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Theatrical Fog, Smoke, and Haze Effects

Monona Rossol

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Singers often are required to perform in the presence of various artistic effects, including stage fogs and smoke, pyrotechnics, and others. Some of these effects create voice problems. Singing teachers should be familiar with these potential impediments to voice performance. This article discusses stage fog, smoke, and haze.

In order to simulate smoke or fog on stage, or to cause the theatrical lights to appear as shafts or beams of light (haze), a fine mist of chemicals is suspended in the air. These atmospheric fog, haze, and smoke chemicals present a unique challenge for singers. No other industry deliberately pollutes the air breathed by its workers (performers and crew) and its customers (the audience).

In the dim, dark theatrical past, smoke and fog effects were created in many ways with many different substances. Included among these chemicals were:

- Real smoke from burning organic matter such as tobacco and incense.
- Fume particles from heating inorganic compounds such as ammonium chloride.
- Mists of kerosene and various grades of fuel oil.
- Mists of industrial grades of highly contaminated oils (e.g., cutting oils).
- A mist suspension of tiny particles of polyethylene glycols (low molecular weight plastic).
- Mists of antifreeze chemicals such as ethylene glycol, along with other glycols such as 1,4-butylene glycol, which metabolizes in the body to produce gamma hydroxybutyrate (GHB). This is a Schedule I street drug used as a type of ecstasy and date rape drug.[1]

Some of these chemicals were known to have acute toxic effects, or to cause cancer, and are no longer used.

In response to numerous complaints, lawsuits, and union pressure, an industry sponsored group called Entertainment Services Technology Association (ESTA) began the process of setting safety and professional practice standards for theatrical special effects. Today, most professional productions in the United States follow these standards, which have now been accepted by the American National Standards Institute (ANSI). Those who would comply with these standards are required to use a restricted list of chemicals and gases for theatrical fog effects. This list is found in ANSI E1.23—2010 (R2015), "Entertainment Technology—Design and Execution of Theatrical Fog Effects."[2] The chemicals are:

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1. **triethylene glycol** CAS# 112–27–6
2. **monopropylene glycol** (proplyene glycol; 1,2-propanediol) CAS# 57–55–6
3. **diethylene glycol** CAS# 111–46–6
4. **dipropylene glycol(s)** CAS# 25265–71–8, 106–62–7, 110–98–5, 108–61–2
5. **1,2-butylene glycol** (1,2-butanediol) CAS# 584–03–2
6. **1,3-butylene glycol** (1,3-butanediol) CAS# 107–88–0
7. **glycerine** (glycerol; 1,2,3-propanetriol) CAS# 56–81–5
8. **white mineral oil**, medicinal or food grade CAS# 8042–47–5
9. **water** CAS 07732–18–5
10. **nitrogen, lilquifed** CAS 7727–37–9
11. **oxygen, liquified** 80937–33–3
12. **carbon dioxide, liquified** 124–38–9

Glycols, glycerin. Chemicals in a class called dihydric and trihydric alcohols, more commonly referred to as glycols and glycerin, are listed in ANSI E1.5 Entertainment Technology—"Theatrical Fog Made With Aqueous Solutions Of Di- and Trihydric Alcohols."[2] These chemicals are the first eight listed above.

All these glycols and glycerine are hygroscopic, meaning they absorb water. This means they can dry and irritate the skin and cause pain and redness in the eyes. Additionally, it is now known from experience and study that irritation can also cause acute laryngitis and tracheitis, such as was observed in a study of Actor's Equity performers.[3]

Some of the glycols also are capable of causing allergies. Asthma also may be related to exposure. Two case reports of occupational asthma either caused by or exacerbated by glycol theatrical fog were reported in 1996 by the New Jersey Department of Health.[4]

Medicines contaminated with diethylene glycol have been responsible for the deaths of adults and children worldwide. The most recent incident was in 2008, when diethylene glycol-tainted teething medicine caused the deaths of 84 Nigerian children. This chemical is still used in theater under the presumption that it is not significantly toxic at the doses delivered by fog effects.

