Monitoring Glycol, Glycerin, and Mineral Oil

This document offers two sets of instructions for monitoring the concentrations of glycol, glycerin, and mineral oil in theatrical fogs. One set, the first, is labeled "A Simple Protocol," and the procedure described is sufficient for ensuring that recognized ceiling limits and maximum time-weighted averages are not exceeded. Following it you will obtain the data you need to see if your fog effects are within recognized limits and for reporting this information to concerned performers, technicians, or audience members by means of posters or notices placed backstage or in the lobby. However, if you are producing a show under a contract with Actors' Equity Association in the United States, that contract may impose additional requirements to demonstrate to Actors' Equity that fog monitoring has been carried out properly. As this is being written, those requirements may include setting the aerosol monitor's calibration factor for the machine/fluid combination being used, logging the test data, transferring the logged data from the aerosol monitor to a computer, printing the logged data, and attaching the printed data to the smoke/haze report that is sent to the Equity Business Representative. The second set of procedures, "Monitoring with Logging," will help you find the sections of the aerosol monitor's Operator Manual that will guide you in setting the calibration factor, downloading the data to a computer, and so on.

If you are working under a contract—an Actors' Equity Association contract or any other—that has requirements for fog exposure control, read the contract and any documents it references to find out what the specific requirements are for your situation. While PLASA's *A Test Is Worth A Thousand Words* fog testing program is designed to ensure that recognized exposure limits are not exceeded and to reassure any concerned parties that they are not, it may not meet the requirements written into a labor contract, tech rider, stage manager's "Theatrical Smoke and Haze Report," or other document that applies to your specific production or situation.

A Simple Protocol

Exposure Guidelines

In the United States, the current, widely recognized exposure limits 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)(4)]
	10 mg/m^3 time-weighted average for an eight-hour period [(4)]
Glycerin:	50 mg/m^3 peak [(3)(4)]
	10 mg/m^3 time-weighted average for an eight-hour period [(3)(4)]
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 29 CFR 1910.1000

(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!

(4) ANSI E1.5-2009, Entertainment Technology - Theatrical Fog Made With Aqueous Solutions of Di-and Trihydric Alcohols

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 PLASA's fog testing program by using the MIE pDR-1000AN aerosol monitor. (MIE has been bought by the Thermo Electron Corporation, so new monitors available for sale are called the Thermo pDR-1000AN. It's functionally the same monitor; only the label has changed.) 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 standardized form of 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 standard 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, good. If those measurements give you numbers above the limits, the fog effect or the location of the people should be changed and the test re-run to confirm that the exposure is now below the limits.

Note: Fog is by nature variable, so it's recommended that you run the tests three times and take the average reading. Also, run the test over the full duration of the time the person will be exposed to the fog, at least until it is absolutely obvious that the fog is dissipating and no more fog is being added to the scene. Do not end the test in the middle of the scene because "Aw, it looks okay."

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 or cloud 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 U.S.-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 pDR-1000AN.

   Press the **ON/OFF** button. The display will show
   START ZERO: ENTER
   GO TO RUN: NEXT
   If you have received the pDR-1000AN from PLASA, it will have been sent to you already zeroed, so press **NEXT**. If you own your own monitor, have received it from another source, or feel that you must re-zero the monitor from PLASA, consult section 6.5.1 on page 14 of the monitor's Operator Manual for information on how to zero the monitor. Zeroing is good for about a week if you keep the monitor out of dusty environments. If dust collects in the monitor after it is zeroed, the dust will cause false high readings. You will actually have less fog on stage than the monitor shows.

   After pressing **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 in the person's breathing zone 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 and passed its maximum fog level, fog production has stopped, and the CONC reading is declining. 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 you 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 pDR-1000AN monitor to determine the actual fog levels.

Remember that the pDR-1000AN 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 standardized 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.

