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SUMMARY

In July and August 1990, the National Institute for Occupational Safety and Health (NIOSH) received requests from the Actors' Equity Association (AEA) and the League of American Theatres and Producers, Inc. (LATP) to investigate possible health effects associated with the use of theatrical "smoke" in Broadway productions. In 1991, NIOSH representatives conducted site visits, summarized in the revised interim report provided as an appendix to this report. In 1993, NIOSH investigators conducted a follow-up investigation to further characterize "smoke" exposures and to determine whether there were measurable respiratory effects among performers.

INITIAL SURVEY: JUNE 17 AND JULY 2, 1991

Four Broadway productions (*Les Miserables, Miss Saigon, Phantom of the Opera,* and *Grand Hotel*) using theatrical "smoke" were selected for study. Dress rehearsals were arranged to conduct personal breathing-zone (PBZ) and general area (GA) air sampling to quantitate the "smoke" exposure. A questionnaire was administered to the actors; it addressed the frequency and severity of irritant and respiratory symptoms associated with exposure to theatrical "smoke." A small number of PBZ air samples were collected on electricians, carpenters, and other personnel who may have been exposed to the theatrical "smoke" during a performance. To determine if the prevalence of symptoms among actors in shows using theatrical "smoke(s)" differed from the symptom prevalence in non-"smoke"-using productions, NIOSH investigators administered the same questionnaire to performers in five Broadway productions in which no theatrical "smoke" was used (*Lost in Yonkers, Gypsy, Getting Married, Once on This Island,* and *Six Degrees of Separation*).

Although theatrical "smoke" was visibly evident during all of the "smoke" performances, concentrations of potential airborne contaminants from all of the PBZ and GA air samples were very low when compared to applicable Occupational Safety and Health Administration (OSHA) Permissible Exposure Limits (PELs), American Conference of Governmental Industrial Hygienists (ACGIH) Threshold Limit Values (TLVs), or NIOSH Recommended Exposure Limits (RELs). For example, acrolein and acetaldehyde, suspected to be possible decomposition products from the heating of the glycol-based fog fluids, were not found in any of the PBZ or GA air samples. None of the PBZ air samples had detectable amounts of formaldehyde.

Although 120 PBZ and GA air samples were collected for glycols (specifically ethylene, propylene, 1,3-butylene, diethylene, and triethylene glycols) during this investigation,

NIOSH chemists subsequently determined that NIOSH Sampling and Analytical Method No. 5500 developed for ethylene glycol was inadequate to identify and quantitate other glycols. In at least one instance, ethylene glycol was incorrectly identified in an air sample. Since it was possible that interferences from other glycol analytes could have occurred, quantitative results could not be reported. Qualitatively, glycols were present in some of the PBZ and GA samples collected in all four theatrical productions in which sampling was conducted.

Air samples (both PBZ and GA) were collected for mineral oil mist during a dress rehearsal of *Miss Saigon*. Concentrations ranged up to 1.35 milligrams per cubic meter (mg/m^3), time-weighted average (TWA) over the duration of the play. The highest levels were measured in GA samples positioned on stage. All of the measured concentrations were well below the OSHA, NIOSH, and ACGIH exposure criteria of 5 mg/m^3 for up to a full-shift (8 to 10 hours) TWA exposure.

All 224 actors from nine Broadway productions completed questionnaires. Of this group, 134 questionnaires (60%) were from actors appearing in the four productions using theatrical "smoke," and 90 questionnaires (40%) were from actors appearing in the five control productions. 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 stuffy 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.

FOLLOW-UP SURVEY: NOVEMBER 18 - DECEMBER 4, 1993

The medical portion of this follow-up was conducted in two phases and designed to evaluate the relationship between acute changes in the lung function and "smoke" exposure status among performers reporting symptoms consistent with occupational asthma. In the first phase of the evaluation, NIOSH investigators administered a screening questionnaire to all performers in three "smoke" productions (*Les Miserables*, *Miss Saigon*, and *Phantom of the Opera*) and three non-"smoke" productions (*Any Given Day*, *She Loves Me*, and *The Sisters Rosenzweig*). The purpose of the screening questionnaire was to identify performers with symptoms suggestive of occupational asthma. All symptomatic performers, and a random sample of non-symptomatic performers, were invited to participate in the follow-up case-control study (Phase II).

The environmental evaluation consisted of GA air samples collected during live performances of *Les Miserables*, *Miss Saigon*, and *Phantom of the Opera*. Since special dress rehearsals could not be arranged, no PBZ air sampling was conducted. Air samples were collected for glycols, aldehydes (formaldehyde and acrolein), mineral oil mist (*Miss Saigon*), and volatile organic compounds.

Thirty-seven symptomatic and 68 non-symptomatic performers made up the Phase II study population of 105 performers. All participants were asked to complete a self-administered questionnaire addressing medical and work history. Participants were also asked to perform, after verbal instruction, serial determinations of their peak expiratory flow rate (PEFR) using portable flow meters. Of the 105 participants, 65 (62%) submitted at least a partial questionnaire or PEFR information. Five persons met the case definition for theatrical work-related occupational asthma. Three of these five were exposed to theatrical "smoke" during the study and two were not. Of the 60 persons who did not meet the case definition, 16 had been identified as being "symptomatic" in the Phase I portion of the evaluation, and were therefore excluded from further analysis. This left 45 non-case performers; 27 of these were "smoke"-exposed and 18 were not. The odds ratio (OR) for the association between being a case and being "smoke"-exposed was 1.0 (95% confidence interval [CI] = 0.1-13.1). This indicates that performers with asthma-like symptoms and abnormal peak-flow meter results ("cases") were not more likely to have been exposed to theatrical "smoke" when compared to persons who did not meet this case definition.

Analysis of the bulk samples revealed the expected glycols, based on information provided by the manufacturers. Two of the three samples contained propylene glycol, 1,3-butylene glycol, and triethylene glycol as the major components. The remaining bulk sample contained ethylene glycol and diethylene glycol as the major components, with trace amounts of triethylene glycol and propylene glycol.

Ethylene glycol was sampled in two of the three productions (*Phantom of the Opera* and *Miss Saigon*) at concentrations of 0.4 mg/m^3 or less, well below the OSHA PEL of 127 mg/m^3. 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 *Les Miserables*, ranging from <0.04 to 3.7 mg/m^3 and 0.16 to 2.1 mg/m^3, respectively. Formaldehyde concentrations, using NIOSH Sampling and Analytical Method 3500 (sodium bisulfite-filled impingers), ranged from <0.002 to 0.04 parts per million (ppm), well below the OSHA and ACGIH exposure criteria. These formaldehyde concentrations are typical of those which NIOSH investigators have measured in non-industrial work places. Acrolein was not detected on any of the GA samples (Minimum Detectable Concentration [MDC] = 0.016 mg/m^3). Oil mist concentrations were below 0.13 mg/m^3, far below NIOSH, OSHA, and ACGIH exposure criteria of 5.0 mg/m^3 (TWA). The thermal desorption analysis revealed that only two samples (from *Phantom of the Opera*) contained even modest concentrations; levels of compounds detected on all other samples were very low. Major compounds detected were mostly C_9-C_{12} aliphatic hydrocarbons and C_9H_{12} alkyl benzenes (trimethyl benzenes, propyl benzenes, etc.). Other compounds identified on these included 1,1,1-trichloroethane, acetaldehyde, acetone, isopropanol, toluene, limonene, siloxanes, and perchloroethylene.

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. Some of the constituents of theatrical "smoke," such as the aerolized glycols and mineral oil, could have irritative or mucous membrane drying properties in some individuals. Therefore, it is reasonable to minimize exposures by such means as relocating "smoke" machines to avoid exposing actors to the direct, concentrated release of the aerosols, minimizing the amount of "smoke" necessary for the production, and using only fog fluids approved by the manufacturers of the machines. The glycols used should be at the level of "food grade" or "high grade." Glycol-based systems should also be designed to heat the fog fluids only to the lowest temperature needed that achieve proper aerolsolization. This would help to avoid overheating the fluid and minimize the generation of decomposition products.

Keywords: SIC 7922 (Theatrical Producers and Miscellaneous Theatrical Services), ethylene glycol, propylene glycol, 1,3-butylene glycol, triethylene glycol, oil mist, fog, aldehydes, formaldehyde, respiratory, irritation, pulmonary function test, questionnaire, actors.

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INTRODUCTION

In July and August 1990, the National Institute for Occupational Safety and Health (NIOSH) received requests for a Health Hazard Evaluation (HHE) from the Actors' Equity Association (AEA) and the League of American Theatres and Producers, Inc. (LATP) to investigate possible health effects associated with the use of theatrical "smoke" in Broadway productions. NIOSH representatives conducted site visits in January and June 1991, which were summarized in the NIOSH revised interim report dated October 1, 1992 (Appendix A). The interim report noted a high prevalence of work-related lower respiratory symptoms (cough, wheeze, chest tightness, and shortness of breath) consistent with occupational asthma among the "smoke"-exposed performers. NIOSH investigators conducted a follow-up investigation to further characterize exposures to the "smoke" and to determine whether there were measurable respiratory effects among performers.

BACKGROUND

THEATRICAL "SMOKE"

Many of the theatrical "smokes" currently used by Broadway theaters, television, and motion pictures utilize heated glycol fluids to produce a visible aerosol. Workers engaged in these various shows are therefore exposed to theatrical "smoke" by inhalation. Although the exact formulations of these fluids are considered proprietary by the manufacturers, some of the more commonly used glycols include ethylene glycol, propylene glycol, 1,3-butylene glycol, diethylene glycol, and triethylene glycol. All of the "smoke" productions included in this survey used a glycol-based "smoke" generation system. Sizes of the glycol-based "smoke" systems ranged from larger units (permanently mounted either on or off stage) to smaller, hand-held devices operated by stage hands during a performance. In addition to the glycol-based "smoke" systems, some of the productions used dry ice (carbon dioxide) fog systems. In one of the Broadway productions (*Miss Saigon*) an unheated mineral oil-based "smoke" generation system was also used. The compounds in theatrical "smoke" are not known to cause or contribute to pulmonary function abnormalities, although only a few studies have addressed this potential problem.[1]

1991 EVALUATION

In the summer of 1991, four Broadway productions (*Les Miserables*, *Miss Saigon*, *Phantom of the Opera*, and *Grand Hotel*) which used theatrical "smoke" were selected for study. Dress rehearsals were arranged to conduct personal breathing-zone (PBZ) and general area (GA) air sampling and to administer a questionnaire to the actors detailing the frequency and severity of irritant and respiratory symptoms following exposure to theatrical "smoke." In addition, a small number of PBZ air samples were collected on electricians, carpenters, and other personnel who may have been exposed to the theatrical "smoke" during a

performance. To determine if the prevalence of symptoms among actors in shows using theatrical "smoke" differed from the symptom prevalence in non-"smoke" productions, NIOSH investigators also administered the same questionnaire to actors in five Broadway productions in which no theatrical "smoke" was used (*Lost in Yonkers*, *Gypsy*, *Getting Married*, *Once on This Island*, and *Six Degrees of Separation*). The actors in these non-"smoke" productions are termed "non-exposed" in this report.

In the 1991 study (Appendix A), all 224 actors from nine Broadway productions completed questionnaires (Appendix B). Of this group, 134 questionnaires (60%) were from actors appearing in the four productions using theatrical "smoke," and 90 questionnaires (40%) were from actors appearing in the five non-"smoke" productions.

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 respiratory symptoms (cough, wheeze, breathlessness, chest tightness) and other symptoms during their performances for the week prior to the survey. Although theatrical "smoke" was visibly evident during all of the performances, concentrations of "smoke" constituents in all of the PBZ and GA air samples collected were very low when compared to current occupational exposure criteria (Occupational Safety and Health Administration [OSHA] Permissible Exposure Limits [PELs], American Conference of Governmental Industrial Hygienists [ACGIH] Threshold Limit Values [TLVs], or NIOSH Recommended Exposure Limits [RELs]). Thus, the reason for the high prevalence of symptoms, especially lower-respiratory symptoms, in the productions that used theatrical "smoke" was not clear since the ACGIH TLV and OSHA PEL for at least one of the glycols (ethylene glycol) are intended to minimize irritation of the respiratory passages. As discussed in Appendix A, heated glycol-based fog solutions have the potential to generate decomposition products such as acrolein and formaldehyde. These compounds have been associated with asthma and asthma-like symptoms.[2,3] However, acrolein, acetaldehyde, and formaldehyde were not detected in any of the PBZ or GA samples in either the initial or follow-up surveys.

Because of the high prevalence of lower-respiratory symptoms in the "smoke"-exposed acting group, further study was undertaken by NIOSH in November 1993. Participants were informed of their test results in August 1994.

EVALUATION DESIGN AND METHODS

INDUSTRIAL HYGIENE

The industrial hygiene portion of the follow-up survey, performed on November 20, 1993, involved collecting GA air samples for glycols (ethylene, propylene, 1,3 butylene, diethylene, and triethylene glycols), mineral oil mist, aldehydes (formaldehyde, acrolein), and volatile organic compounds. Samples were collected at *Les Miserables*, *Miss Saigon,* and *Phantom of the Opera.* Since completing the 1991 NIOSH survey, one play (*Grand Hotel*) had closed. NIOSH investigators decided not to obtain a replacement for this production.

Environmental Design

In the initial environmental survey, PBZ and GA air samples were collected during specially arranged dress rehearsals. However, in this follow-up evaluation, air sampling was only conducted during "live" performances, an arrangement which necessitated collecting only GA samples to avoid disturbing the actors and the performance. The air sampling equipment was positioned so as not to interfere with the performance.

Where possible, air samples were collected on or near the stage.[a] In addition, air samples were collected in the orchestra pit, break/lunch areas, off-stage dressing areas, property rooms, sound and lighting control booths, and the stage manager's office. Sampling times generally exceeded the length of the play since samples needed to be set up approximately 45 minutes to one hour before the play. In *Les Miserables*, several on-stage air samples were set up to compare the differences (if any) in the concentrations of glycols and aldehydes between the first and second acts.

Table 1 summarizes the sampling and analytical methods used in the 1993 follow-up study.

Glycol Bulk Sample Analysis

As during the 1991 survey, bulk samples of fluids used in the glycol-based theatrical fog-generating machines were collected from the devices in use at each of the theaters. These bulk samples were then submitted for laboratory analysis. The bulk samples were heated to specified temperatures[b] and analyzed for volatile organic compounds by gas

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[a] For air samples situated on-stage (or in other off-stage "quiet" areas), the battery operated air flow pump was placed in a sound-attenuating cardboard enclosure and typically hidden in a prop or behind scenery. The collection device, connected to the air flow pump by Tygon® tubing, was placed outside of the pump enclosure.

[b] The temperatures selected for the headspace analysis corresponded to the levels to which the glycol solutions were heated in their respective "smoke" machines.

chromatography-mass spectrophotometry (GC-MS).[4] All of the bulk solutions were also analyzed directly for major glycol constituents.

Development of a New Glycol Air Sampling Method

The most significant change between the 1991 and 1993 environmental surveys was the development of a new NIOSH sampling and analytical method for airborne glycols. Intended as a replacement for the old NIOSH Method 5500 (the glycol method used in the 1991 survey), this new method is currently in internal NIOSH review and should appear as a supplement to the new 4th Edition of the NIOSH Manual of Analytical Methods.

In 1991, following collection of PBZ and GA air samples for glycols during the dress rehearsals, NIOSH chemists subsequently determined that NIOSH Method 5500 had deficiencies when used to identify and quantitate ethylene glycol and other similar glycols. For example, in at least one instance ethylene glycol was incorrectly identified in an air sample. Since it was possible that interferences from other similar glycol analytes could have occurred, the quantitative results initially reported were retracted. (see Appendix A) As a result, the only conclusion which should be drawn from the 1991 glycol air sampling data is that, qualitatively, airborne glycols were present in all four theatrical productions sampled in 1991.

The new NIOSH method uses a sorbent tube manufactured by SKC (No. 226-57). The tube contains 200 and 100 milligrams of XAD-7 in the front and back sections, respectively. It also has a built-in glass fiber pre-filter. Once collected, the samples are stable for at least 14 to 28 days and sample shipment is routine. Following desorption in 2 milliliters of methanol, the samples are analyzed by a gas chromatograph equipped with a flame ionization detector. The estimated analytical limit of detection is between 5 and 10 micrograms per sample.

MEDICAL

The medical portion of this HHE, which was conducted in two phases from November 20, 1993, through December 4, 1993, evaluated the relationship between acute changes in lung function and "smoke" exposure status in performers reporting symptoms consistent with occupational asthma. Prior to the data collection, a conference was held with representatives from the AEA and LATP and interested performers. At this conference, an overview of the study and instructions for participation were given and questions were answered.

Phase I (November 1993) - Selection of Subjects

NIOSH investigators invited all performers in three "smoke" productions (*Les Miserables*, *Miss Saigon*, and *Phantom of the Opera*) and three non-"smoke" productions (*Any Given Day*, *She Loves Me*, and *The Sisters Rosenzweig*) to participate in the medical study. Performers were recruited at the individual theaters. The first phase of the study included a screening questionnaire (Appendix C) which was administered to every available performer to identify individuals with symptoms suggestive of occupational asthma. Respondents reporting either:

(1) wheezing (day or night)

or

(2) both shortness of breath (day or night) and chest tightness

occurring "sometimes," "often," or "always" within the last 10 days were termed "symptomatic" and were invited to participate in Phase II. Performers not reporting these symptoms were selected as controls. All participants signed informed consent forms.

Phase II (November - December 1993) - Case Control Study

The following information was collected on both symptomatic and asymptomatic performers.

Questionnaire

A self-administered questionnaire (Appendix D) was provided that addressed medical and work history and the presence of pre-existing asthma or other respiratory illness. All participants signed a second informed consent form.

Peak Expiratory Flow Rates

To identify changes in the amount of air that can be exhaled over time (both in and out of the workplace), serial determinations of the peak expiratory flow rate (PEFR), using Wrights portable flow meters, were obtained. Peak flow refers to the amount of air in liters per minute that can be blown through the flow meter in one sharp breath. Peak expiratory flow rates were measured serially for two weeks. The measurements were to be taken upon awakening for the day, upon leaving for work, upon arrival to work, immediately prior to the show, immediately after the show, upon arrival home from the show, immediately before going to bed, during the night if awakened for any reason, and at other times respiratory symptoms were being experienced. The participants were instructed in the proper use of the portable flow meters by NIOSH investigators. Three exhalations were recorded each time, and the maximum of the three was accepted as the PEFR determination. Any wheezing, shortness of breath, chest tightness, cough, or other symptoms experienced at the time of a PEFR determination was reported on the peak flow record.

Data Analysis

Analyses were done using Epi Info, version 6.0.[5] The following case definition was used for theatrical "smoke"-related occupational asthma in this evaluation.

1. Symptoms suggestive of asthma as defined above (Phase I).

   AND

2. Symptomatic bronchial lability. The criteria for symptomatic bronchial lability was the participant's contemporaneous report of the following symptoms as his or her PEFR reached the minimum for the day or week:

   (a) wheezing (day or night)

   OR

   (b) both shortness of breath ***AND*** either chest tightness or cough

EVALUATION CRITERIA

GENERAL

As a guide to the evaluation of the hazards posed by workplace exposures, NIOSH field staff employ environmental evaluation criteria for the assessment of a number of chemical and physical agents. These criteria are intended to suggest limits of exposure to which most workers may be exposed up to 10 hours per day, 40 hours per week for a working lifetime without experiencing adverse health effects. It is, however, important to note that not all workers will be protected from adverse health effects even though their exposures are maintained below these limits. A small percentage may experience adverse health effects because of individual susceptibility, a pre-existing medical condition, or a hypersensitivity (allergy). In addition, some hazardous substances may act in combination with other workplace exposures, the general environment, or with medications or personal habits of the worker to produce health effects even if the occupational exposures are controlled at the limit set by the criterion. These combined effects are often not considered in the evaluation criteria. Also, some substances are absorbed by direct contact with the skin and mucous membranes, which may increase the overall exposure. Finally, evaluation criteria may change over the years as new information on the toxic effects of an agent become available.

The primary sources of environmental evaluation criteria for the workplace are the following: (1) NIOSH RELs,[6] (2) the ACGIH TLVs,[7] and (3) the OSHA PELs[8]. The OSHA PELs may be required to take into account the feasibility of controlling exposures in various industries where the agents are used; the NIOSH RELs, by contrast, are based primarily on

concerns relating to the prevention of occupational disease. In evaluating the exposure concentrations and the recommendations for reducing these concentrations found in this report, it should be noted that the lowest exposure criteria was used; however, industry is legally required to meet those limits specified by the OSHA standard.

A time-weighted average (TWA) exposure refers to the average airborne concentration of a substance during a normal 8- to 10-hour workday. Some substances have recommended short-term exposure limits (STELs) or ceiling values which are intended to supplement the TWA where there are recognized toxic effects from high short-term exposures.

INDUSTRIAL HYGIENE CRITERIA

Acrolein, acetaldehyde, and formaldehyde were not constituents of the glycol solutions used to generate theatrical "smoke." However, they are potential decomposition products from heated glycol solutions, and so they are discussed below.

Acrolein

Acrolein is a very intense irritant, causing rapid injury to the respiratory tract, eyes, and skin. The irritation threshold in humans is 0.25 parts per million (ppm) for all mucous membranes.[9] Due to its strong lacrimatory (watering of the eyes) effect, acrolein does offer good warning properties. While skin contact with the vapor or liquid can cause severe burns, inhalation is the most serious hazard. Chronic toxicity has not been shown with this compound, but dermatitis and skin sensitization have been observed.[9]

While the carcinogenic potential of acrolein has not been adequately determined, one of its potential metabolites (glycidaldehyde) is considered to be carcinogenic.[10,11] The OSHA PEL, NIOSH REL, and ACGIH TLV for acrolein is 0.1 ppm for up to a 10-hour TWA.

Acetaldehyde

Acetaldehyde, also an irritant of the mucous membranes at low concentrations, may cause dermatitis and conjunctivitis following repeated exposures to the liquid or vapors. In studies assessing human effects, volunteers who were exposed for 15 minutes to 50 ppm of acetaldehyde experienced mild irritation.[9] In more sensitive human subjects, however, irritation was noted at concentrations of 25 ppm.[9] Generally, the fruity odor of acetaldehyde offers good warning properties.