Mineral oil. Today, only highly refined mineral oils are approved for use. Highly refined mineral oil can be safely ingested when used as a laxative, and it is also soothing to the skin. But when inhaled, mineral oils can cause life threatening lipoid pneumonia. This is why mineral oil is no longer in nose drops and other medications that can be accidentally inhaled. Once in the lungs, mineral oil is "inert," meaning it will not dissolve or metabolize and can remain in the lungs for years, causing additional complications.

Instead of being hygroscopic like the glycols, all of the oils are hydrophobic and repel water. This is why they also cause temporary eye pain and redness. This effect may also cause irritation to other moist membranes in the upper respiratory system.

All hydrocarbon oil mists are extremely combustible at high concentrations in the air. Additionally, while the glycols and glycerin are mixed with water, it is likely that high concentrations of these can also ignite in air.

Cryogenic gases. The two most common gases used in special effects are carbon dioxide (dry ice) and liquid nitrogen. In some cases, other inert gases such as argon are used. Years ago, Freon was in common use.[5] These all rely on the extreme coldness of dry ice or of liquid gases to create fog by condensing water vapor from the air. However, where this fog is visible, the gas that caused it is also present in significant or even deadly amounts.

Dry ice is actually carbon dioxide gas cooled to the point of solidification. Wherever the water-mist dry ice fog is found, the levels of carbon dioxide that cause it are also elevated. Air composed of 70% carbon dioxide can be fatal. In 1997, an opera singer directed to remain lying on a stage near a source of dry ice fog had a seizure from overexposure to carbon dioxide.

Liquid nitrogen and argon can be used to create fog from water vapor in the air, or act as carriers mixed with other gas or chemical effects. These are also dangerous if high levels of the inert gases reduce the oxygen content of the air.

Oxygen. Liquid air fog, a combination of liquid nitrogen and liquid oxygen, is being used in some new applications. This product will eliminate the oxygen deprivation problem. However, there is a risk that the nitrogen, which boils at a lower temperature than oxygen, will boil off first, leaving the oxygen. High levels of oxygen released from such a machine can be a serious fire hazard, since things will burn incredibly rapidly in the presence of high levels of oxygen.

Water mist. Water is usually mixed with the glycols and glycerin fog chemicals. A number of fog systems now use plain water, especially for outdoor work or water shows such as Cirque du Soleil's production of "O." Water's major hazard is biological, since it must not contain microorganisms common in standing water. Fresh potable water that is high in minerals may also produce irritating dust as the mist dries in the air.

ENTERTAINMENT EXPOSURE STUDIES

There have been a number of studies and reviews of the impact of special effects chemicals on performers and crew members. Below are the five most informative studies, along with brief summaries of their findings.

The NIOSH Study

This study by the National Institutes of Occupational Safety and Health (NIOSH) was initiated in 1990 in response to complaints by members of the Actors' Equity Association (AEA). There were four versions of the report: a draft, an Interim report, "A Revised Interim Report" (HETA 90–355), and a "Final Report" released in August 1994 (HETA 1990–355–2449), which also appends the Revised Interim Report.

The questionnaires filled out by fog-exposed performers in this study indicated that significant numbers of those exposed have symptoms, and that a majority of fog-exposed individuals firmly believe that these symptoms are related to the special effects. However, fog manufacturers do not consider the experience and opinions of the performers and musicians to be valid. They say they need proof that the special effects are harmful.

The NIOSH report also provided a sentence that is quoted frequently by special effects manufacturers to support their safety claims. "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" (19). However, NIOSH researchers explain that they found no evidence of the fog/asthma link because their sample was too small. The number of performers participating in the medical phase of this long study was limited to 27 fog-exposed and 18 non-exposed participants. There were three asthmatic performers in the fog-exposed group and two in the non-exposed group—far too small a sample to draw any conclusions whatsoever. In addition, even if the fog doesn't *cause* asthma, its irritative effects certainly could exacerbate existing asthma. They said: "Nevertheless, some of the constituents of theatrical 'smoke' (such as the glycols) have irritative and mucous membrane drying properties. It would therefore be reasonable to modify the factors which may influence a performer's exposure to the 'smoke.'"

