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Theatrical Fog Exposure Assessment Methods, Exposure Limits, and Health Effects – Literature Review

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Executive Summary

There has been considerable research and interest regarding the use of glycols, glycerol, and mineral oil to produce special atmospheric effects such as fog, haze, and artificial "smoke" in the entertainment industry over the past twenty years. In this report, we refer to fog, haze, and artificial smoke as theatrical or atmospheric fog.

In 1997, the Entertainment Services & Technology Association (ESTA) commissioned two literature reviews for specific glycols and glycerol. In 2003, ESTA published a standard addressing theatrical fog ingredients and exposure limits. This standard was approved as an American National Standard by the American National Standards Institute (ANSI), and is designated ANSI Standard E1.5. The standard was revised in 2009 and re-affirmed in 2014.

On behalf of the Phylmar Group, Colden Corporation reviewed and consolidated historical information up to and including the two original ESTA reviews, as well as more recently-published exposure limits, and toxicological and epidemiological literature. In this report, we evaluate the appropriateness of the exposure limits recommended in ANSI Standard E1.5, describe an approach to assessing exposures, and provide further recommendations to minimize adverse health effects.

Our review addresses adult employee exposures to fog throughout the entertainment production industry; including live theater, concerts, television, and motion pictures. Our conclusions may not be applicable to child actors and all audience members.

We included 11 ingredients in this review: nine specific glycols, glycerol, and highly-refined mineral oil. These ingredients are listed on Safety Data Sheets (SDSs) for fogging fluids, included in the 1997 ESTA-commissioned reviews, and/or listed in the ANSI Standard. Based on exposure limits and potential adverse health effects, we recommend not using three of the nine glycols, unless additional evaluation and exposure control planning are performed. One of the three glycols we recommend not using (diethylene glycol) is listed in the current ANSI standard and occurred on two out of approximately 20 SDSs for fogging fluids. One glycol (polyethylene glycol), we recommend can be used, although it is not listed in the ANSI Standard.

Toxicological Studies

As a group, the six glycols that we recommend using and glycerin exhibit low acute and sub-acute toxicity in animal models and are generally characterized as mucous membrane irritants. However, animal studies for diethylene glycol, ethylene glycol, and 1,4-butylene glycol revealed concerning health effects, and we recommend not using fogging fluids containing these ingredients.

Mineral oil mists from highly refined oils, containing no additives or contaminants, also have a low acute and sub-acute toxicity in animals. We do not recommend using mineral oil other than highly-refined. Untreated or mildly treated mineral oil distilled from petroleum can contain toxic impurities.

Epidemiologic Studies

Epidemiologic studies to date have revealed increased prevalence of acute respiratory symptoms including nasal, respiratory, and mucous membrane effects associated with exposure to concentrations below the existing occupational exposure limits set forth in the ANSI E1.5 2009 (2014). The studies further identify inflammation and irritation effects associated with longer exposures to peak glycol concentrations and hypothesize that exposures to "short term" peak concentrations of fog throughout a show may be responsible for the irritation effects uncovered in the actors exposed to fog.

More recent studies conducted by Teschke and Varughese (2005), indicate that the prevalence rates for most chronic respiratory symptoms were higher amongst the entertainment industry employees examined when compared to the reference group. Acute symptoms (cross-shift) including upper airway and voice symptoms were significantly associated with total fog concentration, regardless of its type, oil or glycol even when exposure concentrations did not exceed occupational exposure limits. Evidence of an exposure-response relationship was demonstrated in this study between increasing cumulative measures of fog exposures for both types, and an increased reporting of work-related wheezing and chest tightness, and a decrease in forced vital capacity (FVC).

All of these authors similarly demonstrate the existence of irritation symptoms at concentrations below the existing ANSI long-term average occupational exposure limit of 10 mg/m^3. What remains somewhat unclear is how the exposures to theatrical fog component peaks, both concentration and frequency, are related to the acute and chronic effects noted. There does not appear to be sufficient evidence to recommend a lower exposure limit at this time, however, more effort should be placed on monitoring and ensuring compliance with the existing peak exposure limits outlined in ANSI E1.5 2009 (2014).

Exposure Limits

For the six specific glycols we recommend for continued use and glycerol, we recommend continued, but conditional application of the total aerosol based exposure limits provided in ANSI Standard E1.5. The ANSI standard provides an eight-hour, time-weighted average (TWA) limit of 10 milligrams per cubic meter of air (mg/m^3); and peak limits of 40 and 50 mg/m^3 for glycols and glycerol, respectively.

The ANSI standard does not define averaging times for the peak limits, and does not address extended work shifts (beyond eight-hours). We recommend adjusting the long-

term limit lower based on work shifts exceeding eight hours, and limiting peak exposures based on a one-minute average.

The ANSI standard does not address mineral oil. For long-term exposure to mineral oil, we recommend applying the Threshold Limit Value (TLV) of 5 mg/m^3, which is provided by the American Conference of Governmental Industrial Hygienist (ACGIH) for highly-refined mineral oil. This limit is based on an eight-hour, TWA exposure; and we recommend lowering this TLV based on extended work shifts. We also recommend limiting peak mineral oil exposures to 25 mg/m^3 based on one-minute average exposure. For agents without short-term exposure limits, ACGIH recommends limiting peak exposures to within five times TWA limits.

For the ingredients recommended for use in this report, published literature and available data indicate that controlling total aerosol concentrations within the limits discussed above will prevent exposures to the thermal decomposition byproducts such as formaldehyde from exceeding occupational limits. However, we recommend minimizing temperature settings on fogging machines to the extent feasible as good practice.

For additional ingredients not reviewed in this report, we recommend following available regulatory- and consensuses-based exposure limits, with consideration for the effects of mixtures and extended work shifts.

The available literature, although considerable, does not fully investigate all relationships among exposures and potential health effects. For example, there are no toxicological studies evaluating possible synergistic and additive effects among ingredients and byproducts in mixtures. Health effects based on the frequency and intensity of peak exposures compared with long-term exposures are also not well understood. Therefore, we recommend where practical, that productions put forth effort to minimize exposures below recommended limits.

Exposure Assessment

To anticipate and evaluate exposures for comparison with limits, we recommend an exposure assessment process each time fog is used. This process involves first performing a qualitative assessment weighing risk factors such as fog generation rate, ventilation, space volume, and exposure generation. If risk factors are low, then the qualitative assessment may conclude exposures are unlikely to exceed limits, and no further action is necessary. If it cannot be concluded with confidence that exposures will remain under recommended limits, then controls to reduce exposures and air monitoring should be considered.

Once it is verified that fogging ingredients are limited to those recommended in this report, direct-reading, real-time air monitoring can be performed using readily-available aerosol meters to compare concentrations with the exposure limits recommended in this report, and expressed simply as total aerosol concentrations. Obtaining real-time data

facilitates implementing controls on-site to avoid exceeding limits. However, it is essential to develop custom correlation factors based on specific sets of parameters including the monitoring instrument make and model, fogging fluid, and fogging machine. Available correlations show the need for significate correction.

More complex air monitoring involving laboratory analysis may be necessary to characterize exposures where fogging fluid ingredients do not match ingredients addressed by this review, and where custom correlation factors are not available.

Air sampling strategies should include personal breathing-zone and area sampling. There are challenges to personal monitoring in the production industry due to interferences created by sampling equipment.

1.0 Introduction

There has been considerable research and interest regarding the use of glycols, glycerol, and mineral oil to produce special atmospheric effects such as fog, haze, and artificial "smoke" in the entertainment industry over the past twenty years. In 1997 the Entertainment Services & Technology Association (ESTA) commissioned two literature reviews for specific glycols and glycerol. In this report, we consolidated historical information regarding these ingredients, and augment the data with information produced and published in previous reviews and more recently published literature.

First, a review of the toxicological and epidemiological information regarding the health effects associated with fogging fluids is presented. The occupational exposure limits set forth by United States and international governmental and non-governmental agencies is summarized.

Second, a review of the fogging materials currently in use will be presented with recommendations for practical real-time monitoring strategies to ensure compliance with occupational exposure limits.

In this report, we refer to fog, haze, and artificial smoke as theatrical fog. Our review is not limited to theatrical productions. This report addresses the use of fog throughout the entertainment industry including live theater, concerts, television, and motion pictures.

This report is focused on adult employee exposures. Our conclusions may not be applicable to child actors and audience members.

Devices, referred to as fog machines, work by either condensing vapor generated by heating liquid fogging fluid, or by mechanically generating aerosols directly from liquids. The fog consists of small liquid aerosols suspended in air. The aerosols include the same ingredients as the fluids used in the machines. The fog is not real smoke, soot, or char. It is not generated by thermal decomposition or burning of fluid ingredients, although a small amount of thermal decomposition byproducts may be produced during the process of heating the fluid prior to condensation.

1.1 Overview of Fogging Fluid Ingredients

The most common ingredients in theatrical fog include glycols, glycerol, and highly-refined mineral oil. Glycols include multiple straight-chain (aliphatic) alcohols having two hydroxyl (OH) groups. Ethylene glycol, commonly referred to as glycol, and propylene glycol are examples. Glycerol is a specific chemical with three carbons and three hydroxyl groups (CAS No. 56-81-5), and is similar to glycols. Glycerin is a synonym for glycerol.

Mineral oil is a mixture of alkanes (saturated aliphatic hydrocarbons) containing only carbon and hydrogen, with no substitutions or functional groups. There is an important

difference between highly-refined mineral oil, and mineral oil distilled from petroleum, but not highly-refined. Mineral oil that is not highly refined (untreated or mildly treated) can contain toxic impurities, including carcinogens. Highly refined mineral oils are used in foods and cosmetics.

The following table summarizes ingredients addressed by the 1997 HSE review and the current ANSI standard, compared with ingredient prevalence on SDSs for current fogging solutions used in the entertainment industry. The column entitled SDS Occurrence indicates how many SDSs on which the ingredient was listed out of the 21 SDSs we reviewed.