The OSHA PEL and ACGIH TLV for acetaldehyde is 100 ppm, TWA for an 8- to 10-hour exposure. The International Agency for Research on Cancer (IARC) has concluded that there is sufficient evidence for the carcinogenicity of acetaldehyde in animals but inadequate evidence for carcinogenicity in humans.[12] NIOSH considers that, in the absence of adequate

data on humans, it is reasonable to regard chemicals for which there is sufficient evidence of carcinogenicity in animals as if they present a carcinogenic risk to humans. Since acetaldehyde is an animal carcinogen and, therefore, a potential occupational carcinogen, the NIOSH policy is to reduce exposure to the lowest feasible limit.[12]

Formaldehyde

Exposures to low concentrations of formaldehyde vapor will cause irritation of the eyes and respiratory tract. Because it is readily soluble in water, most of the irritant effects are restricted to the upper respiratory tract where the chemical is quickly absorbed. A concentration of 2 to 3 ppm will cause formication (a term describing the sensation of small insects crawling on the skin) of the eyes, nose, and throat.[9] Ten ppm is tolerated with difficulty by most people for only a short period of time.[9]

Some people may be especially sensitive to formaldehyde and can become symptomatic at concentrations well below 1 ppm. Case reports of asthma apparently induced by formaldehyde have been reported, although a true immunologically mediated allergic response has not been documented.[2,13,14] Formaldehyde has been shown to be carcinogenic in several animal studies.[9] Some research suggests that the potential carcinogenic effects of formaldehyde is particularly enhanced in the presence of hydrochloric acid vapors.[15]

The OSHA PEL for formaldehyde is 0.75 ppm, TWA over an 8-hour work day with a STEL of 2 ppm.[c] NIOSH recommends that formaldehyde be treated as a potential occupational carcinogen and recommends that exposures be kept as low as feasible.[16] The ACGIH TLV is 1 ppm, TWA over an 8-hour work day.

Mineral Oil

Also termed liquid paraffin and white mineral oil, this hydrocarbon mixture is produced by removing the lighter hydrocarbons from petroleum by distillation, followed by charcoal filtering and additional distillation steps.[17] The final product is colorless, tasteless, and generally odorless (when cold). Mineral oil is used in drugs applied to the nasal membranes and as a laxative. It is used as a solvent for inks in the printing industry and as a general lubricant.[9]

Mineral oil mist is considered to have low toxicity. The IARC has determined that there is no evidence that the fully solvent refined oils are carcinogenic to experimental animals in either skin painting or feeding studies.[18] However, the IARC has determined that, based on epidemiologic studies, there is sufficient evidence for carcinogenicity in humans of

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[c] ACGIH considers formaldehyde to be a suspect human carcinogen and has proposed to reduce the TLV to 0.3 ppm as a ceiling limit which should not be exceeded.

uncharacterized mineral oils containing additives and impurities.[18] Fortunately, most of the mineral oils in use today are free of additives and impurities because of improvements in the refining process.[19]

In a study of mineral oil mist exposures in machine shops where the average airborne concentration was 3.7 mg/m^3 (the maximum short-term concentration measured was 110 mg/m^3), no increase in respiratory symptoms or decrement in respiratory performance was observed in the employees.[20] There have been no reported cases of illnesses in other studies, in a variety of industries, of human exposures to mineral oil mist concentrations which averaged less than 15 mg/m^3.[21]

The OSHA PEL, NIOSH REL, and ACGIH TLV for mineral oil mist is 5 mg/m^3, TWA for up to a 10-hour exposure. The OSHA and NIOSH STEL for mineral oil mist is 10 mg/m^3.

Glycols

None of the glycols identified in the bulk samples of the fog solutions used in the Broadway plays surveyed have been found to be mutagenic or carcinogenic. Table 2 lists the major glycols identified in these fluids and describes their health effects.

Since glycols are polyfunctional alcohols, exposures to any of these substances may cause a drying of exposed mucous membranes, resulting in dry, irritated eyes and respiratory tract irritation. Some studies have reported that ethylene glycol and diethylene glycol have had embryo-toxic effects in some test animal species; both have other harmful health effects (e.g., kidney or liver damage) if significant amounts are ingested.[22,23] Other studies, involving human as well as animal subjects, have shown ethylene glycol to cause upper respiratory irritation, although the airborne concentrations necessary to achieve these irritant effects have varied greatly.[24] In one of these studies, the test subjects were exposed for 20 to 22 hours/day to average concentrations which exceeded 30 milligrams of ethylene glycol per cubic meter of air.[1]

The OSHA PEL for ethylene glycol is 127 mg/m^3. This is a ceiling limit which should not be exceeded at any time during the work day. There is no NIOSH REL for ethylene glycol; however, because of the potential teratogenicity and the known respiratory irritation at the level chosen for the OSHA PEL, NIOSH has suggested that OSHA reconsider their current PEL for ethylene glycol.[24] The ACGIH TLV for ethylene glycol is a ceiling limit of 125 mg/m^3 (a level which should not be exceeded at any time during the work day). Ethylene glycol is also under study by the ACGIH TLV Committee. There are no OSHA, NIOSH, or ACGIH exposure criteria for the other glycols.

Volatile Organic Compounds

Volatile organic compounds (VOCs) describe a large class of chemicals which are organic (i.e., containing carbon) and have a sufficiently high vapor pressure to allow some of the compound to exist in the gaseous state at room temperature. These compounds are emitted in varying concentrations from numerous indoor sources including, but not limited to, carpeting, fabrics, adhesives, solvents, paints, cleaners, waxes, cigarettes, and combustion sources.

Studies have measured wide ranges of VOC concentrations in indoor air as well as differences in the mixtures of chemicals which are present. Research also suggests that the irritant potency of these VOC mixtures can vary. Although in some instances it may be useful to identify some of the individual chemicals which may be present, the concept of total volatile organic compounds (TVOC) has been used in an attempt to predict certain types of
health effects. The use of this TVOC indicator, however, has never been standardized. Some researchers have compared levels of TVOCs with human responses (such as headache and irritative symptoms of the eyes, nose, and throat). However, neither NIOSH nor OSHA currently have specific exposure criteria for VOC mixtures in the nonindustrial environment.

RESULTS

INDUSTRIAL HYGIENE

Bulk Sample Analysis

Analysis of the heated bulk samples revealed only the glycols which were expected (based on product information provided by the manufacturers). No decomposition products were detected. Two of the three samples contained propylene glycol, 1,3-butylene glycol, and triethylene glycol as the major components. The remaining bulk sample contained ethylene glycol and diethylene glycol as the major components, with trace amounts of triethylene glycol and propylene glycol.

Air Monitoring Results

Glycols

As shown in Table 3, ethylene glycol was measured in two of the three productions (*Phantom of the Opera* and *Miss Saigon*); however, these concentrations ranged from not detectable to 0.4 mg/m^3, levels well below the OSHA PEL of 127 mg/m^3. 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 *Les Miserables*, ranging from <0.04 to 3.7 mg/m^3 and 0.16 to 2.1 mg/m^3, respectively.

Formaldehyde/Aldehydes

As shown in Table 4, formaldehyde concentrations using NIOSH Sampling and Analytical Method 3500 (sodium bisulfite-filled impingers) ranged from <0.002 to 0.04 ppm. These concentrations are well below the OSHA and ACGIH exposure limits and are typical of concentrations which NIOSH investigators have measured in non-industrial work places. Acrolein was not detected on any of the GA samples (Minimum Detectable Concentration [MDC] = 0.016 mg/m^3).

Oil Mist

Only *Miss Saigon* used a mineral oil-based fog generation system. As shown in Table 5, all oil mist concentrations were less than 0.13 mg/m^3, amounts which are far below NIOSH, OSHA, and ACGIH exposure criteria of 5.0 mg/m^3 (TWA).

Volatile Organic Compounds

Copies of the reconstructed total ion chromatograms (with peak identification) from the analysis of the thermal desorption (TD) tube samples are shown in Figure 1. Only two of the TD samples (both obtained from the *Phantom of the Opera*--one at the Travelator [stage right] and the other from the orchestra pit) contained even modest concentrations; levels of compounds detected on all other samples were very low. Major compounds detected were mostly C_9-C_{12} aliphatic hydrocarbons and C_9H_{12} alkyl benzenes (trimethyl benzenes, propyl benzenes, etc.) Other compounds identified on these included 1,1,1 trichloroethane, acetaldehyde, acetone, isopropanol, toluene, limonene, siloxanes, and perchloroethylene. It should be noted that although thermal desorption is an extremely sensitive method, it is only qualitative.

MEDICAL

Phase I: November 1993

One hundred and thirty five (73%) of approximately 186 performers participated. This included three stage managers and several understudies. The show-specific participation rates are shown in Table 6. Of the 135 participants, 37 (27%) were symptomatic. All the symptomatic participants were recruited for Phase II. In addition, 68 asymptomatic performers (controls) were randomly selected for Phase II, making up a total Phase II study population of 105 performers.

Phase II: November - December 1993

Of the 105 participants, 65 (62%) submitted complete or partial information (peak flow measurements and questionnaires); 40 (38%) submitted no information. Two persons did not participate but gave their peak-flow meter and questionnaire to others (one to another performer, the other to a stage manager). The data from these two persons are not included in the analysis because they were not selected in the same manner as the other participants. (These persons would not have met the case definition.) The participation rate for symptomatic persons was 57% (21/37); the participation rate for non-symptomatic persons was 65% (44/68). The show-specific participation rates are shown in Table 7.

A total of five persons met the above case definition for asthma. Three worked in "smoke"-using productions and two did not. Of the 60 persons who did not meet the case definition, 16 had been identified as being "symptomatic" in the Phase I portion of the evaluation, and were therefore excluded from further analysis. This left 45 non-case performers; 27 of these were "smoke"-exposed and 18 were not. The odds ratio (OR) for the association between being a case and being "smoke"-exposed was 1.0 (95% confidence interval [CI] = 0.1-13.1). (See Table 8.)

DISCUSSION

INDUSTRIAL HYGIENE

All of the GA sample results were well below available exposure criteria. Except for ethylene glycol, however, none of the glycols measured in this study have OSHA, NIOSH, or ACGIH exposure criteria. One of the three bulk samples of glycol-based fog fluids contained ethylene glycol and diethylene glycol as major components (with trace amounts of triethylene glycol and propanetriol). Although these two glycols are not exceptionally toxic when compared to many chemicals, the glycols which were identified in the other two bulk samples (primarily propylene, triethylene, or 1,3 butylene glycols) would be less toxic substitutes.

No decomposition products were observed either in the headspace analysis of the heated bulk samples or in the field samples collected in this follow-up survey. However, in the initial 1991 survey, decomposition products (such as acrolein and acetaldehyde) were detected by NIOSH in a laboratory setting when a glycol-based fog solution was heated to approximately 700^{o}F. (One of the fog systems in use during the 1991 survey heated the fluid to this temperature.) It should be noted that these decomposition products **were not** detected in PBZ and GA air samples collected during the play in which this fog system was used. Regardless, it would still appear to be prudent to use glycol-based fog systems which are designed to operate at the lowest temperature consistent with proper aerolsolization. NIOSH investigators are aware of fog systems which do not heat their glycol fluid beyond 500^{o}F.

MEDICAL

The finding of an OR of 1.0 (CI = 0.1 - 13.1) indicates that performers with asthma-like symptoms and measurable bronchial lability were not more likely to have been exposed to theatrical "smoke" when compared to persons who did not meet this case definition.

There are a number of reasons for finding potential cases of asthma but not finding a significant association between these cases and exposure to theatrical "smoke" in this study. First, theatrical "smoke" may not cause asthma. Second, various occupational and non-occupational conditions can affect PEFR and other measures of pulmonary function. Cigarette-related bronchitis is one of the most common causes of pulmonary function abnormalities among the working population; certain occupational chemical and dust exposures can also cause or contribute to it. Exercise and underlying lung disease may also be expected to produce abnormal pulmonary function tests. Further, asthma is a difficult disease to diagnose; there are no widely accepted criteria by which to reliably establish the diagnosis of asthma. Pulmonary function testing, using such tools as peak-flow meters, along with questionnaire data, have been used in other studies to find potential cases of asthma. However, these methods have limitations. Peak-flow meters are subject to variation based on the meter itself as well as the effort of the operator. In addition, questionnaire data may not accurately reflect the symptoms or medical history of the participants.

Finally, it is important to note the low response rate (62%) for Phase II. This limits our ability to detect differences between "smoke"-exposed and non-"smoke"-exposed performers and diminishes the reliability of the conclusions drawn from these data.

CONCLUSIONS

The HHE request was submitted because of the performers' concern about the acute and possible chronic effects of exposure to theatrical "smoke." 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 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."

RECOMMENDATIONS

Some of the air sampling data collected during the initial 1991 NIOSH survey (see Appendix A) suggests that short-term "peak" exposures to theatrical "smoke" may occur throughout any performance, coinciding with the "smoke" cues for that particular

production. These peak exposures may be sufficiently high to contribute to the work-related irritation reported by some of the actors. "Smoke" machines should therefore be located so as to minimize actors' exposure to the concentrated aerosol as it first exits the machine. The quantity and frequency of use of the various fogs during a performance should be minimized.

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For the purpose of informing affected employees, copies of this report shall be posted by the employer in a prominent place accessible to the employees for a period of 30 calendar days.

TABLE 1
Sampling and Analytical Methods used in 1993 Follow-up Survey
Actors' Equity Association/The League of American Theatres and Producers, Inc.
HETA 90-0355

Method	Collection Device	Sampling Rate	Aanalytical Method	Comments
New NIOSH Method for Glycols in Review	XAD-70 OVS Tube (SKC No. 226-57) 200/100 mg size	1 liter/min	GC, FID	This new method was developed in 1993 to replace existing NIOSH Method 5500 (developed for ethylene glycol). Currently in review, this method can be used to quantitatively measure ethylene, propylene, 1,3 butylene, diethylene, triethylene, and tetraethylene glycols. The estimated limit of detection for this method is 5 to 10 micrograms per sample. This method will appear in a supplement to the 4th Edition of the NIOSH Manual of Analytical Methods.
NIOSH Method 5026 (Mineral Oil)	37 mm PVC filter	2.0 lpm	Infrared Spectrophotometry	Bulk sample required for analysis.
NIOSH Method 2501 (Acrolein)	ORBO 23 adsorbent tubes	100 cc/min	GC, Nitrogen Specific Detector	Personal breathing-zone and general area air samples.
NIOSH Method 2539 (Aldehydes	ORBO 23 adsorbent tubes	100 cc/min	GC, FID and GC/MS	Personal breathing-zone and general area air samples.
NIOSH Method 2541 (Formaldehyde)	ORBO 23 adsorbent tubes	100 cc/min	GC, FID	Personal breathing-zone and general area air samples.
NIOSH Method 3500 (Formaldehyde)	Midget impingers filled with 20 ml of 1% sodium bisulfite solution	1.0 lpm	Visible absorption spectrometry	General area air samples
Volatile Organic Compounds	Three layer thermal desorption tubes (prepared by NIOSH chemist)	30 cc/min	Thermal Desorber, interfaced with a GC-MS	Each thermal tube contained three beds of sorbent materials. The front layer contained 350 mg of Carbotrap C; the middle layer 150 mg of Carbotrap, and the back section contained 150 mg of Carboxen.

ABBREVIATIONS:

GC - Gas chromatography
FID - Flame Ionization Detector
lpm - liters of air per minute
ml - milliliters
MS - Mass Spectrometer
cc/min - cubic centimeters of air per minute
mm - millimeters
mg - milligrams

SOURCE FOR ANALYTICAL METHODS (except new method for glycols): **Eller PM, ed. [1989]. NIOSH manual of analytical methods. 3rd rev. ed. Cincinnati, Ohio: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control, National Institute for Occupational Safety and Health, DHHS (NIOSH) Publication No. 84-100.**

TABLE 2
GLYCOLS: PHYSICAL FORM, USES AND TOXICITY INFORMATION
Actors' Equity Association/The League of American Theatres and Producers, Inc.
HETA 90-0355

Substance[1]	Physical Form	Uses	Toxicology[2]	Exposure Criteria
Ethylene Glycol	Liquid is clear, colorless, thick and practically odorless. Sweet taste.	One of the highest volume chemicals produced in the U.S. Used in antifreeze and coolants, cosmetics, wood stains, pen inks, general solvent, brake fluids.	Not considered carcinogenic or mutagenic. Not readily absorbed through the skin. Not a significant skin irritant. Principal hazard to health is associated with ingestion of large quantities in single doses. Animal data suggest eye exposure to liquid or vapors may cause minor and transient discomfort. Studies with human volunteers exposed to average concentration of 30 mg/m^3 complained of throat irritation, mild headache, and low backache. Animal studies (mice) have shown developmental disorders (decreased litter size, reduced number of viable litter) with this compound.[20,21]	OSHA PEL: 127 mg/m^3 TWA ACGIH TLV: 127 mg/m^3 NIOSH REL: None, but NIOSH asserts that health effects can be observed at the OSHA limit of 127 mg/m^3.
Propylene Glycol	Liquid is clear, colorless, thick, and practically odorless and tasteless.	Preservative (retards mold and fungi); cleansing creams; sun tan lotions; conditioners; brake fluid	Systemic toxicity is especially low and health hazards from this material seem negligible. Has been approved for use in certain pharmaceutical products by FDA since 1942. Also used in some foods and cosmetics. Produces no significant eye or skin injuries. Has not been demonstrated to have carcinogenic, mutagenic, or teratogenic properties in animal studies.	OSHA PEL: NONE ACGIH TLV: NONE NIOSH REL: NONE
1,3 Butylene Glycol	Liquid is thick and nearly colorless.	Used in food additives and flavorings. The substance is also used in production of polyesters, polyurethanes, and as a solvent.	The 1,3 isomer of butylene glycol is especially low in toxicity and is used in certain cosmetic and pharmaceutical applications. Has not been demonstrated to have carcinogenic, mutagenic, or teratogenic effects in animal studies. Not irritating to the skin. In studies involving human exposures, 1-3 butylene glycol has been shown to be capable of causing severe stinging of the eyes.	OSHA PEL: NONE ACGIH TLV: NONE NIOSH REL: NONE
Triethylene Glycol	Liquid is colorless and practically odorless.	Used as a solvent in vinyl, polyester, and resins; in printing inks; and for dehydrating natural gas.	Acute and chronic oral toxicity is very low. Has not been shown to be a significant skin or eye irritant. Unlikely that significant quantities of this compound could be absorbed through the skin.	OSHA PEL: NONE ACGIH TLV: NONE NIOSH REL: NONE
Diethylene Glycol	Liquid is syrupy, colorless and nearly odorless. Sweet taste.	Used as a textile softener; solvent for dyes, oils, adhesives; cosmetics, and in antifreeze solutions.	Minor to insignificant skin or eye irritant. Although animal data suggest little hazard from short-term inhalation, exposures to vapor, fog or mist should be minimized, especially in chronic (i.e. long-term) exposure situations. Animal studies (mice) indicate that this substance is a reproductive toxicant affecting fertility and reproductive performance (when given at high doses).[20,21]	OSHA PEL: NONE ACGIH TLV: NONE NIOSH REL: NONE

Comments:

1. Laboratory analysis revealed the presence of some of the higher molecular weight glycols (tetraethylene, pentaethylene, hexaethylene, etc.). These compounds, which were present in trace amounts, are not discussed in this table.
2. Except as otherwise noted, the information presented in this table was obtained from the following sources: Patty's Industrial Hygiene and Toxicology; Procter, Hughes and Fischman Chemical Hazards of the Work Place; and the American Conference of Governmental Industrial Hygienists' Documentation of the Threshold Limit Values and Biological Exposure Indices.

TABLE 3
Results from General Area Air Samples for Glycols
Actors' Equity Association/The League of American Theatres and Producers, Inc.
HETA 90-0355
Sample Date: November 20, 1993

Production	Sample No.	Sample Location	Sampling Time	Volume (liters)	Concentration (expressed in milligrams per cubic meter)				
					Ethylene Glycol	Propylene Glycol	1,3 Butylene Glycol	Diethylene Glycol	Triethylene Glycol
Phantom of the Opera	P-2	Travelator, Stage R	12:40 → 5:12 pm	272	0.096	0.060	Trace	ND	ND
	P-4	Orchestra Pit	12:55 → 5:04 pm	249	0.073	0.045	Trace	ND	ND
	P-6	Travelator, Stage L	12:50 → 5:09 pm	259	0.444	0.042	Trace	0.141	ND
	P-7	Light Control Area	1:10 → 5:04 pm	234	Trace	0.044	Trace	ND	ND
	P-10	Prop Table, Stage L	1:01 → 5:12 pm	251	0.245	0.338	Trace	Trace	ND
	P-12	Quick Change (Stage Level L)	1:36 → 4:57 pm	201	Trace	0.053	Trace	ND	ND
	P-15	Stage Manager's Office	1:51 → 5:01 pm	190	ND	0.099	Trace	ND	ND
	P-21	Quick Change, (Basement Stage L)	1:50 → 4:59 pm	189	0.130	0.066	Trace	ND	ND
Miss Saigon	MS-33	Pylon 5, Stage L	6:53 → 10:59 pm	246	Trace	0.049	ND	ND	ND
	MS-36	Pylon 5, Stage R	7:01 → 11:00 pm	237	Trace	0.057	ND	ND	ND
	MS-40	On Stage Follow Spot	7:17 → 11:08 pm	234	ND	Trace	ND	ND	ND
	MS-42	Orchestra Pit	6:48 → 11:13 pm	265	Trace	Trace	ND	ND	ND
	MS-46	Sound Booth	7:07 → 11:12 pm	245	ND	0.042	ND	ND	ND
	MS-50	Ho Chi Minh Statue	7:12 → 10:57 pm	225	Trace	0.061	ND	ND	ND
	MS-52	Gun Room (on table)	7:21 → 10:42 pm	201	ND	Trace	ND	ND	ND
	MS-58	Green Room (on table)	7:25 → 10:56 pm	211	ND	0.110	ND	ND	ND
	MS-62	Dressing Area (basement)	7:24 → 10:55 pm	211	ND	0.104	ND	ND	ND

TABLE 3
Results from General Area Air Samples for Glycols
Actors' Equity Association/The League of American Theatres and Producers, Inc.
HETA 90-0355
Sample Date: November 20, 1993

Production	Sample No.	Sample Location	Sampling Time	Volume (liters)	Concentration (expressed in milligrams per cubic meter)				
					Ethylene Glycol	Propylene Glycol	1,3 Butylene Glycol	Diethylene Glycol	Triethylene Glycol
Les Miserables	LM-1	Sound Booth	12:55 → 5:39 pm	284	ND	0.090	0.933	ND	ND
	LM-3	Orchestra Pit	1:08 → 5:25 pm	267	ND	0.120	0.164	ND	Trace
	LM-6	Barricade, Stage L	12:42 → 5:44 pm	302	ND	0.240	0.274	ND	0.271
	LM-7	Barricade, Stage L (Act 1)	12:40 → 1:50 pm	190	ND	0.254	0.311	ND	0.280
	LM-8	Barricade, Stage L (Act 2)	1:50 → 5:42 pm	112	ND	0.383	0.386	ND	0.747
	LM-11	Fog Machine, Stage R (Upstage, Act 1)	12:50 → 1:53 pm	63	ND	1.92	2.11	ND	3.66
	LM-12	Fog Machine, Stage R (Upstage, Act 2)	1:53 → 5:45 pm	232	ND	0.966	1.01	ND	2.05
	LM-14	Quick Change, Stage L	1:05 → 5:29 pm	264	ND	0.247	0.265	ND	0.168
	LM-16	Stage Manager's Office	1:58 → 5:29 pm	231	ND	0.342	0.338	ND	0.576
	LM-20	Wardrobe Area	1:50 → 5:17 pm	207	ND	0.266	0.189	ND	0.180
	LM-24	On Stage Follow Spot	1:20 → 5:37 pm	257	ND	0.416	0.436	ND	0.591
	LM-26	House Spot	1:16 → 5:34 pm	258	ND	0.112	0.163	ND	Trace
Minimum Detectable Concentration (250 liter air sample)					0.020	0.012	0.032	0.020	0.036
Minimum Quantifiable Concentration (250 liter air sample)					0.070	0.040	0.096	0.072	0.124

TABLE 3
Results from General Area Air Samples for Glycols
Actors' Equity Association/The League of American Theatres and Producers, Inc.
HETA 90-0355
Sample Date: November 20, 1993

Production	Sample No.	Sample Location	Sampling Time	Volume (liters)	Concentration (expressed in milligrams per cubic meter)				
					Ethylene Glycol	Propylene Glycol	1,3 Butylene Glycol	Diethylene Glycol	Triethylene Glycol
Evaluation Criteria: (in milligrams per cubic meter)									
OSHA PEL (Ceiling limit)					127	None	None	None	None
ACGIH TLV (Ceiling limit)					127	None	None	None	None
NIOSH REL					a	None	None	None	None

Comments and Footnotes:

a = There is no NIOSH REL for ethylene glycol. However, because of the potential teratogenicity and the known respiratory irritation at the level adopted for the OSHA PEL, NIOSH suggests that OSHA reconsider their current PEL for ethylene glycol.