Machine	Fluid	Fluid type	Calibration factor	Info. source
Barco / High End Systems F-100	Atmosphere HQ Fluid	glycol	1.21	(10)
	Atmosphere Stage Formula	glycol	0.253	(1)
	Atmosphere Cold Flow Formula	glycol	2.41	(1)
Barco / High End Systems FQ-100	Atmosphere HQ Fluid	glycol	0.25	(1)
	Atmosphere Stage Formula	glycol	0.96	(26)
CITC Fantasy FX spray can	Fantasy FX Professional Haze	oil	0.867	(20)
CITC Fog Max	Natural Fogging Fluid	glycol	0.663	(4)

Machine	Fluid	Fluid type	Calibration factor	Info. source
CITC Haze Max	Water Vapor Haze Fluid	glycerin	0.108	(4)
CITC Starhazer	High Performance Fluid	mineral oil	0.867	(4)
Hazebase Base Hazer Pro	Base Hazer Liquid	glycol	0.43	(35)
Le Maitre G100	Regular Fog Fluid	glycol	4.17	(1)
	Directors Choice	glycol	4.17	(1,9)
	Quick Dissipating	glycol	3.45	(1)
	Extra Quick Dissipating	glycol	3.17	(1)
Le Maitre G150	Regular Fog Fluid	glycol	4.17	(1)
	Directors Choice	glycol	4.17	(1,9)
	Quick Dissipating	glycol	3.45	(1)
	Extra Quick Dissipating	glycol	3.17	(1)
	Molecular Fog Fluid	glycol	2.58	(1)
	Pro Beam (Long Lasting)	glycol	1.42	(4)
Le Maitre G300	Molecular Fog Fluid	glycol	0.533	(4)
	Pro Beam (Long Lasting)	glycol	0.667	(4)
	Quick Dissipating	glycol	2.65	(4)
	Directors Choice	glycol	0.304	(4,9)
	Regular Fog Fluid	glycol	0.304	(4)
	Regular Haze Fluid	glycerin	0.09	(10)
	Regular Haze (C-Beam Fluid)	glycerol	0.09	(10, 24, 25)
	Standard Smoke Fluid	glycol	0.30	(4, 9, 24, 25)
Le Maitre G300 with LSG / Freezefog Pro or equivalent chiller	Molecular Fog Fluid	glycol	4.95*	(7, 25, 28))
Le Maitre G-Force	Molecular Fog Fluid	glycol	0.53	(4, 24, 28)
	Quick Dissipating	glycol	2.65	(4, 24, 28)
	Standard Smoke Fluid	glycol	0.30	(4, 9, 24, 25)
Le Maitre LSG-MKII with Power Fog Industrial 9D Low Smoke Generator (LSG MKII-PFi9D)	Molecular Fog Fluid	glycol	0.75	(14)
Le Maitre Mini Mist	Regular Fog Fluid	glycol	2.24	(10)
	Standard Smoke Fluid	glycol	2.24	(10, 25)
Le Maitre Neutron XS	Neutron Haze Fluid	glycerin	0.12	(2)
Le Maitre Opti Mist Ranger	Mini Mist Canister	glycol	3.01	(1, 25)
Le Maitre Power Fog Industrial 9D (PFi9D) with LSG-MKII or equivalent chiller	Molecular Fog Fluid	glycol	0.75	(14)
Le Maitre Power Fog Industrial (PFI) or PFI 9D	Molecular Fog Fluid	glycol	2.77	(4,11)
	Pro Beam (Long Lasting)	glycol	1.36	(4,11)
	Quick Dissipating	glycol	1.37	(4,11)
	Regular Fog Fluid	glycol	0.995	(4,11)
	Directors Choice	glycol	0.995	(4,9,11)
Le Maitre Radiance Hazer	Neutron Haze Fluid	glycerin	0.26	(13)
Le Maitre Show Fogger Pro	Pro Beam (Long Lasting)	glycol	0.436	(4)
	Quick Dissipating	glycol	2.56	(4)
	Regular Fog Fluid	glycol	0.444	(4)
	Directors Choice	glycol	0.444	(4,9)
Le Maitre Stage Fogger Pro	Molecular Fog Fluid	glycol	2.77	(4)
	Pro Beam (Long Lasting)	glycol	1.36	(4)
	Quick Dissipating	glycol	1.37	(4)
	Regular Fog Fluid	glycol	0.995	(4)

