EQUIPMENT-BASED GUIDELINES FOR THE USE OF THEATRICAL SMOKE AND HAZE

Prepared for:

Equity-League Pension and Health Trust Funds
(Sponsor)

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T A B L E S

EXECUTIVE SUMMARY

This document contains Equipment-Based Guidelines for the use of theatrical smoke and haze. The purpose of this document is to provide generic, conservative (health protective) Guidelines for using certain types of smoke- and haze-generating equipment. For various combinations of machines and fluids, the Guidelines provide the amount of time that should be allowed to pass following the release of a smoke or haze cue before an Actor is allowed to be situated within a certain distance of the smoke or haze machine. After that time, it is expected that air concentrations will have been reduced to below the Guidance levels recommended in a recent Health Effects Study (Mt. Sinai and ENVIRON 2000).

These generic Guidelines were developed based on conservative use assumptions. Depending on production-specific conditions, it is likely that the air concentrations for many stages and productions will have actually fallen below the Guidance levels before the times specified in these generic Guidelines. Productions may have stage-specific conditions that would allow Actors to be present in areas that are restricted under these Guidelines but which, in fact, do not exceed the Guidance levels. In those cases, production-specific monitoring (in accordance with the Air Sampling Protocol developed by ENVIRON (2001)) would be recommended to determine whether peak exposure may occur.

I. INTRODUCTION

A. Background

In 1997-99, at the request of Actors' Equity Association (AEA) and the League of American Theaters and Producers (LATP) and with the support of the Equity-League Pension and Health Trust Funds, investigators from the Mount Sinai School of Medicine (Mt. Sinai) and ENVIRON International Corporation (ENVIRON) conducted a study to determine whether the use of smoke, haze, and pyrotechnics special effects in theatrical musical productions is associated with a negative health impact in Actors. This effort was initiated in response to ongoing concerns by Actors that the use of these theatrical effects may have an impact on their health. The results of this study were presented in the report *Health Effects Evaluation of Theatrical Smoke, Haze, and Pyrotechnics* (Mt. Sinai and ENVIRON 2000).

The results of the Mt. Sinai/ENVIRON study indicate that there are certain health effects associated with Actors exposed to elevated or peak levels of glycol smoke and mineral oil. However, as long as peak exposures are avoided, Actors' health, vocal abilities, and careers should not be harmed. Pyrotechnics as used on Broadway at the time of the study did not have an observable effect on Actors' health.

Mt. Sinai and ENVIRON recommended the following guidance levels with respect to glycols and mineral oil:

- The use of glycols should be such that an Actor's exposure does not exceed 40 milligrams per cubic meter (mg/m^3).

- Mineral oil should be used in a manner such that an Actor's exposure does not exceed a peak concentration of 25 mg/m^3.

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

ENVIRON has prepared a set of two reports that can be used to ensure that Actor exposures do not exceed the guidance levels – this Equipment-Based Guidelines document and an Air Sampling Protocol (ENVIRON 2001):

- Equipment-Based Guidelines document – This document provides conservative Guidelines on the distance (with respect to the discharge point on the equipment) and length of time that concentrations exceeding the peak guidance levels may occur for various use patterns. These Guidelines could be used in staging performances in lieu of conducting stage-specific testing.

- Air Sampling Protocol document – The Air Sampling Protocol provides detailed procedures for conducting theater- and production-specific monitoring. Monitoring conducted in accordance with the Air Sampling Protocol can be used to evaluate potential exposures to short-term concentrations of smoke and haze special effects for theatrical productions where the Equipment-Based Guidelines are not applicable. This includes productions that use smoke/haze equipment or fluids other than those for which Equipment-Based Guidelines have been provided in this document, or productions that use equipment or fluids that are included in these Equipment-Based Guidelines, but under conditions other than those utilized in developing the Guidelines.

The sampling procedures used to develop these Equipment-Based Guidelines are based on the ENVIRON Air Sampling Protocol.

B. Use of Equipment-Based Guidelines

In the absence of other information, theater-specific monitoring would be required to determine whether smoke/haze machines are being used in a production in a manner that avoids peak exposures to Actors. The Equipment-Based Guidelines described in this report were developed as an alternative to conducting theater- and production-specific monitoring. These Guidelines were developed under conservative use assumptions (e.g., no ventilation, no on-stage activities or props that would enhance dispersion, cue release at breathing height level). By following these Guidelines, a production can use smoke and haze effects without having to conduct its own stage-specific testing, provided the machines are used in accordance with manufacturer specifications, are well maintained, and are functioning properly. Tables 3 and 4 of this report describe the distance (with respect to the discharge point on the equipment) and length of time that concentrations exceeding the peak guidance levels would occur for various use patterns. Thus, by arranging the blocking and choreography such that an Actor is not situated within the restricted areas during the times specified in Tables 3 and 4, Actors should not receive peak exposures.

It should be noted that these Equipment-Based Guidelines may not be appropriate for all productions. Tables 3 and 4 are based on smoke and haze machines positioned between four and five feet above the ground, and being operated to achieve 10 to 15 seconds of continuous smoke generation or 40 seconds of continuous haze generation. Productions may want to use different configurations for positioning the machines (e.g., different heights), provide on-stage ventilation, or generate smoke and haze for a longer period of time. In addition, many productions may have other stage-specific conditions (e.g., on-stage activities and props that enhance dispersion) that would allow Actors to be present in areas that are restricted under these Guidelines but which, in fact, do not exceed the guidance levels. In those cases, production-specific monitoring would be recommended to determine whether peak exposure may occur. For the smoke and haze fluids included in this testing (see Table 1), the calibration factors summarized in Table 2 can be used, and the calibration step of the ENVIRON Air Sampling Protocol can be bypassed. This will significantly reduce the amount of time and expense required to conduct monitoring. For fluids other than those included in this testing, appropriate calibration factors would need to be developed in accordance with the Air Sampling Protocol.

II. METHODS AND MATERIALS

A. Selection of Chemicals for Sampling

The following types of chemicals used to produce theatrical effects were included in these Guidelines:

- **Glycols for smoke generation**
  Mixtures of various glycols are used to generate smoke effects. Glycol aerosols are generated by heating a glycol/water solution and feeding the vapor through a critical flow orifice. The glycol solutions currently used on Broadway to generate smoke effects consist of mixtures of 1,3-butylene glycol (BG), diethylene glycol (DEG), propylene glycol (PG), dipropylene glycol (DPG), triethylene glycol (TEG), and water.

- **Mineral oil for a haze effect**
  A haze-like effect can be produced by generating an aerosol of mineral oil. Oil mist effects are generated by "cracking" a USDA approved food or pharmaceutical grade mineral oil through a dispersion system using high-pressure air.

While other chemicals are available currently for generating smoke and haze effects (e.g., glycerol), these chemicals were not included in the Mt. Sinai/ENVIRON study. Thus, the conclusions and guidance levels developed and presented in the Mt. Sinai/ENVIRON study will not necessarily be applicable to these alternative chemicals. Comparable guidance levels could be developed for alternative chemicals through an appropriate health effects evaluation.

B. Selection of Smoke and Haze-Generating Equipment and Fog Fluids

ENVIRON contacted the following smoke and haze-generating equipment manufacturers:

- High End Systems, Austin, Texas
- Le Maitre Special Effects, Port Huron, Michigan
- MDG Fog Generators, Ltd., Montreal, Quebec
- Reel EFX, Inc., North Hollywood, California
- Rosco Laboratories, Stamford, Connecticut

These manufacturers provided ENVIRON with the use of their machines and fluids in developing these Guidelines. All of the equipment were shipped to Lightwave Research/High End Systems (HES) in Austin, Texas. HES has a sound stage with adjustable ventilation that was used previously by ENVIRON and NIOSH in conducting method calibration and validation activities.

Table 1 summarizes the equipment and fluids included in these Guidelines. Some of the manufacturers provided additional machines and fluids that were not included in this specific testing for various reasons.[1] For example, equipment designed for use with fluids containing glycerol were not included, as the exposure guidance levels only apply to glycol- and mineral oil-based fluids. Certain other machines were not provided with all of the attachments needed to operate the machines at the time of the testing. Guidelines for these additional machines could be developed at a later date, if requested.

TABLE 1
Summary of Smoke/Haze Machines and Fluids Tested

Manufacturer	Machine	Fluid	Type of Fluid
High End Systems	F-100	Atmosphere HQ Formula Atmosphere Stage Formula Atmosphere Cold Flow Formula	Glycol
Le Maitre Special Effects	G100 G150	Regular Fog Fluid Quick Dissipating Extra Quick Dissipating Molecular Fog Fluid (G150 only)	Glycol
	Opti Mist Ranger	Mini Mist Canister	
MDG Fog Generators, Ltd.	Mini Max	MDG Dense Fluid	Glycol
	MAX 3000 Atmosphere	MDG Neutral Fluid	Oil
Reel EFX, Inc.	DF-50	Diffusion Fluid	Oil
Rosco Laboratories	1600 PF-1000 Alpha 900	Rosco Fog Fluid Rosco Stage & Studio Fluid Rosco Light Fog Fluid Rosco Clear Fog Fluid	Glycol

C. Sampling Equipment and Materials

Monitoring of short-term concentrations was performed using portable real-time aerosol monitors (*personal*DataRAM Model PDR-1000) manufactured by Monitoring Instruments for the Environment, Inc. (MIE). The PDR-1000 is a high sensitivity nephelometric (i.e., photometric) monitor that uses a light scattering sensing chamber to measure the concentration

[1] Machines that use fluids other than glycols and mineral oil were not included in this testing. In addition, certain machines were not provided with all of the attachments necessary to operate them at the time of the testing. The following machines and fluids were provided to ENVIRON, but were not included in this testing: Le Maitre provided a Neutron XS machine, which uses a glycerol-based fluid (Neutron Fluid); a H175 Haze Machine, which uses a glycerol-based fluid (Regular Haze Fluid); and a G300 Fog Machine, which did not have appropriate electrical attachments at the time of the testing. Le Maitre also provided a Long Lasting Fluid for use in its G100 and G150 Fog Machines; this fluid was not included because it consists of a mixture of glycols and glycerol. Rosco provided a 4500 machine, which did not have appropriate electrical attachments at the time of the testing. A Rosco Hazemaker machine was tested; however, the results collected for this machine were not used due to a discrepancy in the analysis of the materials used in this machine.

of airborne particulate matter (liquid or solid), providing a direct and continuous readout as well as electronic logging of the data.

The PDR-1000 aerosol monitors as obtained are calibrated to Arizona road dust over a measurement range of 0.001 to 400 mg/m^3. In order to be utilized to measure short-term glycol or oil mist concentrations, the monitors were first calibrated for the smoke or haze machines and fluids being used. Calibration of the aerosol monitors was conducted by collecting simultaneous measurements with a series of sampling pumps and PDR-1000 aerosol monitors, mounted on tripods.

Gilian GilAir-5 and SKC Aircheck Model 224-44XR sampling pumps were used to draw air through collection media. The type of collection media used depended on the analyte:

- For glycols, OSHA Versatile Sampler (OVS) traps were used as the collection media, each containing two sections of XAD-7 resin (200-mg front section, 100-mg back section, separated by a polyurethane foam [PUF] plug). The XAD-7 resin was used to collect both the particulate and vapor phase of the glycol aerosol. A 13-mm glass fiber filter (GFF) plug precedes the front section and a PUF plug follows the back section. This sampling is based on a variation of NIOSH Method 5523 (NIOSH 1996; Pendergrass 1999).

