

**DEVELOPMENT OF
TIME-AND-DISTANCE GUIDELINES FOR USE OF
THEATRICAL SMOKE EQUIPMENT:**

CITC STARHAZER III

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I. INTRODUCTION

A. Background

In 1997-99, at the request of Actors' Equity Association (AEA) and the League of American Theaters and Producers (LATP) and with the support of the Equity-League Pension and Health Trust Funds, investigators from the Mount Sinai School of Medicine (Mt. Sinai) and ENVIRON International Corporation (ENVIRON) conducted a study to evaluate whether the use of smoke, fog, haze, and pyrotechnics special effects in theatrical musical productions is associated with a negative health impact in actors. The results of this study were presented in the report *Health Effects Evaluation of Theatrical Smoke, Haze, and Pyrotechnics* (Mt. Sinai and ENVIRON 2000).

Based on the results of the study, Mt. Sinai and ENVIRON recommended the following peak guidance levels with respect to glycols and mineral oil:

- 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 $25 \text{ mg}/\text{m}^3$.
- For chronic exposures to mineral oil, the existing standards established for oil mists ($5 \text{ mg}/\text{m}^3$ as an eight-hour time-weighted average) should also be protective for actors in theatrical productions.

Comparable guidance levels were developed for glycerol in a subsequent study (ENVIRON 2001c):

- Glycerol should be used in a manner such that an actor's exposure does not exceed a peak concentration of $50 \text{ mg}/\text{m}^3$.
- For chronic exposures to glycerol, the existing standards established for glycerin mists ($10 \text{ mg}/\text{m}^3$ as an eight-hour TWA) should also be protective for actors in theatrical productions.

To ensure that peak smoke and haze levels are below these guidelines, theaters have the option of conducting production-specific testing at their theaters using an aerosol monitor or following equipment-based time-and distance guidelines. CITC retained ENVIRON to develop time-and-distance guidelines for the use of the **CITC Starhazer III**. The fluid tested with the CITC Starhazer III is the Starhazer III Water Haze Fluid, a glycerol-based fluid.

B. Use of Time-and-Distance Guidelines

In the absence of other information, theater-specific monitoring would be required to evaluate whether smoke/fog/haze machines are being used in a production in a manner that avoids peak exposures to actors. The Time-and-Distance Guidelines described in this report were developed as an alternative to conducting theater-and production-specific monitoring. These Guidelines were developed under conservative use assumptions (e.g., no on-stage activities or props that would enhance dispersion, cue release at breathing height level). By following these Guidelines, a production can use haze effects without having to conduct its own stage-specific testing, provided the machines are used in accordance with manufacturer specifications, are well maintained, and are functioning properly. Table 1 of this report describes the distance (with respect to the discharge point on the equipment) and length of time that concentrations exceeding the peak guidance levels would occur for various use patterns for the Starhazer III. Thus, by arranging the blocking and choreography such that an actor is not situated within the restricted areas during the times specified in Table 1, actors should not receive peak exposures above the Guidelines. Calibration factors and/or Time-and-Distance Guidelines for other CITC machines have also been developed by ENVIRON (2001b, 2002).

It should be noted that these Time-and-Distance Guidelines may not be appropriate for all productions. The Guidelines are based on the Starhazer III being positioned at ground level, and being operated to achieve 15 to 60 minutes of continuous haze generation. Productions may want to use different machine settings, different configurations for positioning the machines (e.g., different heights), provide enhanced on-stage ventilation, or generate haze for a longer or shorter period of time. In addition, many productions may have other stage-specific conditions (e.g., on-stage activities and props that enhance dispersion) that would allow actors to be present in areas that are restricted under these Guidelines but which, in fact, do not exceed the guidance levels. In those cases, production-specific monitoring would be recommended to evaluate whether peak exposure may occur.

II. TESTING METHODOLOGY

A. Monitoring Equipment and Sampling Media

Monitoring of short-term concentrations was performed using portable real-time aerosol monitors (*personal*DataRAM Model PDR-1000) manufactured by Monitoring Instruments for the Environment, Inc. (MIE). The PDR-1000 is a high sensitivity nephelometric (i.e., photometric) monitor that uses a light scattering sensing chamber to measure the concentration of airborne particulate matter (liquid or solid), providing a direct and continuous readout as well as electronic logging of the data.

The PDR-1000 aerosol monitors as obtained are calibrated to Arizona road dust over a measurement range of 0.001 to 400 mg/m³. In order to be utilized to measure short-term glycerol concentrations, the monitors were first calibrated for the haze machine and fluid being used.