Table 1. Fogging Fluid Ingredients

Ingredient	CAS Number(s)	Address by 1997 HSE Review?	Listed in ANSI E1.5 (2014)?	SDS Occurrence
1,3-Butylene Glycol	107-88-0	No	Yes	4
1,2-Butylene Glycol	584-03-2	No	Yes	0
Propylene Glycol	57-55-6	Yes	Yes	12
Triethylene Glycol	112-27-6	Yes	Yes	12
Polyethylene Glycol	25322-68-3	No	No	2
Dipropylene Glycol	25265-71-8, 106-62-7, 110-98-5, 108-61-2	Yes	Yes	2
Glycerin	56-81-5	Yes	Yes	2
Diethylene Glycol[a]	111-46-6	Yes	Yes	2
Ethylene Glycol[a]	107-21-1	No	No	1
1,4 Butylene Glycol[a]	110-63-4	Yes	No	0
Highly Refined Mineral Oil	8042-47-5	No	No	1

(a) Recommend not using without further evaluation and exposure control planning, due to low or lack of exposure limits, or based on toxicology studies.

As indicated in Table 1, three glycols were not addressed in the 1997 HSE review, but were found on multiple SDSs for current fluids. 1,4-butylene glycol was addressed by the 1997 review, but was not listed as an ingredient on our current list of SDSs.

Mineral oil was not addressed in the 1997 HSE report or the ANSI standard, but is included in this review.

2.0 Toxicology of Fogging Fluid Ingredients

The "Literature Review for Glycerol and Glycols" prepared by HSE Consulting and Sampling, Inc. for the Entertainment Services and Technology Association in 1997 summarized in detail the toxicological properties of five specific glycols and glycerol.

For each of the compounds listed below, a brief summary of the toxicity of the specific compound is provided. The summaries highlight relevant historical information and new studies since 1997 regarding human skin, eye, and mucous membrane irritation, along with available human inhalation toxicology. If there are no human data to rely upon, select animal studies have been summarized.

To develop the list of fogging fluid ingredients addressed by this report, we reviewed ingredients listed on Safety Data Sheets (SDSs) for 21 different fluids. We also included all compounds addressed by the 1997 review.

Petroleum distillates (CAS no. 64742-54-7), soybean oil, and frankincense each appeared on only one SDSs, and we did not include these three items in this review. Use of petroleum distillates is discouraged in Safety Bulletin No. 10, 1999; and Actsafe Bulletin, 2016. It is also important to note that Safety Bulletin No. 10, 1999 also discourages the use of mineral oil, ethylene glycol and diethylene glycol.

We included ethylene glycol, polyethylene glycol, 1,3 butylene glycol and highly-refined mineral oil in this study, but these compounds were not addressed by the 1997 review. 1,4-butylene glycol was addressed by the 1997 review, but was not listed as an ingredient in any of the SDSs we reviewed during this project.

2.1 1,3-Butylene Glycol (107-88-0)

Butylene glycol is a strong eye irritant. When applied to the human eye it causes immediate sever stinging, but irrigation with water brings rapid complete relief. It is not irritating to the mucous membranes or skin, but allergic skin reactions may occur in certain people (HSDB, 2017).

There are no reported human inhalation toxicology studies. However, an eight-hour inhalation exposure of 292 milligrams per cubic meter (mg/m^3) of butylene glycol had no lethal effect on rats (ECHA, REACH Registration, 2015).

2.2 Ethylene Glycol (107-21-1)

Ethylene glycol induced minimal dermal irritation, while nasal and or throat irritation were reported in a small number of subjects inhaling ethylene glycol, while higher concentrations caused eye irritation (HSDB, 2012; Lewis et al., 2004). Grant (1986) reported that exposure of human eyes to vapor or aerosol of ethylene glycol at a concentration of 17 mg/m^3 for four weeks resulted in no effects.

In a study of twenty human volunteers exposed to continuous aerosol ethylene glycol ranging from mean daily concentrations of 3.56 to 68.6 mg/m^3 for 20 to 22 hours/day in exposure chambers for four weeks, participants complained of throat irritation and headache. At 140 mg/m^3, there was more pronounced irritation of the upper respiratory tract, and at 203 mg/m^3 of aerosol, the irritation and cough were considered intolerable.

Exposure to 308 mg/m^3 was intolerable, even for a brief period. Blood and urine samples were examined for ethylene glycol and its metabolites and physiological indicators collected during exposure showed no significant difference from 14 unexposed controls (Wills et al., 1974).

2.3 Diethylene Glycol (111-46-6)

Diethylene glycol (112 mg) applied to human skin for three days following the standard Draize protocol resulted in a mild reaction to the skin (European Chemicals Bureau, 2000). Following a patch test on humans, it was determined that diethylene glycol is not sensitizing (European Chemicals Bureau, 2000). Diethylene glycol is not appreciably irritating to the eyes or skin (Bingham, et al., 2001).

Subchronic and prechronic inhalation exposure of rats and mice to diethylene glycol at 5 mg/m^3 for 3-7 months showed structural changes in the central nervous system and endocrine and internal organs along with other pathological effects (Marchenko, 1973).

2.4 Propylene Glycol (57-55-6)

Propylene glycol is not acutely toxic and is essentially nonirritating to the skin and mildly irritating to the eyes (HSDB, 2010). Numerous studies indicate that propylene glycol is not a skin sensitizer (Cosmetic Ingredient Review Expert Panel, 1994; Organization for Economic Cooperation and Development, 2009).

Wieslander and colleagues (2001) exposed twenty seven non-asthmatic volunteers to propylene glycol mist over one minute, during exercise. The geometric mean exposure was 309 mg/m^3, with the highest concentrations in the afternoon. Medical evaluations were conducted before and directly after exposure sessions. The exam included an estimate of tear film stability break up time, nasal patency by acoustic rhinometry, dynamic spirometry and a physician's administered questionnaire on symptoms. After exposure to propylene glycol mist, for one minute, tear film stability decreased, ocular and throat symptoms increased, force expiratory volume in 1 second and forced vital capacity (FEV1/FVC) were slightly reduced, and self-rated severity of dyspnea was slightly increased. No effect was found for nasal patency, vital capacity, FVC, nasal symptoms, dermal symptoms, smell of solvent or any systemic symptoms. Those exposed to the higher concentrations in the afternoon had a more pronounced increase of throat symptoms, and a more pronounced decrease of tear film stability. In four subjects who reported development of irritative cough during exposure, FEV1 was decreased by 5%, but FEV1 was unchanged among those who did not develop a cough. Those who developed a cough also had an increased perception of mild dyspnea. The authors conclude that short exposure to propylene glycol mist from artificial smoke generators may cause acute ocular and upper airway irritation in non-asthmatic subjects. A few may also react with cough and slight airway obstruction.

2.5 Triethylene Glycol (112-27-6)

Triethylene glycol has a very low order of acute toxicity by all routes including inhalation of vapor and aerosol phases. It does not produce primary skin irritation. Acute eye contact with the liquid causes mild local transient irritation but does not induce corneal injury. Multiple studies have concluded that triethylene glycol does not cause skin sensitization (HSDB, 2007).

A nine day repeated study of rats exposed to whole body aerosols of triethylene glycol at concentrations of 0, 494, 2,011 and 4,824 mg/m^3 for six hours per day was conducted. Mortalities occurred at 4,824 mg/m^3 between exposure days two and five. Nonspecific indications of toxicity at 2,011 mg/m^3 were signs of irritation, decreased body weight and increased food and water consumption. At 494 mg/m^3, there were minimal signs of irritation, increased water consumption and slightly increased alkaline phosphatase. A no observable adverse effects level (NOEL) could not be established (Ballantyne et al., 2006).

2.6 Dipropylene Glycol (110-98-5)

Dipropylene glycol has not caused significant eye irritation or injury when tested in the eyes of rabbits and has caused negligible irritation when applied repeatedly (10 applications in 12 days) to the skin of rabbits (Bingham et al., 2001).

There are no human inhalation toxicology studies to report on. Dipropylene glycol vapor and aerosol was examined for acute inhalation toxicity. An aerosol atmosphere of 6,000 to 8,000 mg/m^3 was not lethal to rats or guinea pigs, but vaporized degradation products produced by heating dipropylene glycol to 170°C was lethal to five of six rats exposed for eight hours. No mortality occurred from vapors generated at 120°C. Pathologic abnormalities were not observed in any of the animals (OECD; SIDS Initial Assessment Report for Dipropylene Glycol, 2014).

2.7 Polyethylene Glycol (25322-68-3)

Polyethylene glycol has been used safely as a bowel preparation for decades. Polyethylene glycol administered topically may cause stinging, especially when applied to mucous membranes with reports of hypersensitivity reactions to polyethylene glycols applied topically, including urticaria and delayed allergic reactions (Rowe et al., 2009).

The potential for polyethylene glycol to produce toxicity in rats when exposed to aerosols in a two week exposure regimen was investigated. Rats, eight weeks old at the start of the exposure received whole body exposures (maximum concentration tested, 1,008 mg/m^3) for six hours a day, five days a week for nine exposures during an eleven day period of the two week study. No exposure related clinical signs or ophthalmic changes were noted and no mortality was recorded during the study. The only toxicologically significant organ weight changes were in the lung with significant increases being noted

in absolute and relative lung weight values for both sexes. Histologic lesions were generally minimal to mild in severity and consisted of alveoli containing macrophages with foamy vacuolated cytoplasms. No indication of cellular necrosis or necrotic debris was present in the lung. The findings indicated minimal toxicological occurrences resulting from exposures at mean concentrations of up to 1008 mg/m^3 (Klonne et al., 1989).

2.8 1,4-Butylene Glycol (110-63-4)

It is reported that 1,4-butylene glycol is about eight times as toxic as 1,2-butylene glycol (International Labor Office, 1971) although oral and inhalation toxicology would indicate otherwise. Gauze patches with undiluted 1,4-butylene glycol were applied to the intact and abraded skin of rabbits with occlusive dressing for 24 hours with no reaction in any group after 72 hours (Organization for Economic Cooperation and Development, 2000). When 1,4-butylene glycol was administered to the right conjunctival sac of rabbits, slight reddening of the conjunctiva and small amounts of discharge were observed after one hour with resolution in 48 hours (Organization for Economic Cooperation and Development, 2000).