Trace = Concentration is between the minimum detectable and minimum quantifiable concentration for this sample set.

ND = Not detectable (below the minimum detectable concentration).

TABLE 4
General Area Air Sample Results for Formaldehyde
Actors' Equity Association/The League of American Theatres and Producers, Inc.
HETA 90-0355
Sample Date: November 20, 1993

Production	Sample Number	Area Sample Location	Sample Volume (liters)	Sample Time	Concentration, ppm
Phantom of the Opera	P-13	Stage Left "Quick Change" Area	205	1:40 pm to 5:05 pm	0.007
	P-16	Trap Room	193	1:37 pm to 4:50 pm	0.008
	P-20	Outside theater	165	2:12 pm to 4:57 pm	Trace
Miss Saigon	MS-54	Sample in Gun Room on table against the back wall at approximately waist height	201	7:21 pm to 10:42 pm	0.04
	MS-56	Sample in the Green Room on a table against the wall (near lunch table)	211	7:25 pm to 10:56 pm	0.008
	MS-61	Dressing Area. In the lower level	211	7:24 pm to 10:55 pm	0.007
Les Miserables	LM-18	Sample in the Stage Manager's office on a table at approximately waist height	231	1:58 pm to 5:49 pm	0.01
	LM-22	Sample in Wardrobe Area on top of a file cabinet, approximately 5 ft. off floor	207	1:50 pm to 5:17 pm	0.01
Minimum Detectable Concentration (Assuming a 200 liter air sample)					0.002
Minimum Quantifiable Concentration (Assuming a 200 liter air sample)					0.004
Evaluation Criteria	OSHA Permissible Exposure Limit ACGIH Threshold Limit Value NIOSH Recommended Exposure Limit				0.75 TWA/2.0 STEL 1.0 TWA/2.0 STEL ‡

Comments and Abbreviations:
General area air samples for formaldehyde collected following NIOSH Sampling and Analytical Method 3500 (impingers filled with 1% sodium bisulfite solution). This method offers the best sensitivity for formaldehyde.
‡ NIOSH considers formaldehyde a suspect human carcinogen and recommends that exposures be kept as low as feasible.
TWA = time weighted average STEL = short-term exposure limit (15 minutes)
Trace = Concentration is between the Minimum Detectable and Minimum Quantifiable Concentration

TABLE 5
General Area Air Sample Results for Oil Mist
Actors' Equity Association/The League of American Theatres and Producers, Inc.
HETA 90-0355
Sample Date: November 20, 1993

Production	Sample No.	Sample Location	Sample Time	Sample Volume (Liters)	Concentration (mg/m^3)[a]
Miss Saigon	5123	Pylon 4 Stage Left	6:50 → 10:59 pm	498	Trace
	5124	Pylon 4 Stage Right	7:02 → 11:00 pm	476	Trace
	5136	Orchestra Pit	6:48 → 11:13 pm	530	ND
	5139	Base of Ho Chi Minh Statue	7:12 → 10:57 pm	450	ND
Minimum Detectable Concentration (500 liter air sample)					0.04
Minimum Quantifiable Concentration (500 liter air sample)					0.13
Evaluation Criteria					
National Institute for Occupation Safety and Health Recommended Exposure Limit					5 mg/m^3 (10-hr. TWA) 10 mg/m^3 (15 min. STEL)
Occupational Safety and Health Administration Permissible Exposure Limit					5 mg/m^3 (8-hr. TWA)
American Conference of Governmental Industrial Hygienists Threshold Limit Value					5 mg/m^3 (8-hr. TWA)

COMMENTS AND ABBREVIATIONS:

a = All oil mist concentrations are time-weighted averages over the time period sampled and are expressed in milligrams of oil mist per cubic meter of air.

Trace = These concentrations are between the minimum detectable and minimum quantifiable concentration for this sample set. This means that oil mist was detectable but could not be reliably measured.

TWA = Time-weighted average exposure

TABLE 6
Medical Evaluation Phase I - Participation Rates by Show
Actors' Equity Association/The League of American Theatres and Producers, Inc.
HETA 90-0355
November 20, 1993 - December 4, 1993

Show	No. Participants/ No. Performers in Show*	Rate (%)
Miss Saigon	35/46	76%
Les Miserables	35/38	92%
Phantom of the Opera	30/36	83%
Sub-Total ("Smoke" Shows)	100/120	83%
Any Given Day	12/12	100%
She Loves Me	16/40	40%
Sisters Rosenzweig	7/14	50%
Sub-Total (Non-"Smoke" Shows)	35/66	53%
Total	**135/186**	**73%**

* = approximate number of performers in show, as estimated by AEA and stage managers

TABLE 7
Medical Evaluation Phase II - Participation Rates by Show
Actors' Equity Association/The League of American Theatres and Producers, Inc.
HETA 90-0355
November 20, 1993 - December 4, 1993

Show	**No. Participants**/ No. Performers Selected**	**Rate (%)**
Miss Saigon	13/28	46%
Les Miserables	14/23	61%
Phantom of the Opera	18/24	75%
Sub-Total ("Smoke" Shows)	45/75	60%
Any Given Day	7/10	80%
She Loves Me	8/15	53%
Sisters Rosenzweig	5/5	100%
Sub-Total (Non-"Smoke" Shows)	20/30	67%
Total	**65/105**	**62%**

** = number of participants who submitted ANY data

TABLE 8
Cases and Non-Cases vs "Smoke" and Non-"smoke" Exposed Performers
Actors' Equity Association/The League of American Theatres and Producers, Inc.
HETA 90-0355
November 20, 1993 - December 4, 1993

	CASES	NON-CASES	**TOTAL**
"SMOKE" EXPOSED	3	27	30
NOT "SMOKE" EXPOSED	2	18	20
TOTAL	5	45	50

ODDS RATIO = 1.0
95% CONFIDENCE INTERVAL = 0.1-13.1

Figure 1
Actors' Equity Association/
The League of American
Theatres and Producers, Inc.
HETA 90-0355

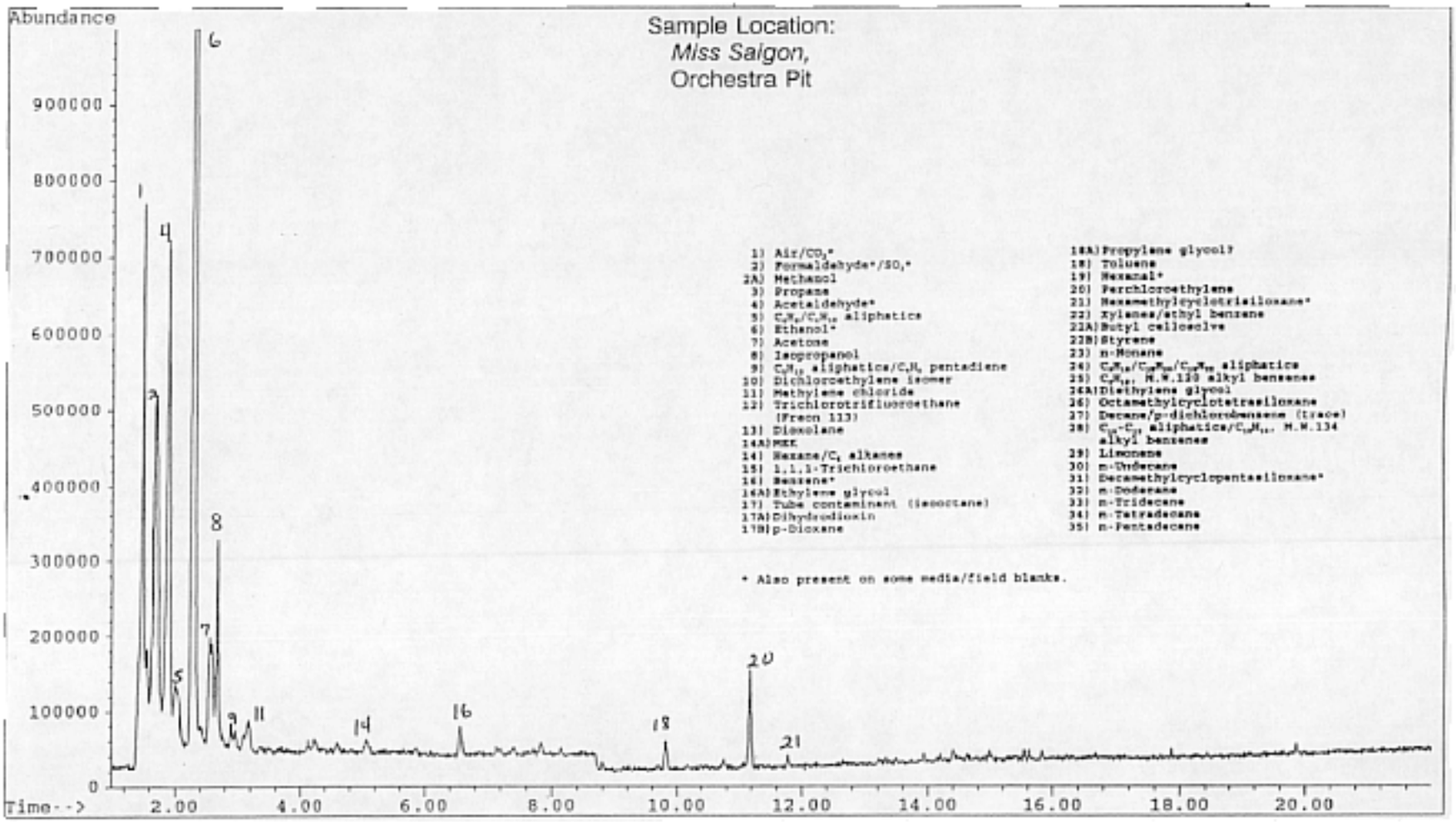


Figure 1 (continued)
Actors' Equity Association/
The League of American
Theatres and Producers, Inc.
HETA 90-0355

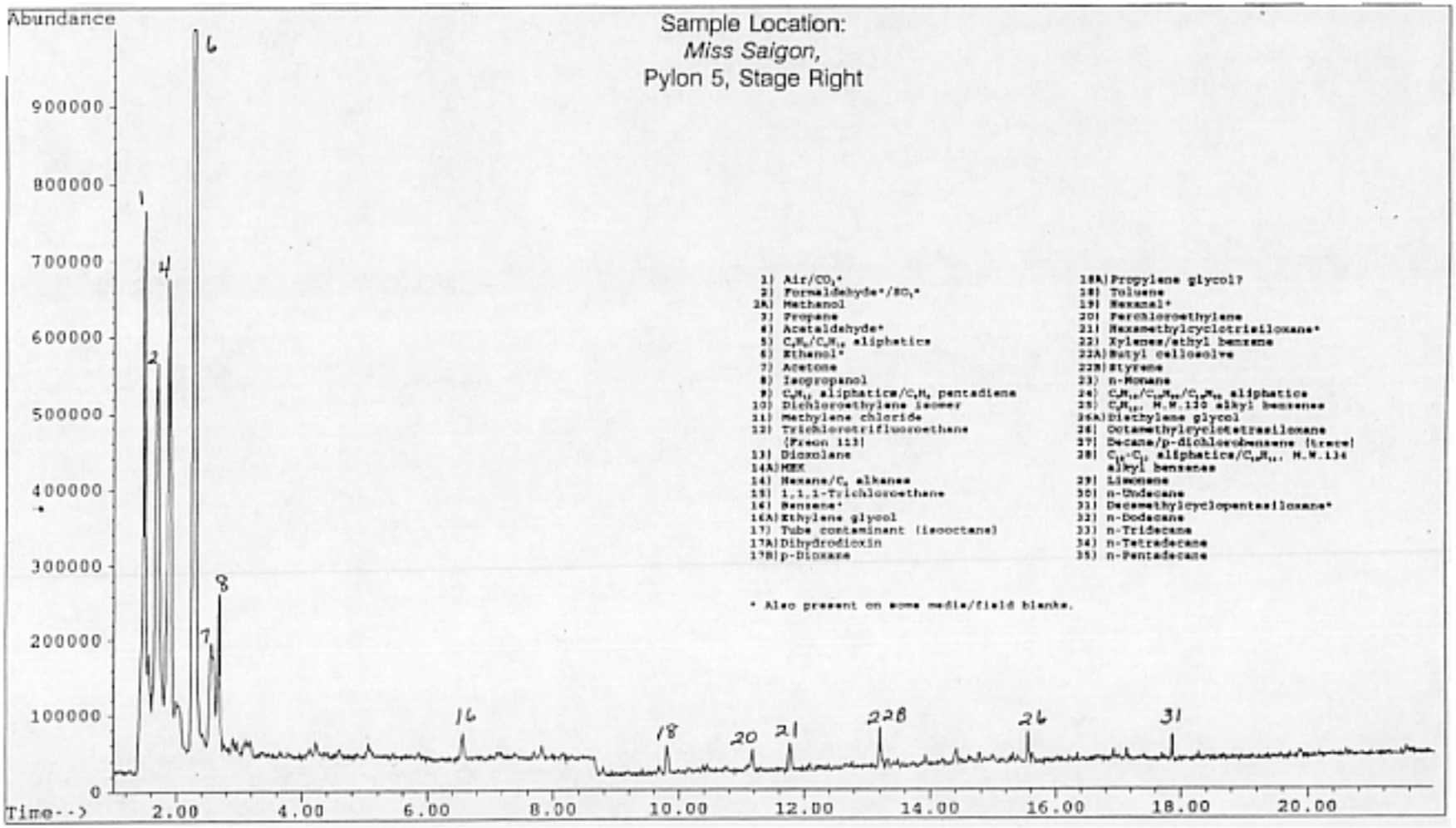


Figure 1 (continued)
Actors' Equity Association/
The League of American
Theatres and Producers, Inc.
HETA 90-0355

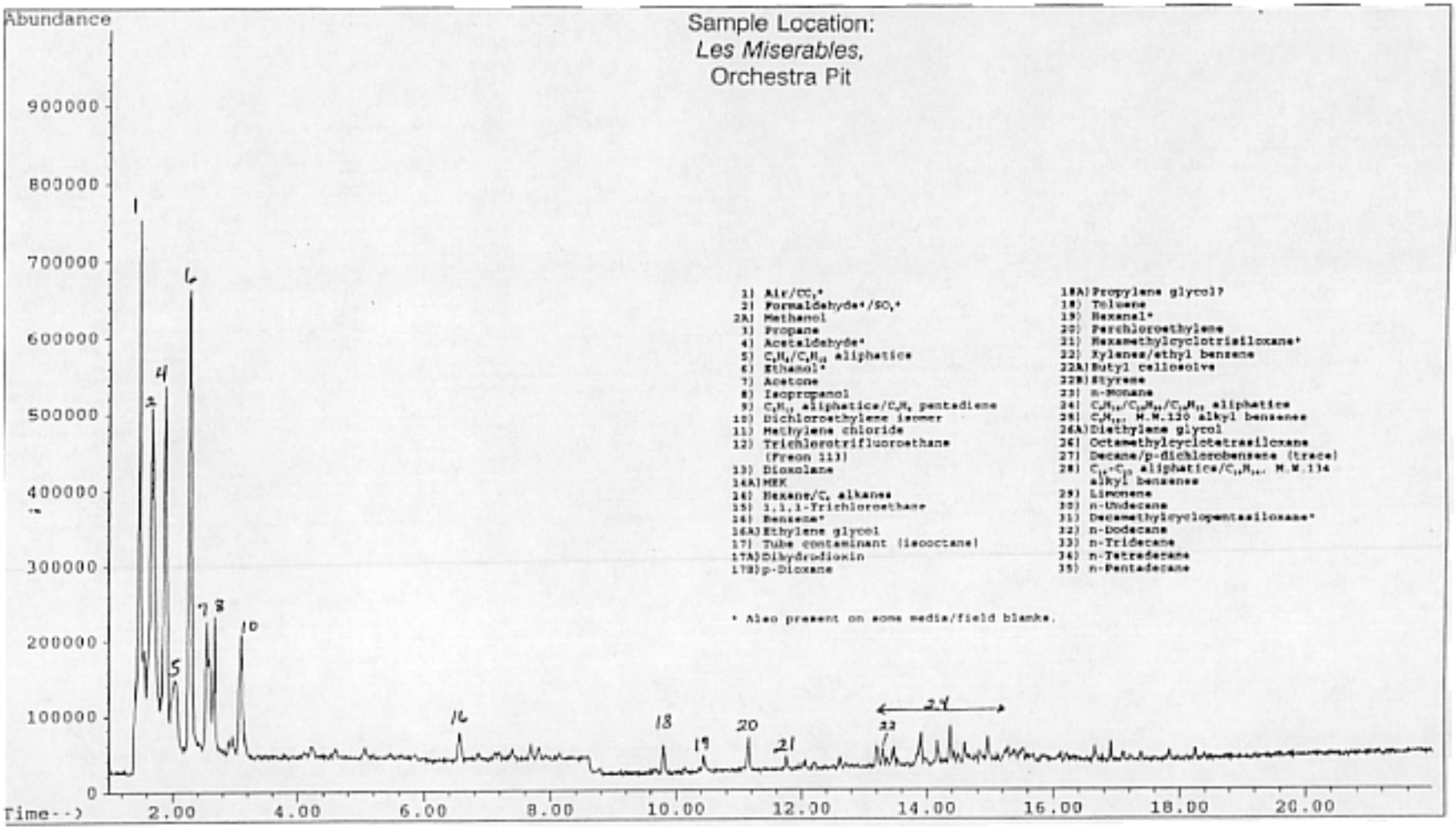


Figure 1 (continued)
Actors' Equity Association/
The League of American
Theatres and Producers, Inc.
HETA 90-0355

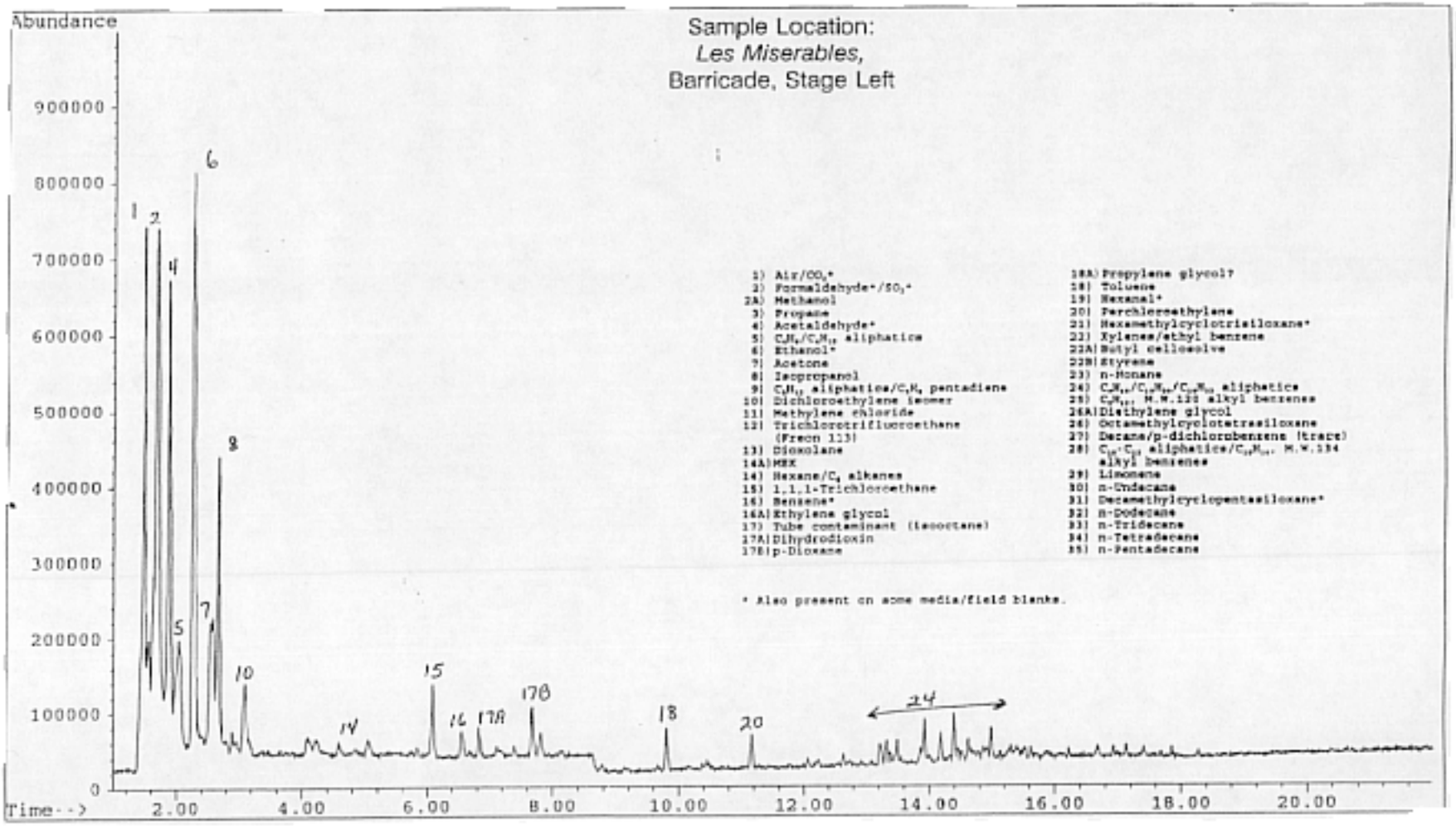


Figure 1 (continued)
Actors' Equity Association/
The League of American
Theatres and Producers, Inc.
HETA 90-0355