- For mineral oil, air was drawn through 37-mm polyvinyl chloride (PVC) membrane filters (5 μm pore size), which were analyzed by infrared spectrophotometry (IR) in conjunction with a custom bulk oil sample. This sampling is based on a custom NIOSH Method 5026 (NIOSH 1994).

This calibration sampling was conducted in conjunction with operating the PDR-1000 aerosol monitors.

C. Sampling and Monitoring Procedures

The testing was conducted in a two-step process. The first step involves collecting sufficient data to calibrate the aerosol monitors for the type of fluid being used. The second step involves using the calibrated aerosol monitor to identify distances from the smoke/haze release point where exceedances of the guidance levels occur. These monitoring data were used to develop general Guidelines under conservative use conditions that can be used to ensure peak exposures to Actors do not occur. The calibration and sampling procedures are discussed in detail in the ENVIRON Air Sampling Protocol.

1. Aerosol Monitor Calibration

Four tripod assemblies were used for calibrating the aerosol monitors, each consisting of a sampling pump, flexible tubing, sampling media (OVS trap for glycols and cassettes for mineral oil), and an aerosol monitor (see Figure 1). The height of each tripod was approximately five feet, corresponding with the breathing zone of a typical

Actor. The room ventilation fans were turned off during each run; no major movement occurred in the testing room during each run that would affect smoke dispersion.

Glycols

a) The sampling pumps were calibrated to 2 lpm using a BIOS DryCal pump calibrator. The aerosol monitors were zeroed, the data logging function of the aerosol monitor was turned on, and the data logging times for all of the aerosol monitors were synchronized.

b) The smoke machine was positioned on a stand to allow a release of smoke at a height of four to five feet. The tripods were placed at distances from the smoke machine release nozzle of 6, 9, 12, and 15 feet (see Figure 2).

c) For machines that have variable release settings, the smoke machine output was adjusted to a medium setting. The sampling pumps were simultaneously turned on. The smoke machine was turned on five to ten seconds after the pumps were turned on for 20 to 30 seconds, allowing sustained smoke generation to occur, and then turned off. In certain instances where the amount of smoke generated was not sufficient to reach all four tripods, the smoke generation time was increased.

d) Air samples were collected for one to two minutes following the initiation of the smoke generation, after which the OVS traps were removed from the tubing and the pumps were turned off. The OVS traps were capped and labeled to identify the type of smoke machine, glycol fluid, sampling location, and other sampling specifics. After being capped and labeled, the OVS traps were placed in a cooler with ice packs.

e) A period of 10 to 30 minutes was allowed between runs to clear residual glycols from the testing area air by room ventilation.

Mineral Oil

a) The sampling pumps were calibrated to 3 lpm using a BIOS DryCal pump calibrator. The aerosol monitors were zeroed, the data logging function of the aerosol monitor was turned on, and the data logging times for all of the aerosol monitors were synchronized.

a) For hazers with a horizontal release point (e.g., MDG Max 3000), the machine was positioned on a stand to allow a release of mineral oil at a height of four to five feet. The tripods were placed at distances from the hazer release nozzle of 6, 9, 12, and 15 feet (see Figure 2). For hazers with a vertical and diffused release point (e.g., Rosco Hazemaker, MDG Atmosphere, Reel EFX DF-50), the hazer was placed on the floor and tripods were positioned at various distances around the hazer at three-foot interval (see Figure 3).

b) For machines that have variable release settings, the hazer output was adjusted to a medium setting. The sampling pumps were simultaneously turned on. The hazer was turned on five to ten seconds after the pumps were turned on for periods ranging from 40 seconds to six minutes, allowing sustained haze generation to occur, and then turned off. The haze generation time was dependent on the time required to generate an aerosol that could be detected at all six tripods.

c) Air samples were collected for one to two minutes following the initiation of the smoke generation, after which the sampling cassettes were removed from the tubing and the pumps were turned off. The cassettes were capped and labeled to identify the type of hazer, mineral oil fluid, sampling location, and other sampling specifics.

b) A period of 10 to 30 minutes was allowed between runs to clear residual mineral oil from the testing area air by room ventilation. Each of the aerosol monitors indicated particulate levels of less than 1 mg/m^3 before the next run was initiated.

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

2. Peak Exposure Characterization

To measure the levels of smoke and haze present at different distances from the release point, a series of six tripods equipped with aerosol monitors was used. The six tripods were placed at distances of 3, 6, 9, 12, 15, and 18 feet from the smoke or haze machine. The smoke machine was turned on for 10 to 30 seconds, allowing sustained smoke generation to occur, and then turned off. The aerosol monitors collected logged data on the smoke levels as the concentrations gradually dissipated. The room ventilation fans were turned off during each run; no major movement occurred in the testing room during each run that would affect smoke dispersion.

E. Laboratory Analyses

All sample analyses were conducted by using validated analytical methodologies, as described in the ENVIRON Air Sampling Protocol.

1. Glycols

Samples were analyzed for glycols using a variation of NIOSH Method 5523, which involves the use of a gas chromatograph with a flame ionization detector (GC/FID). The NIOSH Method 5523 was extended to a validated level of quantification (LOQ) of 4.0 μg of each individual glycol per sample.

2. Mineral Oil

Mineral oil samples were analyzed using a custom NIOSH Method 5026, which involves analysis using infrared spectrophotometry, with a bulk mineral oil sample used instead of a stock mineral oil standard. A maximum LOQ of 50 μg per sample was used.

Figure 1. Experimental set-up for aerosol monitor calibration, consisting of a tripod with sampling pump, tubing, and aerosol monitor.

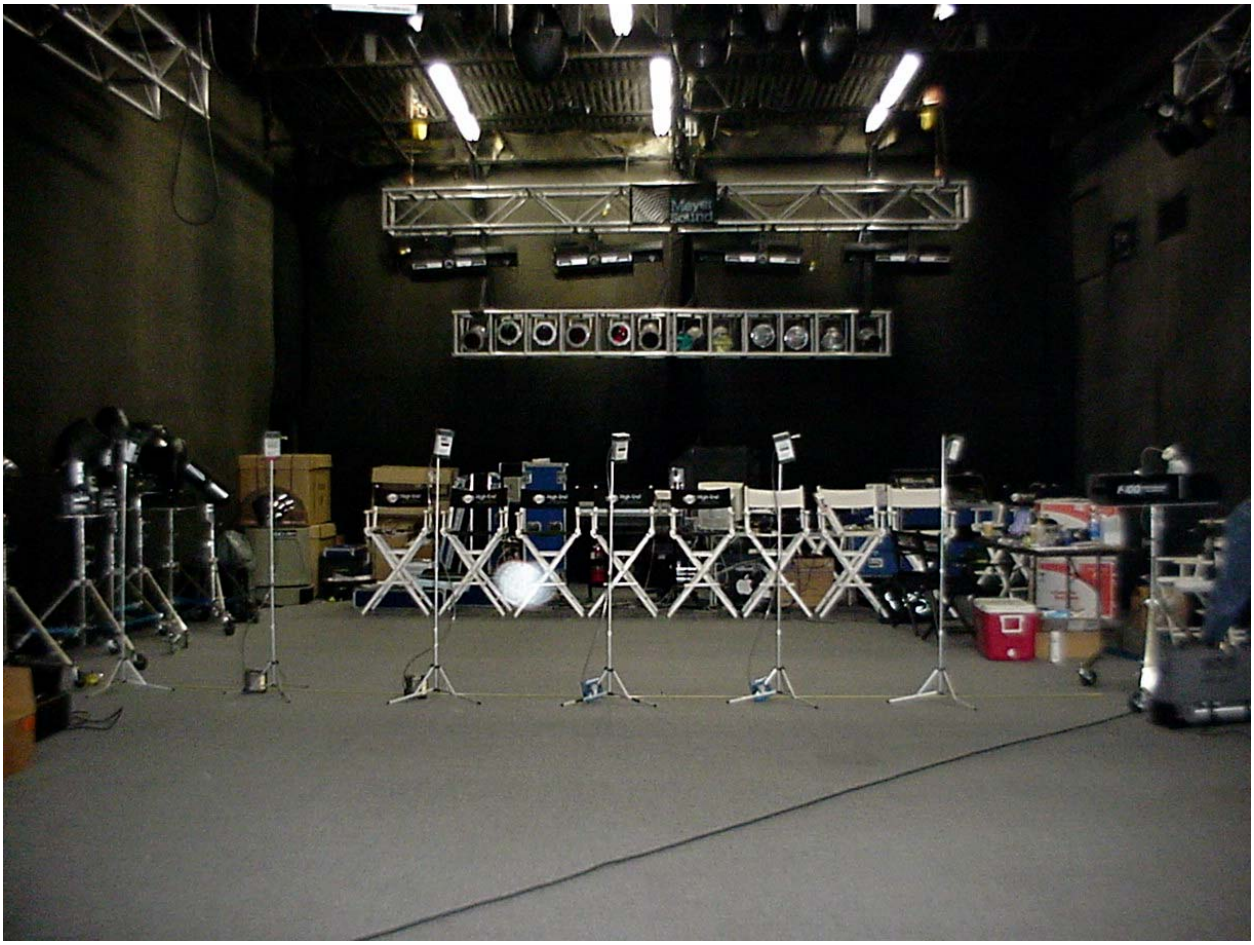

Figure 2. Sampling configuration consisting of six sampling/monitoring tripods situated at three foot intervals from a smoke or haze machine (far right). Each tripod is equipped with an aerosol monitor. The tripods situated at distances of 6, 9, 12, and 15 feet are also equipped with sampling pumps, flexible tubing, and collection media.

Figure 3. Example sampling configuration consisting of six sampling/monitoring tripods situated at three-foot intervals around a vertical-release hazer (center).

III. RESULTS AND DISCUSSION

A. Aerosol Monitor Calibration

1. Glycols

Total glycol concentrations were calculated from the analytical data. Only the glycol species measured in the bulk solution were included. For glycol species that were measured in the bulk solution, but were not detected in the air sample, one half of the detection limit for that glycol species was conservatively used in calculating the total glycol concentration.

To develop a calibration curve for each glycol fluid, the average aerosol monitor readings during the period of time in which air was drawn through the OVS trap for each air sample were calculated and plotted against the total glycol concentration data. The calibration curves for the glycol fluids tested are shown in Figures 4 to 16. First order regression curves are also shown on these figures. The calibration factors for the glycol fluids, calculated from the slopes of these regressions, are summarized in Table 2.

2. Mineral Oil

To develop a calibration factor for each mineral oil fluid, the average aerosol monitor readings during the period of time in which air was drawn through the sampling cassette for each air sample were calculated and plotted against the oil mist concentration data. The calibration factors for the mineral oil fluids, calculated from the slopes of these regressions, are also summarized in Table 2. Among the two fluids tested, only one was emitted in detectable quantities. However, because the composition of the mineral oil fluids is similar for both fluids, the same calibration factor should be applicable for both. The calibration curve for this mineral oil fluid is shown in Figure 17.