SKC Airlite sampling pumps were used to draw air through collection media. The type of collection media used depended on the analyte. For glycerol, air was drawn through 37-mm polyvinyl chloride (PVC) membrane filters (5 µm pore size), which were analyzed gravimetrically to quantify glycerin mist concentrations. This calibration sampling is based on NIOSH Method 0500 (NIOSH 1994), and was conducted in conjunction with operating the PDR-1000 aerosol monitors.

Calibration of the aerosol monitors was conducted by collecting simultaneous measurements with a series of sampling pumps and PDR-1000 aerosol monitors, mounted on tripods.

B. Monitoring Procedures

The testing is typically conducted in a two-step process:

- The first step involves collecting sufficient data to calibrate the aerosol monitors for the equipment and fluid combination being used.
- The second step involves using the calibrated aerosol monitor to identify distances from the haze release point where exceedances of the guidance levels occur.

Testing of the Starhazer III took place at ENVIRON's testing facility and the Groton Dunstable Middle School Performing Arts Center, both located in Groton, Massachusetts

Aerosol Monitor Calibration

Four tripod assemblies were used for calibrating the aerosol monitor, each consisting of a sampling pump, flexible tubing, sampling media (cassettes for glycerol), and an aerosol monitor.

The height of each tripod was approximately three feet. The room exhaust ventilation fans were turned off during each run; no major movement occurred in the testing room during each run that would affect haze dispersion.

- a) The sampling pumps were calibrated to 3 liters per minute (LPM) using a BIOS DryCal pump calibrator. The aerosol monitors were zeroed, the data logging function of the aerosol monitor was turned on, and the data logging times for all of the aerosol monitors were synchronized.
- b) The haze generator was placed on the floor, representative of its typical use in the field. The tripods were placed at various distances from the haze machine release nozzle to achieve a range of exposure concentrations.
- c) The sampling pumps were turned on, followed by the Starhazer III, allowing sustained smoke generation to occur. After a period of approximately one minute, the machine was turned off; pumps were then allowed to draw air for 30 minutes or 45 minutes.
- d) The sampling cassettes were capped and labeled to identify the haze machine, glycerol fluid, sampling location, and other sampling specifics.
- e) The room exhaust ventilation fans were used between runs to clear residual aerosols from the testing area.

The collection media and a bulk fluid sample, along with appropriate field blanks, were submitted for analysis to Analytics Laboratory of Richmond, Virginia, an American Industrial Hygiene Association (AIHA) accredited laboratory. The glycerin mist samples were analyzed gravimetrically using NIOSH Method 0500. A limit of quantification (LOQ) of 10 micrograms (μg) per sample was used.

Time and Distance Monitoring

To measure the levels of glycerol present at different distances from the release point, a series of five tripods equipped with aerosol monitors positioned at breathing height (approx. 5ft above ground) were used. The Starhazer was turned on for durations ranging from 15 to 60 minutes, allowing sustained haze generation to occur, and then turned off. The five tripods were then immediately placed within the haze plume at distances ranging from three to twenty-one feet from the Starhazer III release point. The aerosol monitors collected logged data on the fog levels as the concentrations gradually dissipated.



Figure 1. CITC Starhazer III



Figure 2. Monitoring configuration consisting of five tripod-mounted aerosol monitors situated at three-foot intervals from the Starhazer III machine. Each tripod is equipped with an aerosol monitor.

III. RESULTS AND DISCUSSION

A. Aerosol Monitor Calibration

To develop a calibration curve, the average aerosol monitor readings for each air sample were calculated and plotted against the total glycerol concentration data. The calibration curve for the Starhazer III/Starhazer III Water Haze Fluid combination is shown in Figure 3. A first order regression line is also shown on this figure. The calibration factor, calculated from the slope of this regression, is 0.43 (ug/L) / (mg/m³).

B. Peak Exposure Characterization

For the release durations, monitoring data collected using aerosol monitors placed at distances ranging from three to 18 feet from the Starhazer III at three foot intervals were combined with the calibration factors to quantify the levels of haze at different distances from the release point and times following the release. The real-time aerosol monitor readings were converted to glycerol concentrations using the appropriate calibration factor for the fluid, as follows:

$$CONC = C \times PDR$$

where:

<i>CONC</i>	= air concentration of total glycerol, $\mu\text{g/L}$
<i>C</i>	= aerosol monitor calibration factor, $(\mu\text{g/L}) / (\text{mg/m}^3)$
<i>PDR</i>	= aerosol monitor reading, mg/m^3

Based on these calibrated data, the times after which the concentration of haze at each distance drops below the guidance levels were identified. These average Guideline values are summarized in Table 1.