Inhalation studies were conducted to determine single and repeated exposure responses in rats to 1,4-butylene glycol. In the acute exposure study, male rats were exposed for single four hour periods to 4.6, 9.4, or 15 mg/L 1,4-butylene glycol and sacrificed at 14 days. All rats survived 14 days except for one rat exposed to 15 mg/L that died one day post exposure. 1,4-butylene glycol was considered to be only slightly toxic following acute exposure. In the repeat exposure studies, rats received nose only exposures of 0.20, 1.1, and 5.2 mg/L for six hours/day, five days/week for two weeks. After the tenth exposure and after a two week recovery period, pathological and clinicochemical determinations were made. Although no adverse effects were exhibited by the two lower exposure groups, the highest exposure group exhibited depressed body weight after the third treatment, and increased erythrocyte count and hematocrits along with decreased serum cholesterol concentrations after the last exposure, as well as atrophy of lymphoid cells in the thymus and depressed heart weight. No adverse effects were seen after two weeks of recovery. Both 0.2 and 1.1 mg/L were considered to be the no adverse effects concentrations with the highest concentration associated with reversible systemic effects (Kinney, 1991).

2.9 1,2-Butylene Glycol (584-03-2)

Eye contact with 1,2-butylene glycol may result in corneal injury, but even prolonged skin contact is usually innocuous with respect to primary irritation and absorption toxicity. No adverse effects of vapor inhalation have been reported. (International Labour Office, 1971). No additional toxicological data is available.

2.10 Glycerol (56-81-5)

Glycerol has been considered safe for use in pharmaceutical preparations for decades and is generally considered nontoxic. In human eyes, specular microscopy has shown that repeated applications of glycerol to the surface of the eye causes extensive changes in the appearance of the endothelium, but most of the changes disappeared within 90 minutes after exposure is ended (Grant, 1986). Additionally, the dermal application of 0.5 ml glycerol to rabbit skin for 24 hours did not lead to signs of irritation 24 and 72 hours after application (United Nations Environment Programme, 2009).

Nose only exposure of rats to inhalation exposures of glycerol at concentrations of 0, 33, 165 and 662 mg/m^3 led to decreased triglyceride levels in males at concentrations of 33 and 165 mg/m^3. This effect appears to be of little toxicological significance as there was no dose-response relationship and was seen only in males. There were no treatment related effects on cage side observations, hematology, organ weights or gross pathology Microscopic evaluation of the tissue showed "minimal" or "mild" squamous metaplasia of the epiglottis in 11 animals in total at the highest concentrations. Because the effects on triglycerides did not show a relationship with concentration, was seen in males only and in the absence of any systemic target organ toxicity, the biological relevance of this effect is not considered to be of toxicological significance. Based on an increased incidence of "minimal" to "mild" squamous metaplasia of the epiglottis, the NOACE for local irritant effects to the upper respiratory tract is 165 mg/m^3 and 662 mg/m^3 for systemic effects (United Nations Environment Programme, 2002).

2.11 Highly Refined Mineral Oil (8042-47-5, 8012-95-1)

Mineral oil mists from highly refined oils, containing no additives or contaminants, have a low acute and low sub-acute toxicity in animals (ACGIH, TLV Documentation Mineral Oil, 2010). Numerous animal studies have shown that single and short term (four-months to one year) inhalation exposure to relatively high concentrations, ranging from 50 mg/m^3 to 1500 mg/m^3 have resulted in small increases in macrophage number and protein in lavage fluid, neutrophil influx and a mild thickening of the alveolar walls (Dalbey et al., 1991, 2001, 2003; Selgrade et al., 1987, 1990).

3.0 Epidemiologic Research Summary

Several epidemiologic studies have been conducted over the years in various settings examining various health endpoints. Those studies are summarized below in chronologic order.

3.1 NIOSH, Health Hazard Evaluations

NIOSH representatives began this Health Hazard Evaluation (HHE) in 1991 and completed an interim report numbered 90-0355. A follow up study was conducted in 1993 and a final revised report numbered 90-0355-2449 was issued.

3.1.1 Burr et al., 1994 (HETA 90-0355, 1991)

For the initial 1991 survey, air monitoring was conducted at four Broadway productions and consisted of personal breathing zone (PBZ) and general area (GA) samples on actors, stage managers, and stage crew members (Burr et al., 1994). A total of 120 samples were collected for glycols including; ethylene, propylene, 1,3-butylene, diethylene and triethylene glycol. Samples for potential decomposition products of glycol fogs including; acrolein, acetaldehyde and formaldehyde were also collected. Air monitoring for oil mist was conducted at one show.

To assess the potential health effects associated with exposure to theatrical fog, 134 actors from the four shows using theatrical fog completed health questionnaires. An additional 90 actors were recruited from five shows not using theatrical fog for comparison and asked to complete the same health questionnaire. The questionnaire solicited information regarding the frequency and severity of irritant and respiratory symptoms experienced during performances, and was delivered one week prior to the air monitoring. Each actor was asked background information concerning age, length of time as a professional actor, length of time in the current production, smoking stats and their present health status. Each actor was also asked whether or not they had experienced any of 17 irritant and respiratory symptoms during performances the previous week and asked to rate them for frequency and severity. Symptoms were divided up into upper respiratory tract, lower respiratory tract and an eye symptom. If a participant reported experiencing two or more of a group's symptoms, sometimes, often or always, they considered the symptom present. This group's experience was then compared to the experience of the actors working in productions without theatrical fog. To assess the prevalence of chronic bronchitis in both populations of actors, the frequency of cough producing phlegm was analyzed among all non-smokers.

Unfortunately, NIOSH subsequently determined that their method of sampling for ethylene glycol (NIOSH 5500) was not adequate to detect other glycols and that interferences from other glycols may affect the primary ethylene glycol analysis. The results from this sampling are therefore not reported.

Acrolein and acetaldehyde were not detected in any of the air samples collected in the theaters during this study. Formaldehyde was detected in 10 of the samples collected. The total number of samples collected is not noted. The ten samples collected in the theater with detectable quantities of formaldehyde ranged from 0.05 parts per million (ppm) to 0.02 ppm. Background concentrations of formaldehyde were measured at 0.02 ppm outside two of the theaters. All samples were less than the current 0.75 ppm 8-hour time weighted average (TWA) Occupational Safety and Health Administration (OSHA) Permissible Exposure Limit (PEL), the American Conference of Governmental Industrial Hygienists (ACGIH), Threshold Limit Value (TLV) of 0.1 ppm as an 8-hour TWA and the WorkSafe BC OEL of 0.3 ppm as an 8-hour TWA.

Oil mist sampling was conducted during one dress rehearsal for one show. The thirteen PBZ and three GA sample results ranged from non-detect to 1.35 mg/m^3 as a time weighted average over the duration of the 2.5 hour play. All results were less than the current 5 mg/m^3 8-hour TWA OSHA PEL, which is also the ACGIH TLV for highly-refined mineral oil, as well as the Quebec and Alberta OEL for mineral oil. However, not all samples were less than the WorkSafe BC OEL of 1 mg/m^3.

The authors summarize the following from the questionnaire data analysis, "When compared to actors from the non-"smoke" productions, actors from two or more of the four productions utilizing theatrical "smoke" reported experiencing a significantly greater prevalence of nasal symptoms (sneezing, runny or stuff nose), respiratory symptoms (cough, wheeze, breathlessness, chest tightness), and mucous membrane symptoms (sore throat, hoarseness, dry throat, itchy/burning eyes, dry eyes) during their performances for the week prior to the survey."

Although the concentrations of all stressors monitored were less than all existing US occupational exposure limits, there was a statistically significant increase in mucous membrane irritative symptoms and prevalence of cough, shortness of breath, wheezing and chest tightness amongst those working in the shows utilizing fog compared to actors working in shows without fog. The authors hypothesize that exposures to "short term" peak concentrations of fog throughout a show may be responsible for the irritation effects uncovered in the actors exposed to fog.

The authors do not go into their recruiting strategy for the questionnaire participants in detail in the HHE. Table 7 outlines the participation rates by show. The overall participation rates are relatively low leaving open a concern for recruiting bias. If individuals knew that the health effects of theatrical fog were being investigated, they may have been more or less interested in completing the questionnaire, with those perhaps experiencing more symptoms being overrepresented in the response groups. This may also introduce recall bias among those exposed to fog with an increased reporting of symptoms among those knowing they were exposed. A comparison of a few basic demographic characteristics among the participants and non-participants in each show would have been illustrative. This comparison would have helped to determine if the questionnaire respondents were similar to the non-respondents, and were representative of the shows population.

3.1.2 Burr et al., 1994 (HETA 90-0355-2449, 1993)

In 1993, a follow up study was initiated and consisted of two phases. In the first phase, individuals with screening symptoms suggestive of occupational asthma were recruited from three shows using fog and three shows not using fog. In the second phase of the follow up a case-control study was conducted in which all symptomatic performers and a random sample of non-symptomatic performers were invited to participate.

Ethylene glycol, propylene glycol, triethylene glycol, 1,3-butylene glycol, total volatile organic compounds, formaldehyde and acrolein were sampled in the three shows identified, with oil mist only sampled in the one show where it was used.

Ethylene glycol was detected in samples from two of the three shows at 0.4 mg/m^3 or less. Propylene glycol was detected in samples from all three productions ranging from <0.01 to 1.9 mg/m^3. Triethylene glycol and 1,3-butylene glycol were detected only in one production and ranged from <0.04 to 3.7 mg/m^3 and 0.16 to 2.1 mg/m^3 respectively. Formaldehyde concentrations ranged from <0.002 to 0.04 ppm which are all less than the current 8-hour TWA OSHA PEL of 0.75 ppm, ACGIH TLV of 0.1 ppm and the WorkSafe BC OEL o.f 0.3 ppm. Acrolein was not detected in any samples. Oil mist concentrations were all less than 0.13 mg/m^3, which is less than the 8-hour TWA OSHA PEL and ACGIH TLV for highly refined mineral oil, as well as the Quebec and Alberta OEL for mineral oil. However, not all samples were less than the WorkSafe BC OEL of 1 mg/m^3.

