Monitoring Glycol, Glycerin, and Mineral Oil

Note: This protocol is subject to revision. This version is as of Friday, 15 November 2002.

Exposure Guidelines

In the United States, the current, widely recognized exposure recommendations for fogs, smoke effects, and hazes, and other atmospheric effects using glycol, glycerin, and mineral oil are the following:

Glycol:	40 mg/m^3 peak [(1)]
Glycerin:	50 mg/m^3 peak [(3)]
	10 mg/m^3 time-weighted average for an eight-hour period [(3)]
Mineral oil:	25 mg/m^3 peak[(1)]
	5 mg/m^3 time-weighted average for an eight-hour period [(2)]

[(1)] Recommendations from Health Effects Evaluation of Theatrical Smoke, Haze, and Pyrotechnics, by researchers from the Mt. Sinai School of Medicine and ENVIRON International Corporation for the Equity-League Pension and Health Trust Funds. These guidance levels have been accepted for use in contracts between Equity and the League of American Theatres and Producers.

[(2)] OSHA regulations

[(3)] Recommendations from Theatrical Haze and Fog Testing for Mamma Mia! Winter Garden Theatre, by researchers from ENVIRON International Corporation for Mamma Mia! Broadway and Nina Lannan Associates. These guidance levels have been accepted by Equity for use on the Broadway production of Mamma Mia!

Other exposure recommendations are under development, but the ones listed above are considered the most useful in the United States today.

Measuring – the General Idea

"Fog" is the generic term for an atmospheric effect that is composed of liquid droplets suspended in the air, whether the effect looks like fog, smoke, or haze. In this document, "fog" will be used to refer to all these atmospheric effects, whatever their appearance. They are all created by putting tiny drops of liquid in the air. The sizes of the droplets, their concentrations, and their distributions are what make a particular effect look like fog, smoke, or haze.

The exposure levels for fogs made with droplets of glycol, glycerin, or mineral oil are monitored in ESTA's fog testing program by using the MIE PDR-1000AN aerosol monitor. This hand-held monitor has a digital display that shows instantaneous readings and time-weighted average readings over the time period of a sampling run. The monitor actually measures the light scattering produced by particles in the air, but it reports the results in terms of mass concentration (milligrams per cubic meter, or mg/m^3) with the assumption that the particles in the air are a fine dust. Because different types of particles have different light scattering properties, the readings from the monitor need to be adjusted (or calibrated) when measuring something other than dust (such as fog droplets). The user converts the dust readings to the correct mg/m^3 readings for the

fog droplets by multiplying the dust readings by a *calibration factor* for the particular fog fluid/fog machine combination being used for the fog, smoke, or haze effect.

In general, it's not practical to try to measure all the air everywhere on a stage, so it is recommended that any testing be focused on the air with the most fog, or more specifically, the scenes and areas on the stage where *a person could be exposed to the most fog.* If the results of those measurements give you numbers below the appropriate limits, you are set. If those measurements give you numbers above appropriate limits, the fog effect or the location of the people should be changed.

Note: Fog is by nature variable, so it's recommended that users run the tests three times and take the average reading.

Measuring – Step-by-Step

The best method for testing the levels of fog used in a production is to collect readings in a rehearsal environment during a crew call. During the rehearsal, scenes involving cue releases should be reconstructed with the same timing and movement of props, scenery, curtains, and drops as during a live performance.

1. Determine which scenes involve potential exposures by people to the densest fog or in the fog the longest periods of time. Don't forget to consider the backstage crew members as well as the cast. Note where that person is while he or she is in the fog.

   If you are testing an effect that is a burst of fog, position the monitor where the person's mouth and nose (breathing zone) will be while he or she is in the fog. The monitor can be hand-held as long as the slots under the top end-cap aren't blocked (hold it by the bottom), or it can be clipped to clothing with the belt clip and worn by a person, or it can be mounted on a standard camera tripod by means of the socket on the bottom. The socket takes a standard 1/4" bolt, so the monitor could be bolted to a wall, a set or anything else, too.

   If you are testing a haze effect, the position of the monitor is not so critical because the fog that makes a haze tends to spread throughout the performance space quickly and uniformly. Still, position the monitor where a person will be breathing the haze at its densest.

2. Set up the show conditions — the conditions that would exist when the person is in the fog during a live performance.

   Make sure that the air conditioning or heating for the theatre is on or off as they will be during the performance, and that scenery, scrims, drops, and curtains are where they will be during a performance when the person is in the fog, or are moving if that's what they do during the cue. Make sure that off-stage doors normally closed are closed, and that doors normally open are open.

3. Turn on the MIE PDR.

Press the ON/OFF button. The display will show

START ZERO: ENTER
GO TO RUN: NEXT

The monitor will be sent to you already zeroed, so press NEXT. The display will show

START RUN: ENTER
READY: NEXT

Press ENTER. The sampling is now running, and the display will show a message about logging for a few seconds and then start showing the instantaneous concentrations (CONC) on the top line and the cumulative time-weighted average concentrations (TWA) on the bottom line.