The AEA Study

A study commissioned by the Actors' Equity Association (AEA) called "Health effects of glycol based fog used in theatrical productions," by Harry H. Herman, Jr., A Report to AEA, July 1995. In April 1996 it was presented at the American Chemical Society's annual meeting.

In this study, the medical records of over 1200 performers in the Actors' Equity study showed that performers working in fog shows were diagnosed and treated for respiratory problems 4 or 5 times more often than performers in non-fog shows. But since most of the fog-exposed performers were singers rather than actors or other types of performers, the producers say this is still not proof that special effects caused these documented high illness rates.

The Local 802 Study

A short medical study of 25 Local 802 of the American Federation of Musicians (AF of M) pit orchestra musicians at *Beauty and the Beast* on Broadway, by Dr. Jacqueline M. Moline, Mount Sinai-Irving J. Selikoff Center for Environmental and Occupational Medicine, January 17, 1997.

Actual medical tests administered by Dr. Moline on the lungs of the 25 pit musicians at *Beauty and the Beast* clearly showed that musicians are suffering. Dr. Moline said: "The conditions for the musicians in the music pit at *Beauty and the Beast* are unhealthy. A large percentage of the musicians are suffering from symptoms related to the irritative effects of the work environment. Several musicians now require medical care and medication to treat their symptoms which have developed or worsened since taking part in this production." However, the critics say that data from *Beauty and the Beast* can't be applied to other Broadway shows, because Disney used two small pyrotechnic effects that create a different kind of smoke in addition to fog and haze.

TABLE 1. Various fog, smoke, and haze standards or guidelines.

Source	All glycols	glycerine	oil mist (highly refined)
MT. SINAI/ENVIRON	40 mg/m^3 (peak)	no guideline, not in products studied	25 mg/m^3 (peak) 5 mg/m^3 TWA*
ANSI E1.5	40 mg/m^3 (peak) 10 mg/m^3 TWA	50 mg/m^3 (peak) 10 mg/m^3 TWA	
ANSI E1.23	refers to E1.5	refers to E1.5	refers to OSHA which is 5 mg/m^3 PEL-TWA
ACGIH**	No glycol standards	standard with-drawn due to lack of data	5 mg/m^3 inhalable (10–100μ***) no respirable limit (<10μ**)
OSHA****	No glycol standards	5 mg/m^3 respirable	5 mg/m^3 respirable

*TWA = 8-hour, time-weighted average;
** American Conference of Governmental Industrial Hygienist;
*** particle size diameter in microns (μ);
**** Occupational Health & Safety Administration.

The Shape Study

A report to SHAPE (Safety and Health in Arts, Production, and Entertainment) by the University of British Columbia School of Occupational and Environmental Hygiene called "Atmospheric Effects in the Entertainment Industry, March 27, 2003. The data for this study was also published in the *Journal of Occupational & Environmental Hygiene* in May 2005. This study, evaluating questionnaires and some medical monitoring of over 100 fog-exposed entertainment workers, found that: "Overall, the health study results suggest that exposure to theatrical smokes and fogs is provoking non-specific respiratory irritation and increasing the risk for chronic airflow obstruction among BC theatrical industry employees."

Chronic airway obstruction requires long-term medical management. Eventually, it may lead to diagnosis of chronic obstructive pulmonary disease (COPD), which is a leading cause of death in many countries. It is the position of the author that the industry must seriously consider this finding and limit their use of these special effects as much as possible.

Another significant finding of this study was that a "measurable drop in lung function (over the testing period of about 4 hours on average) was more often seen when mineral oil fog was used." This phenomenon was also seen in the next study.

The Mt. Sinai/ENVIRON Study

A study by Mount Sinai's Dr. Moline, with air monitoring by ENVIRON Corporation (Arlington, VA), called "Health Effects Evaluation of Theatrical Smoke, fog, haze, and Pyrotechnics," was done in 1999 and released on June 6, 2000. This is the most important of the studies, not for its findings, but for the fact that it has been used as the primary source for setting the industry's ANSI E1 exposure limits for these chemicals. The guidelines set by Dr. Moline and her colleague were as follows:

- The use of glycols should be such that an actor's exposure does not exceed 40 milligrams per cubic meter (mg/m^3).
- Mineral oil should be used in a manner such that an actor's exposure does not exceed a peak concentration of 25 mg/m^3.
- For chronic exposures to mineral oil, the existing standards established for oil mists (5 mg/m^3 as an eight-hour time-weighted average) should also be protective for actors in theatrical productions.