Thermal desorption of the three-layered thermal desorption tubes for volatile organic compounds revealed only two samples from one production with even modest concentrations, levels of compounds detected on all other samples were very low.

The case-control study recruited 37 symptomatic and 68 non-symptomatic performers for analysis. All participants were asked to complete a detailed work history and health questionnaire. They were also asked to perform peak expiratory flow measurements using portable flow meters. Of the 105 participants, 62% submitted at least a partial questionnaire or peak expiratory flow rate (PEFR) information. Five performers met the case definition of for theatrical work-related occupational asthma. Three of these five were exposed to theatrical fog and two were not. The odds ratio for the association between a base and exposed to fog was 1.0 (95% confidence interval, 0.1 – 13.1). This indicates that performers with asthma-like symptoms and abnormal PEFR results were not more likely to have been exposed to theatrical "smoke" when compared to persons who do not meet the case definition.

The authors then conclude that, "Based on the results of this study, there is no evidence that theatrical "smoke", at the levels found in the theaters studied, is a cause of occupational asthma among performers. Nevertheless, some of the constituents of theatrical "smoke" (such as glycols), have irritative or mucous membrane drying properties. It would therefore be reasonable to modify the factors which may influence a performer's exposure to the "smoke"."

3.2 Moline et al., 2000

Moline and colleagues examined the potential for health effects in Broadway theater actors as a result of exposures to theatrical, smoke, haze and pyrotechnics (Moline et al., 2000). Based upon toxicology studies and previous epidemiologic reports noting a lack of systemic effects, these authors focused on local irritant effects of the respiratory tract

and eyes. The questionnaire collected information on actors' and stage managers' background, symptoms, activities, and medical information. Medical evaluations to examine Actors' upper airways, voice and respiratory tract before and after a performance using theatrical smoke, haze and pyrotechnics were also conducted.

The health effects evaluations were combined with detailed exposure assessments employing integrated exposure measurements over the course of a full performance, as well as direct reading instruments to determine short term and peak exposures. Integrated exposures to glycol were assessed using NIOSH Method 5523 and a strategy using personal and area air sampling. Integrated exposures to mineral oil were assessed using NIOSH Method 5026 and a strategy using personal and area air sampling. Real-time monitoring for particulates was conducted with a MIE personal/DataRAM Model PDR-1000 capturing 15 second exposure averages. Average glycol concentrations ranged from 0.10 to 7.2 mg/m^3, and mineral oil airborne concentrations ranged from 0.001 to 68 mg/m^3 across all shows. A more detailed review of the exposure assessment techniques employed in this study is reviewed in Section 6.0.

The authors recruited 439 actors performing in 16 different Broadway musicals. Overall the authors reported no significant acute changes in voice quality, pulmonary function, or vocal cord appearance among actors exposed to theatrical smoke, haze or pyrotechnic agents. The authors noted an association between peak glycol exposures and more mucous membrane irritation symptoms (respiratory, throat and nasal symptoms) among a subset of actors (218) for whom a more detailed exposure assessment was conducted. The association between throat symptoms and increasing glycol exposures were statistically significant. The mucous membrane irritation associations noted for peak glycol exposures were not found with peak exposures to mineral oil.

The medical evaluations consisted of assessments of vocal cord appearance and function, voice analysis and pulmonary function on each participant, before and after a matinee performance. The authors observed no statistically significant acute changes after a performance in vocal cord appearance and function, perceptual voice rating or pulmonary function with relation to theatrical effect exposures.

An analysis of actors' pre-performance examinations revealed an association between longer exposures to peak levels of glycols and a statistically significant increase in certain vocal cord appearance parameters indicating an inflammation of the throat or vocal cords. This effect was not seen with exposure to mineral oil.

The author's further report no clinically significant adverse effects on pulmonary function owing to either acute or chronic use of glycols. This is consistent with earlier NIOSH studies that do not reveal increased rates of asthma among actors exposed to theatrical "smoke". There was one surprising finding that actors with the highest mineral oil exposures showed a statically significant decrease in forced vital capacity. The authors do not hypothesize about the potential origin of this finding.

The authors conclude the following: "Based on the observed association between increased signs and symptoms or respiratory irritant effects and exposure to elevated levels of glycols and mineral oil, it is recommended that exposures to these materials by actors performing in musical productions not exceed peak or ceiling concentrations of 40 mg/m^3 for glycols and 25 mg/m^3 for mineral oil. Time-weighted average exposures to mineral oil should be kept below 5 mg/m^3. Based on the results of this study, no change in the current use of pyrotechnics is necessary. As long as peak exposures are avoided, health, vocal abilities and careers of actors should not be harmed."

3.3 Teschke et al., 2005; Varughese, et al., 2005

Teschke, Varughese and colleagues conducted a prospective cohort study examining exposures to glycol fogs and oil mist, and their association with acute and chronic respiratory symptoms among personnel at 19 sites in British Columbia (Teschke et al., 2005; Varughese, et al., 2005). The sites where testing took place and individuals were recruited included television/film production, live theater, music concerts, a video arcade and a dog show. An external comparison group that had previously been studied was identified.

All participants wore a personal monitor, completed a pre- and post- shift pulmonary function test and an interviewer administered questionnaire pre- and post- shift on the frequency and severity of acute symptoms in the previous several hours. In addition, they completed an interviewer administered questionnaire that focused on chronic symptoms and work history. The shifts were approximately four hours long and fog was present for at least some of the time during the shift. Area air monitoring was conducted with a size selective impactor to determine the size fractions of the various fog particles created.

A total of 111 of 144 available subjects (77%) participated in the study with complete data available for 101 of them. The mean concentration for those exposed only to glycol fogs was 0.49 mg/m^3 (maximum 3.22 mg/m^3) and for those exposed only to oil-based fogs was 0.49 mg/m^3 (maximum 4.11 mg/m^3). The majority of particles, 75% on average, were in the thoracic size range (<10 μm mean aerodynamic diameter) and 61% on average were in the respirable range (<3.5 μm mean aerodynamic diameter).

The authors note that the prevalence rates for most chronic respiratory symptoms were higher among the entertainment industry employees recruited when compared to the reference group. Acute symptoms, those noted cross-shift, including upper airway/voice symptoms were significantly associated with total fog concentration, regardless of its type, oil or glycol. Dryness symptoms and systemic symptoms were also associated with exposure to glycol-based fogs, but not with overall concentrations. Evidence of an exposure-response relationship was demonstrated in this study between increasing cumulative measures of fog exposures for both types, and an increased reporting of work-related wheezing and chest tightness, and a decrease in FVC.

This study is strengthened by its examination of varied settings where theatrical fog is used, and by the higher participation rate than other previously published studies. The exposure assessment was comprehensive and the estimated cumulative exposure calculation over the past two years allowed for an analysis of a dose-response relationship between increasing fog exposures over time and the development of respiratory symptoms.

3.4 Wieslander and Norback, 2010

Wieslander and Norback (2010) examined several biomarkers and the ocular, nasal and other symptoms in Swedish house painters associated with the use of glycol-containing water based paint (Wieslander et al., 2010). Asthmatic and non-asthmatic painters were recruited from three major companies along with unexposed janitors for a control group. Recruitment rates were 95% and 94% for asthmatic and non-asthmatic groups respectively.

Exposure assessments were conducted for 17 house painters and revealed arithmetic mean exposures to polyethylene glycol at 2.04 mg/m^3, diethylene glycol monoethyl ether at 0.458 mg/m^3 and to diethylene glycol monobutyl ether at 0.145 mg/m^3. These compounds comprised the majority of the reported exposures. Painters were also monitored for n-butanol, iso-butanol, 2,2,4-trimethyl-1,3-pentanediol monoisobutyrate and 2,24-trimethyl-1,3-pentanediol diisobutyrate along with a suite of microbial volatile organic compounds (MVOCs).

The authors monitored tear film break-up time (BUT); the amount of time the subject can keep their eyes open without pain when watching a fixed point at the wall, nasal patency by acoustic rhinometry, and biomarkers in nasal lavage (NAL) fluid at work and answered a questionnaire administered by a physician. They report an increase in ocular symptoms, decreased BUT, and increased NAL-lysozomes when compared to the controls. There was an association between 8-hour exposures to propylene glycol and NA-eosinophilic cationic protein and the sum of aliphatic glycol ethers and increase NAL-myeloperoxidase.

Although exposure to paint emissions is perhaps more complex than that found in a theater, the large portion of the monitored exposures were to glycols. This study reinforces, in an alternate group of individuals, the health effects on the upper respiratory tract and mucous membranes when individuals are exposed to airborne concentrations of glycols far less than the existing occupational exposure limits.

3.5 Fent et al., 2013 (HETA 2012-0028-3190)

Fent and colleagues from NIOSH conducted an HHE during fire fighter training exercises in which smoke was simulated with mineral oil or glycol based products or both, at concentrations much higher than that found in the entertainment industry. The HHE was requested in response to three firefighter trainers experiencing respiratory symptoms after

exposure to oil based fog for 30 minutes in preparation for a training exercise. One of the trainers was diagnosed with work related pneumonitis/lipoid pneumonia and was hospitalized for a week. None of the three trainers was wearing respiratory protection at the time of the incident.

The facility these three trainers worked, built solely for training firefighters, was used to evaluate exposures to firefighter trainers during five different testing conditions where the type of fogging agent was changed, with propane generated heat introduced to make the exercise more realistic.

Personal and area air sampling were conducted on each of three floors where one trainer was stationed during each sampling trial. Area air samples were collected outside the training rooms as trainers may open the doors to look inside the room without wearing respiratory protection. The trainers within the rooms wore respiratory protection during the exercise. Each exercise lasted for approximately 15 minutes and included 10 minutes of "smoke." Samples were analyzed for mineral oil mist and its particle size distribution, diethylene glycol and its particle size distribution, aldehydes, polycyclic aromatic hydrocarbons, volatile organic compounds and characteristics of carbonaceous particles.