4. Run the fog cue and collect measurements.

   Run the fog cue under show conditions with the monitor positioned near where the person's breathing zone (mouth and nose) will be during the cue. Follow the blocking of the production. If the person is required to walk into the fog, out of the fog, or move through it, move the monitor to duplicate those moves. If an actor is lying on the floor during the cue, keep the monitor at floor level. While you do this, observe the monitor's readings and note the highest concentration reading (CONC) shown during the cue. Try to duplicate the person's speed and timing according to the actual blocking. Don't rush and don't linger.

   If you are only concerned about peak levels, you can stop measuring after the cue has obviously reached its maximum fog level and the CONC reading starts to decline. If you are concerned about TWA levels, keep measuring until CONC shows less than 0.01 mg/m^3 or until the person of concern is off stage and completely out of the fog. Note the final TWA reading and how long you ran the sampling.

5. Stop the sampling run.

   Push EXIT. The display will show

   TERMINATE RUN?
   Y: ENTER N: EXIT

   Push ENTER.

Remember that fog is by nature variable, so it's recommended that users run the tests three times and take the average reading. Be sure to clear the stage of residual fog, using a fan or other means, at the end of each run prior to doing additional runs.

Interpreting the measurements – Applying calibration factors

Apply the calibration factors to the concentrations you noted on the display of the MIE PDR monitor to determine the actual fog levels.

Remember that the MIE PDR measures the size and number of particles in the air by light scattering, and reports the results as mass concentrations (mg/m^3), assuming that the particles are a fine dust. The particles you have measured are fog droplets, not dust, so a calibration factor has to be applied to convert the fine dust readings to real measured concentrations of fog. The calibration factors are machine and fluid specific. Summarized below are the calibration factors available at this time and the sources of this information.

Manufacturer	Machine	Fluid	Fluid type	Calibration factor	Info. source
CITC	Fog Max	Natural Fogging Fluid	glycol	0.663	(4)
	Haze Max	Water Vapor Haze Fluid	glycerin	0.108	(4)
	Starhazer	High Performance Fluid	mineral oil	0.867	(4)
High End Systems	F-100	Atmosphere HQ Fluid	glycol	1.38	(1)
	F-100	Atmosphere Stage Formula	glycol	0.253	(1)
	F-100	Atmosphere Cold Flow Formula	glycol	2.41	(1)
Le Maitre Special Effects	G100	Regular fog fluid	glycol	4.17	(1)
	G100	Quick Dissipating	glycol	3.45	(1)
	G100	Extra Quick Dissipating	glycol	3.17	(1)
	G150	Regular fog fluid	glycol	4.17	(1)
	G150	Quick Dissipating	glycol	3.45	(1)
	G150	Extra Quick Dissipating	glycol	3.17	(1)
	G150	Molecular Fog Fluid	glycol	2.58	(1)
	G150	Pro Beam (Long Lasting)	glycol	1.42	(4)
	G300	Molecular Fog Fluid	glycol	0.533	(4)
	G300	Pro Beam (Long Lasting)	glycol	0.667	(4)
	G300	Quick Dissipating	glycol	2.65	(4)
	G300	Regular Fog Fluid	glycol	0.304	(4)
	Opti Mist Ranger	Mini Mist Canister	glycol	3.01	(1)
	Neutron XS	Neutron Haze Fluid	glycerin	0.12	(2)
	Show Fogger Pro	Pro Beam (Long Lasting)	glycol	0.436	(4)
	Show Fogger Pro	Quick Dissipating	glycol	2.56	(4)
	Show Fogger Pro	Regular Fog Fluid	glycol	0.444	(4)
	Stage Fogger Pro	Molecular Fog Fluid	glycol	2.77	(4)
	Stage Fogger Pro	Pro Beam (Long Lasting)	glycol	1.36	(4)
	Stage Fogger Pro	Quick Dissipating	glycol	1.37	(4)
	Stage Fogger Pro	Regular Fog Fluid	glycol	0.995	(4)
Look Solutions/Theatre Effects	Tiny Fogger	Tiny Fogger Fluid	glycol	0.761	(4)
	Unique Hazer	Unique Fluid	glycol	0.299	(4)
	Viper II (NT)	Viper Fluid	glycol	1.46	(4)
Martin Professional	Jem Glaciator	Jem B2 Heavy Fog Fluid	glycol	3.41	(4)
	Jem ZR12-DMX	Jem Pro-Smoke Super Fluid	glycol	1.12	(4)
MDG Fog Generators	Mini-Max	MDG Dense Fluid	glycol	3.21	(1)
	MAX 300 Atmosphere	MDG Neutral Fluid	mineral oil	0.784	(1)
Reel EFX, Inc.	DF-50	Diffusion Fluid	mineral oil	0.784	(1)
Rosco Laboratories	1600	Rosco Fog Fluid	glycol	1.27	(1)
	1600	Rosco Stage & Studio Fluid	glycol	1.56	(1)
	1600	Rosco Light Fog Fluid	glycol	1.375	(1)
	1600	Rosco Clear Fog Fluid	glycol	1.82	(1)
	PF-1000	Rosco Fog Fluid	glycol	1.27	(1)
	PF-1000	Rosco Stage & Studio Fluid	glycol	1.56	(1)
	PF-1000	Rosco Light Fog Fluid	glycol	1.375	(1)
	PF-1000	Rosco Clear Fog Fluid	glycol	1.82	(1)