With only a few differences, these were apparently the basis for the ANSI standard guidelines. All these standards and guidelines are compared in Table 1.

UNDERSTANDING THESE LIMITS

The most recognized U.S. workplace safety and health organization is the American Conference of Govern-

mental Industrial Hygienists (ACGIH). Their air quality guidelines, called threshold limit values (TLVs), refer to airborne concentrations of chemical substances, and represent conditions under which it is believed that nearly all workers may be repeatedly exposed over a working lifetime without adverse effects. The two types applicable to this review are 1) eight-hour, time-weighted averages or TWAs, and 2) ceiling (or peak) limits that should not be exceeded.

The ACGIH TLVs also may provide two TLVs for the same substance, one for "inhalable" aerosols that have diameters of 10 to 100 microns (μ) and a more restrictive limit for the "respirable" aerosols of under 10 μ in diameter. The small particles can reach the deepest parts of the lungs, where they can remain longer and potentially be absorbed or cause local effects.

The ACGIH currently has no TLVs for the glycols, and they recently withdrew their glycerin TLV-TWA due to insufficient human exposure data. Yet, the ANSI standards have set both TWA and peak limits for these chemicals.

The ACGIH only has a 5 milligram/cubic meter (mg/m^3) TWA for (inhalable) mineral oil only. However, the ANSI limit by reference is an outdated TWA from the Occupational Safety and Health Administration (OSHA) is 5 mg/m^3 for respirable oil mists. The OSHA standards are so out of date that OSHA itself recommends using better limits such as those of the ACGIH.[6] Using OSHA limits when there are better ones is not an ideal practice.

The lack of standard toxicological data on these chemicals is stunning. The only standard animal test done on the fog chemicals was for acute ingestion (LD50). This test is not very useful in determining inhalation hazards. For example, drinking mineral oil only causes a laxative effect, but aspiration into the lungs can cause potentially fatal lipoid pneumonia.

More importantly, the standard animal tests for acute and chronic inhalation effects, the most informative tests used to set inhalation exposure limits, have never been done on the chemicals. None of the glycols nor glycerin were tested for respiratory sensitization (allergy). Only two of the chemicals were tested for acute respiratory toxicity, and both showed adverse effects. Only one chronic test for inhalation was found.[7] Lipoid pneumonia from aspiration of mineral oil was reported, but there was no aspiration data on any of the other chemicals.

PARTICLE SIZE OF THE SPECIAL EFFECTS

The most compelling reason to reject the current ANSI limits as sufficiently protective is the failure of these standards to address particle size. It is now common practice to set more restrictive limits for respirable aerosols than for the larger inhalable ones. Further, it is now known that very small particles within the respirable range, such as the one micron mists in theatrical effects, can reach the deepest parts of the lungs where they can remain longer and potentially be absorbed or cause local effects.

The greater toxicity of the very small particles is also reflected in the Environmental Protection Agency (EPA) air quality standards. EPA sets two standards for outdoor aerosols, one for less than 10 μ and an even more restrictive standard for particles that are 2.5 μ and smaller. Most fog, smoke and haze mists today are under 2.5 μ in diameter; in fact, they are probably less than 1 μ.

Particle size data for smoke and fog is found in a 2013 NIOSH study of firefighters who used oil mist and diethylene glycol theatrical smoke to simulate fire conditions when training recruits.[8] The NIOSH study was initiated after three trainers became ill and one was hospitalized for "acute pneumonitis/lipoid pneumonia, likely developed after inhaling a heavy mineral oil mist over a 30-minute period."