Machine	Fluid	Fluid type	Calibration factor	Info. source
	Directors Choice	glycol	0.995	(4,9)
Le Maitre Stage Fogger DMX	Molecular Fog Fluid	glycol	2.77	(4)
	Pro Beam (Long Lasting)	glycol	1.36	(4)
	Quick Dissipating	glycol	1.37	(4)
	Regular Fog Fluid	glycol	0.995	(4)
	Directors Choice	glycol	0.995	(4,9)
Look Solutions Cryo-Fog	Cryo-Fog Fluid	glycol	0.91	(16, 21)
Look Solutions Low-Fogger	Low-Fogger Fluid	glycol	0.91	(17)
Look Solutions Orka	Regular Fog Fluid	glycol	0.23	(8)
Look Solutions Power Tiny	Power Tiny Fluid	glycol	0.49	(18)
Look Solutions Tiny Company / Tiny C07	Tiny Fluid	glycol	0.76	(4, 21)
Look Solutions Tiny Fogger / Tiny F07	Tiny Fogger Fluid	glycol	0.761	(4, 21)
Look Solutions Tiny FX	Tiny Fluid	glycol	0.71	(31)
Look Solutions Tiny S	Tiny Fluid	glycol	0.69	(31)
Look Solutions Unique/Unique2 Hazer	Unique Fluid	glycol	0.299	(4,12)
Look Solutions Viper II (NT)	Regular Fog Fluid	glycol	1.46	(4,12)
	Quick-Fog Fluid	glycol	2.02	(17)
	Slow-Fog Fluid	glycol	0.90	(31)
Look Solutions Viper NT	Quick Fog Fluid	glycol	2.02	(19)
Look Solutions Viper II / LSG MKII or equivalent chiller	Quick-Fog Fluid	glycol	0.89	(32)
Martin Professional Jem Glaciator	Jem B2 Heavy Fog Fluid	glycol	3.41	(4)
Martin Professional Jem Glaciator X-Stream	Jem C3 Heavy Fog Fluid	glycol	3.23	(23)
Martin Professional Jem Roadie	Jem Pro-Smoke Super ZR Fluid	glycol	0.62	(27)
Martin Professional Jem ZR12-DMX	Jem Pro-Smoke Super Fluid	glycol	1.12	(4)
Martin Professional Jem ZR24/7 Hazer	Jem Pro-Haze Fluid	glycol	0.76	(5)
Martin Professional Jem ZR33 Hi-Mass	Jem Pro-Smoke Super Fluid	glycol	0.79	(23)
	Jem ProSteam Simulation Fluid	glycol	2.31	(23)
Martin Professional Magnum 2500Hz	Jem Pro-Haze Fluid	glycol	0.28	(23)
MDG Mini-Max	MDG Dense Fluid	glycol	3.21	(1)
MDG Atmosphere APS	MDG Neutral Fluid	mineral oil	0.784	(1)
MDG MAX 3000 APS	MDG Neutral Fluid	mineral oil	0.784	(1)
MDG MAX 3000 APS through an accumulator box	MDG Neutral Fluid	mineral oil	0.27	(6)
Reel EFX DF-50	Diffusion Fluid	mineral oil	0.784	(1)
Rosco 1500 / 1600	Rosco Fog Fluid	glycol	1.27	(1)
	Rosco Stage & Studio Fluid	glycol	1.56	(1)
	Rosco Light Fog Fluid	glycol	1.375	(1)
	Rosco Clear Fog Fluid	glycol	1.82	(1)
Rosco 1750	Rosco Fog Fluid	glycol	0.58	(16)
	Rosco Stage & Studio Fluid	glycol	0.67	(16)
Rosco Alpha 900	Rosco Fog Fluid	glycol	1.27	(1)
	Rosco Stage & Studio Fluid	glycol	1.56	(1)
	Rosco Light Fog Fluid	glycol	1.375	(1)
	Rosco Clear Fog Fluid	glycol	1.82	(1)
Rosco Delta 3000	Rosco Fog Fluid	glycol	1.00	(4)
	Rosco Stage & Studio Fluid	glycol	1.97	(4)
	Rosco Light Fog Fluid	glycol	1.35	(4)
	Rosco Clear Fog Fluid	glycol	1.43	(4)
Rosco Delta Hazer	Delta Hazer Fluid	glycol	0.71	(15)

