DEVELOPMENT OF CALIBRATION FACTORS FOR MONITORING THEATRICAL SMOKE AND HAZE:

LOOK SOLUTIONS ORKA WITH REGULAR-FOG FLUID

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C O N T E N T S

F I G U R E S

A P P E N D I X

I. INTRODUCTION

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 determine whether the use of smoke, haze, and pyrotechnics special effects in theatrical musical productions is associated with a negative health impact in actors. This effort was initiated in response to ongoing concerns by actors that the use of these theatrical effects may have an impact on their health. 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 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.

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 mg/m^3.

- For chronic exposures to glycerol, the existing standards established for glycerin mists (10 mg/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. In order to conduct the testing, calibration data must be developed for each equipment/fluid combination.[1] These calibration data are necessary to convert the readings of the aerosol monitor to glycol, mineral oil, or glycerol concentrations. Look Solutions USA Ltd., (Look

[1]See http://www.environcorp.com/practices/article.php?id=61&refsec=practices&refid=2245 for available calibration factor data.

Solutions) retained ENVIRON to develop a calibration factor for the use of Look Solutions Regular-Fog Fluid in an Orka fog generator (Figure 1).

II. METHODS AND MATERIALS

A. Sampling Equipment and Materials

Monitoring of short-term concentrations was performed using a portable real-time aerosol monitor (*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 monitor as obtained is calibrated to Arizona road dust over a measurement range of 0.001 to 400 mg/m^3. In order to be utilized to measure short-term glycol concentrations, the monitor must first be calibrated for the smoke machines and fluids being used. Calibration of the aerosol monitor was conducted by collecting simultaneous measurements with a sampling pump and a PDR-1000 aerosol monitor, mounted on a tripod.

Two SKC Airchek sampling pumps were used to draw air through collection media. Look Solutions Regular-Fog Fluid is a glycol-based fluid. Therefore, OSHA Versatile Sampler (OVS) traps were used as the collection media, each containing two sections of XAD-7 resin (200-mg front section, 100-mg back section, separated by a polyurethane foam [PUF] plug). The XAD-7 resin was used to collect both the particulate and vapor phase of the glycol aerosol. A 13-mm glass fiber filter (GFF) plug precedes the front section and a PUF plug follows the back section. This sampling is based on a variation of NIOSH Method 5523 (NIOSH 1996; Pendergrass 1999). This calibration sampling was conducted in conjunction with operating a PDR-1000 aerosol monitor.

The calibration sampling was performed at a test facility located at ENVIRON's Groton, Massachusetts office.

B. Aerosol Monitor Calibration Procedure

A tripod assembly was used for calibrating the aerosol monitor, consisting of a sampling pump, flexible tubing, sampling media (OVS trap), and an aerosol monitor (see Figure 2). The height of the tripod was approximately five feet, corresponding with the breathing zone of a typical actor. No room ventilation fans were operational during each run; no major movement occurred in the testing room during each run that would affect smoke dispersion.

a) The sampling pump was calibrated to 2 liters per minute (LPM) using a BIOS DryCal pump calibrator. The aerosol monitor was zeroed, and the data logging function of the aerosol monitor was turned on.

b) The fogger was positioned on a pallet resulting in a release of smoke at floor height; upon release, the fog would quickly rise to breathing zone height. The tripod was

placed at various distances from the fogger release nozzle to achieve a range of exposure concentrations.

c) The fogger was turned on for a period of 30 seconds to one minute, and a visually uniform concentration within the test room was allowed to form. Various output levels were used to achieve different aerosol concentrations. The sampling pumps were turned on for a period of approximately six to ten minutes to collect a sufficient sample mass (i.e., longer sampling durations were used at lower fog concentrations).

d) The OVS traps were capped and labeled to identify the type of smoke machine, glycol fluid, sampling location, and other sampling specifics. After being capped and labeled, the OVS traps were placed in a cooler with ice packs.

e) A fan was used between runs to clear residual aerosols from the testing area air by room ventilation.

The collection media and bulk fluid samples, along with appropriate field blanks, were submitted for analysis to Analytics Laboratory of Richmond, Virginia, an American Industrial Hygiene Association (AIHA) accredited laboratory.