Two types of chemical smoke were used by the trainers: mineral oil and diethylene glycol. The oil mist smoke was generated by an MDG(TM) built in fogger and the diethylene glycol smoke was created by handheld High End Systems(TM) foggers. Both machines are commonly used in theatrical settings.

The NIOSH study found that the oil smoke particles ranged from 0.5 to 0.7 μ in diameter. Diethylene glycol mist is semivolatile, and the particles become smaller when some of the mist evaporates during air sampling, which would make NIOSH's measurements a bit off. But the researchers determined the diethylene glycol aerosol was definitely less than 1 μ in diameter.

These very small particles can penetrate deep into the lungs where they are difficult, or even impossible, to clear. It is utterly unknown just how toxic these tiny glycol, glycerin and oil mist particles are and what they do, or where they go, in the body.

DR. MOLINE'S STATEMENT

On July 17, 2015, Dr. Jacqueline Moline wrote a letter to the author (Monona Rossol) in which she makes it clear that the Mt. Sinai/ENVIRON study "was not designed to provide data that would be comprehensive enough for a standard to be set . . ." Instead, the study was limited "only to one group of workers (Actors) and only included materials that were used in the performances on Broadway during the period of the study [1999]."[9] The study's purpose was to provide guidance for "smoke, fog and pyrotechnic effects" that would lead "to a decrease in complaints among Actors related to the health consequences of these effects . . ."

The author agrees with Dr. Moline's conclusion that further studies should be done rather than relying on a highly limited 15 year old study and literature review. Further, one of the issues that should be examined is the study's finding that "Actors with the highest exposure to mineral oil had a statistically significant decrease in one pulmonary function parameter—forced vital capacity. This finding was surprising, as decreases in forced vital capacity are usually associated with interstitial lung processes or interference with taking a deep breath from external pressures, such as pleural thickening or obesity. While an effect was noted, it is important to note that Actors still have pulmonary function within the normal range."

However, the performance of singers, actors, and musicians can be adversely affected by a decrease in pulmonary function. And it is unknown whether this change in lung capacity occurring repeatedly could develop into a chronic condition. It is also disturbing that this same effect was noted in the SHAPE study. Both Dr. Moline and the author have called for further study.

SUMMARY AND CONCLUSION

The ANSI standard exposure limits for all eight special effects chemicals are unsupported by data. Both the ANSI 8-hour, time weighted average (TWA) limits and the peak limits are no longer supported by the 15 year old AEA study and are not corroborated by ACGIH limits or by most other occupational safety organizations. In addition, the very small particle size (< 1 μ) of the effects almost surely increases their toxicity, yet this has not been taken into account in the ANSI standards.

Actions That Should Be Taken

- **Honor adult workers' right to know.** All theatrical and entertainment workers exposed to any of these chemical effects have a right to know both what is known and what is *not* known about them. Their only source of information should not be the promotional literature from the manufacturers. Producers should take the following actions:
  - — Provide notice at the time of hire that airborne chemical effects will be used.
  - — Use no trade secret or proprietary chemicals whose identity is undisclosed by the manufacturer.
  - — As soon as the types of effects are determined, hold toolbox meetings about the potential hazards and provide the manufacturers safety data sheets as required by OSHA.
  - — Make it clear to cast and crew that while many people have been exposed to these effects without apparent harm, there are some people who have reported asthma, respiratory symptoms, or other adverse reactions. Also, make it clear that there are no studies of either humans or animals that have determined whether or not there are long-term (chronic) effects from repeated exposures.
  - — Provide information on the method the special effects people will use to monitor cast and crew exposures as required by ANSI E1.23–2009 Entertainment Technology—Design and Execution of Theatrical Fog Effects.
  - — Explain to workers that the limits below which exposures will be kept during production were set to protect only most healthy adult (age 18 to 64) workers and that today there are serious reservations about the data used to set these limits.
  - — Avoid any unnecessary exposure. Position people in low- or no-effects areas when possible. Provide ventilation that can clear out the effects quickly between scenes or in emergencies.
  - — Follow all of the safety and proper use rules for fog-, smoke-, and haze-generating machines in the manufacturer's operating manuals and the ANSI E1 standards.
  - — Accommodate workers who do not want to accept this unknown risk or who have adverse reactions to the chemicals when they are used. Accommodation

can include assigning work farther from the effects, relocating machines, providing ventilation to flush effects away when they are no longer needed, providing an OSHA voluntary respiratory protection program and appropriate respirators, etc.