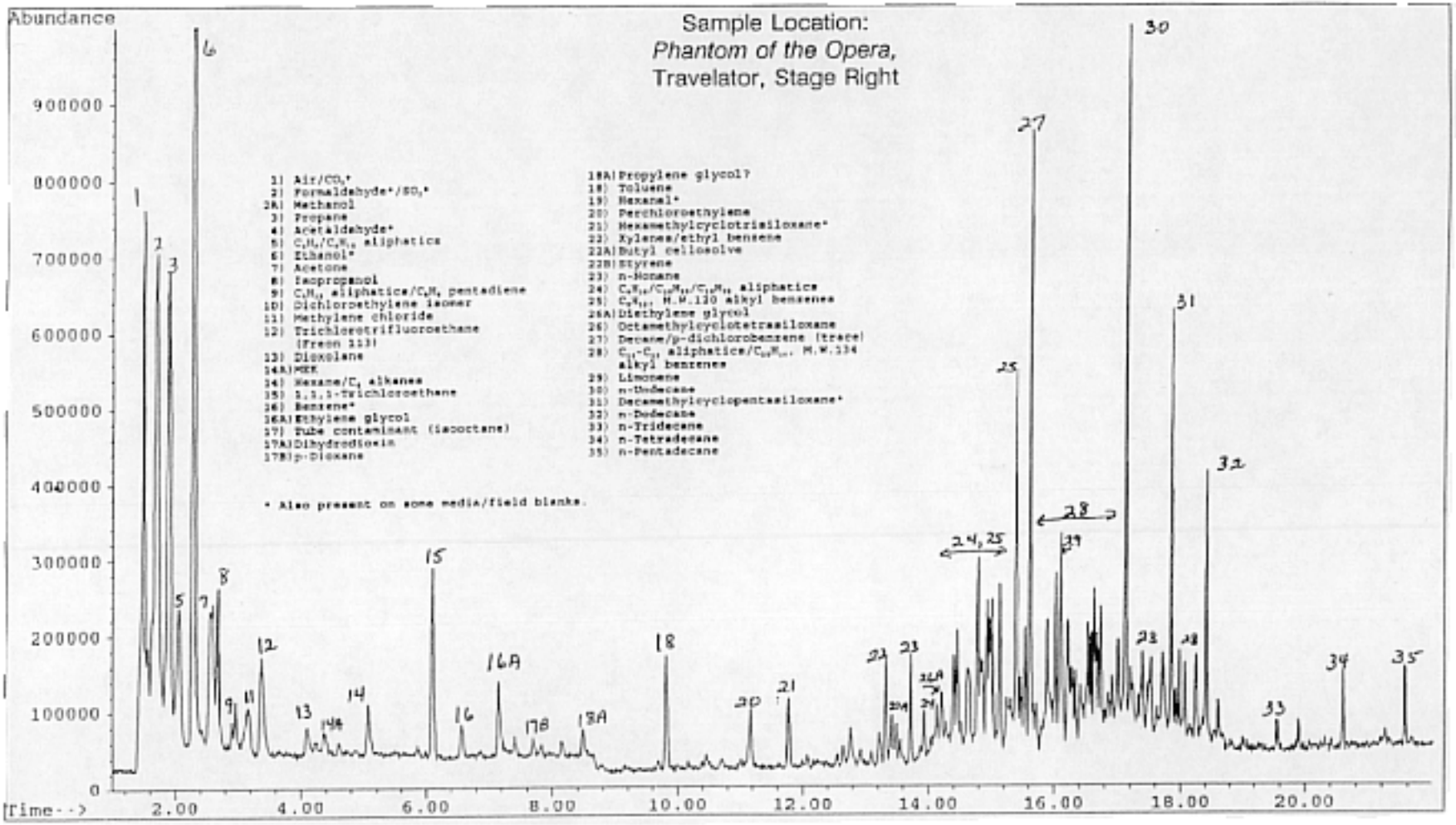


Figure 1 (continued)
Actors' Equity Association/
The League of American
Theatres and Producers, Inc.
HETA 90-0355

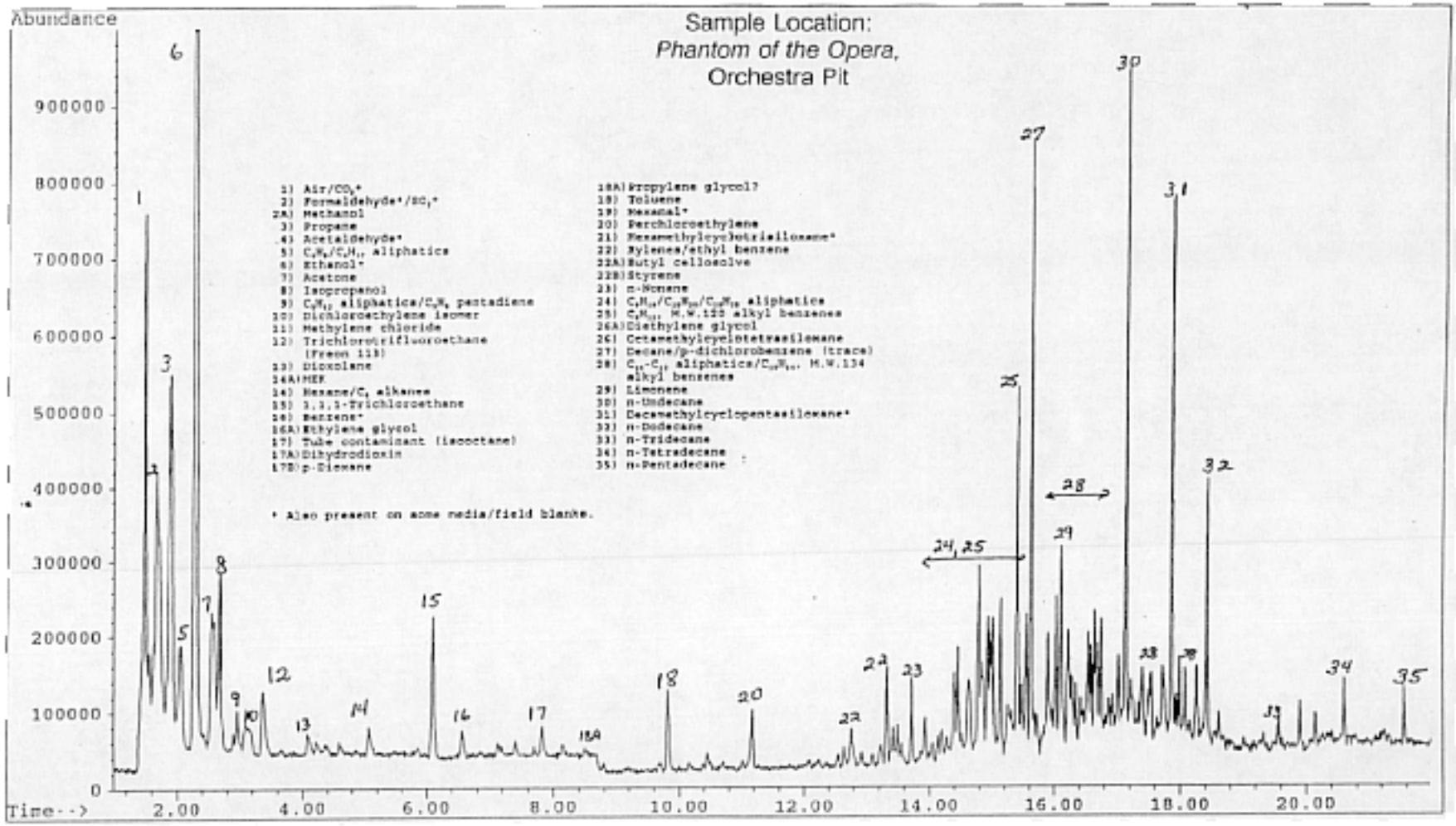


Figure 1 (continued)
Actors' Equity Association/
The League of American
Theatres and Producers, Inc.
HETA 90-0355

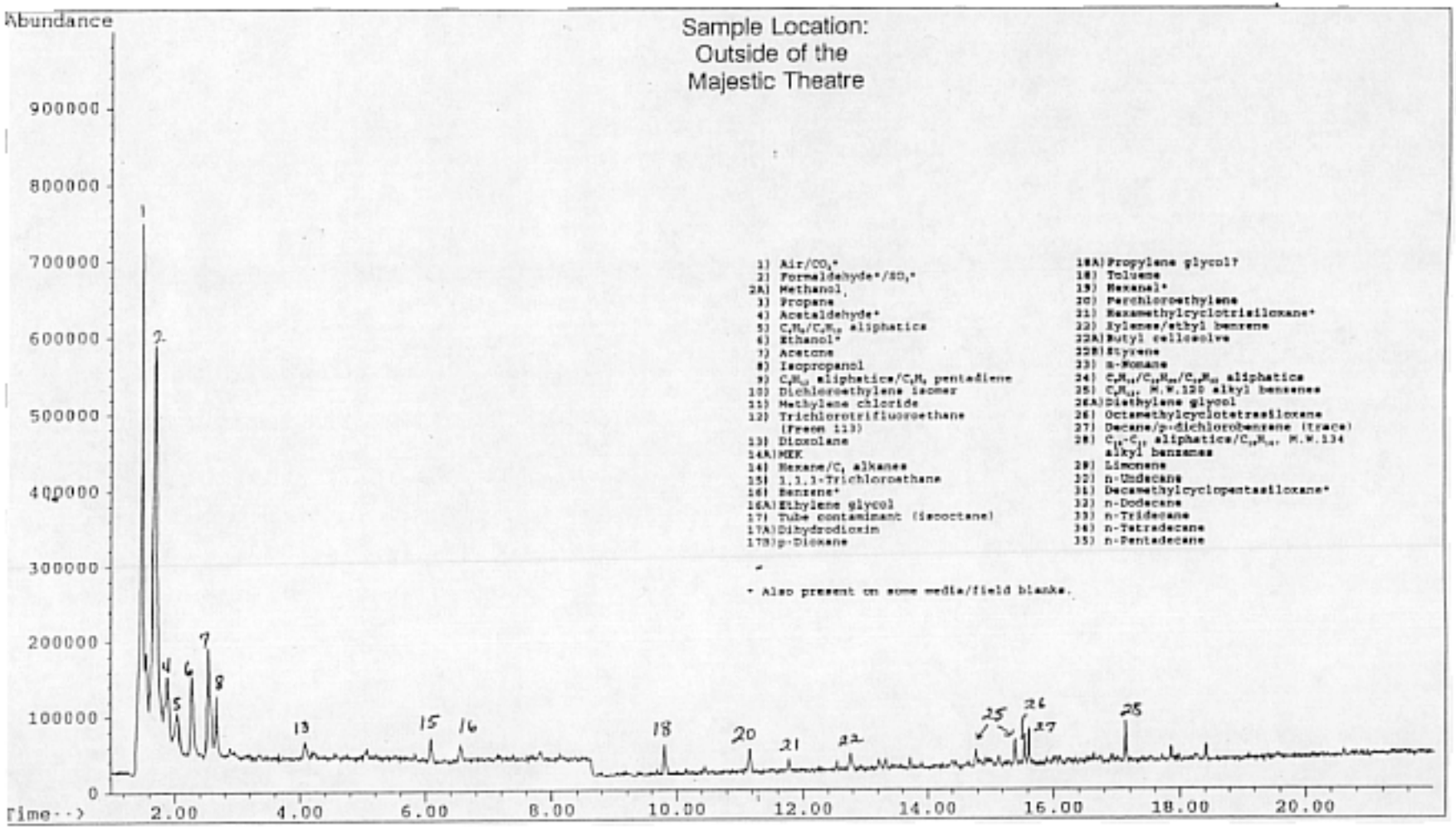
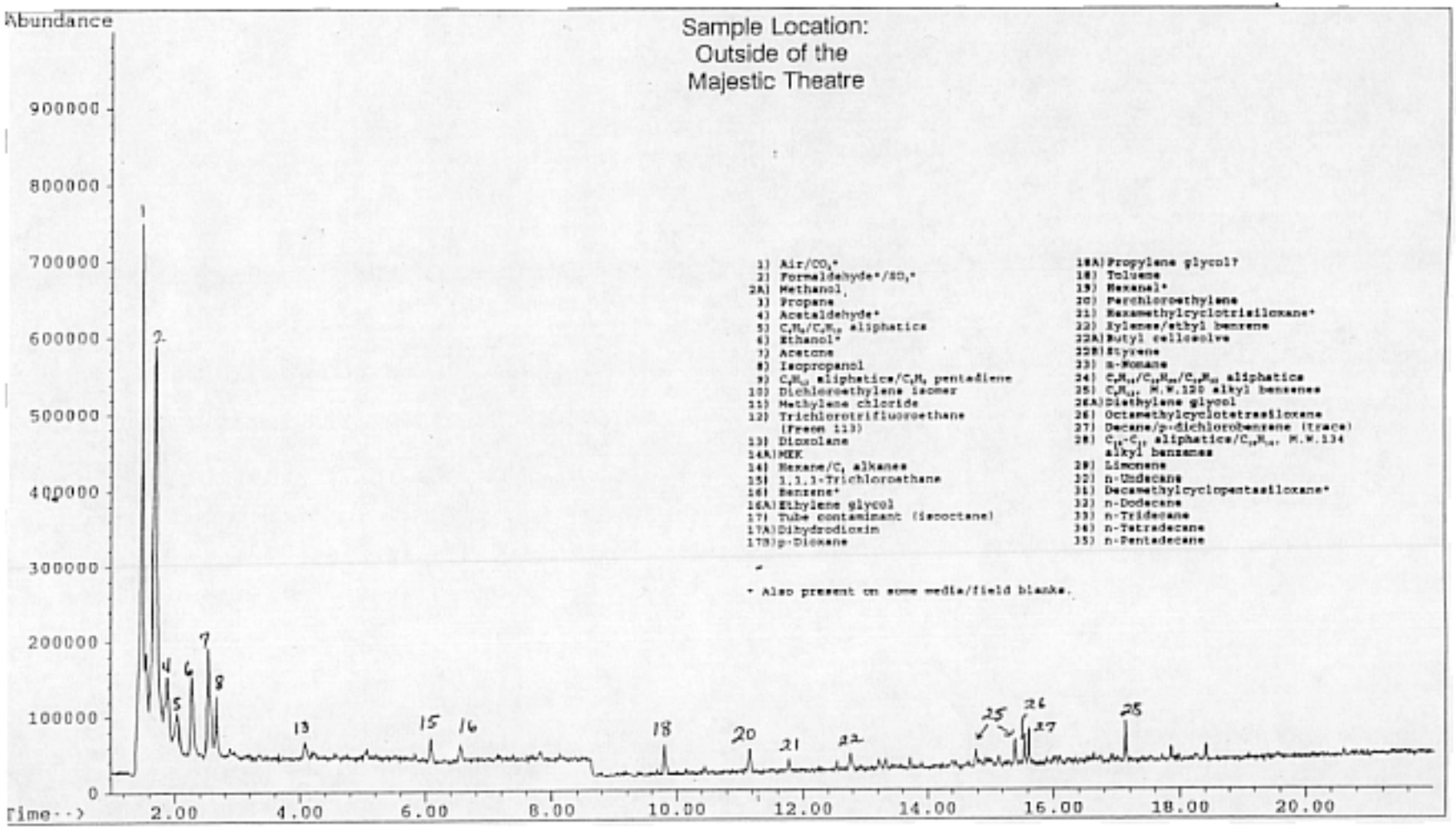


Figure 1 (continued)
Actors' Equity Association/
The League of American
Theatres and Producers, Inc.
HETA 90-0355



APPENDIX A

NATIONAL INSTITUTE FOR OCCUPATIONAL
SAFETY AND HEALTH
HEALTH HAZARD EVALUATION PROGRAM

REVISED* INTERIM REPORT No. HETA 90-355

ACTORS' EQUITY ASSOCIATION AND
THE LEAGUE OF AMERICAN THEATRES AND
PRODUCERS, INC.
NEW YORK, NEW YORK

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***Revision Date: 10/01/92**

SUMMARY

In July and August, 1990 the National Institute for Occupational Safety and Health (NIOSH) received requests from the Actors' Equity Association (AEA) and the League of American Theatres and Producers, Inc. to investigate possible health effects associated with the use of theatrical "smokes" in Broadway productions.

Four Broadway productions (*LES MISERABLES, MISS SAIGON, PHANTOM OF THE OPERA, AND GRAND HOTEL*) which used theatrical smoke were selected and dress rehearsals were arranged to conduct personal breathing-zone (PBZ) and general area (GA) air sampling and to administer a questionnaire to the actors detailing the frequency and severity of irritant and respiratory symptoms (if any) when exposed to theatrical smoke. A small number of PBZ air samples were collected on electricians, carpenters, and other personnel who may have been exposed to the theatrical smoke during a performance. To determine if the prevalence of symptoms among actors in shows using theatrical smoke(s) differed from the symptom prevalence in non-smoke productions, NIOSH investigators also administered the same questionnaire to actors in five Broadway productions in which no theatrical smoke was used (*LOST IN YONKERS, GYPSY, GETTING MARRIED, ONCE ON THIS ISLAND, AND SIX DEGREES OF SEPARATION*). The actors in these non-smoke productions are termed "controls" in this report.

Air sampling at the smoke productions was completed during dress rehearsals held between June 17 and July 2, 1991. Questionnaires were administered during this same time period to all of the selected Broadway productions. Although theatrical smoke was visibly evident during all of the performances, results from all of the PBZ and GA air samples collected were very low when compared to applicable Occupational Safety and Health Administration (OSHA) Permissible Exposure Limits (PELs), American Conference of Governmental Industrial Hygienists (ACGIH) Threshold Limit Values (TLVs), or NIOSH Recommended Exposure Limits (RELs). For example, acrolein and acetaldehyde, suspected to be possible decomposition products from the heating of the glycol-based fog fluids, were **not** found on any of the PBZ or GA air samples collected during this survey. **None of the PBZ air samples** had detectable amounts of formaldehyde.

Only 21 of the 120 PBZ and GA air samples collected for glycols (specifically ethylene, propylene, 1,3 butylene, diethylene, and triethylene glycols) during this investigation had detectable amounts of these substances. Excluding the results obtained from two GA air samples situated directly adjacent to the on-stage smoke machines used in *LES MISERABLES*, all of the remaining **glycol concentrations were extremely low**, ranging up to 2.1 milligrams per cubic meter (mg/m^3). These concentrations were well below the OSHA PEL for ethylene glycol of 127 mg/m^3 (short-term exposure limit of 15 minutes). There is no NIOSH REL for ethylene glycol; however, because of the potential teratogenicity and the

*NIOSH Sampling and Analytical Method No. 5500 was developed for ethylene glycol alone. NIOSH investigators have recently determined that this method may **have deficiencies** when used to identify and quantitate other similar glycols as were encountered in this evaluation (such as propylene, butylene, diethylene, and triethylene glycols). In at least one instance ethylene glycol was incorrectly identified in an air sample. Since it is possible that interferences from other glycol analytes may have occurred, only **qualitative** glycol sampling data will be discussed in the final report. The sections of this revised interim report affected by these analytical problems have been highlighted. A thorough discussion of the analytical problems encountered while using NIOSH Sampling and Analytical Method 5500 for these glycols will be contained in the final report.*

known respiratory irritation at the level chosen for the OSHA PEL, NIOSH has suggested that the current OSHA PEL be revised. There are no OSHA, NIOSH, or ACGIH exposure criteria for the other glycols.

Air samples (both PBZ and GA) were collected for mineral oil mist during a dress rehearsal of *MISS SAIGON*. Concentrations ranged up to 1.35 mg/m^3, TWA over duration of the play. The highest levels were measured in GA samples positioned on stage. All of the measured concentrations were well below the OSHA, NIOSH, and ACGIH exposure limits of 5 mg/m^3 for up to a full-shift (8 to 10 hours) TWA exposure.

All 224 actors from nine Broadway productions completed questionnaires. Of this group, 134 questionnaires (60%) were from actors appearing in the four productions using theatrical smokes, and 90 questionnaires (40%) were from actors appearing in the five control productions.

When compared to actors from the non-smoke productions, actors from two or more of the four productions utilizing theatrical smoke reported experiencing significantly greater prevalence of nasal symptoms (sneezing, runny or stuffy 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 some of the constituents of theatrical smoke (primarily the glycols) have irritative properties, the reason for the high symptom prevalence in the productions that use theatrical smoke is not clear, since the time-weighted average concentrations of the glycols measured during the performances were quite low. It is possible however, that the smoke concentrations could be sufficiently high during the short periods of time that the smoke is generated to contribute to the symptoms reported by the actors.