TABLE 2
Summary of Calibration Factors

Manufacturer	Fluid	Type of Fluid	Calibration Factor, (ug/L)/(mg/m^3)
High End Systems	Atmosphere Cold Flow Formula	Glycol	2.41
	Atmosphere HQ Formula	Glycol	1.38
	Atmosphere Stage Formula	Glycol	0.253
Le Maitre Special Effects	Extra Quick Dissipating Fluid	Glycol	3.17
	Molecular Fog Fluid	Glycol	2.58
	Quick Dissipating Fluid	Glycol	3.45
	Regular Fog Fluid	Glycol	4.17
	Mini Mist Canister	Glycol	3.01

TABLE 2 Summary of Calibration Factors			
Manufacturer	**Fluid**	**Type of Fluid**	**Calibration Factor, (ug/L)/(mg/m^3)**
MDG Fog Generators, Ltd.	MDG Dense Fluid	Glycol	3.21
	MDG Neutral Fluid	Oil	0.784
Reel EFX, Inc.	Diffusion Fluid	Oil	0.784 (a)
Rosco Laboratories	Rosco Clear Fog Fluid	Glycol	1.82
	Rosco Fog Fluid	Glycol	1.27
	Rosco Light Fog Fluid	Glycol	1.375
	Rosco Stage & Studio Fluid	Glycol	1.56
Notes: a Based on the calibration factor for MDG Neutral Fluid			

B. Peak Exposure Characterization

Monitoring data collected using aerosol monitors placed at distances of 3, 6, 9, 12, 15, and 18 feet from the smoke or haze machine were combined with the calibration factors to determine the levels of smoke and haze at different distances from the release point and times following the release. The real-time aerosol monitor readings were converted to glycol or mineral oil concentrations using the appropriate calibration factor for the fluid, as follows:

$$CONC = C \times PDR$$

where:

CONC = air concentration of total glycols or mineral oil mist, μg/L
C = aerosol monitor calibration factor (from Table 2), (μg/L)/(mg/m^3)
PDR = aerosol monitor reading, mg/m^3

Based on these calibrated data, the times after which the concentration of smoke or haze at each of the six distances drops below the guidance levels were determined. These Guideline values are summarized in Table 3 for glycols and Table 4 for mineral oil. Bar plots showing the change in concentration at each location with time are presented in Figures 18 through 49.[2]

C. How to Use the Equipment-Based Guidelines Tables

For various distances from the cue release point, Tables 3 and 4 provide the time (in seconds) after the end of the cue release after which the glycol or mineral oil concentrations will

[2] The Guideline times provided in Tables 3 and 4 were estimated from Figures 18 to 42, taking into consideration potential "bounceback" effects where the levels are shown to increase at later times at distances close to the far wall of the testing room. This was treated as an artifact in the testing methodology.

have fallen below the guidance levels. Thus, in order to prevent peak exposures to Actors, the blocking and choreography should be arranged such that Actors are not situated within a particular distance from the front of the smoke/haze release point until the amount of time listed in Tables 3 and 4 has elapsed following the end of the cue. For example, if a production is using a Rosco 1600 smoke machine (medium setting) with Stage & Studio fluid, an Actor should not be situated within six feet from the front of the cue release point until at least 80 seconds following the end of the cue release; an Actor should not be situated within 12 to 18 feet from the front of the cue release point until at least 30 seconds following the end of the cue release.

It should be reiterated that the Equipment-Based Guidelines provided in Tables 3 and 4 are intended to allow a production to use smoke and haze effects without conducting monitoring. However, these Equipment-Based Guidelines may not be appropriate for all productions. Tables 3 and 4 are based on smoke and haze machines positioned between four and five feet above the ground, and being operated to achieve 10 to 15 seconds of continuous smoke generation or 40 seconds of continuous haze generation. Productions may want to use different configurations for positioning the machines (e.g., different heights), provide on-stage ventilation, or generate smoke and haze for a longer period of time. In addition, many productions may have other stage-specific conditions (e.g., on-stage activities and props that enhance dispersion) that would allow Actors to be present in areas that are restricted under these Guidelines but which, in fact, do not exceed the guidance levels. In those cases, production-specific monitoring would be recommended to determine whether peak exposure may occur. For the smoke and haze fluids included in this testing (see Table 1), the calibration factors summarized in Table 2 can be used, and the calibration step of the ENVIRON Air Sampling Protocol can be bypassed. This will significantly reduce the amount of time and expense required to conduct monitoring. For fluids other than those included in this testing, appropriate calibration factors would need to be developed in accordance with the Air Sampling Protocol.

TABLE 3
Summary of Equipment-Based Guidelines for Smoke Generation

Manufacturer	Machine	Fluid	Machine Setting	Time (in sec) After Which Air Concentrations Are Below Guidance Level (40 mg/m^3)					
				3 ft	6 ft	9 ft	12 ft	15 ft	18 ft
High End Systems	F-100	Atmosphere Cold Flow Formula	Full	70	30	30	30	30	30
			Medium	40	40	30	30	0	0
		Atmosphere HQ Formula	Full	190	190	180	20	0	0
			Medium	170	80	70	0	0	0
		Atmosphere Stage Formula	Full/Med	0	0	0	0	0	0
Le Maitre Special Effects	G100	Extra Quick Dissipating Fluid	On	100	40	40	40	30	30
		Quick Dissipating Fluid	On	150	150	40	40	30	30
		Regular Fog Fluid	On	150	30	30	0	0	0
	G150	Extra Quick Dissipating Fluid	Full	50	40	40	30	30	30
			Medium	50	0	0	0	0	0
		Molecular Fog Fluid	Full	90	50	40	0	0	0
			Medium	90	0	0	0	0	0
		Quick Dissipating Fluid	Full	60	60	40	0	0	0
			Medium	60	0	0	0	0	0
		Regular Fog Fluid	Full	110	80	70	70	0	0
			Medium	60	50	50	0	0	0
	Opti Mist Ranger	Mini Mist Canister	Full	110	80	60	60	0	0
			Medium	110	80	60	60	0	0
MDG Fog Generators, Ltd.	Mini Max	MDG Dense Fluid	Full	150	80	50	0	0	0
			Medium	130	40	40	0	0	0

TABLE 3
Summary of Equipment-Based Guidelines for Smoke Generation

Manufacturer	Machine	Fluid	Machine Setting	Time (in sec) After Which Air Concentrations Are Below Guidance Level (40 mg/m^3)					
				3 ft	6 ft	9 ft	12 ft	15 ft	18 ft
Rosco Laboratories	1600	Rosco Clear Fog Fluid	Full	230	150	60	0	0	0
			Medium	230	70	60	0	0	0
		Rosco Fog Fluid	Full	170	100	80	40	40	40
			Medium	170	100	80	40	40	40
		Rosco Light Fog Fluid	Full	150	70	70	70	60	50
			Medium	150	50	50	50	50	50
		Rosco Stage & Studio Fluid	Full	80	80	50	40	40	40
			Medium	80	80	40	30	30	30
	PF-1000	Rosco Fog Fluid	Full	60	40	0	0	0	0
			Medium	60	0	0	0	0	0
		Rosco Stage & Studio Fluid	Full	100	70	60	60	0	0
			Medium	100	70	0	0	0	0
	Alpha 900	Rosco Fog Fluid	On	220	220	180	180	160	110
		Rosco Stage & Studio Fluid	On	140	140	140	130	50	30

TABLE 4 Summary Equipment Based Guidelines for Haze Generation								
Manufacturer	**Machine**	**Fluid**	**Time (in sec) After Which Air Concentrations Are Below Guidance Level (25 mg/m^3)**					
			3 ft	**6 ft**	**9 ft**	**12 ft**	**15 ft**	**18 ft**
MDG Fog Generators, Ltd.	MAX 3000	MDG Neutral Fluid	100	100	100	100	100	0
	Atmosphere	MDG Neutral Fluid	190	190	120	0	0	0
Reel EFX, Inc.	DF-50	Diffusion Fluid	0	0	0	0	0	0

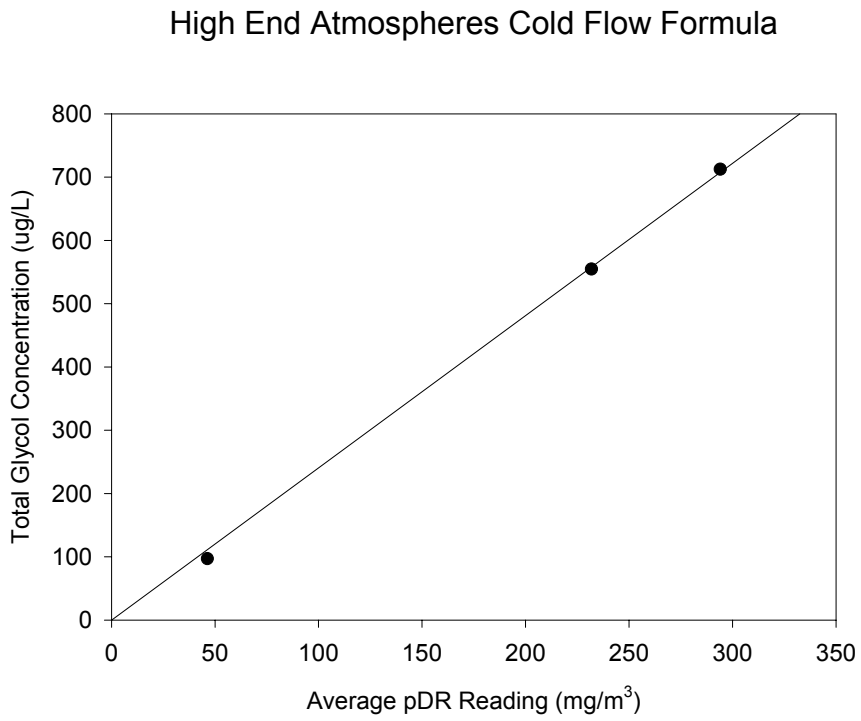

Figure 4. Calibration curve for High End Systems Atmospheres Cold Flow Formula Fluid. Calibration factor, based on slope of curve, is 2.41 (ug/L)/(mg/m^3).

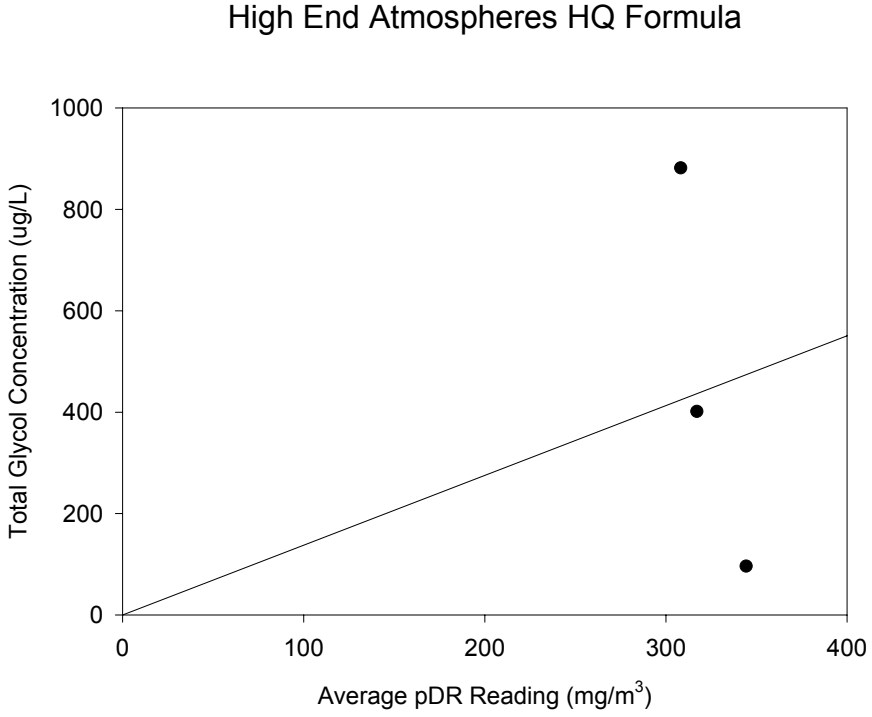

Figure 5. Calibration curve for High End Systems Atmospheres HQ Fluid. Calibration factor, based on slope of curve, is 1.38 (ug/L)/(mg/m^3).