C. Laboratory Analyses

All sample analyses were conducted by using validated analytical methodologies, as described in the ENVIRON Air Sampling Protocol (ENVIRON 2001a). Samples were analyzed for glycols using a variation of NIOSH Method 5523, which involves the use of a gas chromatograph with a flame ionization detector (GC/FID). The NIOSH Method 5523 was extended to a validated level of quantification (LOQ) of between 4.0 and 15.0 micrograms (μg) of each individual glycol per sample.

III. RESULTS

A. Aerosol Monitor Calibration

Total glycol concentrations were calculated from the analytical data. Only the glycol species measured in the bulk solution were included. For glycol species that were measured in the bulk solution, and were detected in the air sample but not above the LOQ, one half of the LOQ for that glycol species was conservatively used in calculating the total glycol concentration. To develop a calibration curve for the glycol-based Look Solutions Regular-Fog Fluid, the average aerosol monitor readings during the period of time in which air was drawn through the OVS trap for each air sample were calculated and plotted against the total glycol concentration data (see Figure 2). Based on the slope of this calibration curve, a calibration factor of **0.23 $(mg/m^3)/(mg/m^3$ aerosol)** was developed.

B. Use of Calibration Factor

The real-time aerosol monitor readings can be converted to glycol concentrations using the appropriate calibration factor for the fluid, as follows:

$$CONC = C \times PDR$$

where:

CONC = air concentration of total glycols, mg/m^3
C = aerosol monitor calibration factor, $(mg/m^3$ glycols$)/(mg/m^3$ aerosol)
PDR = aerosol monitor reading, mg/m^3

For example, an uncalibrated reading of 100 mg/m^3 on the aerosol monitor would correspond to a glycol concentration of 23 mg/m^3. These calculated concentrations can then be compared with the peak guidance levels. The peak guidance level for glycols of 40 mg/m^3 would correspond to an uncalibrated aerosol monitor reading of 174 mg/m^3.