While some mucous membrane irritative symptoms (eyes, nose, throat) might be expected, the high prevalence of work related lower respiratory symptoms (cough, wheeze, chest tightness, and shortness of breath) reported by the smoke-exposed actors was surprising. It is possible that the questionnaire was too sensitive in its design and caused an over-reporting of symptoms, the constituents of theatrical
smoke may be more irritative at low concentrations than previously documented, or there may be other factors involved. Since the etiology is unclear at this time, a return visit is planned to gather further information on the nature of these symptoms.

In this interim period, the NIOSH investigators recommend that only smoke fluids which are approved by the manufacturers be used. For the glycols which are used, their purity should be at the level of "food grade" or "high grade" to minimize the presence of impurities. Relocating the smoke machine(s) (either glycol or mineral oil-based) to avoid exposing actors

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to the direct, concentrated release of the aerosols may be advantageous in reducing complaints. Additionally, reducing the amount of theatrical smoke to the minimum necessary is also advisable.

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INTRODUCTION

In July 1990, the National Institute for Occupational Safety and Health (NIOSH) received a request from the Actors' Equity Association (AEA) for a series of health hazard evaluations (HHE) to investigate possible health effects associated with the use of theatrical "smokes" in Broadway productions. A similar request was received from the League of American Theatres and Producers, Inc. Both requests have been combined into this interim report.

On January 9-10, 1991, NIOSH investigators conducted an initial site visit to investigate the possibility of conducting industrial hygiene and medical surveys on Broadway actors exposed to the various theatrical fogs used during specific productions. The opening conference was attended by representatives from AEA, the League of American Theatres and Producers, the various Broadway productions that utilized the fogs, and private industrial hygiene consulting firms. This initial conference covered the NIOSH HHE program and the scope and purpose of the evaluation.

BACKGROUND

Many of the theatrical smokes currently in use in Broadway theaters, in television, and in motion pictures utilize heated glycol fluids to produce a visible aerosol. While the exact formulations of these fluids are considered proprietary by the manufacturers, some of the more commonly used glycols include ethylene glycol; propylene glycol; 1,3 butylene glycol; diethylene glycol; and triethylene glycol. Some of the higher molecular weight glycol compounds, such as tetra-, penta-, hexa-, and heptaethylene glycols, may also be used. All four of the "smoke" productions included in this survey used a glycol-based smoke generation system.[d] Sizes of the glycol-based smoke systems ranged from larger units (permanently mounted either on or off stage) to smaller, hand-held devices operated by stage hands during a performance. In one of the Broadway productions (*MISS SAIGON*) an unheated mineral oil-based smoke generation system was also used. Table 1 summarizes the brands of smoke producing systems in use during this evaluation and where they were used.

[d] In addition to the glycol-based smoke systems, some of the productions used dry ice (carbon dioxide) fog systems.

EVALUATION DESIGN AND METHODS

Four Broadway productions (*LES MISERABLES, MISS SAIGON, GRAND HOTEL, AND PHANTOM OF THE OPERA*) were selected for studying actor's exposures to theatrical smoke. With the cooperation of the AEA and the League of American Theatres and Producers, special dress rehearsals were arranged with each production company to allow NIOSH investigators to conduct personal breathing-zone (PBZ) and general area (GA) air sampling during the performance of the play and also to administer a questionnaire to the actors. In addition to the performers, a small number of PBZ air samples were collected on electricians, carpenters, and other personnel who may have been exposed to the theatrical smoke during a performance.

All four of the "smoke" productions, *LES MISERABLES, MISS SAIGON, GRAND HOTEL, AND PHANTOM OF THE OPERA*, were previewed by NIOSH investigators prior to conducting the air sampling and administering the symptoms questionnaire. This was to acquaint the investigators with the smoke cues, meet with the production managers and actors, and to select sites for GA samples. The air sampling strategy was to collect the PBZ and GA air samples during the play with minimal disruptions.[e] With the exceptions of the actors not being in full costume and the orchestra being absent (background music provided from tape and/or piano), everything in these dress rehearsals was conducted (including smoke cues and any other special effects) as if they were actual performances before an audience.

The four dress rehearsals, along with the theater where the play was performed, were scheduled as follows.

- June 18, 1991 - *PHANTOM OF THE OPERA* **(Majestic Theatre)**
- June 20, 1991 - *GRAND HOTEL* **(Martin Beck Theatre)**
- June 25, 1991 - *MISS SAIGON* (first time)[f] **(Broadway Theatre)**
- July 2, 1991 - *LES MISERABLES* **(Imperial Theatre)**
- July 2, 1991 - *MISS SAIGON* (second time) **(Broadway Theatre)**

In all of these productions the use of theatrical smokes (either glycol, mineral oil, or carbon dioxide-based) were precisely timed. A list of smoke cues was provided by the production managers prior to the dress rehearsals to help in selecting the appropriate actors and stage

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[e] Short-term GA and PBZ air samples were collected for glycols and formaldehyde in *PHANTOM OF THE OPERA* and *GRAND HOTEL*.

[f] Personal and general area air samples were collected during the dress rehearsal of MISS SAIGON on June 25, 1991. General area air samples (both on-stage and off-stage) were collected during a live evening performance on July 2, 1991.

locations to sample. A smoke cue would prompt the stage electrician (or whoever was in charge of operating the smoke machines) to provide a specific amount of smoke. The quantity of smoke was determined by controlling the time the smoke machine ran (typically 5 to 10 seconds). Some leeway was given to the person controlling the smoke based on whether the necessary visual appearance was achieved on stage. If the smoke effects were not sufficient, the play's director would ask the smoke controller to provide additional smoke. It was apparent from watching the actual performances and the dress rehearsals that it was seldom necessary for the stage crew controlling the smoke machines to deviate from the established cue times.

Based simply on visual observations, the quantities of smoke varied greatly between each of the four plays. For example, in *GRAND HOTEL* the glycol-based smoke machines operated before the play actually began in order to create the required "smokey" ambience over the entire stage. The smoke machines, however, were not used again until a train scene which occurred late in the play. For comparison, *MISS SAIGON* used glycol and mineral oil-based smoke systems throughout the play to create the desired atmosphere of wartime Saigon and Bangkok, where the play was situated.

Using visual observations, NIOSH investigators qualitatively ranked the four productions in the following order on the amount of smoke used during the performance. Cigarette smoking was minimal during all except *GRAND HOTEL*, a play in which the actors were required to smoke during several scenes.

PRODUCTION	USE OF SMOKE	TYPES OF SMOKES
GRAND HOTEL	LIGHT	GLYCOLS
PHANTOM OF THE OPERA	MEDIUM	GLYCOLS, CARBON DIOXIDE
LES MISERABLES	MEDIUM TO HEAVY	GLYCOLS, CARBON DIOXIDE
MISS SAIGON	HEAVY	GLYCOLS, MINERAL OIL

BULK SAMPLE ANALYSIS

Four bulk samples of fluids used in theatrical fog-generating machines were submitted for laboratory analysis. Three of the bulks (the glycol-containing solutions) were heated to

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specified temperatures[g] (ranging from 290 to 370°C) and the effluent analyzed for volatile organic compounds by gas chromatography-mass spectrophotometry (GC-MS).[1] All of the bulk solutions were also analyzed directly for major constituents.

WORKPLACE AIR MONITORING

PBZ and GA air sampling was performed for a variety of substances. Most of the glycols which were analyzed for, including propylene, ethylene, diethylene, triethylene, tetraethylene, and 1,3 butylene glycols, were present in the bulk samples of the theatrical smoke fluids. Air samples were collected for aldehydes (specifically acetaldehyde, formaldehyde, and acrolein). These were considered by NIOSH investigators to be the most likely decomposition products from the heating of the glycol solutions. Samples were also collected for mineral oil mist during a performance of *MISS SAIGON*.

Table 2 summarizes the methods used to collect and analyze the PBZ and GA air samples. The air sampling was generally conducted for the length of each performance (approximately two hours for all but *LES MISERABLES*, which exceeded three hours). Most of the actors wore one sampling pump during the play. However, some principal actors were required to wear two sampling pumps if they were on stage during the scenes in which theatrical smoke was used. The air sampling was conducted so as to cause minimal disruptions during each dress rehearsal. One exception was the collection of three short-term GA air samples during the magic mirror/dressing room scene in *PHANTOM OF THE OPERA*; this procedure required the actors to stop for approximately five minutes. The collection of three short-term GA air samples during *GRAND HOTEL*, however, did not disrupt the flow of the play.

MEDICAL EVALUATION

A questionnaire detailing the frequency and severity of irritant and respiratory symptoms experienced during performances the week prior to the survey was administered to actors exposed to theatrical smoke in four Broadway productions. To determine if the prevalence of symptoms among actors in shows using theatrical smokes differed from the prevalence in productions not using smoke, the same questionnaire was administered to actors in five

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[g] The temperatures selected for the headspace analysis corresponded to the levels to which the glycol solutions were heated in their respective smoke machines.

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Broadway productions (*LOST IN YONKERS, GYPSY, GETTING MARRIED, ONCE ON THIS ISLAND, AND SIX DEGREES OF SEPARATION*) in which no theatrical smoke was used; these participants served as controls.

Each actor was asked to respond to background questions concerning age, length of time as a professional actor, length of time spent on stage in the current production, smoking status, and specific questions about his or her present state of health. Each actor was also asked whether or not he or she had experienced any of a list of 17 irritant and respiratory symptoms during performances the previous week. Participants were then asked to rate the frequency (never, rarely, sometimes, often, always) and severity (1-mild to 5-severe) of each symptom. Symptoms were then divided into an upper respiratory tract symptom group (stuffy nose, sneezing, coughing, sore throat, and dry throat), a lower respiratory tract symptom group (wheezing, shortness of breath, and chest tightness), and an eye symptom group (dry eyes, sore/itchy/watery eyes, and burning eyes). If a participant reported experiencing two or more of a group's symptoms "sometimes," "often," or "always," we considered that group's symptoms to be present. The prevalence of such positive responses among actors in smoke-utilizing productions was then compared to those among actors in control (non-smoke-utilizing) productions.

Actors in each production were asked if they usually had a cough which produced phlegm as much as twice per day, four or more days of the week. (Duration of the phlegm production was not asked.) Those answering yes to these criteria were considered (for the purposes of this evaluation) to have symptoms compatible with chronic bronchitis. Since cigarette smoking can cause chronic bronchitis, (and would therefore be a confounder in the analysis) we eliminated smokers from the analysis of chronic bronchitis.

EVALUATION CRITERIA

GENERAL

As a guide to the evaluation of the hazards posed by workplace exposures, NIOSH field staff employ environmental evaluation criteria for the assessment of a number of chemical and physical agents. These criteria are intended to suggest limits of exposure to which most workers may be exposed up to 10 hours per day, 40 hours per week for a working lifetime without experiencing adverse health effects. It is, however, important to note that not all workers will be protected from adverse health effects even though their exposures are maintained below these limits. A small percentage may experience adverse health effects because of individual susceptibility, a pre-existing medical condition, and/or a hypersensitivity (allergy). In addition, some hazardous substances may act in combination with other workplace exposures, the general environment, or with medications or personal habits of the worker to produce

health effects even if the occupational exposures are controlled at the limit set by the criterion. These combined effects are often not considered in the evaluation criteria. Also, some substances are absorbed by direct contact with the skin and mucous membranes, and thus potentially increase the overall exposure. Finally, evaluation criteria may change over the years as new information on the toxic effects of an agent become available.

The primary sources of environmental evaluation criteria for the workplace are the following: 1) NIOSH Recommended Exposure Limits (RELs),[2] 2) the American Conference of Governmental Industrial Hygienists' (ACGIH) Threshold Limit Values (TLVs),[3] and 3) the U.S. Department of Labor, Occupational Safety and Health Administration (OSHA) Permissible Exposure Limits (PELs)[4]. The OSHA PELs may be required to take into account the feasibility of controlling exposures in various industries where the agents are used; the NIOSH RELs, by contrast, are based primarily on concerns relating to the prevention of occupational disease. In evaluating the exposure concentrations and the recommendations for reducing these concentrations found in this report, it should be noted that the lowest exposure criteria was used; however, industry is legally required to meet those limits specified by the OSHA standard.

A time-weighted average (TWA) exposure refers to the average airborne concentration of a substance during a normal eight- to ten-hour workday. Some substances have recommended short-term exposure limits (STELs) or ceiling values which are intended to supplement the TWA where there are recognized toxic effects from high short-term exposures.

SPECIFIC SUBSTANCES

Acrolein, acetaldehyde, and formaldehyde were not constituents of the glycol solutions used to generate theatrical smoke. However, they are potential decomposition products from heated glycol solutions, so they are discussed below.

Acrolein

Acrolein is a very intense irritant, causing rapid injury to the respiratory tract, eyes, and skin. The irritation threshold in humans is 0.25 parts per million (ppm) for all mucous membranes.[5] Due to its strong lacrimatory (watering of the eyes) effect, acrolein does offer good warning properties. While skin contact with the vapor or liquid can cause severe burns, inhalation is the most serious hazard. Chronic toxicity has not been shown with this compound, but dermatitis and skin sensitization has been observed.

While the carcinogenic potential of acrolein has not been adequately determined, one of its potential metabolites (glycidaldehyde) is considered to be carcinogenic.[6,7] The OSHA PEL, NIOSH REL, and ACGIH TLV for acrolein is

0.1 ppm for up to a 10-hour TWA.

Acetaldehyde

Acetaldehyde, also an irritant of the mucous membranes at low concentrations, may cause dermatitis and conjunctivitis following repeated exposures to the liquid or vapors. In studies assessing human effects, volunteers who were exposed for 15 minutes to 50 ppm of acetaldehyde experienced mild irritation.[5] In more sensitive human subjects, however, irritation was noted at concentrations of 25 ppm.[5] Generally the fruity odor of acetaldehyde offers good warning properties.

The OSHA PEL and ACGIH TLV for acetaldehyde is 100 ppm, TWA for an eight to ten hour exposure. The International Agency for Research on Cancer (IARC) has concluded that there is sufficient evidence for the carcinogenicity of acetaldehyde in animals but inadequate evidence for carcinogenicity in humans.[8] NIOSH considers that, in the absence of adequate data on humans, it is reasonable to regard chemicals for which there is sufficient evidence of carcinogenicity in animals as if they presented a carcinogenic risk to humans. Since acetaldehyde is an animal carcinogen and, therefore, a potential occupational carcinogen, the NIOSH policy is to reduce exposure to the lowest feasible limit.[8]

Formaldehyde

Exposures to low concentrations of formaldehyde vapor will cause irritation of the eyes and respiratory tract. Because it is readily soluble in water, most of the irritant effects are restricted to the upper respiratory tract where the chemical is quickly absorbed. A concentration of two to three ppm will cause formication (a term describing the sensation of small insects crawling on the skin) of the eyes, nose, and throat.[5] Ten ppm is tolerated with difficulty by most people for only a short period of time.[5]

Some people may be especially sensitive to formaldehyde and can become symptomatic at concentrations well below one ppm. Case reports of asthma apparently induced by formaldehyde have been reported, although a true immunologically mediated allergic response has not been documented.[9,10,11] Formaldehyde has been shown to be carcinogenic in several animal studies.[5] A large historic cohort study of industrial workers with exposure to formaldehyde did not identify any excesses of leukemia, brain cancer, or nasal cancer.[12] Some research suggests that the potential carcinogenic effects of formaldehyde is particularly enhanced in the presence of hydrochloric acid vapors.[13]

The OSHA PEL and ACGIH TLV for formaldehyde is one ppm, TWA over an eight-hour work day with a short-term exposure limit of two ppm.[h] NIOSH recommends that formaldehyde be treated as a potential occupational carcinogen and recommends that exposures be kept as low as feasible. This is based on the mutagenic activity formaldehyde has shown in several test systems and that it has induced nasal cancer in rats and mice.[14]

Mineral Oil

Also termed liquid paraffin and white mineral oil, this hydrocarbon mixture is produced by removing the lighter hydrocarbons from petroleum by distillation, followed by charcoal filtering and additional distillation steps.[15] The final product is colorless, tasteless, and generally odorless (when cold). Mineral oil is used in drugs applied to the nasal membranes and as a laxative. It is used as a solvent for inks in the printing industry and as a general lubricant.[5]

Mineral oil mist is considered to have low toxicity. The IARC has determined that there is no evidence that the fully solvent refined oils are carcinogenic to experimental animals in either skin painting or feeding studies.[16] However, the IARC has determined that, based on epidemiologic studies, there is sufficient evidence for carcinogenicity in humans of uncharacterized mineral oils containing additives and impurities.[16] Fortunately, most of the mineral oils in use today are free of additives and impurities because of improvements in the refining process.[17]

In a study of mineral oil mist exposures in machine shops where the average airborne concentration was 3.7 mg/m^3 (the maximum short-term concentration measured was 110 mg/m^3), no increase in respiratory symptoms or decrement in respiratory performance was observed in the employees.[18] There have been no reported cases of illnesses in other studies which covered a variety of industries and involved human exposures to mineral oil mist concentrations which averaged less than 15 mg/m^3.[19]

The OSHA PEL, NIOSH REL, and ACGIH TLV for mineral oil mist is 5 mg/m^3, TWA for up to a ten-hour exposure. The OSHA and NIOSH short-term exposure limit for mineral oil mist 10 mg/m^3.

Glycols

[h] ACGIH considers formaldehyde to be a suspect human carcinogen and has proposed to reduce the TLV to 0.3 ppm as a ceiling limit which should not be exceeded.

None of the glycols identified in the bulk samples of the fog solutions used in the Broadway plays surveyed have been found to be mutagenic or carcinogenic. Table 3 lists the major glycols identified in these fluids and describes their health effects.

Since glycols are polyfunctional alcohols, exposures to any of these substances may cause a drying of exposed mucous membranes, resulting in dry, irritated eyes and respiratory tract irritation. Some recent studies have reported that ethylene glycol and diethylene glycol have had embryo-toxic effects in some test animal species; both have other harmful health effects (e.g., kidney or liver damage) if significant amounts are ingested.[20,21] Other studies, involving human as well as animal subjects, have shown ethylene glycol to cause upper respiratory irritation, although the airborne concentrations necessary to achieve these irritant effects have varied greatly.[22] In one of these studies the test subjects were exposed for 20 to 22 hours/day to average concentrations which exceeded 30 milligrams of ethylene glycol per cubic meter of air.[23]

The OSHA PEL and ACGIH TLV (short-term exposure limits) for ethylene glycol is 127 mg/m^3. There is no NIOSH REL for ethylene glycol; however, because of the potential teratogenicity and the known respiratory irritation at the level chosen for the OSHA PEL, NIOSH has suggested that OSHA reconsider their current PEL for ethylene glycol.[24] There are no OSHA, NIOSH, or ACGIH exposure criteria for the other glycols.

RESULTS

BULK SAMPLES

Bulk samples from Rosco®, The Great American Market®, and Theater Magic® were qualitatively analyzed to identify major constituents. The fluids contained mixtures of several glycols, including ethylene, propylene, 1,3 butylene, and diethylene and triethylene glycols. In one bulk sample higher molecular weight glycol compounds (such as tetraethylene, pentaethylene, hexaethylene, and heptaethylene) may also have been present.

Headspace analysis by NIOSH chemists was also performed on the three glycol mixtures by heating them in a micro-combustion furnace to temperatures which approximated the temperatures to which the fluids were heated in the manufacturer's smoke generators. These temperatures ranged from 290° to 370°C. The effluent was then analyzed using charcoal and ORBO® 23 sorbent tubes for volatile organic compounds by GC-MS.

Analysis of the charcoal tube air samples collected from heated bulk samples of two of the three glycol fluids detected no decomposition compounds (with the exception of the

glycols previously identified in the unheated fluids). It should be noted that these samples were heated to either 290° or 315°C. In both cases, the non-volatility of the glycols and the fact that they condensed in the oven outlet prior to reaching the sorbent tubes contributed to the low concentrations measured.

Results of the qualitative headspace analysis from the third bulk glycol sample (a mixture which, according to the manufacturer, could be heated to a higher temperature [370°C, ≈700°F] to achieve a high quality of "smoke"), detected the presence of both acetaldehyde and formaldehyde. In addition, some acrolein and propanal was also detected. Although these results are only qualitative, the aldehydes as a group are skin, eye, and upper respiratory irritants. Their detection in the headspace analysis of the bulk sample heated to ≈700°F (but not in the glycol bulk samples heated to lower temperatures) may be significant in estimating the irritant potential of the theatrical smoke during actual use conditions.

AIR MONITORING

Considering that the vast majority of the PBZ and GA air samples collected in this evaluation had non-detectable (ND) amounts of the substances of interest, only those air samples which had detectable amounts are listed in the tables. Results from PBZ and GA air samples collected for glycols during this survey are shown in Table 4. The glycols detected included ethylene, propylene, 1,3 butylene, diethylene, and triethylene glycols. Ethylene glycol concentrations (the only glycol for which there are established exposure criteria) ranged from ND to 20.8 mg/m^3, TWA.[i] All of the ethylene glycol levels measured are below the OSHA and ACGIH exposure criteria of 127 mg/m^3 (for a 15 minute short-term exposure). As previously stated, there is no NIOSH REL for ethylene glycol. However, NIOSH has suggested that OSHA reconsider their current PEL for ethylene glycol.[24] There are no OSHA, NIOSH, or ACGIH exposure criteria for the other glycols.

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[i] The highest measured ethylene glycol concentration came from an area air sample located directly adjacent to a smoke machine positioned on stage during LES MISERABLES. This level should not be considered representative of an actor's personal exposure.

*NIOSH Sampling and Analytical Method No. 5500 was developed for ethylene glycol alone. NIOSH investigators have recently determined that this method may **have deficiencies** when used to identify and quantitate other similar glycols as were encountered in this evaluation (such as propylene, butylene, diethylene, and triethylene glycols). In at least one instance ethylene glycol was incorrectly identified in an air sample. Since it is possible that interferences from other glycol analytes may have occurred, only **qualitative** glycol sampling data will be discussed in the final report. The sections of this revised interim report affected by these analytical problems have been highlighted. A thorough discussion of the analytical problems encountered while using NIOSH Sampling and Analytical Method 5500 for these glycols will be contained in the final report.*

As shown in Table 5, formaldehyde was detected in low concentrations in only a few GA air samples.[j] Formaldehyde concentrations ranged up to 0.05 ppm, slightly above the ambient formaldehyde levels of 0.02 ppm measured outside two of the Broadway theaters. All of the formaldehyde concentrations were below applicable OSHA and ACGIH exposure criteria. NIOSH considers formaldehyde to be a suspect human carcinogen and recommends that exposures be kept to their lowest feasible levels. Acrolein and acetaldehyde (by-products produced by heating the glycol mixtures in the laboratory) were not detected on any of the air samples collected in the theaters during this study.