Machine	Fluid	Fluid type	Calibration factor	Info. source
Rosco Mini-V	Rosco Fog Fluid	glycol	0.55	(34)
	Rosco Stage & Studio Fluid	glycol	0.85	(34)
Rosco PF-1000	Rosco Fog Fluid	glycol	1.27	(1)
	Rosco Stage & Studio Fluid	glycol	1.56	(1)
	Rosco Light Fog Fluid	glycol	1.375	(1)
	Rosco Clear Fog Fluid	glycol	1.82	(1)
Vapour	Rosco Fog Fluid	glycol	0.44	(34)
	Rosco Stage & Studio Fluid	glycol	0.85	(34)
Vapour Plus	Rosco Fog Fluid	glycol	0.82	(34)
	Rosco Stage & Studio Fluid	glycol	0.78	(34)
SFX Fog Master FM-1	Aquafog Fluid	glycol	0.19	(3)
Smoke Factory Tour Hazer	Tour Hazer Fog Fluid	glycol	0.299	(4)
Ultratec Special Effects G100	Directors Choice	glycol	4.17	(1, 9, 25)
	Extra Quick Dissipating	glycol	3.17	(1, 25)
	Quick Dissipating	glycol	3.45	(1, 25)
Ultratec Special Effects G150	Directors Choice	glycol	4.17	(1, 9, 25)
	Extra Quick Dissipating	glycol	3.17	(1, 25)
	Quick Dissipating	glycol	3.45	(1, 25)
	Molecular Fog Fluid	glycol	2.58	(1, 25)
	Pro Beam (Long Lasting)	glycol	1.42	(4, 25)
Ultratec Special Effects G3000	Directors Choice	glycol	0.30	(4, 9, 24, 25)
	Regular Haze Fluid	glycol	0.09	(10, 24, 25)
	Quick Dissipating	glycol	2.65	(4, 24, 25)
	Molecular Fog Fluid	glycol	0.53	(4, 24, 25)
	Pro Beam (Long Lasting)	glycol	0.67	(4, 24, 25)
Ultratec G3000/LSG or equivalent chiller	Molecular Fog Fluid	glycol	4.95*	(7, 25)
Ultratec Power Fog Idustrial (PFI) or PFI 9D	Directors Choice	glycol	0.99	(4, 9, 11, 25)
	Molecular Fog Fluid	glycol	2.77	(4, 11, 25)
	Pro Beam (Long Lasting)	glycol	1.36	(4, 11, 25)
	Quick Dissipating	glycol	1.37	(4, 11, 25)
Ultratec Power Fog Industrial 9D (PFI 9D) with LSG-MKII or equivalent chiller	Extra Quick Dissipating	glycol	1.23	(22, 25)
	Molecular Fog Fluid	glycol	0.75	(13, 25)
	Quicck Dissipating	glycol	0.21	(22, 25)
Ultratec Radiance Hazer	Neutron / Luminous 7 Haze Fluid	glycerol	0.26	(14, 25)
Show Fogger Pro	Directors Choice	glycol	0.44	(4, 9, 25)
	Pro Beam (Long Lasting)	glycol	0.44	(4, 25)
	Quick Dissipating	glycol	2.56	(4, 25)
Stage Fogger DMX	Directors Choice	glycol	0.99	(4, 9, 25)
	Molecular Fog Fluid	glycol	2.77	(4, 25)
	Pro Beam (Long Lasting)	glycol	1.36	(4, 25)
	Quick Dissipating	glycol	1.37	(4, 25)
* Due to monitor overloading during the calibration testing for this combination, the resulting calibration factor of 4.95 is known to be overestimated. This value can be used as a conservative (i.e., health protective) screening value. If monitoring results using this calibration factor result in exposures exceeding the guidance levels, it is recommended that additional testing to refine this calibration factor be conducted.				

(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.

(5) Development of Calibration Factors for Monitoring Theatrical Smoke and Haze: Jem 24/7 Hazer with Pro-Haze Fluid, by researchers from ENVIRON International Corporation for Martin Professional, 2003.

(6) Theatrical Smoke and Haze Testing, Wicked the Musical, Gershwin Theatre, prepared by ENVIRON International Corporation for Stone Productions, 2004.

(7) Theatrical Smoke Testing at Bombay Dreams, prepared by ENVIRON International Corporation for Bombay Dreams NY L.L.C., 30 July 2004.

(8) Development of Calibration Factors for Monitoring Theatrical Smoke and Haze: Look Solutions Orka with Regular-Fog Fluid, prepared by ENVIRON International Corporation for Look Solutions, 1 April 2005.