Figure 1. Look Solutions Orka Fog Generator

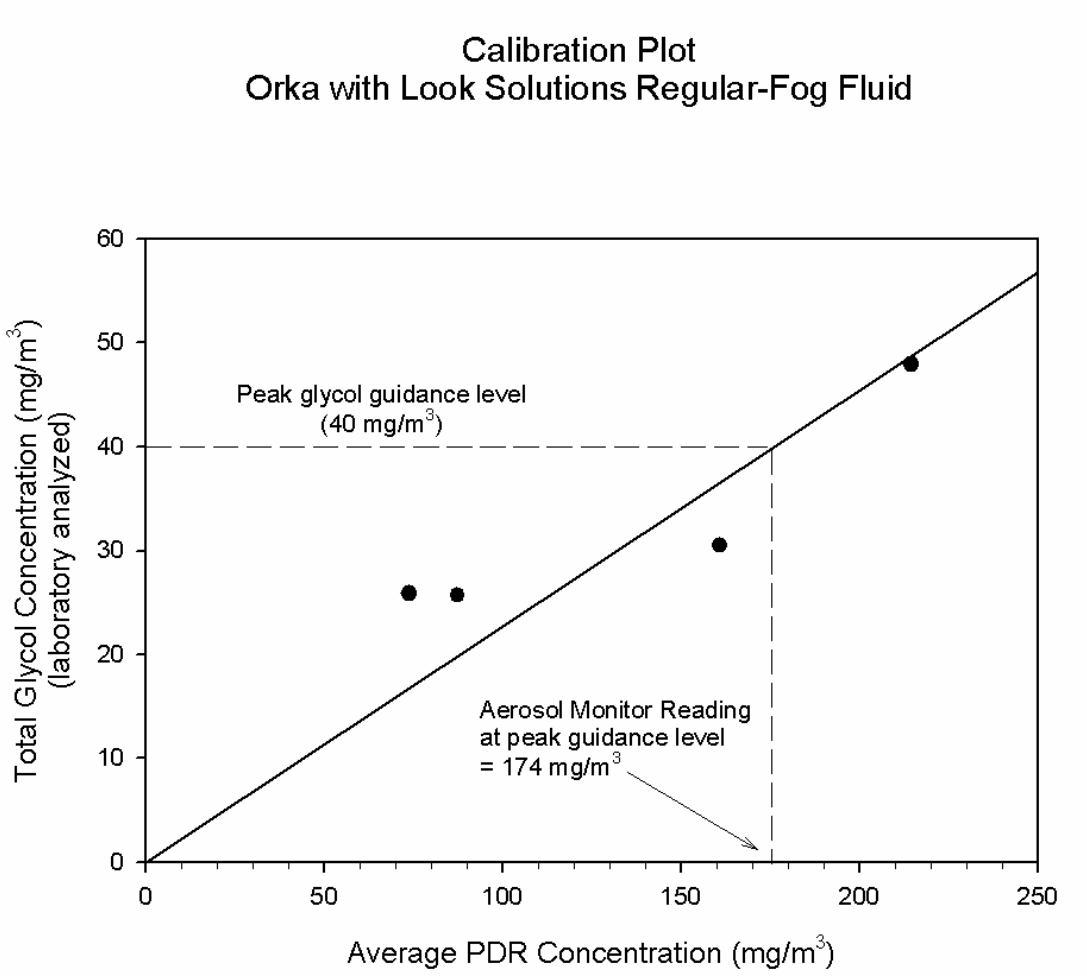

Figure 2. Calibration curve for Look Solutions Regular-Fog Fluid used in Orka fog generator. Calibration factor, based on linear regression, is 0.23 (mg/m^3 glycols)/(mg/m^3 aerosol).

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.

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). 1996. Method 5523: Glycols, Issue 1. NIOSH Manual of Analytical Methods (NMAM). Fourth Edition. May 15.

Pendergrass, S.M. 1999. Determination of glycols in air: Development of sampling and analytical methodology and application to theatrical smokes. *AIHA Journal*, **60**:452-457.

APPENDIX A

Material Safety Data Sheet

MATERIAL SAFETY DATA SHEET (MSDS)

SECTION 1 - PRODUCT IDENTIFICATION

Product Name: Look Solutions Fog Fluid
Look Solutions Haze Fluid

Product Label: Tiny Fluid
Quick Fog
Regular Fog
Slow Fog
Unique Fluid

Manufacturer: Look Solutions
Planetenring 12
D-30952 Ronnenberg
Germany
Phone: +49-511-463742

Distributor: Look Solutions USA, Ltd.
114 W. Third St.
Waynesboro, PA 17268
U.S.A.
Phone: 1-800-426-4189

SECTION 2 - INGREDIENTS

Contains one or more of the following:

Triethylene Glycol	CAS# 112-27-6
Monopropylene Glycol	CAS# 57-55-6
Demineralized Water	CAS# 7732-18-5

For exposure limits, see ANSI 1.5-2003 available free at www.esta.org/tsp/

SECTION 3 - PHYSICAL DATA

Physical State:	Liquid
Color:	Colorless
Odor:	Neutral
Freezing Point:	<0°C
Boiling Point:	>100°C
Vapor Pressure:	<0.1 mbar
Vapor Density:	>1.0 g/ccm
Solubility in Water:	Complete
pH:	6-8 at 20°C
Hazardous Categorization:	None

SECTION 4 - FIRE AND EXPLOSION DATA

Flammability:	Not Flammable
Flash Point:	>177°C
Ignition Temperature:	>370°C
Means of Extinction:	Water Spray, Foam, CO2, Dry Power
Special Fire Hazards:	None

SECTION 5 - REACTIVITY DATA

Stability:	Stable
Incompatibility:	Strong Oxidizing Agents, Strong Bases, Strong Acids
Thermal Decomposition:	No Known Dangerous Products
Hazardous Reaction:	None

SECTION 6 - HEALTH DATA

Acute Oral Toxicity:	>17,000mg/kg
Skin:	No Irritation
Eye:	No Irritation
Sensitization:	None Known
Carcinogenicity:	None

SECTION 7 - PRECAUTIONS FOR HANDLING

Handling:	No Special Procedure
Storage:	Keep Out of Reach of Children, Keep Container Tightly Closed Until Use
Leak and Spill Procedure:	Spilled Fluid or Splashed Fluid Droplets Can Cause Slip Hazard, Mop Up the Fluid and Dispose of it According to Regulations
Environmental Protection:	Review Federal, State and Local Government Requirements

SECTION 8 - FIRST AID

General:	No Special Procedure
Eye:	Flush With Water. Obtain Medical Attention in Case of Irritation.
Skin:	Wash Off With Water.
Ingestion:	Do Not Induce Vomiting. Rinse Mouth With Water, Then Drink Water. Obtain Medical Attention in Case of Irritation.

SECTION 9 - PREPARATION DATA

Date:	July 1, 2004
Prepared By:	Look Solutions USA, Ltd.