As expected, the area air concentrations inside the training room were at or greater than personal air concentrations, which were at or greater than area air concentrations outside the room. The highest area oil-mist concentrations were measured during the oil based only fog experiment, and ranged from 0.920 mg/m^3 to 450 mg/m^3 with most airborne particles <0.77 µm in mean aerodynamic diameter. In most cases this far exceeded the 8-hour TWA OSHA PEL, the Quebec and Alberta OEL of 5 mg/m^3, and the WorkSafe BC OEL of 1 mg/m^3. All area and personal samples for diethylene glycol during the glycol only fog experiment were greater than 100 mg/m^3 and far exceeded the ANSI OEL and AIHA WEEL of 10 mg/m^3. The formaldehyde concentrations were greater than 33 ppm.

Five trainers were interviewed regarding work related health symptoms. The most commonly reported symptom was cough with three of the five reporting shortness of breath, difficulty breathing, chest tightness and burning eyes. The most commonly noted illness was pneumonia, while another reported having been diagnosed with chronic bronchitis.

Although these exposure concentrations far exceed those produced in the entertainment industry, this study underscores the serious nature of the potential health effects associated with peak exposures.

4.0 Occupational Exposure Limits

The available occupational exposure limits for the main constituents of theatrical fog are summarized in Appendix A. Occupational exposure limits from the following organizations were reviewed and included in the table;

- American Conference of Governmental Industrial Hygienists, Threshold Limit Values (TLVs)
- US Occupational Safety and Health Administration, Permissible Exposure Limits (PELs)
- National Institute of Occupational Safety and Health, Recommended Exposure Limits (RELs)
- Deutsche Forschungsgemeinschaft, Maximum Concentrations at the Workplace (MAKs)
- American Industrial Hygiene Association, Workplace Environmental Exposure Levels (WEELs)
- California Occupational Safety and Health, Permissible Exposure Limits (PELs)
- United Kingdom, Maximum Exposure Level (MELs)
- Worksafe British Columbia, Occupational Exposure Limits
- Ontario Ministry of Labor, Occupational Exposure Limits
- Australia, Occupational Exposure Limits
- Russia, Occupational Exposure Limits
- Limits noted in the ANSI E1.5 2009 (2014) Document
- Limits proposed by the Cohen Group in 1997
- Government of Alberta, Occupational Exposure Limits for Chemical Substances (2009)
- Quebec, Permissible Exposure Values for Airborne Contaminants

All of the glycols, glycerin and mineral oil addressed in this report have a noted OEL from either a governmental entity or a consensus document.

4.1 ANSI E1.5-2009 (R2014) Exposure Limits

The Entertainment Services and Technology Association (ESTA) Technical Standards Committee has created several versions of this standard as new information has become available. The original document, among other materials, relied upon the information solicited in reports produced in 1997 by the Cohen Group (Raymond, 1997) and HSE Consulting and Sampling (1997).

The current version of the standard sets long term, time weighted average exposures, and peak (never to be exceeded) exposures for select glycols and a peak exposure limit only for glycerin. The limits presented by ANSI E1.5-2009 (R2014) for the glycols are the most conservative, with 8-hour time weighted average OELs set at 10 mg/m^3 and peak exposure OELs set at 40 mg/m^3. They also set a peak exposure of 50 mg/m^3 for glycerin.

The data presented by Teschke (2003, 2005) and Varughese (2005), indicate time weighted average exposures less than the ANSI limit of 10 mg/m^3 for glycols, yet they note cross-shift dose dependent increases in symptom reporting, and a dose response trend associating increased symptom reporting and decreased lung function with an increase in a cumulative previous two-year exposure index. They also present peak

exposure data by percentage of time over certain concentrations, with a fair number of their study environments having sustained peaks over 10 mg/m^3. They do not outline peaks over 40 mg/m^3 and they do not present a detailed analysis of peak only exposures and symptom reporting.

These data, taken with previous epidemiological studies, would indicate that greater control of both peak and longer duration exposures would result in a reduction of both acute and long term health effects. There are not enough data to warrant a revision of the current ANSI standards, however monitoring for and documenting compliance with them should be a priority.

4.2 Occupational Exposure Limits for Mixtures

The American Conference of Governmental Industrial Hygienists (ACGIH) recommends that "when two or more hazardous substances have a similar toxicological effect on the same target organ or system, their combined effect, rather than that of either individually, should be given primary consideration. In the absence of information to the contrary, different substances should be considered as additive where the health effect and target organ or system is the same."

ACGIH also recommends, in discussion of Threshold Limit Values (TLVs) expressed as ceiling limits, that exposure limits based on physical irritation should be considered no less binding than those based on physical impairment. ACGIH justifies this recommendation based on evidence that physical irritation may initiate, promote, or accelerate adverse health effects through interaction with other chemical or biological agents, or through other mechanisms.

ACGIH recommends that if the sum of (C1/T1) + (C2/T2) + …(Cn/Tn) exceeds unity, then the exposure limit of the mixture should be considered as exceeded. Where C equals the airborne concentration of each airborne compound, and Tn represents the TLV for that compound.

To demonstrate this concept, let us take the ANSI E1.5-2009 (R2014), 8-hour TWA limit of 10 mg/m^3 for propylene glycol and triethylene glycol, one of the most common mixtures of glycols in fogging fluid. If we know in a given scenario that the airborne concentration of each ingredient is 7 mg/m^3, we can determine if the exposure limit for the mixture is exceeded by examining the following calculation: (7/10) + (7/10) = 1.4. The exposure limit for the mixture is considered exceeded, because the result is greater than 1.

There are no toxicological data examining the health effects of mixtures of fogging fluid ingredients, potential thermal decomposition byproducts, such as aldehydes, and other volatile organic compounds potentially present in the theater and studio environments at this time. As such, there are no data to indicate whether the effects are additive, synergistic, or neither, but in an abundance of caution, it would be best to assume that the

effects are at least additive, and that airborne exposures should be minimized, to the extent feasible.

4.3 Adjustment for Extended Work Shifts

Entertainment employees are often called upon to work extended shifts, often upwards of and exceeding 12 hours. We recommend consideration be given to adjusting exposure limits for fog ingredients.

With the exception of a few chemicals that have specific standards, for enforcement purposes, OSHA does not adjust exposure limits for extended work schedules. However, ACGIH recommends adjusting exposure limits in light of the extended work shifts for hazardous agents having chronic health effects or that cannot be eliminated from the body during off-work hours. Also, it is good industrial hygiene practice to adjust exposure limits based on health effects. A summary of adjustment methods was published in the September/October 2001 *American Industrial Hygiene Association Journal*, recommending application of the method presented by Paustenbach, and established categories for adjustment of specific chemicals (Brodeur et al., 2001).

Depending on the health effects of specific chemicals, the cited reference may recommend adjusting exposure limits based on exceeding the standard eight-hour work shift, or exceeding a 40-hour work week. The cited reference does not recommend the need to adjust exposure limits for chemicals having weak effects, including specific chemicals having exposure limits based on irritation (e.g., ammonia).

Although irritation is the primary health effect of our subject ingredients (glycols and glycerin), and the health effects of our individual ingredients are relatively weak, we do propose a straight-forward adjustment of the full-shift TWA OELs based on a standard eight-hour work shift. Even though the health effects of our subject ingredients are relatively weak and primarily based on irritation, we recommend adjusting the exposure limit based on a standard eight-hour work shift, because recent epidemiologic evidence suggests there are cumulative, dose-responsive respiratory health effects associated with chronic exposures (Varughese, 2005).

For example, for extended work shifts, we recommend adjusting exposure limits down by a factor of 8/(extended shift length in hours). For example, the total aerosol exposure limit of 10 mg/m^3 in ANSI E1.5, for individuals working a 10-hour shift would be limited to an adjusted concentration of (8/10)(10 mg/m^3) = 8 mg/m^3. This recommended adjustment is less conservative than that noted by WorkSafeBC "G5.50 Extended work periods", prescribing an adjustment of 0.7 for a ten hour shift for example.

We do not recommend it is necessary to adjust short-term, peak, or ceiling exposure limits that are based on irritation. However, the number and intensity of peak exposures during a shift affects the TWA exposure. Therefore, limiting peak exposures will need to be considered during extended work shifts.

5.0 Review of Frequently Used Fluid Safety Data Sheets

The SDSs for 21 commonly used flogging fluids, supplied by the working group, were reviewed, and a summary of the constituents was generated and is presented in Appendix B. The ingredients recommended and discouraged by various technical documents and bulletins is noted with the use of color coded highlighting.

This exercise highlights the variability in the types of fogging agents currently in use. There appears to be a wide range of single compound products and mixtures of compounds in use. The combination of propylene glycol and triethylene glycol seems to be the most common.

It is worth noting there are reports of fogging ingredients formulated on site as a "home brew". This practice should be prohibited as the amounts and types of ingredients cannot be accurately controlled and reported on.

6.0 Exposure Assessment Methods

This section discusses industrial hygiene approaches for anticipating exposures qualitatively prior to production, and for quantitatively measuring exposures using laboratory methods and direct-reading instruments. We also discuss personal breathing-zone and area air sampling.

Exposure assessments can be qualitative or quantitative. A qualitative assessment considers factors affecting exposure without air monitoring, while a quantitative assessment involves air monitoring. Air monitoring may quantify the airborne concentrations of specific individual ingredients, or estimate total aerosol concentration without identifying individual constituents. Identifying the concentrations of individual ingredients typically requires laboratory analysis. Total aerosol concentrations can be determined by laboratory methods, or by using direct-reading instruments.

6.1 Qualitative Assessment

We recommend, at a minimum, performing a qualitative exposure assessment prior to using atmospheric fog effects. A qualitative assessment, sometimes referred to as an industrial hygiene risk assessment, helps anticipate whether exposure limits to fogging fluid ingredients may be exceeded. If a qualitative assessment yields with confidence a low probability of exceeding exposure limits, then it may not be necessary to perform quantitative air monitoring.

The following factors potentially affect exposures, and should be considered when qualitative assessing exposure:

- Ingredients having lower exposure limits involve a higher risk of exceeding exposure limits, other factors being equal. The SDSs for fogging fluids must be

reviewed to determine ingredients and exposure limits. The relative concentrations of ingredients, along with respective exposure limits should also be considered. When applying exposure limits based on total aerosol concentrations, such as the limits recommended in this report, it is important to verify that the SDS ingredients match the referenced ingredients.