- **Provide information to guardians of child actors, to senior workers, and to other high risk individuals.** In addition to providing the information for adult workers listed above, ensure that high risk workers know that those safety precautions apply only to healthy adults. There currently are no workplace air quality limits apply to children or other high risk individuals. Even the ANSI standards recognize this limitation. The Scope of the ANSI E1–5 standard says, "This standard describes the composition of theatrical fogs or artificial mists that are not likely to be harmful to otherwise healthy performers, technicians, or audience members of normal working age, which is 18 to 64 years of age, inclusive."

  Children, the elderly, and people with various physical limitations were never covered by the ANSI standards or any other workplace air quality guidelines. Children, in particular, should not be exposed to these chemicals in airborne special effects until there is enough human inhalation and acute and chronic animal data to firmly establish safe limits for children.
- **Provide information to the audience.** Audiences will consist of a mixture of adults, children, and elderly. People with various physical limitations, disabilities, and illnesses can be expected to be present at times. Ethically, children and other high risk individuals should not be exposed to any of these inadequately studied chemicals at any level. However, the current public and producer demand for these effects makes it unlikely that ethics will prevail. At the very least, producers should take the following actions:
  — Provide notices at the box office, in programs, and in the theater lobby or arena entrances that airborne chemical effects will be used.
  — Make available on request the actual identity of the airborne chemicals that will be used.
  — Use no trade secret or proprietary chemicals whose identity is undisclosed by the manufacturer.
  — Disclose how little is known about the effects of these chemicals by inhalation. More specifically, theatergoers should not be told the products have been proven to be safe in the amounts used.
  — Follow all of the safety and proper use of fog-, smoke-, and haze-generating machinery from the manufacturer's operating manuals and the ANSI E1 standards.

Most pop singers and many classical singers will encounter stage effects that affect the performance environment. The more singing teachers and performers know about these special effects, the chemicals used to make them, and their potential effects on the voice, the chances of avoiding or minimizing adverse effects on the voice.

NOTES

1. 76 *FR* 68168–70, November 2, 2011, a *Federal Register* notice of a $1.3M civil penalty against Spin Master® for failing to recall their Aqua Dots® toy product promptly after receiving reports of serious illnesses in children who ingested its tiny soft plastic dots containing 1,4-butylene glycol.
2. ANSI E1.23—2010 (R2015) and ANSI E1.23—2010 (R2015), can be downloaded from www.plasa.org.
3. Harry H. Herman, Jr., "Health effects of glycol based fog used in theatrical productions" (Report to Actor's Equity Association, July 1995; also presented at the American Chemical Society's annual meeting).
4. Occupational Health Surveillance Update, "Occupational Asthma: Interesting Case Reports," New Jersey Department of Health (January 1996), 2, notes occupational asthma in an opera singer and a stage hand.
5. In 1987, I was the Technical and Press Representative for Actors' Equity during a strike at *Cats* in Her Majesty's Theater, Melboure, Australia, when the performers and crew attempted unsuccessfully to change the Producer's use of Freon for special effects. Designers of the show worldwide specified this now banned, ozone damaging gas.
6. The 29 CFR 1910.1000 Z-1 table permissible exposure limits (PELs) for mineral oil mist is 5 mg/m^3. But OSHA itself cast doubt on the safety of their standards. OSHA has provided the following statement in the introduction to their "Permissible Exposure Limits—Annotated Tables:"
   - OSHA recognizes that many of its permissible exposure limits (PELs) are outdated and inadequate for ensuring protection of .adoption of the Occupational Safety and Health (OSH) Act in 1970, and have not been updated since that time.