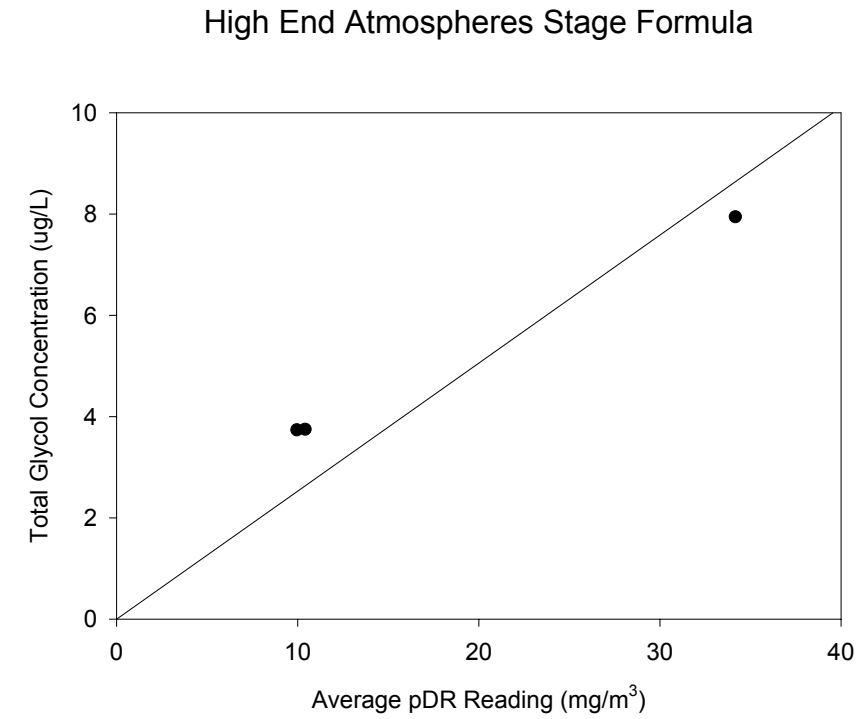

Figure 6. Calibration curve for High End Systems Atmospheres Stage Fluid. Calibration factor, based on slope of curve, is 0.253 (ug/L)/(mg/m^3).

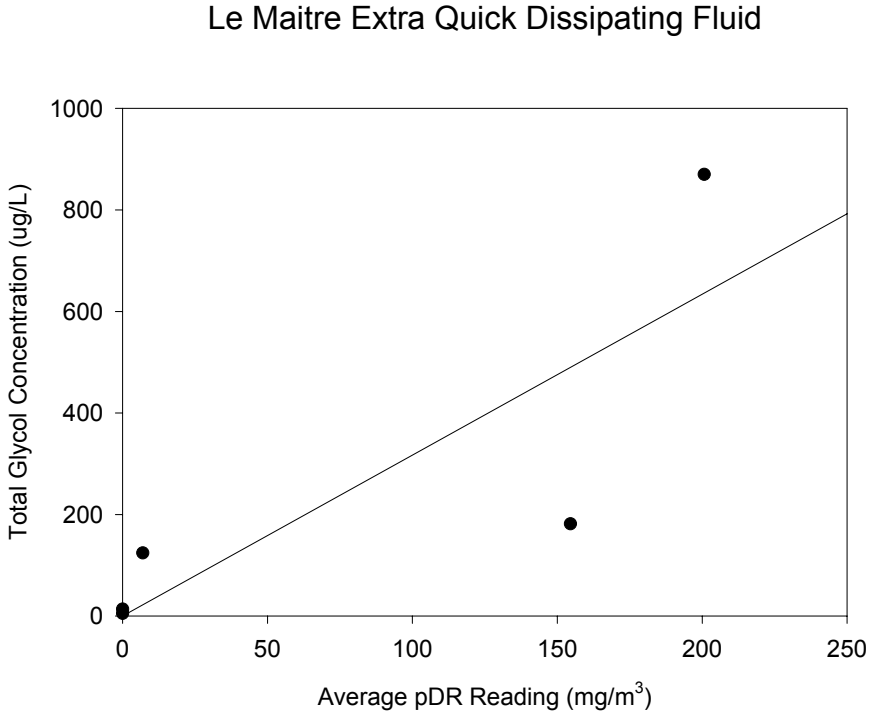

Figure 7. Calibration curve for Le Maitre Extra Quick Dissipating Fluid. Calibration factor, based on slope of curve, is 3.17 (ug/L)/(mg/m^3).

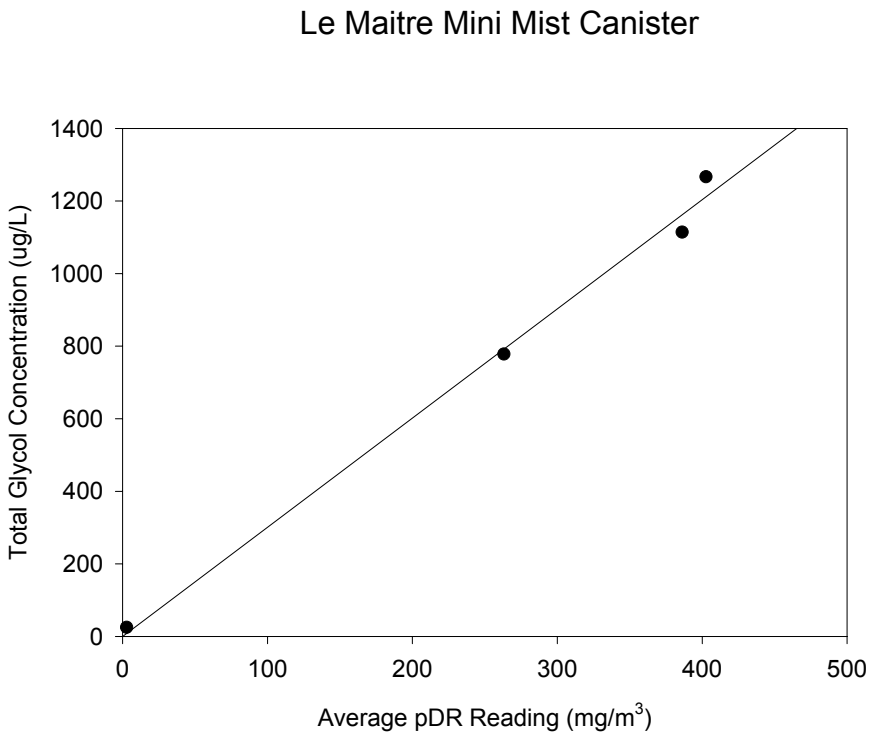

Figure 8. Calibration curve for Le Maitre Mini Mist Canisters. Calibration factor, based on slope of curve, is 3.01 (ug/L)/(mg/m^3).

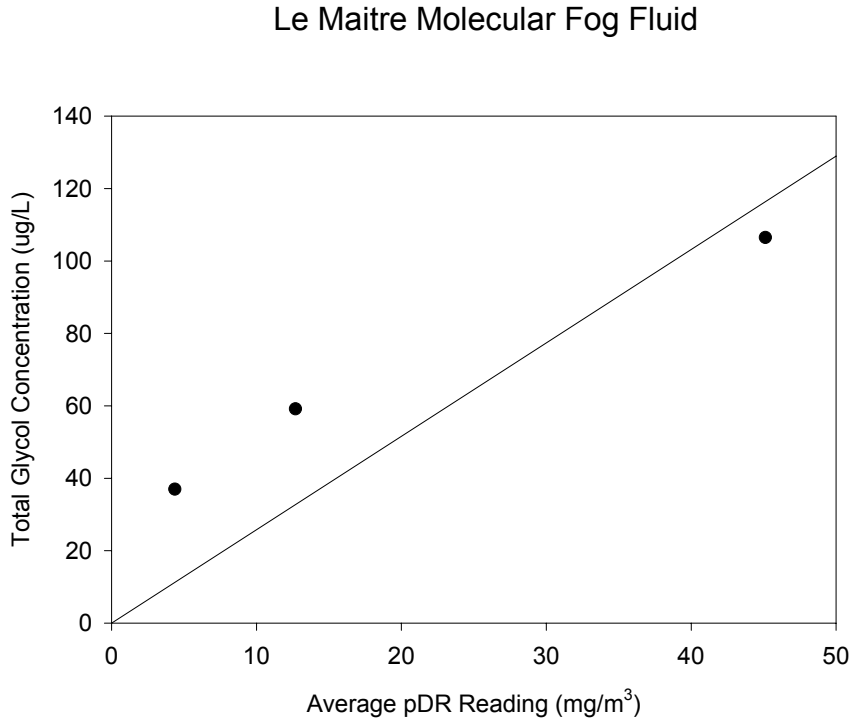

Figure 9. Calibration curve for Le Maitre Molecular Fog Fluid. Calibration factor, based on slope of curve, is 2.58 (ug/L)/(mg/m^3).

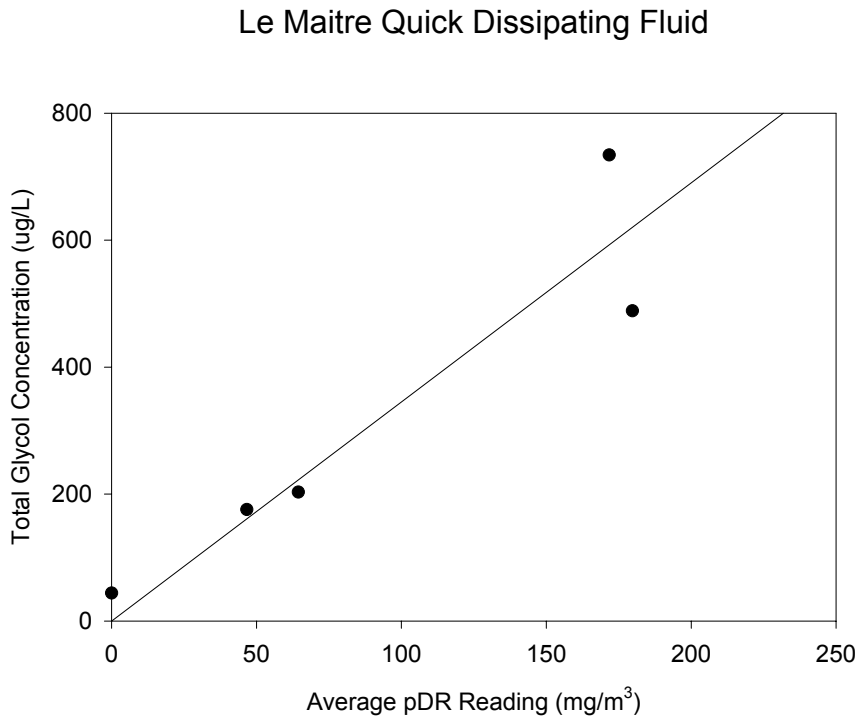

Figure 10. Calibration curve for Le Maitre Quick Dissipating Fluid. Calibration factor, based on slope of curve, is 3.45 (ug/L)/(mg/m^3).