- Fog machine generation rate, based on machine capabilities and settings (e.g., fan speed).
- Number of fogging machines used simultaneously.
- Natural ventilation on outdoor sets will dilute and dissipate fog, lowering exposure when compared with indoor sets.
- Working in a confined area, smaller room, or a space with a lower ceiling involves higher risks of exposures exceeding limits.
- If the space is serviced by mechanical ventilation systems, higher ventilation rates will more effectively reduce exposures. Studios may be equipped with ventilation systems designed to purge air following atmospheric effects. However, it may not be feasible to use mechanical ventilation at certain locations.
- Shorter exposure durations involving fewer and less intensive peaks will involve lower risks.
- Exposures often decrease significantly with increased distance from the source fog machines.

6.2 Quantitative Monitoring

Where the results of a qualitative exposure assessment are inconclusive, production should consider industrial hygiene air monitoring to document exposures and compare them with limits. Air monitoring may involve using validated methods to measure concentrations of individual ingredients, or screening to measure total aerosol concentrations. Monitoring may involve laboratory analysis of samples collected on media, or using a direct-reading, real-time instrument.

6.3 Laboratory Methods

Air sampling to quantify ingredients using validated laboratory methods provides more defensible documentation of exposures. This approach involves collecting samples on media such as filters or sorbent tubes, and sending the sample to a laboratory for analysis. There are no practical, direct-reading instruments that will both identify and quantify specific fog ingredients in real time. For shorter, one-time productions, laboratory reports will not be available until after the work is done, leaving no opportunity for adjusting controls. However, for long-running, repeat productions such as theater, it may be desirable to perform a compressive industrial hygiene survey using validated methods early, and make adjustments if necessary.

In addition to the time it takes to receive results, laboratory methods also have the disadvantage of not quantifying peak exposures over durations shorter than approximately 15-minutes. When laboratory methods are used, and when there is potential for peak exposures to exceed limits, we recommend supplemental monitoring using a direct-reading instrument capable of measuring short-term exposures over a one-minute or shorter time period.

NIOSH Method 5523 is validated for quantifying multiple glycols in air. This method involves drawing air through a tube containing both a filter for aerosols and a treated sorbent for vapor. From the same tube, the laboratory can independently quantify both aerosol and vapor phases of multiple glycols.

NIOSH Method 5026 is validated for mineral oil in air. This method involves drawing air through a filter and laboratory analysis using infrared spectrophotometry. Multiple other aerosols can interfere with this method. If both glycol and mineral oil fogs are used at the same time, this method may not quantify oil mist accurately. We recommend talking with the laboratory before attempting to quantify oil mist in the presence of any other aerosols.

SDSs may contain ingredients not listed in sampling and analysis guides published by laboratories. When this is the case, we encourage contacting laboratory technical representatives to determine if existing methods for similar chemicals can be modified to accommodate listed ingredients.

6.4 Direct-Reading Monitoring

Direct-reading instruments are readily available to rent or purchase. These instruments provide real-time estimates of total aerosol concentrations. Commonly-available meters operate by detecting light scattered by particles passing through the instrument optics. Examples include the MIE DataRam and the TSI DustTrak. These meters output results in weight per volume of air, matching to the units in which exposure limits are expressed for glycols, glycerin, and mineral oil. However, it is important to realize that these meters do not directly measure aerosol weight, and they quantify all aerosols present, without identifying the aerosols. They are factory-calibrated against dust standards having optical properties different than atmospheric fog. For instance, the TSI DusTrak is typically factory-calibrated against a standard call Arizona road dust.

Instrument manufacturers recommend generating custom correlation coefficients for different aerosols so that their outputs can be adjusted to compensate for response differences. Based on data we have collected and our review of published data, we recommend producing custom correlation coefficients accounting for the following variables:

- Instrument manufacturer. Manufactures use different optic components and configurations, which can affect results.

- Instrument family within manufacturer. For example, TSI sells DustTrak and SidePack instrument lines. TSI recommends developing custom correlation coefficients for each because of the differences in internal optics.
- Fogging fluid. Various ingredients and ingredient mixtures likely have different optical diffraction properties.
- Fogging machines, which may produce different aerosol profiles with regard to particle size.

The 2005 Teschke publication describes the process of developing a correlation coefficient. Side-by-side samples are collected using a direct-reading instrument and a validated sampling method involving drawing air through a filter and laboratory analysis. The results are plotted on a chart, and a linear regression model is developed. The regression model yields an equation, which can be used to convert the instrument reading to a corrected concentration. Based on the slope of a best-fit line represented by model, the correction factor may vary with fog aerosol concentration. This process may not yield a single correction factor, which can be applied across a range of concentrations.

The 2005 Teschke publication correlated an MEI DataRam with actual fog aerosol concentrations. The study compiled data from multiple types of fog, and did not attempt to correlate the meter against specific fluids. We have correlated a TSI DustTrak against a range of aerosol concentrations using a specific fluid and fogging machine (Look Solutions fluid and Unique 2.1 machine). In both of these examples, the aerosol meters responded by almost double actual fog aerosol concentrations. In other words, where the laboratory method yielded 10 mg/m^3, the instrument read approximately 18 mg/m^3. Using the instrument without developing a correlation coefficient would have been protective, but would have over-estimated aerosol concentration and potentially unnecessarily restricted production parameters.

Both the aerosol and vapor phases of fog machine emissions should be accounted for while developing correction factors. It would also be ideal to verify concentrations of thermal decomposition products, such as carbon monoxide and aldehydes while developing correction factors.

Just as an uncorrelated meter can over-estimate exposures, it is possible that meter may under-estimate exposures to fog having different light-scattering properties.

We reviewed a report titled ***Theatrical Smoke, Fog and Haze Testing: Calibration Factors***, produced by Ramboll Environ (formerly ENVIRON) and dated September 2015. This report includes a table of calibration factors said to have been developed and approved by Actors' Equity Association and the Broadway League for use in measuring theatrical smoke, fog, and haze. The table includes correction factors by fluid name and fog machine model. It lists references dated 2001 through 2015. The summary report does not detail methods used to produce the correction factors, or the ingredients of the fluids. These details are likely included in the references.

From the summary report alone, it's difficult to verify that correction factors developed many years ago are applicable today. This is because fluid manufactures may have changed ingredients, and the manufacturers of fog machines and aerosol monitors may have altered devices. Also, for correction factors developed on location, it cannot be verified from the summary report whether or not there were aerosol sources present that could have interfered with developing the correction factor. The report does not detail the protocol for developing correction factors. It cannot be verified form the summary report if both the vapor and aerosol phases of the produced fog were measured using validated laboratory methods.

6.5 Area and Personal Samples

Occupational exposure limits are based on personal, breathing-zone concentrations of agents. The breathing zone is the inhalation area within inches of the nose and mouth. Breathing zone samples are also referred to as personal samples. It is often not practical to sample air in employees' breathing zones as they perform their work. Employees may move frequently and trade-off responsibilities. Personal samples are collected by attaching sampling equipment to the subject. A battery-powered sampling pump is typically worn on the belt, and the sampling media inlet clipped to the shirt collar. This equipment can interfere with production visually and by producing noise.

One option to avoiding interferences is sampling during a production sequence dedicated to monitoring and without filming. This takes time and may be cost prohibitive, but should be considered, where feasible. For certain productions, this may be feasible during a rehearsal.

Another option is to perform area monitoring representing personal, breathing-zone exposures. Area samples involve positioning sampling equipment at stationary locations. Direct-reading instruments can also be hand-held by the person conduction sampling. It may be feasible to collect samples at breathing-zone locations immediately prior to or after filming, before fog levels change significantly. Area samples have the potential to under- or over-represent exposures. Where an employee passes closer to a source than the position of an area sampling device, the device may under-estimate exposure. Where an area sample is positioned near a fogging machine for a long time, but where employees do not spend much time, the result may over-estimate exposures. The industrial hygienist must use professional judgement to ensure sampling results represent exposures.

7.0 Recommendations

Recommendations forwarded in this report are summarized here for reference.

1) Ensure compliance with the exposure limits set forth in Table 2. For the six glycols recommended in this report and glycerin, the toxicological and epidemiological data

available to date do not warrant revision of the exposure limits in the current ANSI E1.5-2009 (2104) standard. However, note that although diethylene glycol is listed in the ANSI Standard, we do not recommend applying the ANSI exposure limits to diethylene glycol.

Table 2. Recommended Ingredients and Exposure Limits

Ingredient	CAS Number(s)	8-Hour Time Weighted Average (mg/m^3)	Peak (mg/m^3)
1,3-Butylene Glycol	107-88-0	10	40
1,2-Butylene Glycol	584-03-2	10	40
Propylene Glycol	57-55-6	10	40
Triethylene Glycol	112-27-6	10	40
Polyethylene Glycol	25322-68-3	10	40
Dipropylene Glycol	25265-71-8, 106-62-7, 110-98-5, 108-61-2	10	40
Glycerin	56-81-5	10	50
Mineral oil (highly-refined only)	8042-47-5	5/1[a]	25

(a) The US OSHA PEL, ACGIH TLV, Quebec OEL and Alberta OEL are all 5 mg/m^3. Worksafe BC has an OEL of 1 mg/m^3 for mineral oil.

Note: If mixtures of the above ingredients are used, the total concentration cannot exceed the noted limits.
mg/m^3 – milligrams per cubic meter
NA – not applicable
Peak – One-minute average, not to be exceeded

2) Animal studies for diethylene glycol, ethylene glycol, and 1,4-butylene glycol revealed concerning health effects, and we recommend not using fogging fluids containing these ingredients.

3) Do not apply the total aerosol based exposure limits recommended in Table 2 unless it is verified that the ingredients of the fogging fluid are limited to those listed in Table 2. Compare ingredients listed on fogging fluid SDSs with the ingredients recommended in Table 2.

4) Prohibit the use of "home-brew" fogging fluids, and only use commercially-available fluids with approved ingredients.

5) Do not use fogging fluids in a given machine, other than fluids specifically recommended by the machine's manufacturer.

6) When using mineral oil, verify that only highly- or severely-refined mineral oil is used. Mineral oil refined from petroleum, but not highly refined can contain toxic contaminants.