In addition to the glycol and aldehyde sampling, PBZ and GA air samples were collected for mineral oil mist during a dress rehearsal of *MISS SAIGON*. These concentrations, shown in Table 6, ranged from ND to 1.35 mg/m^3, TWA over duration of the play (approximately 2.5 hours). The highest levels were measured in GA samples positioned on stage. All of the measured concentrations were well below the OSHA, NIOSH, and ACGIH exposure limits of 5 mg/m^3 for up to a full-shift (8 to 10 hours) TWA exposure.

MEDICAL

All 224 actors from the nine Broadway productions completed questionnaires. Of this group, 134 questionnaires (60%) were from actors appearing in the four productions using theatrical smokes, and 90 questionnaires (40%) were from actors appearing in five control productions (Table 7).

Participants had a mean age of 34 (range 9 to 74 years), and had been professional actors for an average of 14 years (range 3 months to 45 years). The average length of time an actor had been a member of the cast was 14 months (range 1 to 52 months). Smoke-exposed actors and controls had a comparable distribution of ages, years as a professional actor, and number of months as a member of the cast (Table 8). Smoke-exposure productions, however, had a higher proportion of male actors than controls (62% vs. 54% respectively, p=0.057).

Responses of "sometimes," "often," or "always" to the occurrence during performances in the previous week of one or more irritant and/or respiratory symptoms among smoke

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[j] Formaldehyde was only detected in GA air samples collected using the most sensitive method (sodium bisulfite-filled impingers, NIOSH method no. 3500).

NIOSH Sampling and Analytical Method No. 5500 was developed for ethylene glycol alone. NIOSH investigators have recently determined that this method may ***have deficiencies*** *when used to identify and quantitate other similar glycols as were encountered in this evaluation (such as propylene, butylene, diethylene, and triethylene glycols). In at least one instance ethylene glycol was incorrectly identified in an air sample. Since it is possible that interferences from other glycol analytes may have occurred, only* ***qualitative*** *glycol sampling data will be discussed in the final report. The sections of this revised interim report affected by these analytical problems have been highlighted. A thorough discussion of the analytical problems encountered while using NIOSH Sampling and Analytical Method 5500 for these glycols will be contained in the final report.*

exposed actors (grouped by show) were compared to responses from control productions (Figure 1). Productions in which a statistically significant difference could be observed between the prevalence of symptoms among smoke exposed vs. control responses are marked with an asterisk ($p < 0.05$).

Grand Hotel

Members of the cast in *GRAND HOTEL* were 2.73 times more likely to report problems during performances with wheezing (Relative Risk (RR)=2.73; 95% Confidence Interval (CI): 1.11-6.68), and breathlessness (RR=2.73; 95% CI:1.11-6.68) than were cast members in control productions. Five of the 33 cast members met the case definition for the lower respiratory tract symptoms (See Evaluation Design and Methods--Medical Evaluation), 19 (58%) met the case definition for upper respiratory tract symptoms, and five (15%) met the definition for eye symptom group. These numbers, however, were not sufficiently high to show a statistically significant increase over controls. When we excluded smokers from the analysis, actors in this production had an increased prevalence of frequent sputum production compatible with bronchitis when compared to controls (RR=2.63; 95% CI:1.05-6.54).

Les Miserables

LES MISERABLES cast members were more likely than controls to report headaches (RR=2.57; 95% CI:1.52-4.34), nausea (RR=3.21; 95% CI:1.38-7.47), runny nose (RR=2.46; 95% CI:1.62-3.74), stuffy nose (RR=2.67; 95% CI:1.84-3.87), sneezing (RR=2.70; 95% CI:1.68-4.33), coughing (RR=3.29; 95% CI:2.04-5.30), wheezing (RR=3.54; 95% CI:1.55-8.05), shortness of breath (RR=4.18; 95% CI:1.90-9.20) chest tightness (RR=5.66; 95% CI:2.12-15.11), dry eyes (RR=4.00; 95% CI:2.56-6.24), sore/itchy/watery eyes, (RR=3.60; 95% CI:1.77-7.33), burning eyes (RR=3.97; 95% CI:2.07-7.61), sore throat (RR=2.57; 95% CI:1.71-3.87), hoarseness (RR=1.73; 95% CI:1.37-2.19), and dry throat (RR=2.40; 95% CI:1.72-3.36).

Twelve of the 35 actors from *LES MISERABLES* met the case definition for the lower respiratory tract symptoms compared to controls: (RR=5.14; 95% CI:2.09-12.64), 31 met the definition for upper respiratory tract symptoms (RR=2.21; 95% CI:1.67-2.93), and 17 met the definition for eye symptoms (RR=4.86; 95% CI:2.39-9.85). Actors in this production also had a prevalence of frequent sputum production almost five-times that of controls (RR=4.88; 95% CI:2.32-10.24).

Phantom of the Opera

PHANTOM OF THE OPERA actors were more likely than controls to report runny nose (RR=2.00; 95% CI:1.24-3.23), stuffy nose (RR=2.31; 95% CI:1.53-3.48), sneezing (RR=2.10; 95% CI:1.22-3.62), coughing (RR 2.17; 95% CI:1.21-3.88), shortness of breath (RR=3.00; 95% CI:1.23-7.30), dry eyes (RR=2.50; 95% CI:1.45-4.32), sore/itchy/watery eyes (RR=4.20; 95% CI:2.09-8.44), burning eyes (RR=2.45; 95% CI:1.13-5.34), and hoarseness (RR=2.00; 95% CI:1.17-3.42).

Seven of the 30 actors from *PHANTOM OF THE OPERA* met the case definition for lower respiratory tract symptoms compared to controls: (RR=3.5; 95% CI:1.28-9.60), 20 met the definition for upper respiratory tract symptom (RR=1.67; 95% CI:1.17-2.38), and 14 met the definition for eye symptoms (RR=4.72; 95% CI:2.25-9.67).

Miss Saigon

MISS SAIGON cast members were more likely than controls to report headaches (RR=2.50; 95% CI:1.48-4.23), stuffy nose (RR=2.40; 95% CI:1.63-3.55), sneezing (RR=2.00; 95% CI:1.18-3.40), coughing (RR=2.50; 95% CI:1.48-4.23), shortness of breath (RR=4.06; 95% CI:1.84-8.96), chest tightness (RR=5.50; 95% CI:2.06-14.71), dry eyes (RR=3.06; 95% CI:1.87-4.98), sore/itchy/watery eyes (RR=3.75; 95% CI:1.86-7.56), burning eyes (RR=2.73; 95% CI:1.33-5.61), sore throat (RR=2.60 95% CI:1.74-

3.91), hoarseness (RR=2.74 95% CI:1.75-4.28) dry throat (RR=2.33; 95% CI:1.66-3.28).

Eight of the 36 actors from *MISS SAIGON* met the case definition for lower respiratory tract symptoms compared to controls: (RR=3.33; 95% CI:1.24-8.93), 29 met the definition for upper respiratory tract symptoms (RR=1.67; 95% CI:1.17-2.38), and 17 met the definition for eye symptoms (RR=4.72; 95% CI:2.32-9.60).

DISCUSSION

Based on the results of this evaluation, actors performing in the Broadway productions which used either a glycol-based or mineral oil-based theatrical smoke were more likely to report work-related mucous membrane irritation, upper respiratory symptoms, and lower respiratory symptoms. With the exception of theatrical smoke, no significant differences in the production environment were identified by the NIOSH investigators.

According to information provided by the manufacturers of the glycol-based smoke systems encountered during this evaluation, the three glycol solutions were normally heated to different temperatures in their respective smoke generating machines (290^{o}, 315^{o}, and 370^{o}C). Aldehydes were detected in the headspace analysis of the one bulk sample which was heated to 370^{o}C ($\approx$700^{o}F). Although the analysis is only qualitative, the presence of these aldehydes as decomposition products in the bulk sample heated to 370^{o}C (and not in the glycol bulk samples heated to lower temperatures) may be significant in assessing the irritant potential of theatrical smoke. As a group, the aldehydes are well known skin, eye, and upper respiratory irritants.

Although theatrical smoke was visibly evident during all of the dress rehearsals and live performances, PBZ and GA air samples collected on actors, stage managers, and stage crew had very low concentrations of smoke constituents when compared to applicable OSHA, ACGIH, or NIOSH exposure limits. For example, acrolein and acetaldehyde, suspected by investigators to be possible decomposition products from the heating of the glycol-based fog fluids, were **not** found on any of the PBZ or GA air samples collected during this survey. Results from all of the **PBZ air samples** collected for formaldehyde were **not detectable**. The results from three **GA air samples** collected for formaldehyde during a performance of *MISS SAIGON* ranged from 0.02 to 0.05 ppm. These formaldehyde levels, which were similar to ambient formaldehyde concentrations measured outside several of the theaters where the "smoke productions" were held, are too low to cause irritation in most people.

*NIOSH Sampling and Analytical Method No. 5500 was developed for ethylene glycol alone. NIOSH investigators have recently determined that this method may **have deficiencies** when used to identify and quantitate other similar glycols as were encountered in this evaluation (such as propylene, butylene, diethylene, and triethylene glycols). In at least one instance ethylene glycol was incorrectly identified in an air sample. Since it is possible that interferences from other glycol analytes may have occurred, only **qualitative** glycol sampling data will be discussed in the final report. The sections of this revised interim report affected by these analytical problems have been highlighted. A thorough discussion of the analytical problems encountered while using NIOSH Sampling and Analytical Method 5500 for these glycols will be contained in the final report.*

As shown in Table 3, only 21 out of the 120 PBZ and GA air samples collected for glycols (ethylene, propylene, 1-3 butylene, diethylene, and triethylene) during this investigation had detectable amounts of these substances. Excluding the results from two GA air samples for glycols collected adjacent to smoke machines used during the *LES MISERABLES* dress rehearsal, all of the remaining **glycol concentrations were very low**, ranging from not detectable to 2.1 mg/m^3.

Two of the GA air samples collected during *LES MISERABLES* were obtained at floor level directly next to the smoke machines (stage right and stage left). Levels of ethylene glycol in these samples ranged up to 21 mg/m^3, TWA over the sampling period (approximately three hours). While these results were the highest measured during all of the productions, the samplers were positioned near each smoke machine outlet and, thus, were not representative of an actor's personal exposure. Nevertheless, all of the glycol concentrations were well below the short-term (15 minutes) OSHA PEL and ACGIH TLV of 127 mg/m^3 for ethylene glycol. There are no OSHA, NIOSH, or ACGIH exposure criteria for the other glycols.

CONCLUSIONS

The evaluation request was submitted because of the performers' concern about the acute and possible chronic effects of exposure to theatrical smoke. The results from the questionnaire show that the actors in productions that utilize theatrical smoke report significantly more mucous membrane irritative symptoms than do the performers in the "non-smoke" productions. The results also show a higher prevalence of cough, shortness of breath, wheezing, and chest tightness among the actors in the "smoke productions."

Although some of the constituents of theatrical smoke (primarily the glycols) have irritative and mucous membrane drying properties, the reason for the high symptom prevalence in the productions that use theatrical smoke is not clear, since the TWA concentrations of the glycols measured during the performances are quite low. It is possible however, that the smoke concentrations could be sufficiently high during the short periods of time that the smoke is generated to contribute to the symptoms reported by the actors. One NIOSH investigator experienced throat irritation when encountering the theatrical smoke while performing the survey.

*NIOSH Sampling and Analytical Method No. 5500 was developed for ethylene glycol alone. NIOSH investigators have recently determined that this method may **have deficiencies** when used to identify and quantitate other similar glycols as were encountered in this evaluation (such as propylene, butylene, diethylene, and triethylene glycols). In at least one instance ethylene glycol was incorrectly identified in an air sample. Since it is possible that interferences from other glycol analytes may have occurred, only **qualitative** glycol sampling data will be discussed in the final report. The sections of this revised interim report affected by these analytical problems have been highlighted. A thorough discussion of the analytical problems encountered while using NIOSH Sampling and Analytical Method 5500 for these glycols will be contained in the final report.*

The air sampling data suggest that short-term "peak" exposures to glycol or mineral oil aerosols occur throughout a performance, coinciding with the periods during which the smoke is used during that play. If these peak exposures are sufficiently high to produce the work-related irritation reported by some of the actors, it would be reasonable to modify the factors which may influence an actor's exposure to the smoke. For example, relocating the smoke machine(s) to avoid exposing actors to the direct, concentrated release of the glycol (or mineral oil) aerosols may be advantageous in reducing complaints. Additionally, reducing the amount of theatrical smoke to the minimum necessary would also be advisable.

RECOMMENDATIONS

The air sampling data collected during this survey suggest that short-term "peak" exposures to theatrical smoke probably occur throughout any performance, coinciding with the smoke cues for that particular production. These peak exposures may be sufficiently high to help cause the work-related irritation reported by some of the actors. Smoke machines should be located to minimize actors' exposure to the concentrated aerosol as it first exits the machine. The quantity and frequency of use of the various fogs during a performance should be minimized.

FUTURE ACTIONS

1. While some mucous membrane irritative symptoms (eyes, nose, throat) might be expected, the high prevalence of work-related lower respiratory symptoms (cough, wheeze, chest tightness, and shortness of breath) reported by the smoke-exposed actors was surprising. It is possible that the questionnaire was too

sensitive in its design and caused an over-reporting of symptoms by the respondents or the constituents of theatrical smoke may be more irritative at low concentrations than previously documented. It is also possible that there may be other factors involved. Since the etiology of the respiratory symptoms is unclear at this time, a return visit is planned to gather further information regarding the nature of these symptoms.

2. Development of a new NIOSH Sampling and Analytical Method for propylene, ethylene, diethylene, triethylene, tetraethylene, and 1,3 butylene glycols has been requested from the NIOSH Division of Physical Sciences and Engineering. Although not planned at this time, additional PBZ and/or GA air samples for these glycols may be collected as part of a follow-up evaluation.

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For the purpose of informing affected employees, copies of this report shall be posted by the employer in a prominent place accessible to the employees for a period of 30 calendar days.

APPENDIX A
TABLE 1
COMPOSITION OF SMOKE SYSTEMS
Actors' Equity Association/The League of American Theatres and Producers, Inc.
HETA 90-355

PRODUCTION	SMOKE SYSTEM	COMPOSITION	TEMPERATURE	SAMPLING PROTOCOL
Miss Saigon	NuHaze® Aqua Fog® Aqua Haze®	Mineral Oil Glycol Mixture	Mineral oil unheated Glycols heated to 555^{o}	Aliphatic Hydrocarbons ($C_{21}H_{44}$)
Les Miserables	Rosco®	Glycol Mixture	600^{o}F	Formaldehyde Acetaldehyde Acrolein Glycols
Grand Hotel	Fog Power®	Glycol Mixture	700^{o}F	Formaldehyde Acetaldehyde Acrolein Glycols
Phantom of the Opera	Aqua Fog® Aqua Haze® Rosco®	Glycol Mixture	555^{o}F 600^{o}F	Formaldehyde Acetaldehyde Acrolein Glycols

Comments:

1. Heating temperatures are approximate and are based on information obtained from the manufacturers.
2. The aldehydes included in the sampling protocol were suspected of being likely decomposition by-products after heating the glycol solutions.

APPENDIX A
TABLE 2
SAMPLING AND ANALYTICAL METHODS
Actors' Equity Association and The League of American Theatres and Producers, Inc.
HETA 90-355

METHOD	COLLECTION DEVICE	SAMPLING FLOW RATE	ANALYTICAL METHOD	COMMENTS
NIOSH Method 5500 (Glycols)	13 mm glass fiber filter followed by silica gel tube (100/50 mg)	200 cc/min	GC, FID	Glass fibers transferred to glass vials containing 1 ml of 2:98 2-propanol and water directly after sampling. **Due to potential interferences from other glycol analytes, the results obtained from this method SHOULD NOT be considered quantitative.**
NIOSH Method 5026 (Mineral Oil)	37 mm PVC filter	2.0 lpm	Infrared Spectrophotometry	Bulk sample required for analysis.
NIOSH Method 2501 (Acrolein)	ORBO 23 adsorbent tubes	100 cc/min	GC, Nitrogen Specific Detector	Personal breathing-zone and general area air samples.
NIOSH Method 2539 (Aldehydes	ORBO 23 adsorbent tubes	100 cc/min	GC, FID and GC/MS	Personal breathing-zone and general area air samples.
NIOSH Method 2541 (Formaldehyde)	ORBO 23 adsorbent tubes	100 cc/min	GC, FID	Personal breathing-zone and general area air samples.
NIOSH Method 3500 (Formaldehyde)	Midget impingers filled with 20 ml of 1% sodium bisulfite solution	1.0 lpm	Visible absorption spectrometry	General area air samples

ABBREVIATIONS:
GC - Gas chromatography
FID - Flame Ionization Detector
lpm - liters of air per minute
MS - Mass Spectrometry
cc/min - cubic centimeters of air per minute
mm - millimeters

ml - milliliters mg - milligrams

SOURCE FOR ANALYTICAL METHODS:

Eller PM, ed. [1989]. NIOSH manual of analytical methods. 3rd rev. ed. Cincinnati, Ohio: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control, National Institute for Occupational Safety and Health, DHHS (NIOSH) Publication No. 84-100.

APPENDIX A

TABLE 3

GLYCOLS: PHYSICAL FORM, USES AND TOXICITY INFORMATION

Actors' Equity Association/The League of American Theatres and Producers, Inc.

HETA 90-355

Substance[1]	Physical Form	Uses	Toxicology[2]	Exposure Criteria
Ethylene Glycol	Liquid is clear, colorless, thick and practically odorless. Sweet taste.	One of the highest volume chemicals produced in the U.S. Used in antifreeze and coolants, cosmetics, wood stains, pen inks, general solvent, brake fluids.	Not considered carcinogenic or mutagenic. Not readily absorbed through the skin. Not a significant skin irritant. Principal hazard to health is associated with ingestion of large quantities in single doses. Animal data suggest eye exposure to liquid or vapors may cause minor and transient discomfort. Studies with human volunteers exposed to average concentration of 30 mg/m^3 complained of throat irritation, mild headache, and low backache. Animal studies (mice) have shown developmental disorders (decreased litter size, reduced number of viable litter) with this compound.[20,21]	OSHA PEL: 127 mg/m^3 TWA ACGIH TLV: 127 mg/m^3 NIOSH REL: None, but NIOSH asserts that health effects can be observed at the OSHA limit of 127 mg/m^3.
Propylene Glycol	Liquid is clear, colorless, thick, and practically odorless and tasteless.	Preservative (retards mold and fungi); cleansing creams; sun tan lotions; conditioners; brake fluid	Systemic toxicity is especially low and health hazards from this material seem negligible. Has been approved for use in certain pharmaceutical products by FDA since 1942. Also used in some foods and cosmetics. Produces no significant eye or skin injuries. Has not been demonstrated to have carcinogenic, mutagenic, or teratogenic properties in animal studies.	OSHA PEL: NONE ACGIH TLV: NONE NIOSH REL: NONE
1,3 Butylene Glycol	Liquid is thick and nearly colorless.	Used in food additives and flavorings. The substance is also used in production of polyesters, polyurethanes, and as a solvent.	The 1,3 isomer of butylene glycol is especially low in toxicity and is used in certain cosmetic and pharmaceutical applications. Has not been demonstrated to have carcinogenic, mutagenic, or teratogenic effects in animal studies. Not irritating to the skin. In studies involving human exposures, 1-3 butylene glycol has been shown to be capable of causing severe stinging of the eyes.	OSHA PEL: NONE ACGIH TLV: NONE NIOSH REL: NONE
Triethylene Glycol	Liquid is colorless and practically odorless.	Used as a solvent in vinyl, polyester, and resins; in printing inks; and for dehydrating natural gas.	Acute and chronic oral toxicity is very low. Has not been shown to be a significant skin or eye irritant. Unlikely that significant quantities of this compound could be absorbed through the skin.	OSHA PEL: NONE ACGIH TLV: NONE NIOSH REL: NONE
Diethylene Glycol	Liquid is syrupy, colorless and nearly odorless. Sweet taste.	Used as a textile softener; solvent for dyes, oils, adhesives; cosmetics, and in antifreeze solutions.	Minor to insignificant skin or eye irritant. Although animal data suggest little hazard from short-term inhalation, exposures to vapor, fog or mist should be minimized, especially in chronic (i.e. long-term) exposure situations. Animal studies (mice) indicate that this substance is a reproductive toxicant affecting fertility and reproductive performance (when given at high doses).[20,21]	OSHA PEL: NONE ACGIH TLV: NONE NIOSH REL: NONE

Comments:

1. Laboratory identification of some of the higher molecular weight glycols (tetraethylene, pentaethylene, hexaethylene, etc.) in one of the bulk samples was not possible. These compounds are not discussed in this table.

2. Except as otherwise noted, the information presented in this table was obtained from the following sources: Patty's Industrial Hygiene and Toxicology; Proctor, Hughes and Fischman Chemical Hazards of the Work Place; and the American Conference of Governmental Industrial Hygienists' Documentation of the Threshold Limit Values and Biological Exposure Indices.