C. How to Use the Time-and-Distance Guidelines Table

For various distances from the cue release point, Table 1 provides the average time (in seconds) after the end of the cue release after which the glycerol concentrations will have fallen below the guidance levels. Thus, in order to prevent peak exposures to actors, the blocking and choreography should be arranged such that actors are not situated within a particular distance from the front of the haze release point until the amount of time listed in Table 1 has elapsed following the end of the cue. In the case of the Starhazer III, no exceedances were measured at any distance following 15 to 60 minute cue duration, even at the maximum fog output setting. Based on ENVIRON's testing, the Starhazer III generates a thin haze that remains suspended in air for a long period. Under the highest haze output setting (100%), no exceedances of the peak

guidance level were identified for haze release durations of up to 60 minutes. Therefore, an actor can be situated at any distance beyond 3 ft from the front of the cue release point immediately following the end of the cues with durations of up to 60 minutes.

It should be reiterated that the Time-and-Distance Guidelines provided in Table 1 are intended to allow a production to use the Starhazer III without conducting monitoring. However, these Guidelines may not be appropriate for all productions. Table 1 is based on the Starhazer III being positioned at ground level, and being operated to achieve 15 to 60 minutes of continuous haze generation. Productions may want to use different machine settings, different configurations for positioning the machine (e.g., different heights), provide on-stage ventilation, or generate haze for a shorter or longer period of time. In addition, many productions may have other stage-specific conditions (e.g., on-stage activities and props that enhance dispersion) that would allow actors to be present in areas that are restricted under these Guidelines but which, in fact, do not exceed the guidance levels. In those cases, production-specific monitoring would be recommended to evaluate whether peak exposure may occur.

TABLE 1					
Summary of Time-and-Distance Guidelines for Haze Generation Starhazer III with Water Haze Fluid					
Release Duration (min)	Time (in sec) After Which Air Concentrations Are Below Guidance Level (50 mg/m³)				
	3 ft	6 ft	9 ft	15 ft	21 ft
15	0	0	0	0	0
30	0	0	0	0	0
60	0	0	0	0	0
<p>Note: Concentrations were found to be below the Guidance Level at all areas except directly above the release point (i.e., one foot away). Concentrations at all other areas typically ranged from less than 5 mg/m³ up to 20 mg/m³, which are well below the guidance level of 50 mg/m³. In addition, since these measurements were collected in a 50'x20'x9' test room, which is smaller than most stages, the concentrations present in a stage would likely be even lower.</p>					