Manufacturer	Machine	Fluid	Fluid type	Calibration factor	Info. source
Rosco Laboratories (continued)	Alpha 900	Rosco Fog Fluid	glycol	1.27	(1)
	Alpha 900	Rosco Stage & Studio Fluid	glycol	1.56	(1)
	Alpha 900	Rosco Light Fog Fluid	glycol	1.375	(1)
	Alpha 900	Rosco Clear Fog Fluid	glycol	1.82	(1)
	Delta 3000	Rosco Fog Fluid	glycol	1.00	(4)
	Delta 3000	Rosco Stage & Studio Fluid	glycol	1.97	(4)
	Delta 3000	Rosco Light Fog Fluid	glycol	1.35	(4)
	Delta 3000	Rosco Clear Fog Fluid	glycol	1.43	(4)
SFX	Fog Master FM-1	Aquafog Fluid	glycol	0.19	(3)
Smoke Factory	Tour Hazer	Tour Hazer Fog Fluid	glycol	0.299	(4)

(1) Equipment-Based Guidelines for the Use of Theatrical Smoke and Haze, by researchers from ENVIRON International Corporation for the Equity-League Pension and Health Trust Funds, 2001.

(2) Theatrical Haze and Fog Testing for Mamma Mia! Winter Garden Theatre, by researchers from ENVIRON International Corporation for Mamma Mia! Broadway and Nina Lannan Associates, 2001.

(3) Theatrical Smoke and Haze Testing for The Phantom of the Opera, Majestic Theatre, by researchers from ENVIRON International Corporation for Alan Wasser Associates, 2002

(4) Development of Calibration Factors for Monitoring Theatrical Smoke and Haze, by researchers from ENVIRON International Corporation for the Entertainment Services and Technology Association, 2002.

The formula for applying the calibration factors is:

> PDR reading (CONC or TWA) X calibration factor = actual air concentration (CONC or TWA)

For example, let's say your production uses a Rosco 1600 machine with Rosco Stage & Studio Fluid, and your highest reading on the monitor during a cue release was 20 mg/m^3. Applying the appropriate calibration factor for this machine/fluid combination of 1.56, the actual glycol smoke concentration is 20 mg/m^3 x 1.56 or 31 mg/m^3, which is below the peak guidance level of 40 mg/m^3 for glycols.

The above formula works for both peak levels and TWA levels over the sampling time, but the TWA levels need an additional calculation to compare them to the TWA recommendations that are set based on an 8-hour period.

Interpreting the measurements – Converting to 8-hour TWAs

If you took TWA measurements and the person is in the fog only once during the day (i.e., one performance during the day), the following formula will convert the measurement you took to an equivalent 8-hour TWA level:

$$E_{8\text{-hour}} = (C \times T)/8$$

Where:

E is the equivalent 8-hour exposure
C is the TWA level during the measured period of time T
T is the measured period of time in hours

If the person is in the fog several times during the day (i.e., multiple performances during the day), you need to compute the cumulative exposure with the following formula:

$$E_{8\text{-hour}} = (C_a T_a + C_b T_b + \ldots C_n T_n)/8$$

Where:

E is the equivalent 8-hour exposure
C is the TWA level during the measured period of time T
T is the measured period of time in hours

Interpreting the measurements – Judging peak levels

If you are concerned about peak exposure levels, the concentrations you calculated by multiplying the highest monitor reading by the calibration factor is the peak level. Fog is by nature variable, so it's recommended that users run the tests three times and take the average reading.

$$(CONC_1 + CONC_2 + CONC_3)/3 = CONC_{average}$$

If the average is below the peak guidance level for the particular type of fog, no changes are needed. If the average level is above the peak guidance level, either the blocking should be changed so the person is moved to a location where the fog is less dense and below the peak guidance level, or the fog cue should be modified so that the fog is less dense and below the peak guidance level where the person is located. Careful siting of the fog equipment and the use of hoses, ducts, or fans can put the fog in front of or around a person, and leave the person in a relatively fog-free area. Careful use of lighting can make a small amount of fog look denser than a lot of fog with poor lighting.

Interpreting the measurements – Judging TWA levels

Because fog is by nature variable, it would be good to run the tests three times, calculate the 8-hour TWAs from them, and then calculate the average TWA.

$$(TWA_{1(8\text{-hour})} + TWA_{2(8\text{-hour})} + TWA_{3(8\text{-hour})})/3 = TWA_{average\ (8\text{-hour})}$$

If the average TWA is below the allowable TWA level for the particular type of fog, no changes are needed. If the average level is above the allowable TWA level, either the blocking should be changed so the person does not spend as much time during a performance in fog, or the fog cues

should be modified so that the fog is less dense where people are located. Careful use of lighting can make a small amount of fog look denser than a lot of fog with poor lighting.

Questions?

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