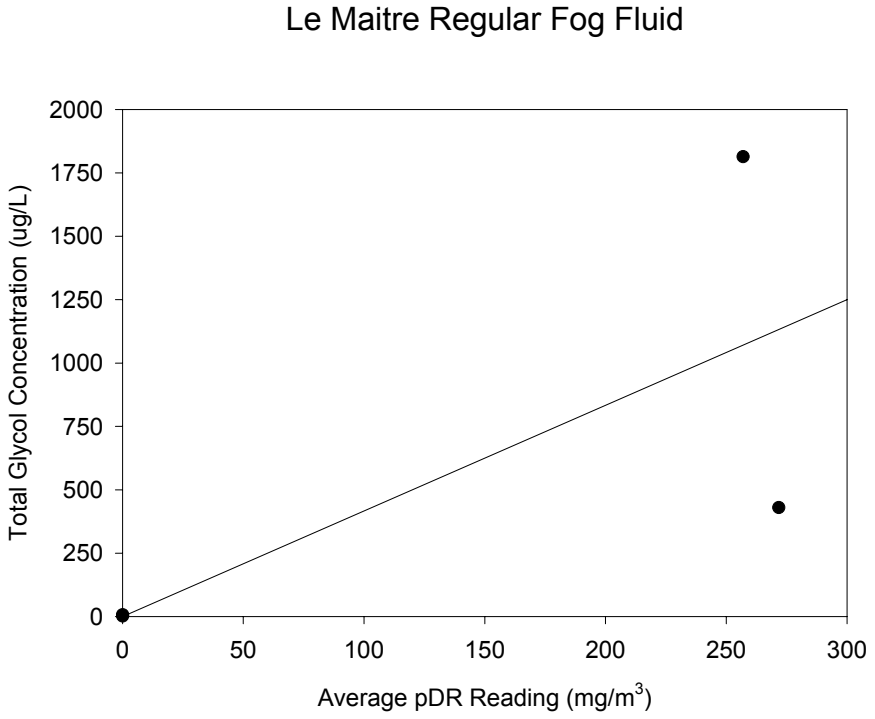

Figure 11. Calibration curve for Le Maitre Regular Fog Fluid. Calibration factor, based on slope of curve, is 4.17 (ug/L)/(mg/m^3).

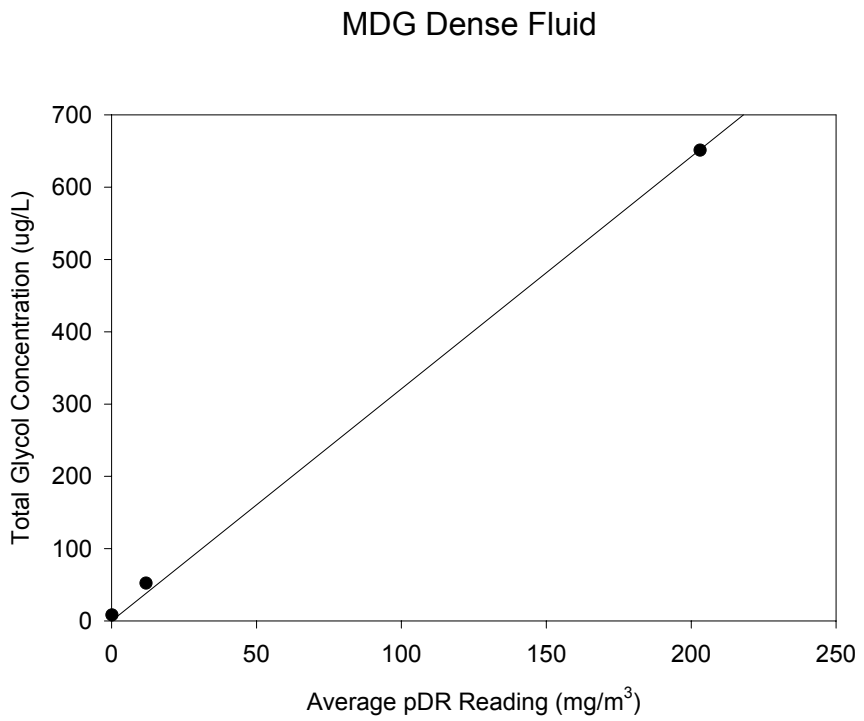

Figure 12. Calibration curve for MDG Dense Fluid. Calibration factor, based on slope of curve, is 3.21 (ug/L)/(mg/m^3).

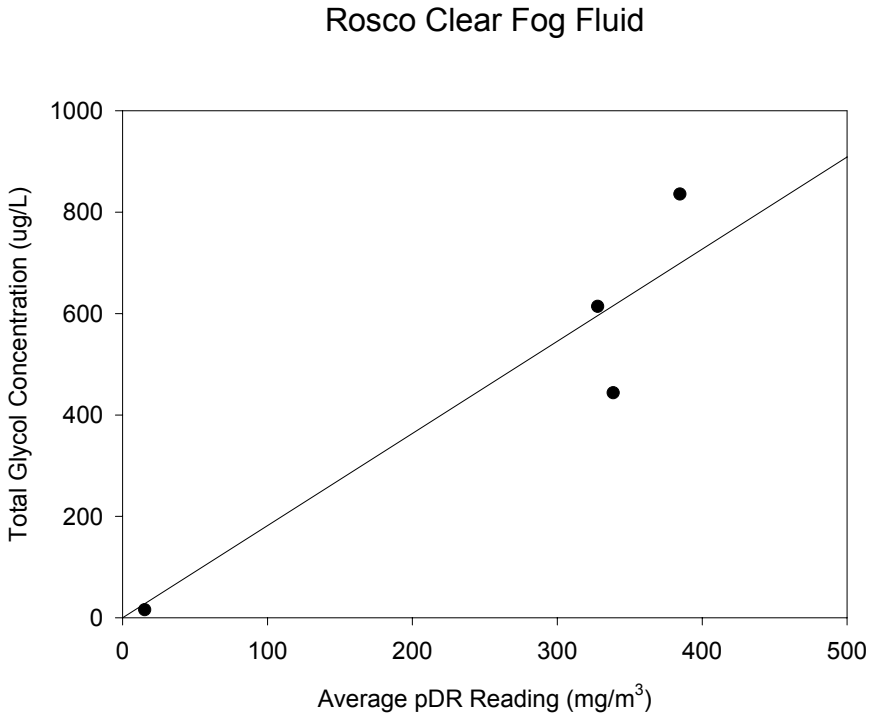

Figure 13. Calibration curve for Rosco Clear Fog Fluid. Calibration factor, based on slope of curve, is 1.82 (ug/L)/(mg/m^3).

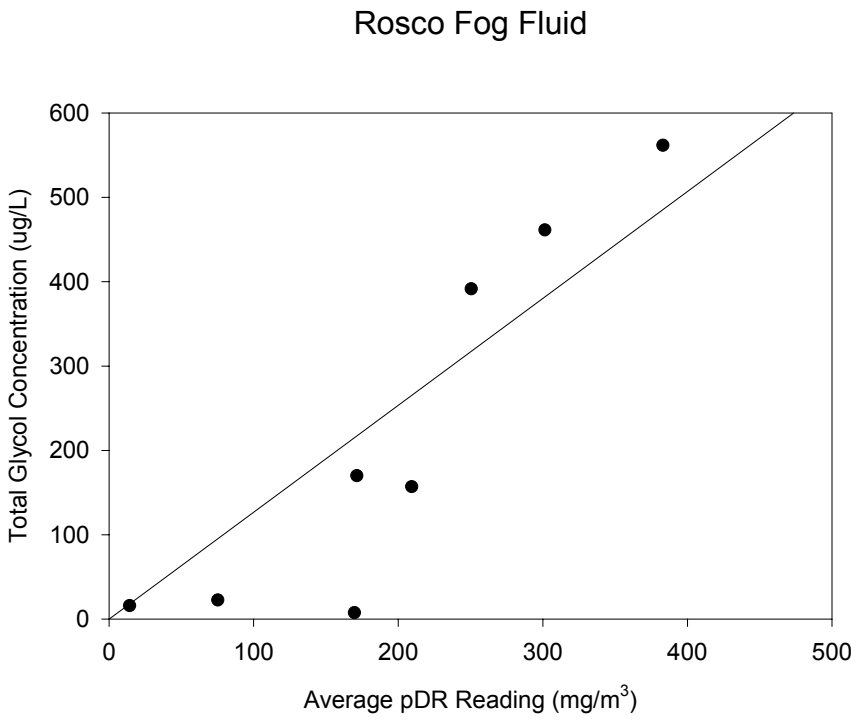

Figure 14. Calibration curve for Rosco Fog Fluid. Calibration factor, based on slope of curve, is 1.27 (ug/L)/(mg/m^3).

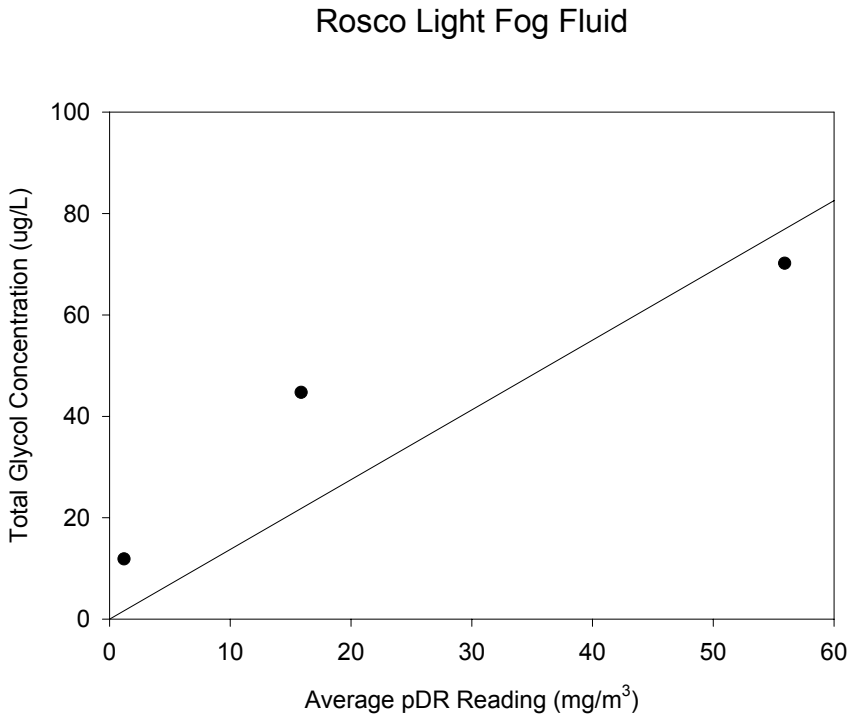

Figure 15. Calibration curve for Rosco Light Fog Fluid. Calibration factor, based on slope of curve, is 1.375 (ug/L)/(mg/m^3).