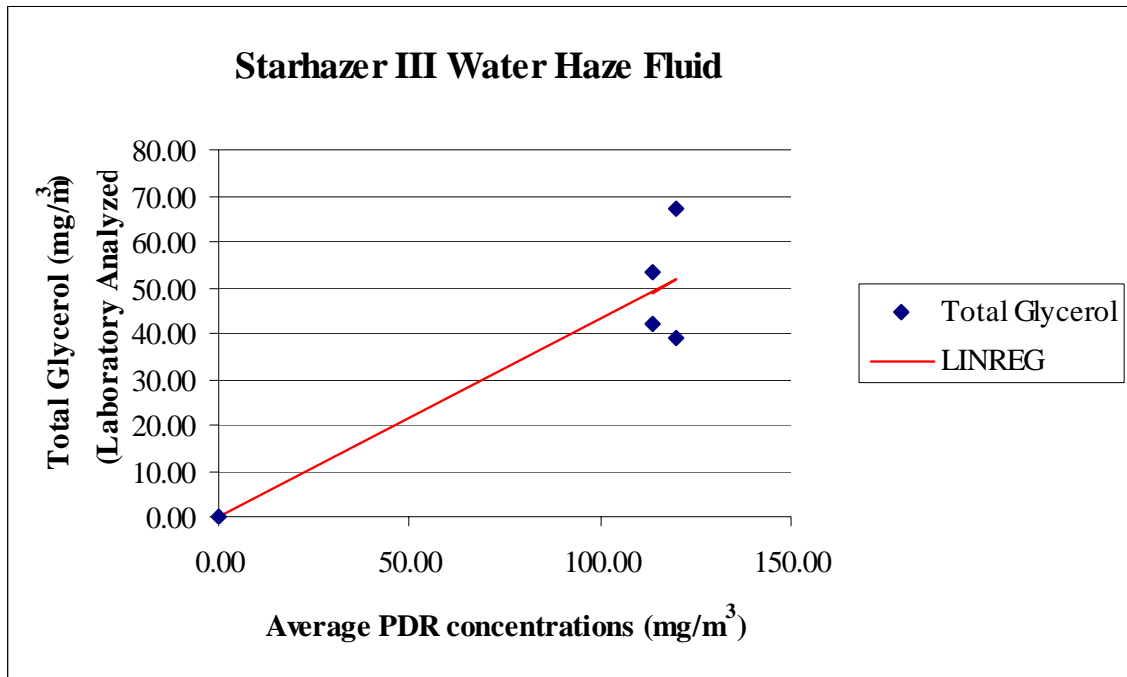


Figure 3. Calibration curve for Starhazer III Water Haze Fluid in Starhazer III. Calibration factor, based on slope of curve, is 0.43 (mg/m³ glycerol)/ (mg/m³ aerosol).

IV. REFERENCES

- ENVIRON International Corporation (ENVIRON). 2001a. *Evaluation of short-term exposures to theatrical smoke and haze: Air sampling protocol*. Prepared for Equity-League Pension and Health Trust Funds. May 14.
- ENVIRON International Corporation (ENVIRON). 2001b. *Equipment-based guidelines for use of theatrical smoke and haze. Revision 1*. Prepared for Equity-League Pension and Health Trust Funds. June 8.
- ENVIRON International Corporation (ENVIRON). 2001c. *Theatrical haze and fog testing for Mamma Mia! Winter Garden Theatre*. Prepared for Mamma Mia! Broadway and Nina Lannan Associates. November 12.
- ENVIRON International Corporation (ENVIRON). 2002. *Development of calibration factors for monitoring theatrical smoke and haze*. Prepared for Entertainment Services and Technology Association. November 11.
- Mount Sinai School of Medicine and ENVIRON International Corporation (Mt. Sinai and ENVIRON). 2000. *Health effects evaluation of theatrical smoke, haze, and pyrotechnics*. Prepared for Equity-League Pension and Health Trust Funds. June 6.
- National Institute for Occupational Safety and Health (NIOSH). 1994. Method 0500: Particulates Not Otherwise Regulated, Total, Issue 2. NIOSH Manual of Analytical Methods (NMAM). Fourth Edition. August 15.

APPENDIX A

Material Safety Data Sheet

Material Safety Data Sheet

Section I – Product

Product Name: StarHazer III™ Water Haze Fluid
Date of Revision: 02/21/07
Produced By: CITC
2100 196th Street SW, #138
Lynnwood, WA 98036
Prepared By: MSDS Coordinator
Emergency Phone: CHEM-TEL, INC. 1-800-255-3924
Product Code: 150600-B
WHMIS Class: Not controlled
Health: 1
Flammability: 1
Reactivity: 0

Section II – Hazardous Ingredients

None

Section III – Physical Data

Boiling Point (C°): Starts at 545° F, (285° C)
Vapor Pressure (mm Hg): N/A
Vapor Density (Air = 1): 5.17
Water Solubility: Easily Soluble in cold water
Specific Gravity: (H2O = 1): 1.1274
% Volatile (Wt. %): N/A
Evaporation Rate (Water=1): >1
Viscosity: 17.5 cps at 77° F, (25° C)
Appearance and Odor: Colorless, transparent liquid, slight characteristic odor
Odor Threshold (ppm): N/A

Section IV – Fire and Explosion Hazard Data

Flammability: May be combustible at high temperature >700°F, (372° C)
Flash point (TCC, °C): Not combustible at 275°F, (135° C)
Hazardous Combustion Products: These products are carbon oxides (CO, CO2)
Auto-Ignition Temp.(°C): 372° C, (700° F)
Means of Extinction:
Small Fire: Use DRY chemical powder.
Large Fire: Use water spray, fog or foam. Do not use water jet.
Special Fire Hazards: N/A

Other Protective Equipment: For large spills, Splash goggles. Full suit. Waterproof boots Gloves. Use extreme caution due to slippery surface. Extremely slippery. Suggested protective clothing might not be sufficient, consult a specialist before handling this product.

Section IX – Shipping & Labeling Data
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DOT Hazard Classification: None Required – Do not freeze. See label.
Proper DOT Shipping Name: Not a DOT controlled Material (United States).

Section XI – User's Responsibility

The responsibility to provide a safe workplace remains with the user. The user should consider the health hazards and safety information contained herein as a guide and should take those precautions required in an individual operation to instruct employees and develop work practice procedures for a safe work environment.