples is below the mean for the non-fog exposed samples, or if the mean is higher but the probability of the difference being attributable to chance is above 0.9. The fog generator produces an aerosol that is acceptable if the null hypothesis is not rejected.

2.2.6.3.2 The test described in 2.2.6.3.1 shall be judged to be unnecessary and it shall be permissible to judge the aerosol reasonably unlikely to serve as a vector for microorganisms if the water used for the fog is taken directly from a source of potable water known to be free of legionella pneumophila without being stored within a tank or bladder in the fog generator for longer than 12 hours. In addition, the user operating instructions must state these requirements that the water be potable and free of legionella pneumophila and that, if a holding tank or bladder is used, that the holding tank or bladder must be cleaned at least every 12 hours, or its contents entirely consumed in 12 hours or less, or its contents be filtered and disinfected at an interval sufficient to ensure that microbe contamination is limited to levels lower than those permissible in potable water and is free of legionella pneumophila.

2.2.7 Markings and warnings

Clauses 20.18, 31.2.2, 40.6, 75.19, 75.23, 75.25, 75.26, 75.27, 75.29, 76.1.1, 76.1.2, 76.1.4, 78.1, 78.2, 78.5, and 78.9 in the referenced ANSI/UL 998 give warnings and cautionary notices in English that are to be marked on the product, printed on an instruction sheet, or in some other way conveyed to the end-user or service person. Annex B gives French translations for these warning phrases. It shall be acceptable to present the warnings in other languages besides English and French if the intended audience does not read English or French, as long as the translations adequately convey the same information and sense of urgency and importance as the English warnings and cautions.

2.2.8 User operating instructions

User operating instructions or user manuals shall be provided with the product and shall conform to the current edition of ANSI E1.14. It shall be acceptable to publish the user manual in a language in addition to English if the intended audience does not read English. That second language shall be the language of the intended audience.