APPENDIX A
TABLE 4
RESULTS FROM PERSONAL BREATHING-ZONE AND GENERAL AREA AIR SAMPLES FOR GLYCOLS
Actors' Equity Association and The League of American Theatres and Producers, Inc.
HETA 90-355

Production	Sample No.	Actor's Name	Character's Name	Volume (liters)	Ethylene Glycol	Propylene Glycol	1,3 Butylene Glycol	Diethylene Glycol	Triethylene Glycol
Phantom of the Opera Sampling Date: 6/18/91	SG-2	Suzanne Ishee	"Christine" Double	29	~~1.5~~	~~0.25~~	~~ND~~	~~ND~~	~~ND~~
	SG-7	Patrice Pickering	"Madame Giry"	29	~~0.45~~	~~0.38~~	~~ND~~	~~ND~~	~~ND~~
	SG-8	Walter Murphy	Automation Operator	29	~~0.33~~	~~0.27~~	~~ND~~	~~ND~~	~~ND~~
	SG-9	Mary Stahl	Ensemble	29	~~0.41~~	~~0.33~~	~~ND~~	~~ND~~	~~ND~~
	SG-11	Kenneth Walter	Ensemble	29	~~0.41~~	~~0.42~~	~~ND~~	~~ND~~	~~ND~~
	SG-13	James Romick	"Raoul"	29	~~0.83~~	~~0.48~~	~~ND~~	~~0.48~~	~~ND~~
	SG-15	Lee Iwanski	Stage Crew, Fly Men	29	~~0.67~~	~~ND~~	~~ND~~	~~ND~~	~~ND~~
Grand Hotel Sampling Date: 6/20/91	SG-32	Pascale Faye-Williams	"Countess"	25	~~0.49~~	~~ND~~	~~ND~~	~~ND~~	~~ND~~
	SG-34	Area Sample: Front pillar, Stage Right		25	~~0.49~~	~~ND~~	~~0.65~~	~~ND~~	~~ND~~

Les Miserables Sampling Date: 7/2/91 (cont.)	SG-37	Area Sample: Adjacent to Smoke Machine, Stage Left		38	~~20.8~~	~~11.4~~	~~ND~~	~~ND~~	~~ND~~
	SG-38	Area Sample: Adjacent to Smoke Machine, Stage Right		38	~~2.1~~	~~2.8~~	~~2.6~~	~~ND~~	~~14.3~~
	SG-40	Lisa Grant	Ensemble	38	~~0.66~~	~~0.97~~	~~0.94~~	~~4.6~~	~~ND~~
	SG-41	Sam Fontana	"Montparnasse"	38	~~ND~~	~~0.82~~	~~0.79~~	~~ND~~	~~ND~~
	SG-42	Natalie Toro	"Eponine"	38	~~0.32~~	~~0.12~~	~~ND~~	~~ND~~	~~ND~~
	SG-43	H. Blanchen	Asst. Stage Manager	38	~~0.42~~	~~ND~~	~~ND~~	~~ND~~	~~ND~~
	SG-44	J. Mark McVey	"Jean Valjean"	38	~~0.50~~	~~ND~~	~~ND~~	~~ND~~	~~ND~~
	SG-45	J.C. Sheets	"Brujon"	38	~~0.24~~	~~ND~~	~~ND~~	~~ND~~	~~ND~~
	SG-47	Larry Alexander	"Babet"	38	~~0.32~~	~~ND~~	~~ND~~	~~ND~~	~~ND~~

TABLE 4, continued
RESULTS FROM PERSONAL BREATHING-ZONE AND GENERAL AREA AIR SAMPLES FOR GLYCOLS
Actors' Equity Association and The League of American Theatres and Producers, Inc.
HETA 90-355

Production	Sample No.	Actor's Name	Character's Name	Volume (liters)	Ethylene Glycol	Propylene Glycol	1,3 Butylene Glycol	Diethylene Glycol	Triethylene Glycol
Miss Saigon 7/2/91	SG-54	Area Sample: Actor's break area, basement, near soft drink machine		38	~~0.92~~	~~0.50~~	~~0.61~~	~~3.4~~	~~ND~~
	SG-55	Area Sample: Base of "Ho Chi Min" Statue, on stage		38	~~0.34~~	~~ND~~	~~ND~~	~~ND~~	~~ND~~
	SG-58	Area Sample: Helicopter track, Stage left.		38	~~2.1~~	~~ND~~	~~ND~~	~~ND~~	~~ND~~

Evaluation Criteria: (all expressed in milligrams of contaminant per cubic meter of air)					
OSHA PEL (Short-term ceiling limit)	127	None	None	None	None
ACGIH TLV (Short-term ceiling limit)	127	None	None	None	None
NIOSH REL	a	None	None	None	None

Comments and Footnotes:

~~All air concentrations are expressed in milligrams of material per cubic meter of air (mg/m^3).~~ All of the concentrations shown above were calculated as the time-weighted average over the period sampled. The sampling period was the duration of the play.

a There is no NIOSH REL for ethylene glycol. However, because of the potential teratogenicity and the known respiratory irritation at the level adopted for the OSHA PEL, NIOSH suggests that OSHA reconsider their current PEL for ethylene glycol.

APPENDIX A
TABLE 5
GENERAL AREA AIR SAMPLE RESULTS FOR FORMALDEHYDE[A]
Actors' Equity Association/The League of American Theatres and Producers, Inc.

Production	Sample Number	Area Sample Location	Sample Volume (liters)	Sample Time (military)	Concentration, ppm
Phantom of the Opera	21	Inside "magic" mirror during the dressing room scene. Short-term area air sample	13	1440 to 1453	(0.05)
	22	Outside of the Majestic Theatre	158	1425 to 1703	(0.01)
	23	Orchestra pit, during the dress rehearsal	156	1434 to 1710	(0.01)
Grand Hotel	28	Behind backdrop. Short-term sample collected during "train station" scene with the countess	27	1645 to 1712	(0.03)
	29	On front pillar, stage right	123	1530 to 1733	0.02
	30	Orchestra Level, Stage left[b]	122	1530 to 1732	0.02
	31	Orchestra Level, Stage right[b]	140	1530 to 1750	0.02
Les Miserables	32	Adjacent to smoke generating machine, stage left	215	1400 to 1735	(0.01)
	33	Adjacent to smoke generating machine, stage right	214	1400 to 1734	0.01
	34	Orchestra pit, during dress rehearsal	215	1400 to 1735	0.01

Evaluation Criteria	OSHA Permissible Exposure Limit ACGIH Threshold Limit Value NIOSH Recommended Exposure Limit	1.0 TWA/2.0 STEL 1.0 TWA/2.0 STEL c

Comments and Abbreviations:

a General area air samples for formaldehyde collected following NIOSH Sampling and Analytical Method 3500 (impingers filled with 1% sodium bisulfite solution). This method offers the best sensitivity for formaldehyde.
b Orchestra level located above the stage in *GRAND HOTEL*. In all the other productions the orchestra was located in front of and below the stage level.
c NIOSH considers formaldehyde a suspect human carcinogen and recommends that exposures be kept as low as feasible.
TWA = time weighted average
STEL = short-term exposure limit (15 minutes)

APPENDIX A
TABLE 6
PERSONAL BREATHING-ZONE AND GENERAL AREA AIR SAMPLE RESULTS FOR OIL MIST

Production	Sample No.	Actor's Name	Character's Name	Sample Volume (Liters)	Concentration (mg/m^3)[a]
Miss Saigon	3565	JoAnn Hunter	Opening and Ensemble	310	0.48
	3551	Billy Porter	Chorus	310	0.52
	3556	Annette Calud	"Kim"	62	ND
	3560	Sean McDermott	"Chris"	310	0.39
	3559	Zar Acayan	"Thuy"	310	0.42
	3557	Jason Ma	Ensemble	310	0.39
	3553	Jade Stice	Ensemble	310	0.55
	3562	Area sample: Automation Booth, Above Stage		310	0.94
	3321	Area sample: Dressing Room, Beneath Stage		330	0.24[b]
	3552	Leonard Joseph	"John"	310	0.55
	3546	Tom O'Leary	Ensemble	310	0.29[b]
	3330	Bruce Winant	Chorus	310	0.48
	3558	Stage Crew	Engineer	324	0.15
	3564	Area sample: Helicopter Track, stage right, rear pillar		310	1.35
	3566	Matthew Pedersen	Chorus	310	0.13
	3555	Annette Calud	"Kim"	190	0.37[b]

EVALUATION CRITERIA: OIL MIST

OSHA Permissible Exposure Limit: 5 mg/m^3

NIOSH Recommended Exposure Limit: 5 mg/m^3 (10 hour time-weighted average exposure limit)
10 mg/m^3 (15 minute short-term exposure limit

ACGIH Threshold Limit Value: 5 mg/m^3

COMMENTS AND ABBREVIATIONS:

a All oil mist concentrations are time-weighted averages over the time period sampled and are expressed in milligrams of oil mist per cubic meter of air.

b These concentrations fell between the limit of detection and limit of quantitation for this sample set. This means that oil mist was detectable but could not be reliably measured because of the small amount present.

APPENDIX A
TABLE 7
ACTOR PARTICIPATION BY SHOW
Actors' Equity Association/The League of American Theatres and Producers, Inc.
HETA 90-355

Production	Number of Participants	Percentage of Total	Grouping
Grand Hotel	33	6%	Smoke Exposed Productions
Les Miserables	35	21%	
Phantom of the Opera	30	13%	
Miss Saigon	36	16%	
SUB-TOTAL (exposed)	134		
Getting Married	13	6%	Control Productions
Gypsy	33	15%	
Lost In Yonkers	11	5%	
Once On This Island	12	5%	
Six Degrees of Separation	21	9%	
SUB-TOTAL (controls)	90		
Totals	224	100%	

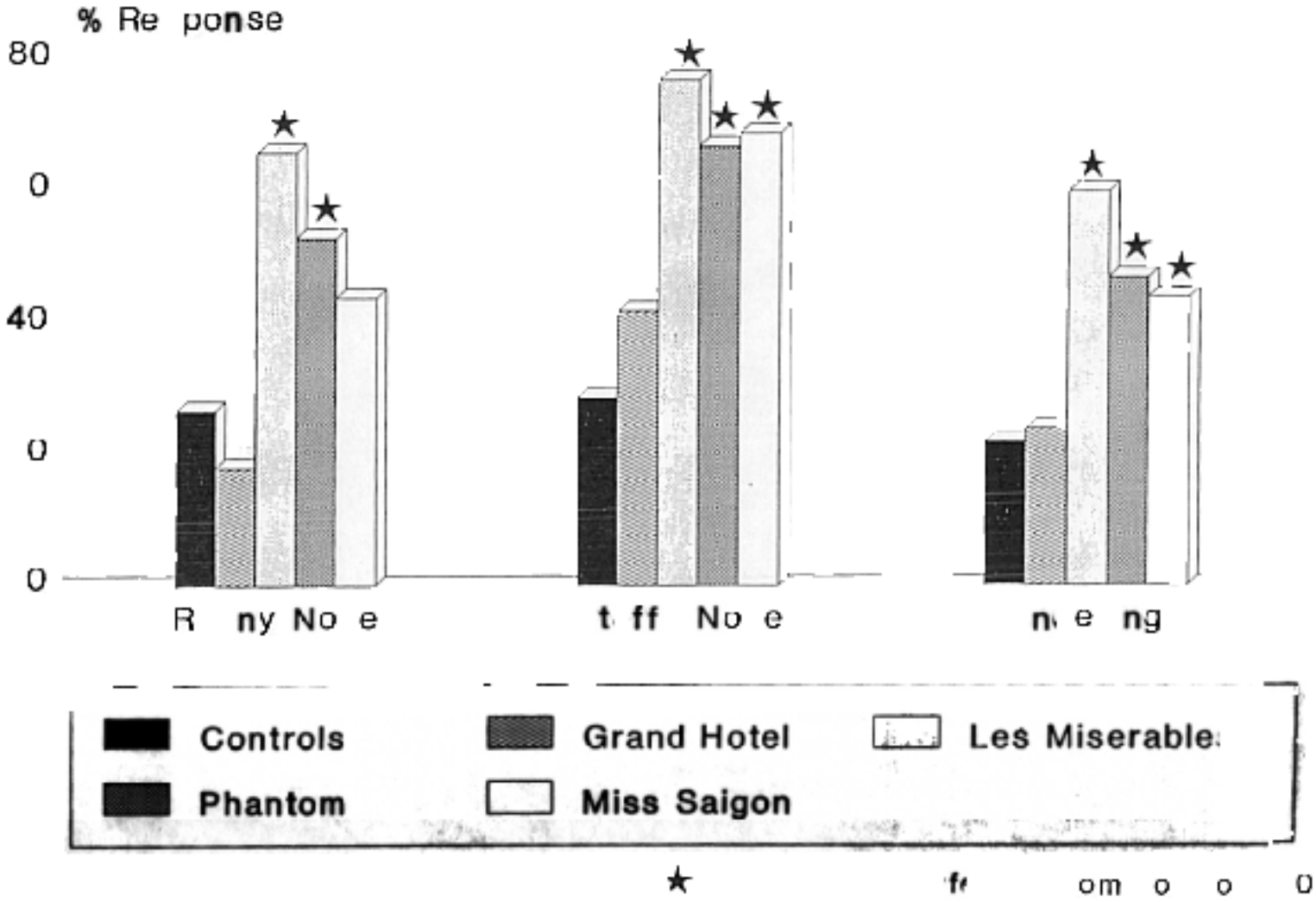
APPENDIX A
TABLE 8
COMPARABILITY OF EXPOSED VS. CONTROL GROUPS
Actors' Equity Association/The League of American Theatres and Producers, Inc.

	Comparison of Questionnaire Participants	
	Smoke Exposed Actors	**Controls**
Age	33 (range 9-69)	35 (range 11-74)
Sex	Male 83 (62%) Female 50 (37%) 1 did not answer	Male 49 (54%) Female 36 (40%) 5 did not answer
Years as an Actor	13 (range .25-38)	15 (range .41-45)
Total Participants	134	90