(9) Letter from Le Maitre Special Effects to ENVIRON International Corporation regarding name change of Regular Fog Fluid to Directors Choice, 5 December 2005.

(10) Theatrical Smoke and Haze Testing for The Phantom of the Opera, Forrest Theatre, prepared by ENVIRON International Corporation for Alan Wasser Associates, January 2003.

(11) Letter from Le Maitre Special Effects to ENVIRON International Corporation regarding Stage Fogger DMX, Power Fog Industrial, and Power Fog Industrial 9D, 12 April 2006.

(12) Letter from Look Solutions to ENVIRON International Corporation regarding Viper Fluid, Unique2 Hazer, and Viper II/NT, 5 May 2006.

(13) Development of Time-And-Distance Guidelines for Use of Theatrical Smoke Equipment: Le Maitre Radiance Hazer, prepared by ENVIRON International Corporation for Le Maitre Special Effects, Inc., August 2006.

(14) Development of Time-And-Distance Guidelines for Use of Theatrical Smoke Equipment: Le Maitre LSG-MKII with Power Fog Industrial 9D (PFi9D) Low Smoke Generator, prepared by ENVIRON International Corporation for Le Maitre Special Effects, Inc., August 2006.

(15) Development of Time-And-Distance Guidelines for Use of Theatrical Smoke Equipment: Rosco Delta Hazer, prepared by ENVIRON International Corporation for Rosco Laboratories, August 2006.

(16) Development of Time-And-Distance Guidelines for Use of Theatrical Smoke Equipment: Rosco Model 1750, prepared by ENVIRON International Corporation for Rosco Laboratories, August 2006.

(17) Development of Time-And-Distance Guidelines for Use of Theatrical Smoke Equipment: Look Solutions Low-Fogger, prepared by ENVIRON International Corporation for Look Solutions and Look Solutions USA, Ltd., August 2006.

(18) Development of Time-And-Distance Guidelines for Use of Theatrical Smoke Equipment: Look Solutions Power Tiny, prepared by ENVIRON International Corporation for Look Solutions and Look Solutions USA, Ltd., August 2006.

(19) Development of Time-And-Distance Guidelines for Use of Theatrical Smoke Equipment: Look Solutions Viper NT, prepared by ENVIRON International Corporation for Look Solutions and Look Solutions USA, Ltd., August 2006.

(20) Development of Time-And-Distance Guidelines for Use of Theatrical Smoke Equipment: Fantasy FX Professional Haze, prepared by ENVIRON International Corporation for Richard Frankel Productions Inc., 14 December 2006.

(21) Letter from Look Solutions to ENVIRON International Corporation regarding Tiny-Compact, Tiny F07, Tiny C07, and Cryo-Fog, January 24, 2007.

(22) *Development of Calibration Factors and Time-And-Distance Guidelines for Use of Theatrical Smoke Equipment: Le Maitre LSG-MKII with Power Fog Industrial 9D (PFi9D) Low Smoke Generator with Extra Quick Dissipating and Quick Dissipating Fluid*, prepared by ENVIRON International Corporation for 321 Management, February 2007.

(23) *Development of Calibration Factors for Monitoring Theatrical Fog: Jem ZR33 Hi-Mass with ProSmoke Super (ZR-mix) Fluid, Jem ZR33 Hi-Mass with ProSteam Simulation Fluid, Magnum 2500Hz with Pro Haze Fluid, Jem Glaciator X-Stream with C3 Fluid*, prepared by ENVIRON International Corporation for Martin Professional A./S, August 2008.

(24) Letter from Le Maitre Special Effects to ENVIRON International Corporation, June 2, 2008.

(25) Letter from Ultratec Special Effects Inc. to ENVIRON International Corporation regarding separation of Le Maitre Special Effects Inc. from Le Maitre Ltd., and renaming of Le Maitre Special Effects Inc., to Ultratec Special Effects Inc, June 10, 2009.

(26) *Calibration Factors and Time-And-Distance Guidelines for Use of Theatrical Fog Equipment: Barco FQ-100 with Atmospheres Stage Fluid and Barco FQ-100 with Atmospheres HQ Fluid*, prepared by ENVIRON International Corporation for Barco Lighting Systems, Inc., December 2010.