7) Adjust exposure limits for extended work shifts (longer than 8-hours), as follows.

   - For the US, the Brief and Scala Adjustment is recommended. Decrease the noted 8-hour TWA OEL by a factor of (8/extended shift length).
     - 10 hour adjusted TWA = (8/10) * 10 mg/m^3 = 8.0 mg/m^3
     - 12 hour adjusted TWA = (8/12) * 10 mg/m^3 = 6.7 mg/m^3
     - 14 hour adjusted TWA = (8/14) * 10 mg/m^3 = 5.7 mg/m^3

   - For Canadian provinces the following adjustments are required. The ANSI 8-hour TWAs would be reduced by multiplying the TWA limit by the following factors:

Length of Work Period (in hours)	Adjustment Factor	Adjusted ANSI TWA (mg/m^3)
More than 8, but not more than 10	0.7	= (0.7) * 10 mg/m^3 = **7 mg/m^3**
More than 10, but not more than 12	0.5	= (0.5) * 10 mg/m^3 = **5 mg/m^3**
More than 12, but not more than 16	0.25	= (0.25) * 10 mg/m^3 = **2.5 mg/m^3**
More than 16	0.1	= (0.1) * 10 mg/m^3 = **1 mg/m^3**

mg/m^3 – milligrams per cubic meter

8) Proactively assess exposures, at least qualitatively, each time atmospheric fog is used. If multiple risk factors are low, then quantitative monitoring may not be necessary. When a qualitative assessment does not indicate with confidence that exposures will remain below recommended exposure limits, consider implementing controls and conducting quantitative monitoring on-location.

9) When a qualitative exposure assessment does not indicate with confidence that exposures will remain below recommended limits, conduct direct-reading, real-time air monitoring on-location. The monitoring will document exposures for future reference, and allow implementing timely controls such as increasing ventilation or limiting exposure duration.

10) For each combination of air direct-reading monitoring instrument, fogging fluid, and fogging machine, develop a custom correlation factor so that results from direct-reading instrument can be adjusted properly. Existing data show that results from factory-calibrated, readily-available optical instruments need to be adjusted significantly for fog aerosols.

11) Minimize exposures to the extent practical, beyond solely complying with recommended exposure limits. The effects of mixtures and the relationships among health effects, exposure intensities, and exposure durations are not fully understood.

12) Follow and consider supporting new technology for potential substitution options. Lower-hazard approaches may be developed in the future for producing atmospheric effects. For example, we are aware of the use of nano-scale, non-wetting water mists in laboratory settings for carrying nano-particles. This mist can appear as dense fog.

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Appendix A. Occupational Exposure Limits for Fog Ingredients*

Component	Synonyms	CAS No(s)	ACGIH TLV	OSHA PEL	German MAK	AIHA WEEL	California OSHA	UK OES	Work Safe British Columbia	Ontario OEL	Alberta OEL	Quebec OEL	Australian OEL	ANSI E1.5 2009 (R2014)
Butylene Glycol	1,3 Butanediol 1,3-Butylene glycol	107-88-0	-	-	-	-	-	-	40 mg/m³	-	-	-	-	10 mg/m³ 40 mg/m³ Ceiling
Ethylene Glycol	1,2-Ethanediol Monoethylene glycol	107-21-1	25 ppm TWA (vapor) 50 ppm STEL (vapor) 10 mg/m³ STEL (inhalable, aerosol)	-	-	-	40 ppm Ceiling	20 ppm 40 ppm STEL	100 mg/m³ (C, aerosol) 20 mg/m³ (particulate) 50 ppm (C, vapour)	100 mg/m³ Ceiling	100 mg/m³ Ceiling	127 mg/m³ Ceiling 50 ppm Ceiling	-	
Diethylene Glycol	DEG Diglycol Ethylene diglycol 2,2'-oxydiethanol 2-(2-hydroxyethyl) ethanol	111-46-6	-	-	44 mg/m³	10 mg/m³	-	101 mg/m³ 23 ppm	-	-	-	-	100 mg/m³ 23 ppm	10 mg/m³ 40 mg/m³ Ceiling
Propylene Glycol	Monopropylene glycol 1,2-Propanediol 1,2-dihydroxypropane methyl ethylene glycol methyl glycol propane-1,2-diol	57-55-6	-	-	-	10 mg/m³	-	474 mg/m³ (total) 10 mg/m³ (particulate for visibility)	40 mg/m³	155 mg/m³ (total vapor and aerosol) 10 mg/m³ (aerosol visibility)	-	-	10 mg/m³	10 mg/m³ 40 mg/m³ Ceiling
Triethylene Glycol	Triglycol Glycol BIS(hydroxyethyl) ether	112-27-6	-	-	1000 mg/m³ (inhalable)	-	-	-	40 mg/m³	-	-	-	-	10 mg/m³ 40 mg/m³ Ceiling
Dipropylene Glycol	1,1'-Oxybis-2-Propanol Bis(2-Hydroxypropyl) Ether 2,2'-Dihydroxy Dipropyl Ether	110-98-5 108-61-2 106-62-7 25265-71-8	-	-	100 mg/m³	-	-	-	-	-	-	-	-	10 mg/m³ 40 mg/m³ Ceiling
Polyethylene Glycol		25322-68-3	-	-	1000 mg/m³ (inhalable)	10 mg/m³	-	-	40 mg/m³	-	-	-	-	

Appendix A. Occupational Exposure Limits for Fog Ingredients*

1,4 Butylene Glycol	1,4-Butanediol Butane-1,4-diol Sucol B 1,4-Dihydroxybutane	110-63-4	-	-	-	-	-	-	-	-	-	-	-	
1,2-Butylene Glycol	1,2-Butandediol ; Butylene Glycol	584-03-2	-	-	-	-	-	-	-	-	-	-	-	10 mg/m³ 40 mg/m³ Ceiling
2,3 Butanediol	Limits	513-85-9	-	-	-	-	-	-	-	-	-	-	-	
Glycerol	Glycerin 1,2,3-Propanediol Glycerine Trihydroxypropane	56-81-5	-	15 mg/m³ (total dust) 5 mg/m³ (respirable)	200 mg/m³ (inhalable)	-	-	10 mg/m³	10 mg/m³ (8-hour TWA) 15 mg/m³ (30-min maximum) 50 mg/m³ (Ceiling, at any point)	-	10 mg/m³ (8-hour TWA)	10 mg/m³ (8-hour TWA)	10 mg/m³	50 mg/m³ Ceiling
Methyl Ester	Soybean Oil	67784-80-9	-	-	-	-	-	-		-	-	-	-	-
Petroleum Distillates	Hydrotreated Heavy Paraffinic	64742-54-7	-	-	-	-	-	-	-	-	-	-	-	-
Petroleum Distillates	Hydrotreated Middle Distillates	64742-46-7	-	-	-	-	-	-	-	-	-	-	-	-
Frankincense		8050-07-5	-	-	-	-	-	-	-	-	-	-	-	-
Highly or Severly Refined Mineral Oil		8042-47-5	5 mg/m³ (inhalable)	-	5 mg/m³ (respirable)	-	-	-	1 mg/m³	-	-	5 mg/m³ (8-hour TWA) 10 mg/m³ (STEL, 15-min. TWA)	-	-

	Prohibited by Safety Bulletin No. 10 and by Worksafe BC
	Recommended by Safety Bulletin No. 10 and by Worksafe BC
	Recommended by Worksafe BC

*There are currently no NIOSH RELs for the components listed.

Appendix B. Review of Safety Data Sheets for Fogging Fluids

Component	1997 HSE Review	Colden Review	No. of SDSs present	Synonyms	CAS Number	Froggy's Fog LLC-Backwood Bay Long Lasting Fog Fluid	Froggy's Fog LLC-Designer Select Backwood Bay	LeMaitre Ltd-Lemaitre Haze Fluid	Look Solutions USA, Ltd.-Look Solutions Fog Fluid, Look Solution Haze Fluid (2012)	Look Solutions USA, Ltd. - Look Solutions Fog Fluid, Look Solution Haze Fluid (2014)	Martin by Harman-Martin Smoke and Haze Fluid	MDG Fog Generators Ltd-MDG Neutral Fluid	Reel EFX Inc.-Reel EFX Oil-less Diffusion Fluid (2014)	Reel EFX Inc.-Reel EFX Oil-less Diffusion Fluid (2016)
Butylene Glycol		y	4	1,3 Butanediol 1,3-Butylene glycol	107-88-0 584-03-2		Present		Present			Present		
Ethylene Glycol		y	1	1,2-Ethanediol Monoethylene glycol	107-21-1									
Diethylene Glycol	y	y	2	DEG Diglycol Ethylene diglycol 2,2'-oxydiethanol 2-(2-hydroxyethyl) ethanol	111-46-6									1%

Component	1997 HSE Review	Colden Review	No. of SDSs present	Synonyms	CAS Number	Froggy's Fog LLC-Backwood Bay Long Lasting Fog Fluid	Froggy's Fog LLC-Designer Select Backwood Bay	LeMaitre Ltd-Lemaitre Haze Fluid	Look Solutions USA, Ltd.-Look Solutions Fog Fluid, Look Solution Haze Fluid (2012)	Look Solutions USA, Ltd. - Look Solutions Fog Fluid, Look Solution Haze Fluid (2014)	Martin by Harman-Martin Smoke and Haze Fluid	MDG Fog Generators Ltd-MDG Neutral Fluid	Reel EFX Inc.-Reel EFX Oil-less Diffusion Fluid (2014)	Reel EFX Inc.-Reel EFX Oil-less Diffusion Fluid (2016)
Propylene Glycol	y	y	12	Monopropylene glycol 1,2-Propanediol 1,2-dihydroxypropane methyl ethylene glycol methyl glycol propane-1,2-diol	57-55-6	Present	Present		Present	Present	Present	Present		
Triethylene Glycol	y	y	12	Triglycol Glycol BIS(hydroxyethyl) ether	112-27-6	Present	Present		Present	Present	Present	Present	100%	
Polyethylene Glycol		y	2		25322-68-3									
1,4 Butylene Glycol	y	y	0	1,4-Butanediol Butane-1,4-diol Sucol B 1,4-Dihydroxybutane	110-63-4									