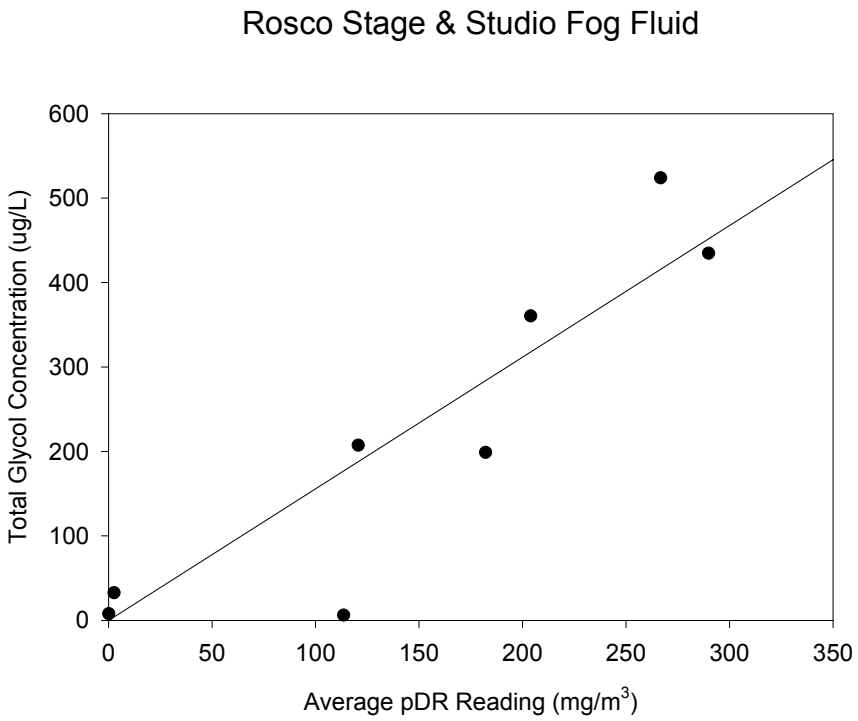

Figure 16. Calibration curve for Rosco Stage & Studio Fog Fluid. Calibration factor, based on slope of curve, is 1.56 (ug/L)/(mg/m^3).

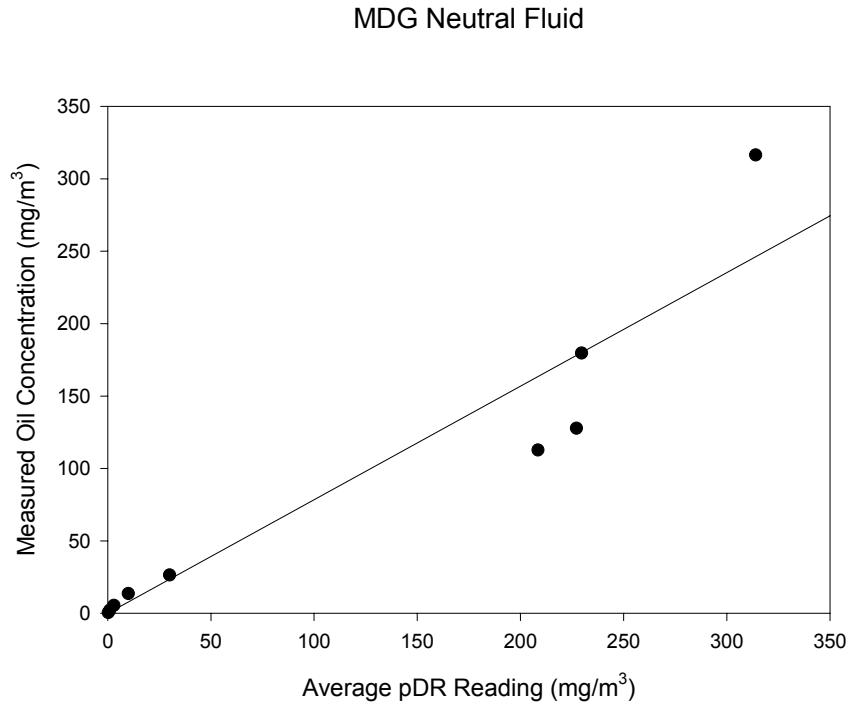

Figure 17. Calibration curve for MDG Neutral Fluid. Calibration factor, based on slope of curve, is 0.784 (mg/m^3)/(mg/m^3).

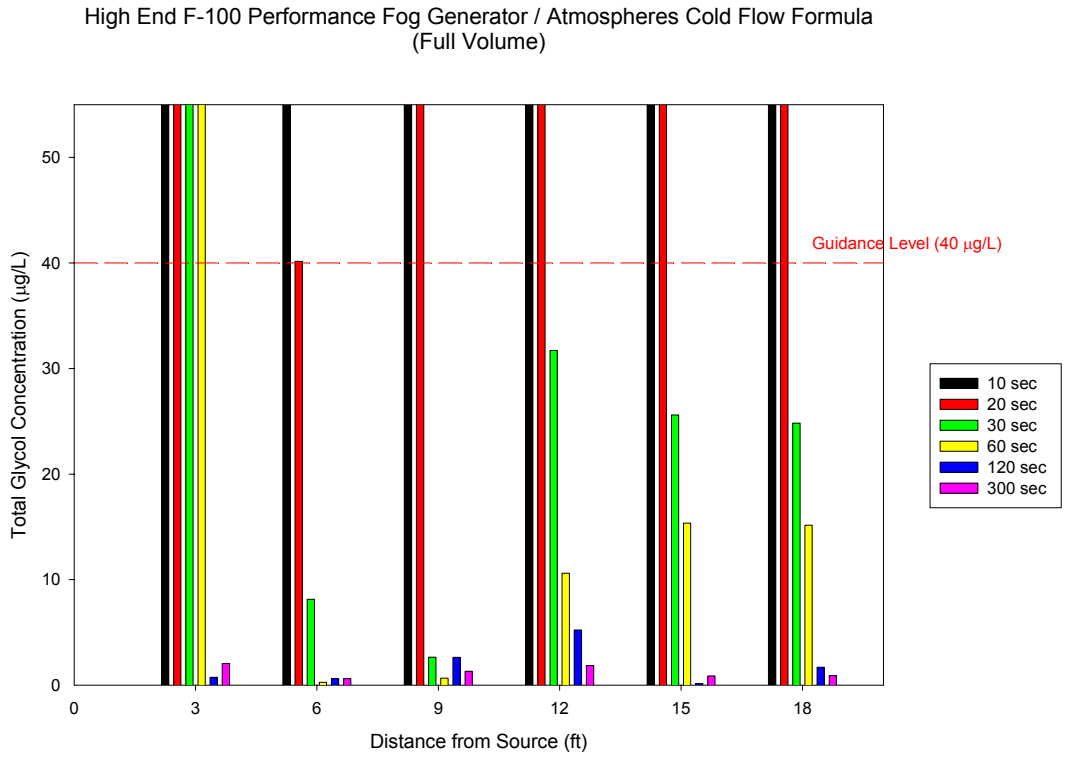

Figure 18. Guidelines for use of Atmospheres Cold Flow Formula in High End Systems F-100 smoke machine at a full volume setting.

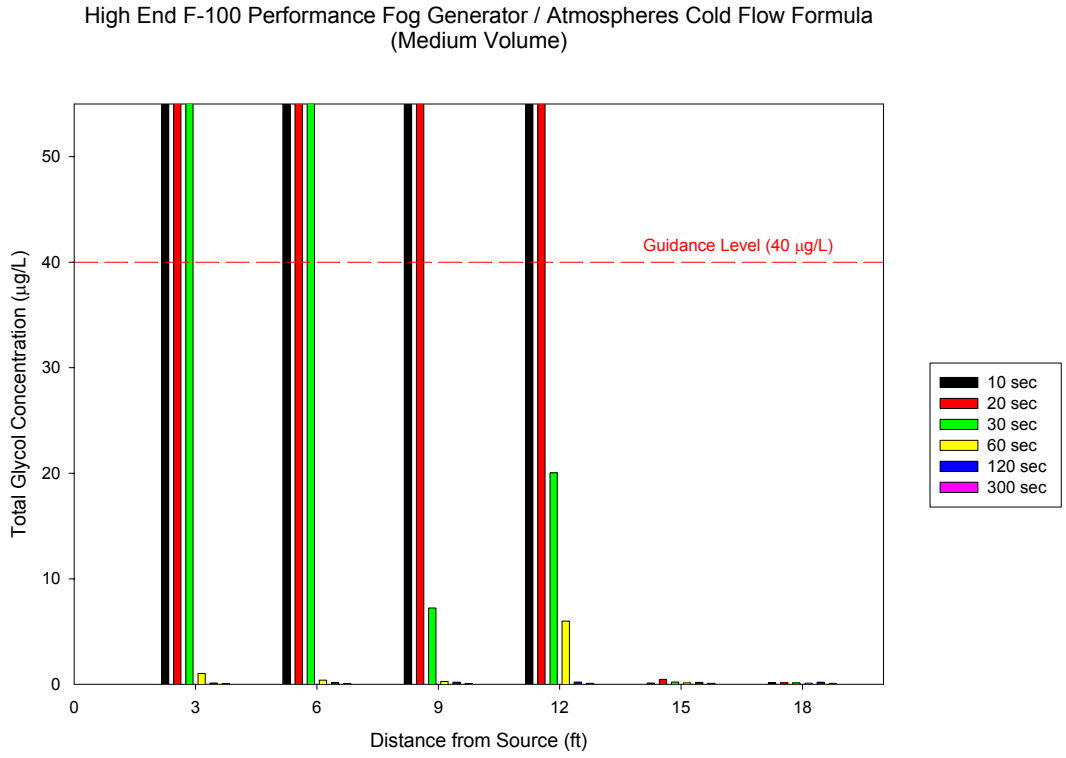

Figure 19. Guidelines for use of Atmospheres Cold Flow Formula in High End Systems F-100 smoke machine at a medium volume setting.

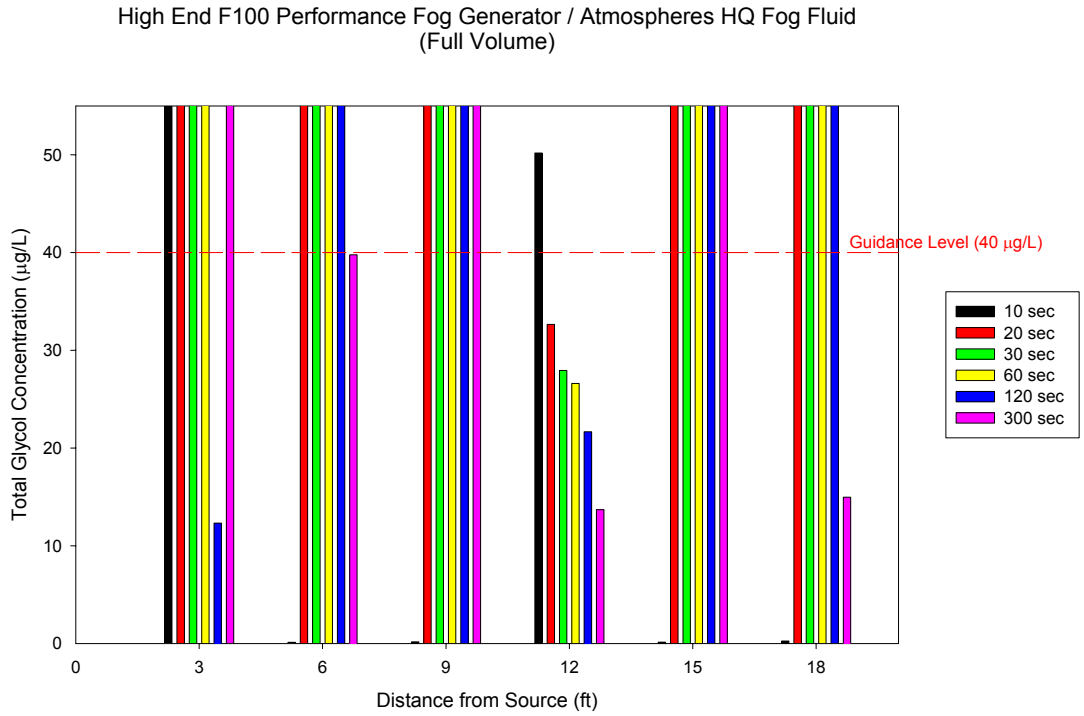

Figure 20. Guidelines for use of Atmospheres HQ Formula in High End Systems F-100 smoke machine at a full volume setting.