(27) *Development of Calibration Factors for Monitoring Theatrical Smoke and Haze: Jem Roadie with ZR Fluid*, prepared by ENVIRON International Corporation for Cirque du Soleil, September 2003.

(28) E-mail correspondence from Le Maitre Ltd to ENVIRON International Corporation, March 4, 2011.

(29) *Calibration Factors and Time-And-Distance Guidelines for Use of Theatrical Fog Equipment: Tiny FX with Tiny Fluid, Tiny S with Tiny Fluid, Viper NT with Slow-Fog Fluid, Viper NT with Regular-Fog Fluid, and Unique 2.1 with Unique Fluid,* prepared by ENVIRON International Corporation for Look Solutions USA, Ltd., February 2014.

(30) *Theatrical Smoke and Haze Testing for The Lion King Gazelle Tour, Paramount Theater*, prepared by ENVIRON International Corporation for Disney Worldwide Services, Inc., March 2014.

(31) *Calibration Factors and Time-And-Distance Guidelines for Use of Theatrical Fog Equipment: Aquamax with Organic Haze Fluid and HazeMax with Water Vapour Haze Fluid*, prepared by ENVIRON International Corporation for CITC, August 2014.

(32) *Calibration Factors and Time-And-Distance Guidelines for Use of Theatrical Fog Equipment: Vapour with Rosco Stage & Studio Fluid, Vapour with Rosco Fog Fluid, Vapour Plus with Rosco Stage & Studio Fluid, Vapour Plus with Rosco Fog Fluid, Mini-V with Rosco Stage & Studio Fluid, Mini-V with Rosco Fog Fluid, and V-Hazer with V-Hazer Fluid,* prepared by ENVIRON International Corporation for Rosco Laboratories, May 2014.

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. Multiplying this number by the 1.56 calibration factor for this machine/fluid combination gives the actual glycol fog concentration of 31 mg/m^3.

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
and the subscripts (a, b, and so on) indicate that C and T are for different performances

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.

Monitoring with Logging

Using the logging function built into the pDR-1000AN requires that the aerosol monitor be connected to a computer to set the calibration factor and logging interval, and also to download the logged data. It does not need to be connected to the computer while it is monitoring the air, collecting the data.

You will need, in addition to the pDR-1000AN aerosol monitor, the following things:

1. A Windows 95, 98, or XP computer with a DB-9 RS232 serial port
2. Some way of printing data that will be downloaded from the aerosol monitor to the computer
3. The pDR communications software
4. A proprietary serial cable for the aerosol monitor that has an RJ-11 phone connector on one end and a DB-9 connector on the other

Installing the software

Installing the software is covered in section 9.2 on page 23 of the Operator Manual. The manual assumes that you have a 3.5" floppy drive. However, it seems to make no difference what medium the software is on, so if you have a copy of the software on a CD-ROM, you can install it from that.

The Manual also offers instructions for installing the software if you have Windows 3.1, but it also says the minimum operating system is Windows 95. Obviously these statements are inconsistent, but are unlikely to be a problem since Windows 95 was released over a decade ago, and there are probably few Windows 3.1 machines still being used.

If you are using Windows XP, it would be wise to set a System Restore point before you install the software. This will allow you to undo any changes to your computer if the installation does not work well.

The Device Manager is also useful for seeing what COM serial ports your machine has available. The pDR communications software uses an RS-232 COM port, which must be manually selected.

The communications program is quite small and installs in seconds.

Setting the calibration factor and other configuration parameters

Section 9.3 on page 24 of the manual covers connecting the pDR-1000AN to the computer and outlines what monitor configuration parameters can be set using the computer. Most of these will probably be unimportant, but you will want to check that the time and date and the calibration factor for the machine/fluid combination you are using are correct. If you don't set the time and date, the data you collect will all be marked as having been collected at some other time, some other day than when you actually did it. That's simply an invitation for grief. There is a radio button that will set the date and time on the pDR to match the date and time on your computer. Use it, unless your computer time is set wrong.