Component	1997 HSE Review	Colden Review	No. of SDSs present	Synonyms	CAS Number	Froggy's Fog LLC-Backwood Bay Long Lasting Fog Fluid	Froggy's Fog LLC-Designer Select Backwood Bay	LeMaitre Ltd-Lemaitre Haze Fluid	Look Solutions USA, Ltd.-Look Solutions Fog Fluid, Look Solution Haze Fluid (2012)	Look Solutions USA, Ltd. - Look Solutions Fog Fluid, Look Solution Haze Fluid (2014)	Martin by Harman-Martin Smoke and Haze Fluid	MDG Fog Generators Ltd-MDG Neutral Fluid	Reel EFX Inc.-Reel EFX Oil-less Diffusion Fluid (2014)	Reel EFX Inc.-Reel EFX Oil-less Diffusion Fluid (2016)
Dipropylene Glycol	y	y	2	1,1'-Oxybis-2-Propanol Bis(2-Hydroxypropyl) Ether 2,2'-Dihydroxy Dipropyl Ether	110-98-5 25265-71-8				Present	Present				
2,3 Butanediol		y	0		513-85-9									
Glycerol	y	y	2	Glycerin 1,2,3-Propanediol Glycerine Trihydroxypropane	56-81-5			Present						
Methyl Ester			1	Soybean Oil	67784-80-9									
Petroleum Distillates			1	Hydrotreated Heavy Paraffinic	64742-54-7									
Petroleum Distillates			1	Hydrotreated Middle Distillates	64742-46-7									

Component	1997 HSE Review	Colden Review	No. of SDSs present	Synonyms	CAS Number	Froggy's Fog LLC-Backwood Bay Long Lasting Fog Fluid	Froggy's Fog LLC-Designer Select Backwood Bay	LeMaitre Ltd-Lemaitre Haze Fluid	Look Solutions USA, Ltd.-Look Solutions Fog Fluid, Look Solution Haze Fluid (2012)	Look Solutions USA, Ltd. - Look Solutions Fog Fluid, Look Solution Haze Fluid (2014)	Martin by Harman-Martin Smoke and Haze Fluid	MDG Fog Generators Ltd-MDG Neutral Fluid	Reel EFX Inc.-Reel EFX Oil-less Diffusion Fluid (2014)	Reel EFX Inc.-Reel EFX Oil-less Diffusion Fluid (2016)
Frankincense			1		8050-07-5									
Highly or Severly Refined Mineral Oil		y	1		8042-47-5							>99.9%		
Water					7732-18-5	Present	Present	Present	Present	Present	Present	Present		
SDS Date									2012	2014			2014	2016
Comments														Other components below reportable levels

Component	1997 HSE Review	Colden Review	No. of SDSs present	Synonyms	CAS Number	Roger George Rentals-Bio Fog Fluid	Roger George Rentals-Fog Fluid (Water Based)	Roger George Rentals-Fog Oil(2006)	Roger George Rentals-Fog Oil(2015)	Roger George Rentals - Le Maitre Fog Fluid	Roger George Rentals-LeMaitre Pro Beam Long Lasting Fog Fluid	Roger George Rentals-Olibanum
Butylene Glycol		y	4	1,3 Butanediol 1,3-Butylene glycol	107-88-0 584-03-2							
Ethylene Glycol		y	1	1,2-Ethanediol	107-21-1		1%					

Component	1997 HSE Review	Colden Review	No. of SDSs present	Synonyms	CAS Number	Roger George Rentals- Bio Fog Fluid	Roger George Rentals- Fog Fluid (Water Based)	Roger George Rentals- Fog Oil(2006)	Roger George Rentals- Fog Oil(2015)	Roger George Rentals - Le Maitre Fog Fluid	Roger George Rentals- LeMaitre Pro Beam Long Lasting Fog Fluid	Roger George Rentals- Olibanum
				Monoethylene glycol								
Diethylene Glycol	y	y	2	DEG Diglycol Ethylene diglycol 2,2'-oxydiethanol 2-(2-hydroxyethyl) ethanol	111-46-6		4%					
Propylene Glycol	y	y	12	Monopropylene glycol 1,2-Propanediol 1,2-dihydroxypropane methyl ethylene glycol methyl glycol propane-1,2-diol	57-55-6					Present	Present	
Triethylene Glycol	y	y	12	Triglycol Glycol BIS(hydroxyethyl) ether	112-27-6						Present	
Polyethylene Glycol		y	2		25322-68-3		99%					
1,4 Butylene Glycol	y	y	0	1,4-Butanediol Butane-1,4-diol Sucol B	110-63-4							

Component	1997 HSE Review	Colden Review	No. of SDSs present	Synonyms	CAS Number	Roger George Rentals- Bio Fog Fluid	Roger George Rentals- Fog Fluid (Water Based)	Roger George Rentals- Fog Oil(2006)	Roger George Rentals- Fog Oil(2015)	Roger George Rentals - Le Maitre Fog Fluid	Roger George Rentals- LeMaitre Pro Beam Long Lasting Fog Fluid	Roger George Rentals- Olibanum
				1,4-Dihydroxybutane								
Dipropylene Glycol	y	y	2	1,1'-Oxybis-2-Propanol Bis(2-Hydroxypropyl) Ether 2,2'-Dihydroxy Dipropyl Ether	110-98-5 25265-71-8							
2,3 Butanediol		y	0		513-85-9							
Glycerol	y	y	2	Glycerin 1,2,3-Propanediol Glycerine Trihydroxypropane	56-81-5					Present		
Methyl Ester			1	Soybean Oil	67784-80-9	>99 %						
Petroleum Distillates			1	Hydrotreated Heavy Paraffinic	64742-54-7				99.99%			
Petroleum Distillates			1	Hydrotreated Middle Distillates	64742-46-7			100%				
Frankincense			1		8050-07-5							100%
Highly or Severly Refined Mineral Oil		y	1		8042-47-5							

Component	1997 HSE Review	Colden Review	No. of SDSs present	Synonyms	CAS Number	Roger George Rentals- Bio Fog Fluid	Roger George Rentals- Fog Fluid (Water Based)	Roger George Rentals- Fog Oil(2006)	Roger George Rentals- Fog Oil(2015)	Roger George Rentals - Le Maitre Fog Fluid	Roger George Rentals- LeMaitre Pro Beam Long Lasting Fog Fluid	Roger George Rentals- Olibanum
Water					7732-18-5					Present	Present	
SDS Date						2015	2015	2006	2015	2015	2006	
Comments												

Component	1997 HSE Review	Colden Review	No. of SDSs present	Synonyms	CAS Number	Rosco Laboratories Inc. -Rosco Delta Haze Fluid	Rosco Laboratories Inc. - Rosco Fog Fluid & Smoke Simulation	Rosco Laboratories Inc. - Rosco Light Fog Fluid	Rosco Laboratories Inc.-Rosco New Hazemaker Fluid	Rosco Laboratories Inc.-Rosco V-Hazer Fluid
Butylene Glycol		y	4	1,3 Butanediol 1,3-Butylene glycol	107-88-0 584-03-2		Present			
Ethylene Glycol		y	1	1,2-Ethanediol Monoethylene glycol	107-21-1					
Diethylene Glycol	y	y	2	DEG Diglycol Ethylene diglycol 2,2'-oxydiethanol 2-(2-hydroxyethyl) ethanol	111-46-6					
Propylene Glycol	y	y	12	Monopropylene glycol 1,2-Propanediol 1,2-dihydroxypropane methyl ethylene glycol methyl glycol propane-1,2-diol	57-55-6	Present	Present	Present		Present
Triethylene Glycol	y	y	12	Triglycol Glycol BIS(hydroxyethyl) ether	112-27-6	Present	Present	Present		Present

Component	1997 HSE Review	Colden Review	No. of SDSs present	Synonyms	CAS Number	Rosco Laboratories Inc. -Rosco Delta Haze Fluid	Rosco Laboratories Inc. - Rosco Fog Fluid & Smoke Simulation	Rosco Laboratories Inc. - Rosco Light Fog Fluid	Rosco Laboratories Inc.-Rosco New Hazemaker Fluid	Rosco Laboratories Inc.-Rosco V-Hazer Fluid
Polyethylene Glycol		y	2		25322-68-3				Present	
1,4 Butylene Glycol	y	y	0	1,4-Butanediol Butane-1,4-diol Sucol B 1,4-Dihydroxybutane	110-63-4					
Dipropylene Glycol	y	y	2	1,1'-Oxybis-2-Propanol Bis(2-Hydroxypropyl) Ether 2,2'-Dihydroxy Dipropyl Ether	110-98-5 25265-71-8					
2,3 Butanediol		y	0		513-85-9					
Glycerol	y	y	2	Glycerin 1,2,3-Propanediol Glycerine Trihydroxypropane	56-81-5					
Methyl Ester			1	Soybean Oil	67784-80-9					
Petroleum Distillates			1	Hydrotreated Heavy Paraffinic	64742-54-7					
Petroleum Distillates			1	Hydrotreated Middle Distillates	64742-46-7					

Component	1997 HSE Review	Colden Review	No. of SDSs present	Synonyms	CAS Number	Rosco Laboratories Inc. -Rosco Delta Haze Fluid	Rosco Laboratories Inc. - Rosco Fog Fluid & Smoke Simulation	Rosco Laboratories Inc. - Rosco Light Fog Fluid	Rosco Laboratories Inc.-Rosco New Hazemaker Fluid	Rosco Laboratories Inc.-Rosco V-Hazer Fluid
Frankincense			1		8050-07-5					
Highly or Severly Refined Mineral Oil		y	1		8042-47-5					
Water					7732-18-5	Present	Present	Present	Present	Present
SDS Date						2015	2015	2015	2015	2014
Comments						Incorrect OELs noted on SDS	Incorrect OELs noted on SDS	Incorrect OELs noted on SDS	Incorrect OELs noted on SDS	Incorrect OELs noted on SDS

	Prohibited by Safety Bulletin No. 10 and by Worksafe BC
	Recommended by Safety Bulletin No. 10 and by Worksafe BC
	Recommended by Worksafe BC