- To provide employers, workers, and other interested parties with a list of alternate occupational exposure limits that may serve to better protect workers, OSHA has annotated the existing Z-Tables with other selected occupational exposure limits. OSHA has chosen to present a side-by-side table with the Cal/OSHA PELs, the NIOSH Recommended Exposure Limits (RELs) and the ACGIH® TLV®s.
- OSHA's mandatory PELs in the Z-Tables remain in effect. However, OSHA recommends that employers consider using the alternative occupational exposure limits because the Agency believes that exposures above some of these alternative occupational exposure limits may be hazardous to workers, even when the exposure levels are in compliance with the relevant PELs.

7. There are workplace air quality limits for propylene and diethylene glycol set by the Toxicology Excellence for Risk Assessment (TERA) group. This is *not* a group that is listed as providing better standards on the OSHA website. I have reviewed the data on which these two limits were based and most of their cited studies were old, not related to inhalation, and seriously inadequate. (My Report on Theatrical Special Effects Air Quality Standards, August 10, 2015, in which I evaluate this source is available on request.)

   However, TERA lists in their standard for diethylene glycol (DEG), the only chronic inhalation study available to my knowledge on any of the ANSI-listed glycols. It was done at doses of 4–5 mg/m^3 which are comparable to actual human exposures to fog. The aerosol-vapor mixture was produced by heating DEG in a petri dish at 30°C-35°C and it was used to expose groups of 16 female mice (mixed strains) via inhalation for 2 hr/day for a period of 7 months. However, there was no information presented on how the actual exposure level was determined. A control group composed of 20 female mice was included in the study. The treated animals exhibited bronchitis and interstitial pneumonia. Ten of 12 treated mice developed a tumor within 2.5 to 11 months after the end of the inhalation exposure. Adenocarcinomas of the mammary glands were observed in 7 treated mice. No tumors were observed in the control group. Cf., Y. P. Sanina, "Remote Consequences of Long-Term Inhalation of Diethylene Glycol," *Gigiena i Sanitaria* 33 (1968): 191–195.

   TERA decided to ignore this study in the setting of there 10 mg/m^3 TWA and to rely instead on very limited acute animal data only.

8. HETA 2012–0028–3190 (July 2013), "Evaluation of Chemical Exposures during Fire Fighter Training Exercises Involving Smoke Simulant," *NIOSH*, 2013; www.niosh.gov.

9. Jacqueline Moline, MD, letter to Monona Rossol (July 17, 2015; available on request).

Monona Rossol. Born into a theatrical family, Monona began working as a professional entertainer at three years of age. She enrolled in the University of Wisconsin where she earned a BS in Chemistry with a minor in math, and MS and MFA degrees in art, minoring in music. She worked as a research chemist to support her studies, won two national art awards, performed with University music and theater groups, and worked yearly in summer stock. After moving to New York City, she performed in musical and straight acting roles in Off and Off Off Broadway theaters and cabaret, taught ceramics at various colleges and art schools, and began working as a consultant in art safety. She was accepted for full membership by the American Industrial Hygiene Association in 1984.

Currently, Monona is President/founder of Arts, Crafts & Theater Safety, and the Safety Officer for Local USA829 of the International Alliance of Theatrical Stage Employees (IATSE). She lectures, has written 9 books, provides regulatory compliance training, and consults on building planning. One of the buildings for which she did the industrial ventilation specifications won the AIA COTE (Committee on the Environment) for environmental design. She has worked in the US, Canada, Australia, England, Mexico, Portugal, the Netherlands, and the United Arab Emirates.

The splendour falls on castle walls
And snowy summits old in story:
The long light shakes across the lakes,
And the wild cataract leaps in glory:
Blow bugle, blow, set the wild echoes flying,
Blow, bugle: answer, echoes, dying, dying, dying.

O, hark, O hear! how thin and clear,
And thinner, clearer, farther going!
O, sweet and far from cliff and scar
The horns of Elfland faintly blowing!
Blow, let us hear the purple glens replying,
Blow, bugle; answer, echoes, dying, dying, dying.

O love, they die in yon rich sky,
They faint on hill or field or river;
Our echoes roll from soul to soul,
and grow forever and forever.
Blow, bugle, blow, set the wild echoes flying,
And answer, echoes, answer, dying, dying, dying.

"Nocturne," Alfred Lord Tennyson