The default calibration factor is 1.00, which is appropriate for standardized dust and one fog machine/fluid combination. All the other machine/fluid combinations in the industry have calibration factors above or below that number. Set it to the correct factor for the machine/fluid combination you are using. A list of all the calibration factors known to PLASA can be found in the table on pages 4, 5, and 6 of this set of instructions. If you don't set the calibration factor, all the data recorded will be correct only if you are measuring standard dust or the fog from that one fog machine with that one fluid. For all other machines, you will have to multiply by hand or with a spreadsheet the hundreds or thousands of data points you collected to correct them. Better to let the monitor do the multiplying for you.

Measuring with logging—Step-by-Step

This is a condensed version. See section 8.0 Operation, starting on page 18 of the Operator Manual, for more details.

1. Turn on the pDR-1000AN.

   Press the **ON/OFF** button. The display will show
   START ZERO: ENTER
   GO TO RUN: NEXT

   If you have received the pDR-1000AN from PLASA, it will have been sent to you already zeroed, so press **NEXT**. If you own your own monitor, have received it from another source, or feel that you must re-zero the monitor from PLASA, consult section 6.5.1 on page 14 of the monitor's Operator Manual for information on how to zero the monitor. Zeroing is good for about a week if you keep the monitor out of dusty environments. If dust collects in the monitor after it is zeroed, the dust will cause false high readings. You will actually have less fog on stage than the monitor shows.

   After pressing **NEXT**, the display will show
   START RUN: ENTER
   READY: NEXT
   Press **NEXT**.

   The display will show either
   LOGGING DISABLED or
   LOG INTERVAL 60s (or some other interval)
   TAG #1 (or some other number)

   If it says **LOGGING DISABLED**, press **ENTER**, and the display will change to
   LOG INTERVAL 60s (or some other interval)
   TAG #1 (or some other number)

   Press **NEXT** again, and cycle through the displays until you see the display show
   START RUN: ENTER
   READY: NEXT
   Then press **ENTER**. You should see the logging interval displayed, and then after a few seconds the real-time concentrations will be shown.

   If the display doesn't say **LOGGING DISABLED** but says
   LOG INTERVAL 60s (or some other interval)
   TAG #1 (or some other number)

   Press **NEXT** again, and cycle through the displays until you see the display show
   START RUN: ENTER
   READY: NEXT
   Then press **ENTER**. You should see the logging interval displayed, and then after a few seconds the real-time concentrations will be shown.

   NOTE: There will be an ***** shown next to **CONC** if logging is turned on (**CONC***). If there is no * shown, logging is not turned on and no data is being logged.

   Note that the log interval may not be 60s. It can be changed via the PC connection. The default is 60 seconds, but that is probably rather coarse for a fog cue. Thirty seconds or 15 seconds might be better. The pDR-1000AN has enough memory to collect 13,391 data points; you could log data every 15 seconds for a fog cue lasting two hours and use only 480 of the data points.

With the real-time concentrations being shown, 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.

2. 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 in the person's breathing zone at floor level. Try to duplicate the person's speed and timing according to the actual blocking. Don't rush and don't linger.

   If you are doing data logging, you probably want to run the entire cue and collect data throughout the whole cue. That is, don't stop the testing run when the levels appear to be dropping and you think you are past the peak. The Equity Business Representative reviewing the stage manager's smoke/haze report will want to know that you monitored the concentrations during the entire time that the actor was exposed to the fog.

3. Stop the sampling run.

   Push **EXIT**. The display will show
   TERMINATE RUN?
   Y: ENTER N: EXIT
   Push **ENTER**.

4. Transferring the logged data to your PC.

   Connect the serial cable from the phone connector on the pDR monitor to the DB-9 serial port on your computer. Launch pDR-COM, the communications program. Turn on the monitor and press NEXT until the display says **CONNECT TO PC.**

   Click on pDR on the top menu of pDR-COM on your computer, and then select "Get data." You should then be able to see it on the "Logged data" tab. Little pictures on the side of the pDR-COM window offer you options for what you can do with the data. The software is pretty simple and obvious.

   You can also delete the logged data from the pDR's memory with your computer using pDR-COM.

If you get complete confused with the settings of the pDR monitor, it can be reset by pressing **EXIT** and **ENTER** at the same time while the monitor is off, and then pressing **ON/OFF**. The monitor will turn on and go through a diagnostic self-test, and in the process clear its memory and go back to the factory defaults--including the default sampling interval and 1.00 calibration factor. Resetting it probably should be considered a last resort.

Questions?

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