APPENDIX A

Figure 1

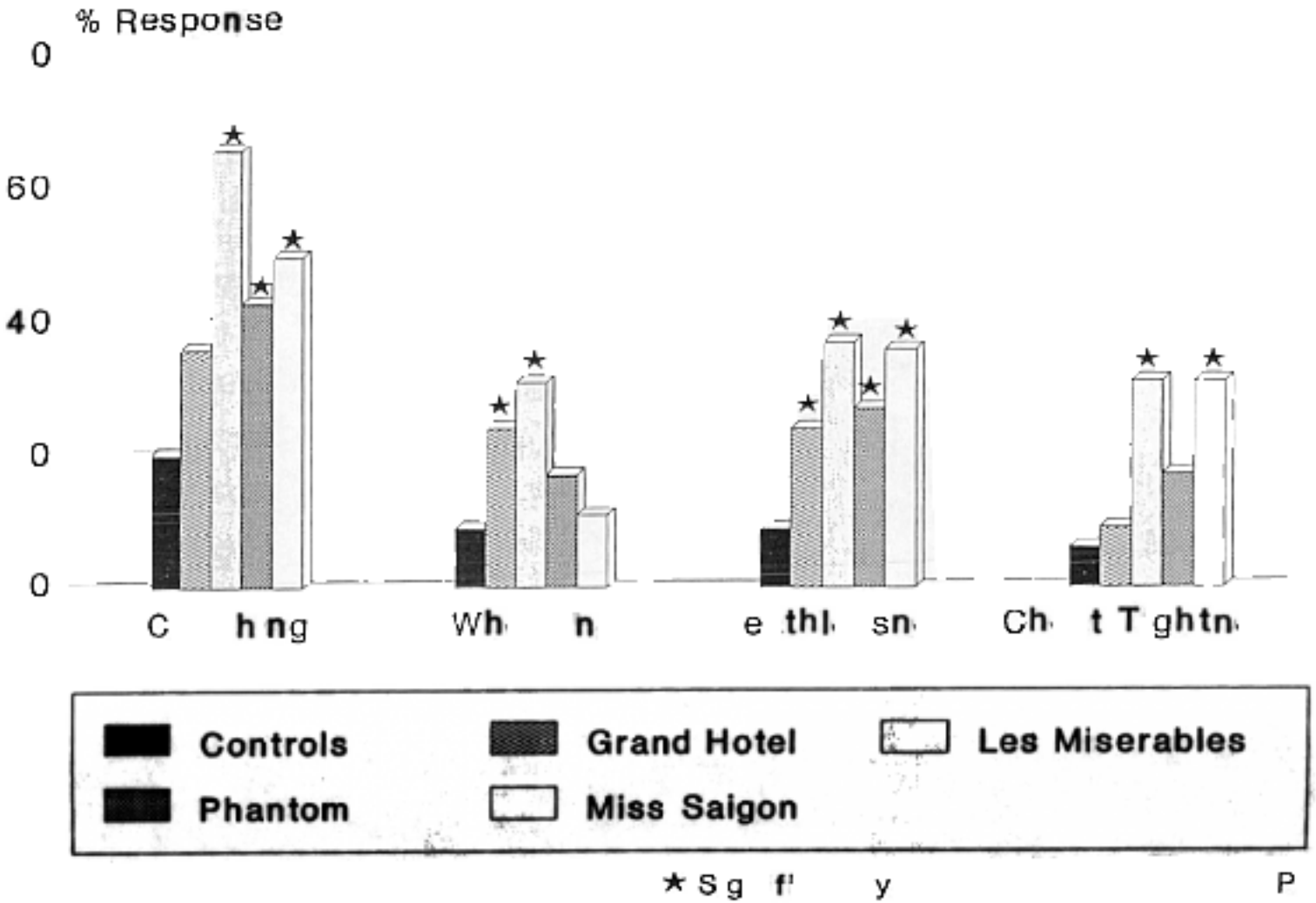
Compar' on of Symptom By Produc ion



APPENDIX A

Figure 1 continued

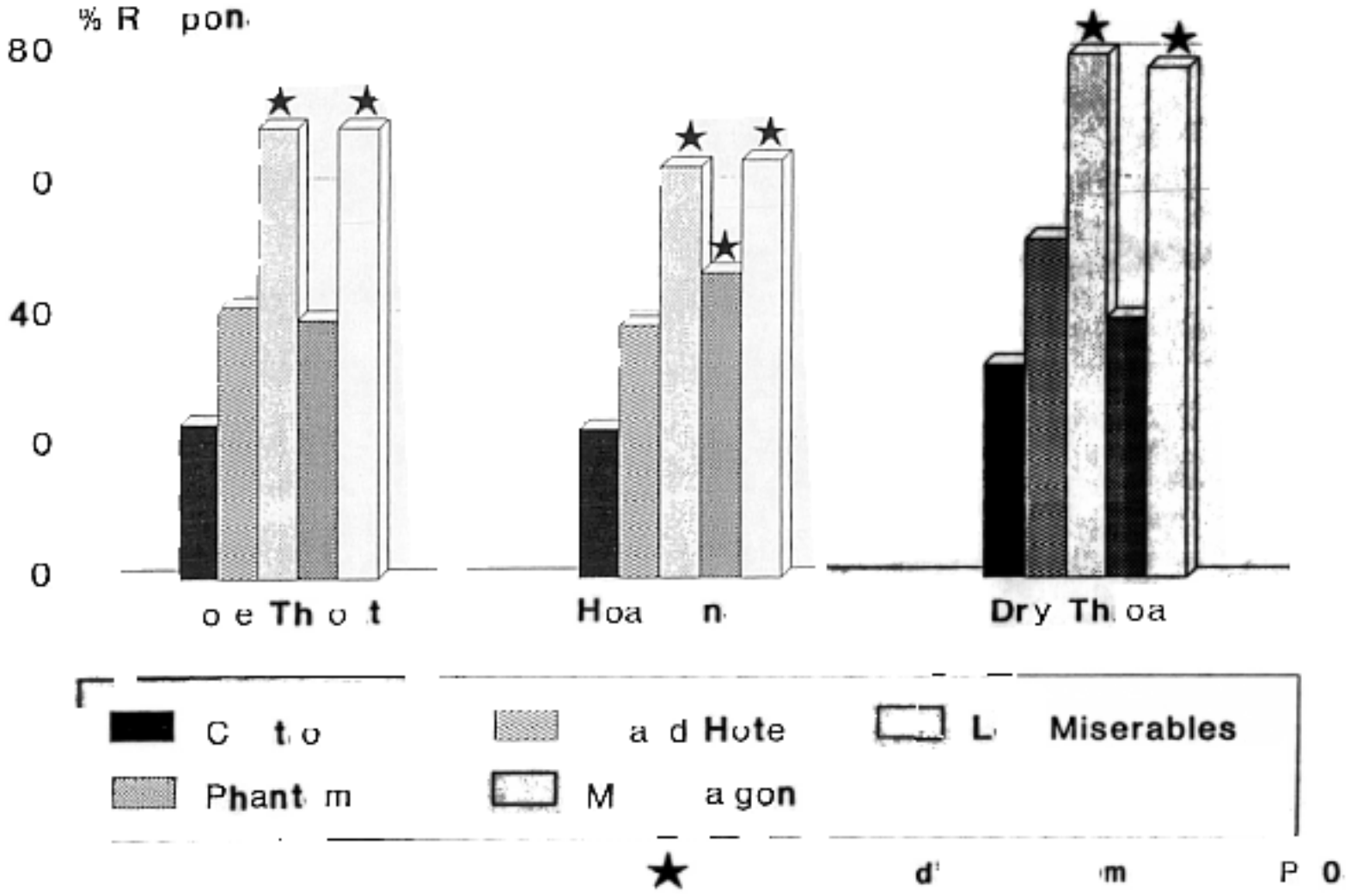
Comparison Of Symptom By Production



APPEND X A

F gure 1 cont nued

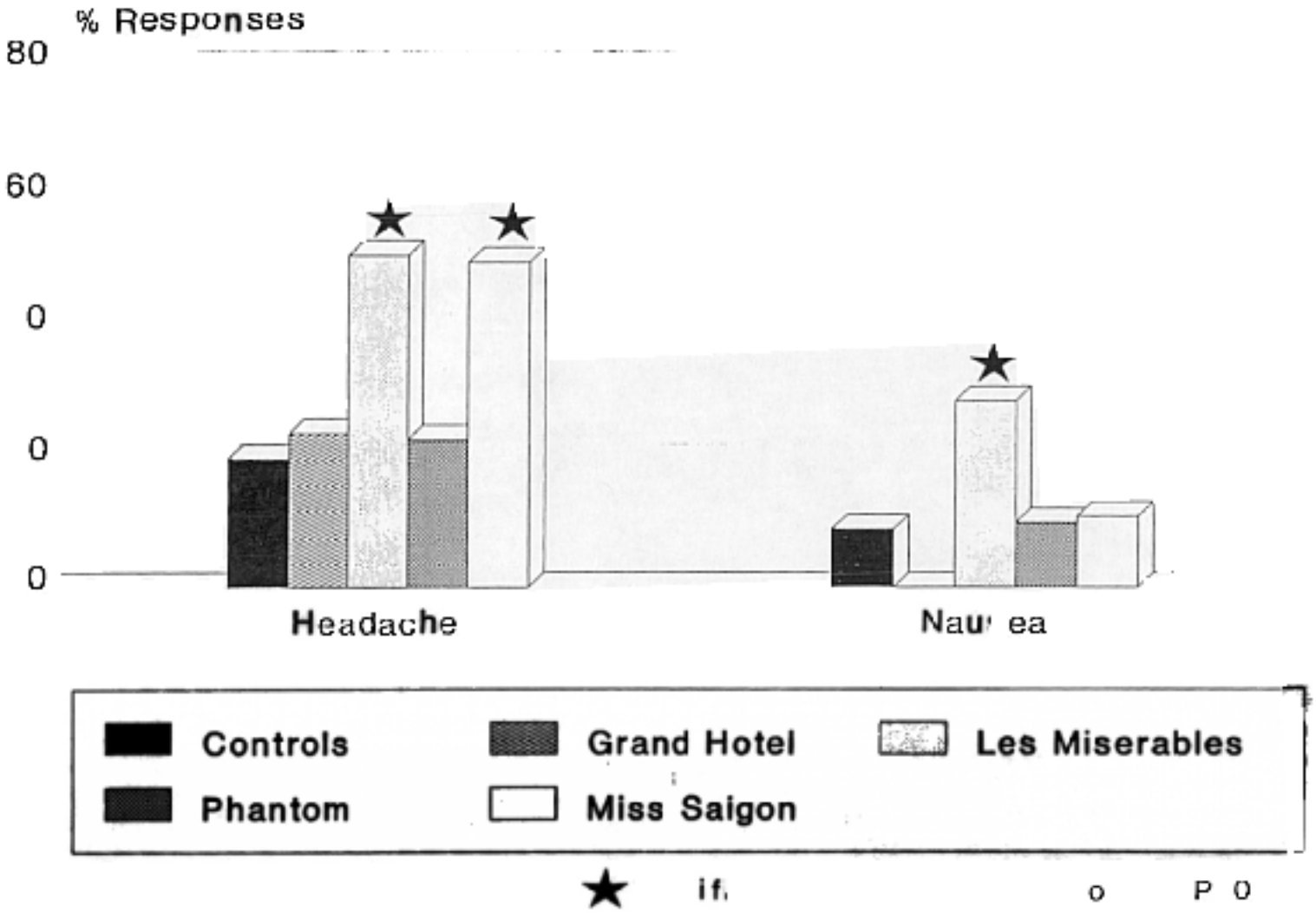
Comparison Of Symp oms By Produc ion



APPENDIX A

Figure 1 continued

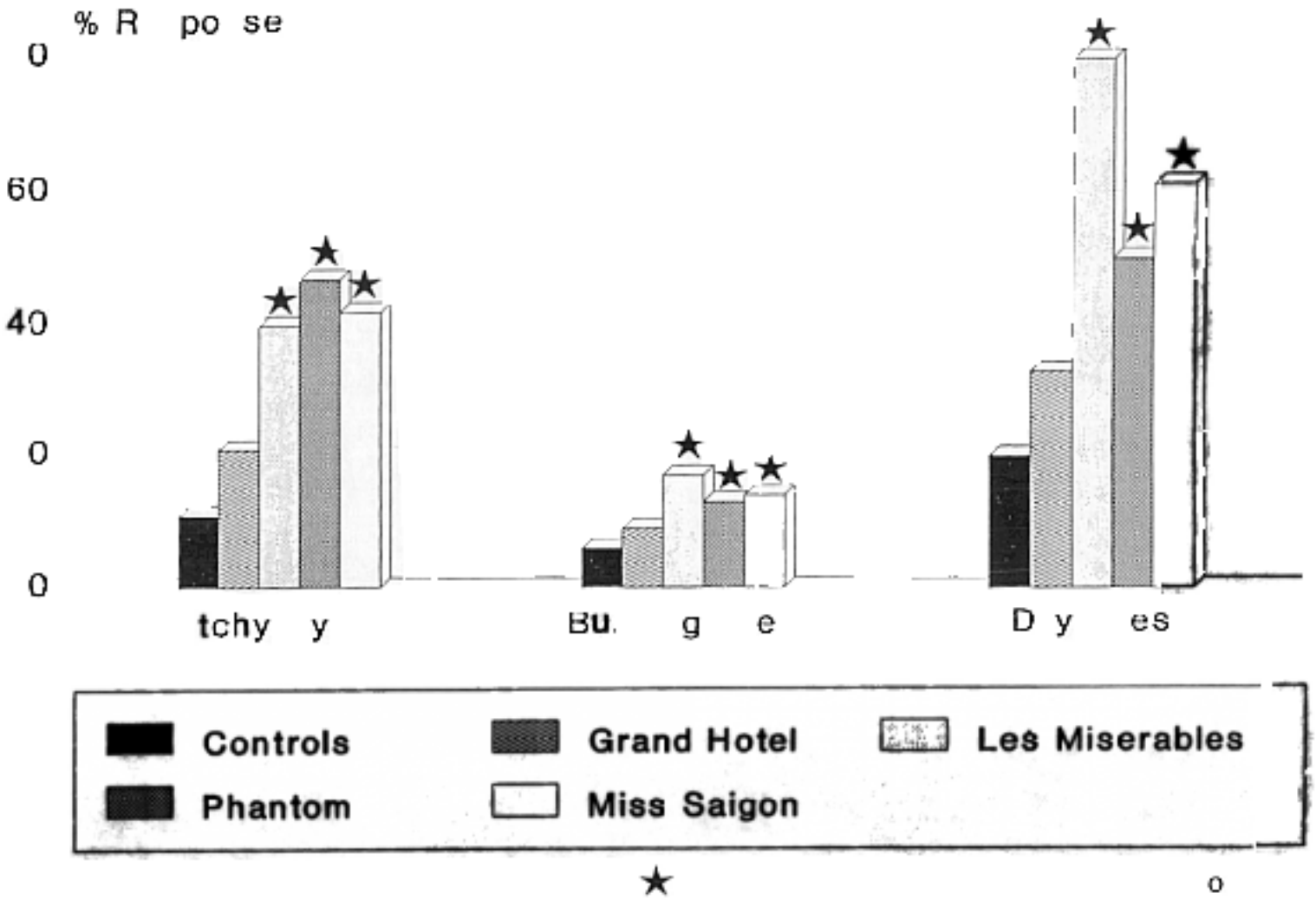
Comparison Of Symptoms By Production



APPENDIX A

Figure 1 continued

Comparison Of Symptom By Production



APPENDIX B

APPENDIX B
Screening Questionnaire
Used In 1991 Survey
HETA 90-355

Please fill in or check the appropriate box.

Male [1]

1. Age [ ][ ] (1-4) 2. Gender Female [2] (11)

3. How long have you appeared in this production? [ ][ ][ ] (months) (14-16)

4. How long have you been a professional actor ? [ ] (years) [ ] (months) (17-18)

5. Please approximate the percent of time you are on stage during your performance

30 min. or less	[1]
30 min-1 hr.	[2]
1 to 1.5 hrs	[3]
1.5 to 2 hrs	[4]
2 hrs +	[5]

(19)

6. Do you smoke cigarettes? (do not count smoking in a performance)

Yes	[1]
No	[0]

(20)

If yes: 6a. How many cigarettes per day do you smoke? [ ][ ] Cigarettes per day (21-22)

6b. What is the total number of years you have smoked? [ ][ ] Years smoked! (23-24)

7. Does the role you play require you to smoke during a performance

Yes	[1]
No	[0]

(25)

8. Have you had a cold in the last week?

Yes	[1]
No	[0]

(26)

9. Have you been affected by allergies in the last week?

Yes	[1]
No	[0]

(27)

11a. If yes: What are you allergic to?

_____

10. Do you have any of the following respiratory conditions?

	Yes	No	
Chronic Bronchitis			(28)
Asthma			(29)
Recurrent Infections			(30)

11. Do you usually cough up phlegm from your chest?

Yes	[1]
No	[0]

(31)

11a. If yes: Do you usually cough up phlegm like this as much as twice a day, four or more days out of the week?

Yes	[1]
No	[0]

(32)

12. Are you currently taking any medications?

Yes	[1]
No	[0]

(33)

12a. If yes please specify: _____

_____

[ ] (34)

Please continue on other side.....

Answer the first question for each symptom. If the response is 'never', then go down the list to the next symptom.

Symptoms	Indicate how often in the last week you have experienced this symptoms during a performance. Never	Rarely	Sometimes	Often	Always	Severity of Symptom mild....moderate...severe					Does the symptom usually change when not at work? Gets Worse	Stays Same	Gets Better	
13. Headache	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	
14. Nausea	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	
15. Runny Nose	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	
16. Stuffy Nose/Congestion	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	
17. Sneezing	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	
18. Cough	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	
19. Wheezing or Whistling	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	
20. Shortness of Breath	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	
21. Chest Tightness	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	
22. Dry, Itching, or Tearing Eyes	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	
23. Sore/Strained Eyes	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	
24. Blurry/Double Vision	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	
25. Burning Eyes	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	
26. Problems with Contact Lenses	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	
27. Sore Throat	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	
28. Hoarseness	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	
29. Dry Throat	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	

APPENDIX C

APPENDIX C
Screening Questionnaire
Used in 1993 Survey
HETA 90-355

Last name: __/__/__/__/__/__/__/__/__/__/__/__/__/__	First name: __/__/__/__/__/__/__/__/__/__/__/__/__/__

Home phone number: (__/__/__) __/__/__/ -__/__/__/__	Work phone number: (__/__/__) __/__/__/ -__/__/__/__

Birth date: ___/___/___ Sex: 1. M G 2. F G

Which production do you appear in? _____

How many days out of the last month have you worked in a production which uses theatrical "smoke"? ___

APPENDIX C
Screening Questionnaire
Used in 1993 Survey
HETA 90-355

Indicate how often in the LAST MONTH you have experienced each of the following symptoms.

Check only ONE column for each symptom.

SYMPTOMS	Not in last month	Rarely	Some-times	Often	Always
chest pain					
difficulty breathing					
bringing up phlegm upon awakening					
awakening from sleep short of breath					
chest tightness					
wheezing or whistling in chest					
awakening from sleep with an attack of wheezing					
shortness of breath					

Have you had BRONCHITIS or other RESPIRATORY TRACT INFECTION in the last month?

1. Yes G 2. No G

If yes, please specify_____

Have you been diagnosed by a doctor as having a medical condition (e.g., a heart condition) which would account for these symptoms?

1. Yes G 2. No G

If yes, please specify _____

APPENDIX D

APPENDIX D
Study Participant
Questionnaire Used in
1993 Survey
HETA 90-355

ID#_____ {1-4}

HETA 90-355
IDENTIFYING INFORMATION

Last name: {5-17} __/__/__/__/__/__/__/__/__/__/__/__	First name: {18-30} __/__/__/__/__/__/__/__/__/__/__/__

CARD 01 {79-80}

Street address: {5-30} __/__/__/__/__/__/__/__/__/__/__/__ __/__/__/__/__/__/__/__/__/__/__/__	City/Town: {31-43} __/__/__/__/__/__/__/__/__/__/__/__
State: {44-45} __/__	Zip Code: {46-50} __/__/__/__/__
Home phone number: {51-60} (__/__/__) __/__/__/ -__/__/__/__	Work phone number: {61-70} (__/__/__) __/__/__/ -__/__/__/__

Age: ___ (years) {71-72} Sex: 1. M G 2. F G {73} CARD 02 {79-80}

COUGH

1. Do you usually **cough** first thing in the **morning**?
   1. Yes G 2. No G {5}

   Count a cough with the first cigarette or on first going out of doors.
   Exclude clearing the throat or a single cough.
   "Usually" means 4 or more days per week.

2. Do you usually **cough** during the **day**?
   1. Yes G 2. No G {6}

   Ignore an occasional cough.
   "Usually" means 4 or more days per week.

   (If "NO" to BOTH questions #1 and #2, go to the "PHLEGM" section below.)
   (If "YES" to either #1 or #2 answer questions in the box below and continue.)

2a. Do you cough like this on most days for as much as three months during the year?
   1. Yes G 2. No G {7}

2b. If yes, how many years have you coughed like this? _____# years. {8-9}

PHLEGM

3. Do you usually bring up any **phlegm** from your chest on **getting up**, or **first thing in the morning**?
   1. Yes G 2. No G {10}

   Count phlegm with first cigarette or on first going out of doors.
   Exclude phlegm from the nose.
   Count swallowed phlegm.
   "Usually" means 4 or more days per week.

4. Do you usually bring up **phlegm** from your chest **during the day**?
   1. Yes G 2. No G {11}

   "Usually" means 4 or more days per week.
   Answer "YES" if it occurs twice or more.

   (If "NO" to BOTH questions #3 and #4, go to question #5.)
   (If "YES" to either #3 or #4, answer questions in the box below and continue.)

4a. Do you bring up phlegm like this on most days for as much as three months during the year?
1. Yes G 2. No G {12}

4b. If yes, how many years have you brought up phlegm like this? _____# years {13-14}

RESPIRATORY

5. Are you troubled by **shortness of breath** when hurrying on level ground or walking up a slight hill?
1. Yes G 2. No G {15}

(If "YES" to #5, answer questions in the box below. If "NO," go to question #6.)

5a. Do you get short of breath walking with other people of your own age on level ground?
1. Yes G 2. No G {16}

5b. Do you have to stop for breath when walking at a normal pace at level ground?
1. Yes G 2. No G {17}

6. Does your chest ever **feel tight** or your **breathing become difficult**?
1. Yes G 2. No G {18}

(If "YES" to #6, continue with questions 6a-10. If "NO," skip to question #11)

6a. What time of day? (choose one)
G 1. No set pattern
G 2. Before entering the work site?
G 3. After entering the work site?
G 4. Shortly after leaving the work site (1-3 hours)?
G 5. Some hours after leaving the work site (3-8 hours)? {19}

7. Are/were the attacks of **chest tightness** accompanied by either **fever** or **shivering**?
1. Yes G 2. No G {20}

8. Are/were the attacks accompanied by **headache**?
1. Yes G 2. No G {21}

9. Are/were the attacks accompanied by **muscle ache**?

1. Yes G 2. No G {22}

10. Does your chest tightness or your breathing difficulty occur on any particular day of the week?
1. Yes G 2. No G {23}

(If "YES" to #10, answer questions in the box below. If "NO," go to question #11)

10a. Which day? (choose one)
1. G Monday
2. G Tuesday
3. G Wednesday
4. G Thursday
5. G Friday
6. G Saturday
7. G Sunday {24}

10b. Is the day you checked the first day of your work week?
1. Yes G 2. No G {25}

11. Do you ever have **wheezing** or **whistling noises** in your chest?
1. Yes G 2. No G {26}

(If "YES" to # 11, answer question in box below. If "NO," go to question #12)

11a. Does this happen as often as once per week?
1. Yes G 2. No G {27}

12. Have you ever had attacks of **shortness of breath** with wheezing?
1. Yes G 2. No G {28}

(If "YES" to #12, answer questions in box below. If "NO," go to question #13)

12a. Was your breathing absolutely normal between attacks?
1. Yes G 2. No G {29}

12b. How many **attacks** like this have you had in the **past three years**? ___# attacks {30-31}

12c. How many **years** have you had attacks like this? _____# years {32-33}

13. Since childhood, have you ever had:

Hay fever	1. Yes G	2. No G	{34}
Emphysema	1. Yes G	2. No G	{35}
Tuberculosis	1. Yes G	2. No G	{36}
Bronchitis	1. Yes G	2. No G	{37}
Pneumonia	1. Yes G	2. No G	{38}

14. Have you ever had **asthma**? (check the number for the best answer)
    - G 1. No, I have never had asthma.
    - G 2. Yes, I had asthma as a child and it has continued as an adult.
    - G 3. Yes, I had asthma as a child, the symptoms went away, but started again.
    - G 4. Yes, I had asthma as a child but it went away and has not returned.
    - G 5. Yes, I have asthma as an adult but I never had it when I was a child. {39}

(If "YES" to #14, answer questions in box below. If "NO," go to question #15)

14a. If you have had asthma has it ever been **confirmed by a physician**?
1. G Yes 2. G No {40}

14b. Have you developed asthma or has your asthma gotten worse since starting work on this production?
1. G Yes 2. G No {41}

14c. Have you ever taken a **prescription medication** for asthma?
1. G Yes 2. G No {42}

SINUS/NASAL

15. Do you usually have a stuffy nose, or drainage at the back of your nose?
1. Yes G 2. No G {43}

16. During the **past 12 months**, have you had two or more episodes of blocked, itchy, or runny nose?
1. Yes G 2. No G {44}

(If "YES" to #15 or #16, answer questions on the next page. If "NO" to both #15 and #16, go to question #17)

16a. Do you usually have these nose symptoms at any **particular time of year**?
1. Yes G 2. No G {45}

If "Yes", which is the worst season? (choose one)
1. G Winter
2. G Spring
3. G Summer
4. G Fall {46}

16b. When you have nose symptoms, do you usually have fever, headache, or general body ache?
1. Yes G 2. No G {47}

16c. Were these nose symptoms mainly due to one of the following? (choose one)
1. G cold or flu
2. G hay fever
3. G other allergies
4. G something else {48}
(specify: _____) {49-51}

16d. Do the nose symptoms seem better or worse when you are away from work, such as on weekends, vacation, sick leave, or lay-off? (choose one)
1. G neither better nor worse away from work
2. G better away from work
3. G worse away from work {52}

EYES

17. During the **past 12 months**, have your eyes been red, itchy, or watery more than twice?
1. Yes G 2. No G {53}

(If "YES" to #17, answer questions #17a-17e in the box on the next page. If "NO," go to question #18)

17a. Over the past year, about how often have you noticed these eye symptoms? (choose one)
1. G less than 1-2 days altogether
2. G less than 7 days
3. G less than 30 days
4. G more than 30 days {54}

17b. Do you usually have these **eye symptoms** at any particular time of the year?
1. Yes G 2. No G {55}

If "Yes" which is the worst season? (choose one)
1. G Winter
2. G Spring
3. G Summer
4. G Fall {56}

17c. When you have **eye symptoms**, do you usually have fever, headache, or general body ache?
1. Yes G 2. No G {57}

17d. Were these **eye symptoms** mainly due to one of the following? (choose one)
1. G contact lenses
2. G cold or flu
3. G hay fever
4. G other allergies
5. G something else {58}
(specify _____) {59-61}

17e. Did/do the **eye symptoms** seem better or worse when you were away from work, such as on weekends, vacation, sick leave, or lay-off? (choose one)
1. G stayed the same
2. G got better
3. G got worse {62}

SKIN

18. During the **last 12 months** have you had a **skin rash**, **dermatitis**, **hives**, or **eczema**?
1. Yes G 2. No G {63}

(If "YES" to #18, answer questions in box below. If "NO," go to question #19)

18a. Is/was this rash related to anything you do at work?
1. G Yes 2. G No {64}

If "YES" to #18a what is this rash related to? _____) {65-67}

18b. What parts of your body were affected?

Scalp	1. G Yes 2. G No	{68}
Face	1. G Yes 2. G No	{69}
Hands or arm	1. G Yes 2. G No	{70}
Trunk	1. G Yes 2. G No	{71}
Groin or private parts	1. G Yes 2. G No	{72}
Feet or legs	1. G Yes 2. G No	{73}
Other	1. G Yes 2. G No	{74}
	(Specify: _____)	{75-77}

18c. Did/does your skin seem better or worse when you were away from work such as weekends, vacation, sick leave, or lay-off? (choose one)
1. G stayed the same
2. G got better
3. G got worse {78}

19. Have you seen a doctor for **any** problem in the **last year**? CARD 03 {79-80}
1. Yes G 2. No G {5}
If "Yes", please specify: _____. {6-8}

20. Do you presently take **any** medications, including non-prescription medicine, for **any** reason?
1. Yes G 2. No G {9}
If "Yes", please specify: _____. {10-12}

SMOKING HISTORY

21. Have you smoked, altogether, as many as 5 packs of cigarettes during your entire life?
1. Yes G 2. No G 3. Never smoked G {13}

(If "YES" to #21, answer questions in box below. If "NO," go to question #22)

21a. Over the years that you smoked, on average how many cigarettes do (did) you smoke?
G 1. less than ½ pack per day
G 2. one pack per day
G 3. 1-2 packs per day
G 4. more than two packs per day {14}

21b. How old were you when you started smoking? _____ years old {15-16}

21c. If you have stopped smoking, how old were you when you stopped?
_____ years old {17-18}

21d. During the years that you smoked, did you ever quit for a year or more?
1. Yes G 2. No G {19}
If "Yes," how long? ____# years. {20-21}

22. Does the role you play require you to smoke **during a performance**?
1. Yes G 2. No G {22}

OCCUPATIONAL HISTORY

23. How long have you been a **professional actor**? ___ (years) {23-24}

24. How long have you appeared in **this production**? ___ (years) {25-26}

25. How many **performances** of your present show do you appear in **per week**?_____ {27-28}

26. How many **minutes** per performance do you appear **on stage**?_____ {29-31}

27. How many **minutes** per performance do you appear on stage with **theatrical "smoke"** present?_____ {32-34}

28.

Indicate how often in a **typical** performance of **THIS SHOW** you perform each of the following activities.

Check only ONE column for each activity.

ACTIVITIES	Not in this show (1)	Rarely (2)	Sometimes (3)	Often (4)	Always (5)	
singing (solo)						{35}
singing (in chorus)						{36}
dancing						{37}
acrobatics/tumbling						{38}
speaking						{39}

29. Have you ever worked in **other productions** using **theatrical "smoke"**?
1. Yes G 2. No G {40}
If yes, please specify:
name of production(s)_____ {41-43}
months in show_____ {44-46}
name of production(s)_____ {47-49}
months in show_____ {50-52}
name of production(s)_____ {53-55}
months in show_____ {56-58}

30. Other than your performance in this show, are you **currently** working at **any other job**?
1. Yes G 2. No G {59}
If yes, please specify: **theatrical**_____ {60-62}
non-theatrical_____ {63-65}

31. Other than your performance in this show, have you had **other exposures** to **theatrical "smoke"** (e.g., at a nightclub, concert) in the past month?
1. Yes G 2. No G {66}
If yes, please specify _____ {67-69}

32. Using the rating scale shown below, please rate the OVERALL **physical effort** level demanded by your role(s) during a typical performance. {70-71}

Please **CIRCLE** the most appropriate **number** on the following scale.

20
19--Very, very hard
18
17--Very hard
16
15--Hard
14
13--Somewhat hard
12
11--Fairly light
10
9--Very light
8
7--Very, very light
6

CARD 04 {79-80}