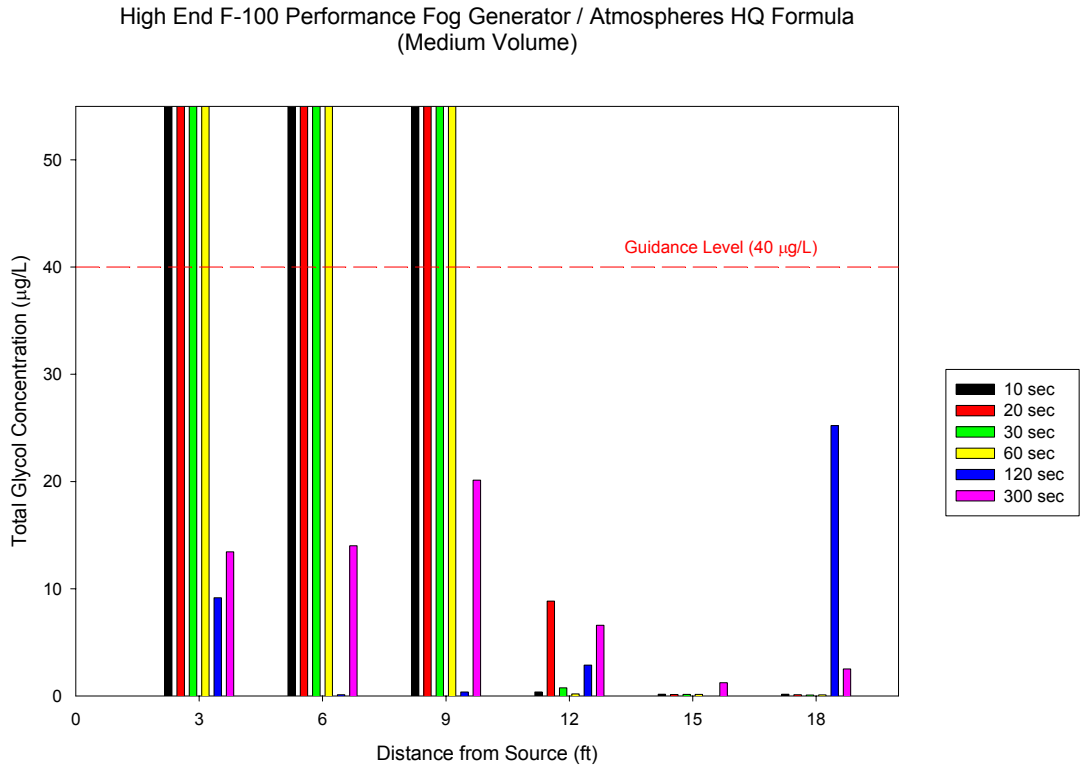

Figure 21. Guidelines for use of Atmospheres HQ Formula in High End Systems F-100 smoke machine at a medium volume setting.

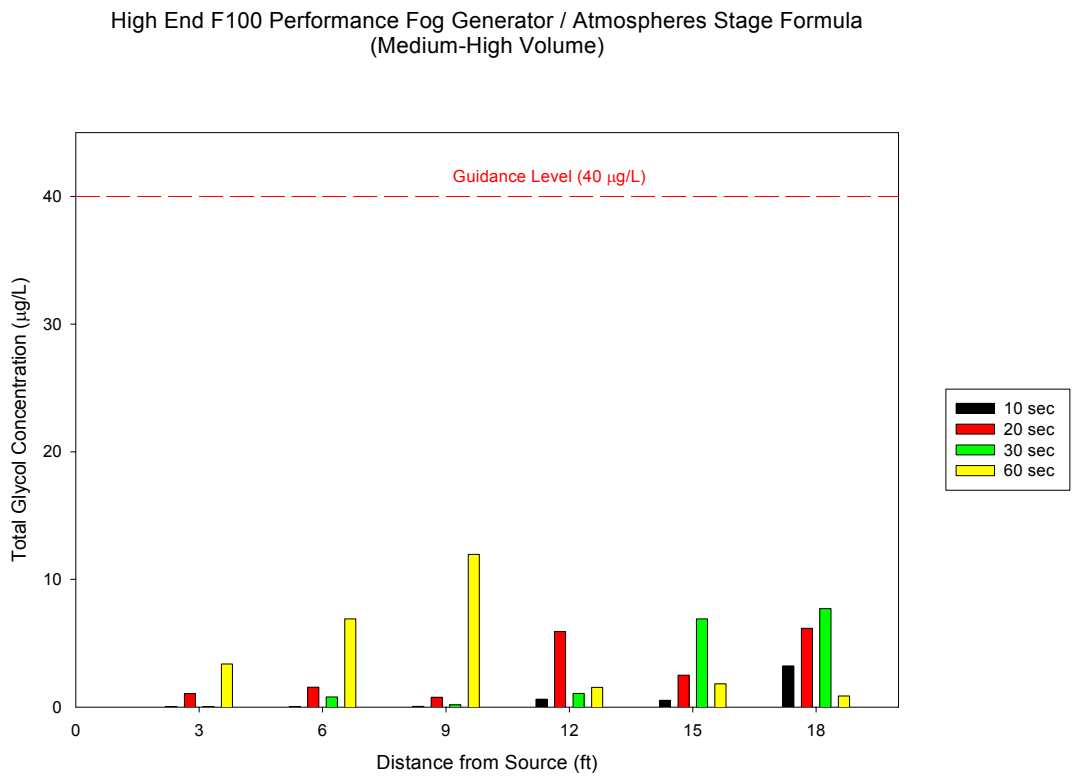

Figure 22. Guidelines for use of Atmospheres Stage Formula in High End Systems F-100 smoke machine at a medium-to-full volume setting.

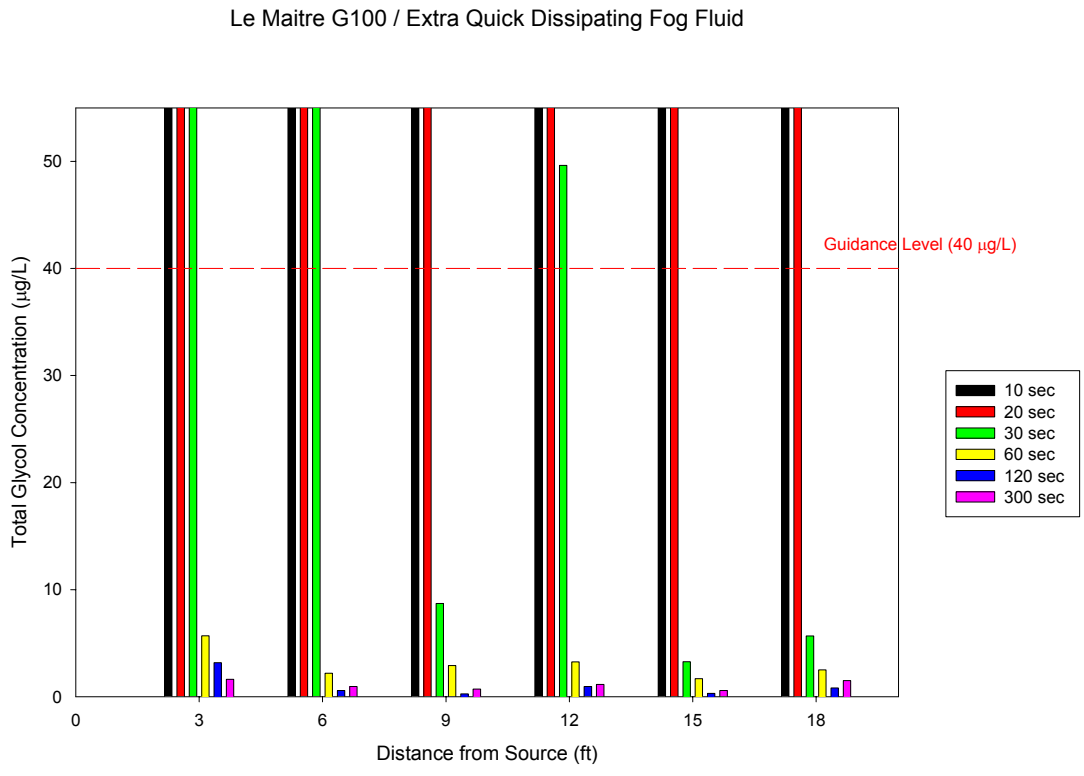

Figure 23. Guidelines for use of Extra Quick Dissipating Fog Fluid in Le Maitre G100 smoke machine.

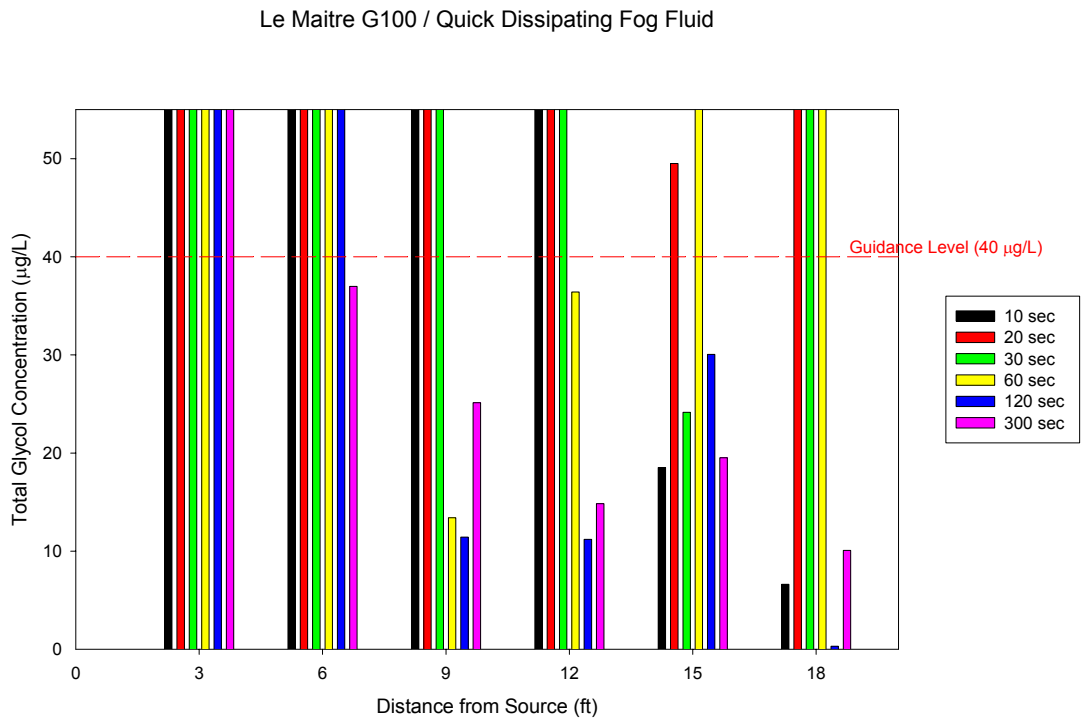

Figure 24. Guidelines for use of Quick Dissipating Fog Fluid in Le Maitre G100 smoke machine.

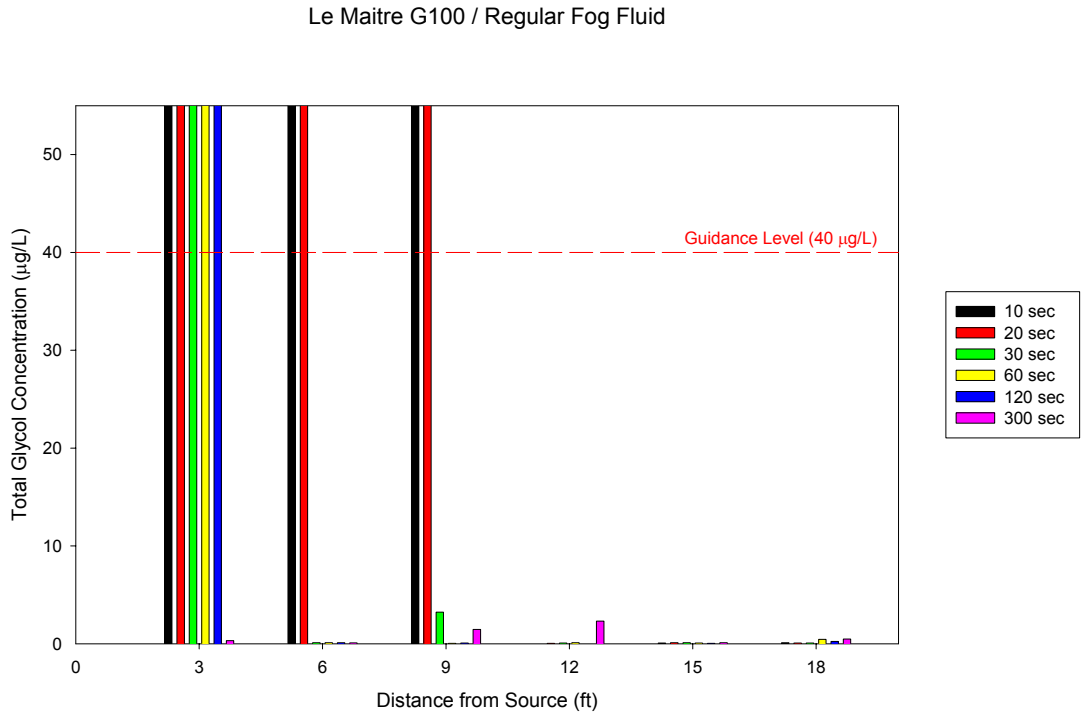

Figure 25. Guidelines for use of Regular Fog Fluid in Le Maitre G100 smoke machine.

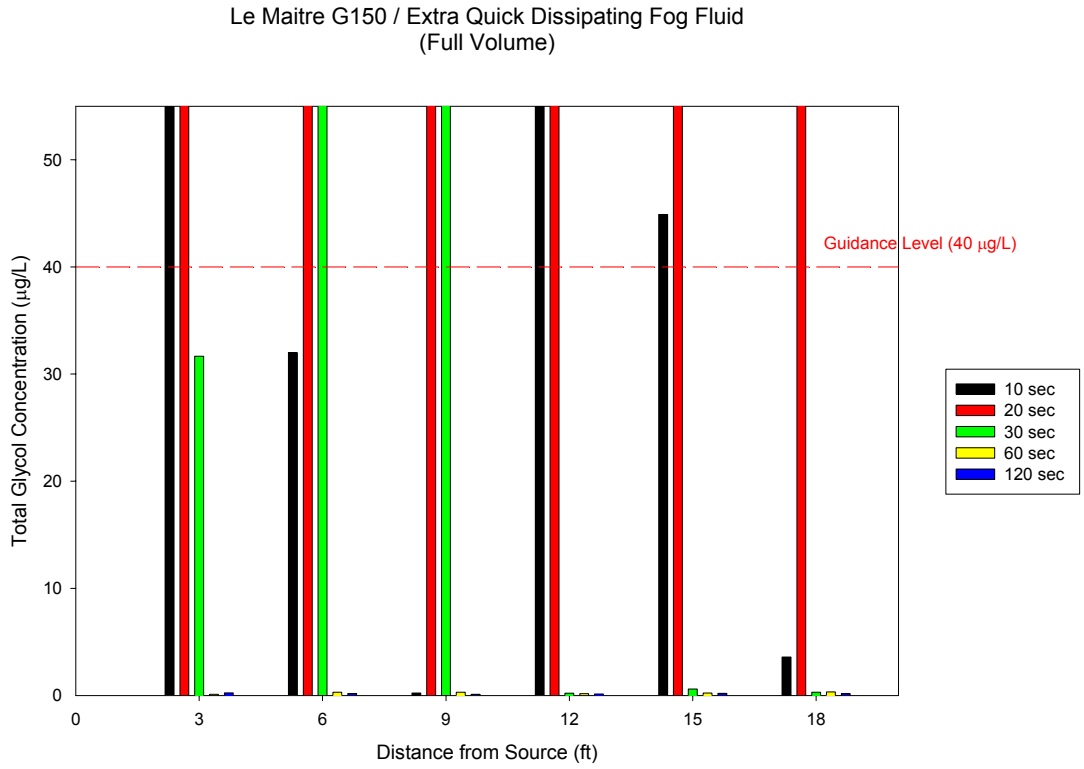

Figure 26. Guidelines for use of Extra Quick Dissipating Fog Fluid in Le Maitre G150 smoke machine at a full volume setting.

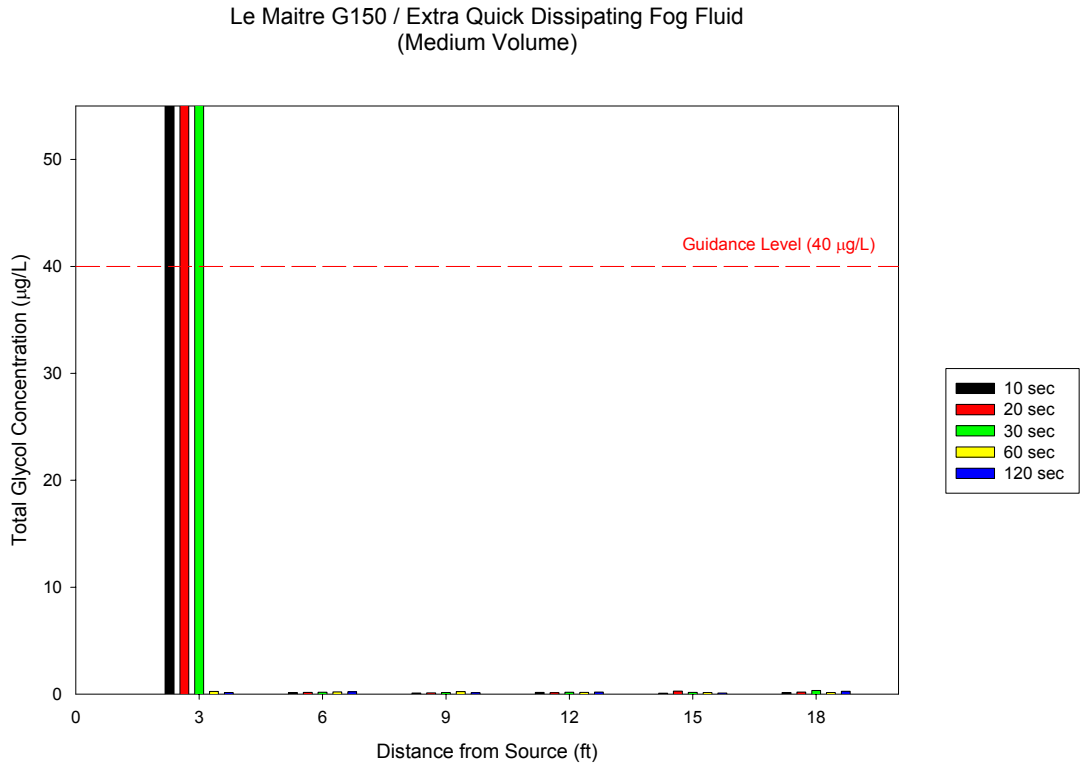

Figure 27. Guidelines for use of Extra Quick Dissipating Fog Fluid in Le Maitre G150 smoke machine at a medium volume setting.

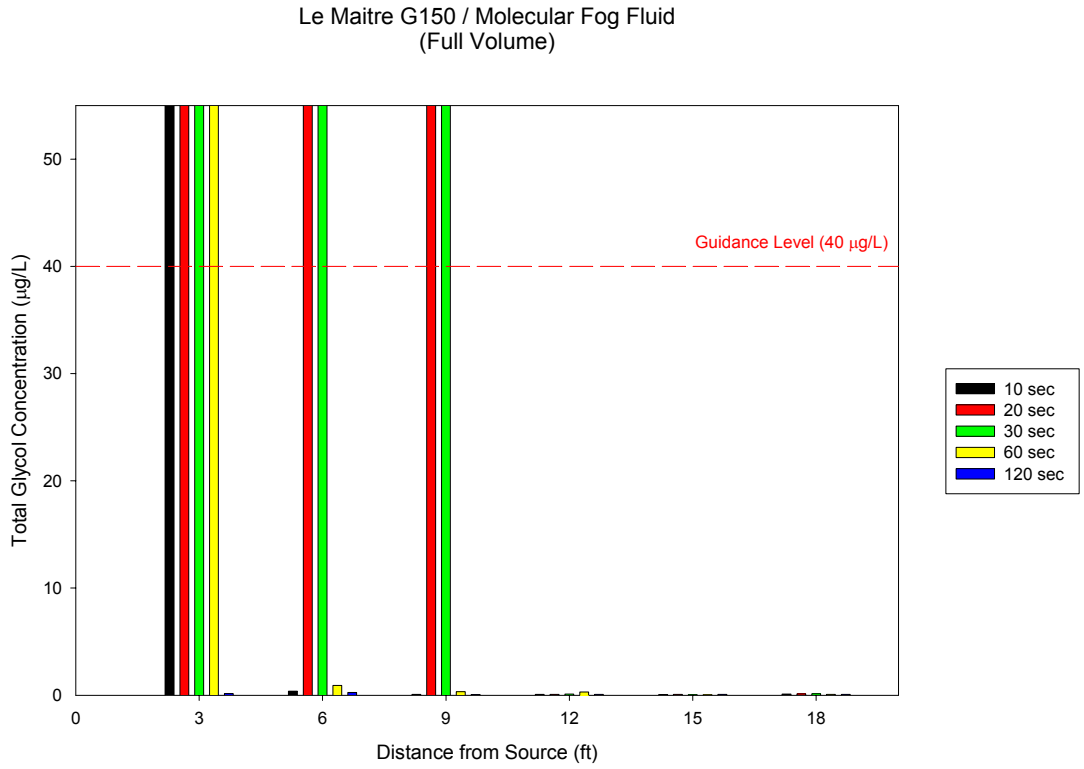

Figure 28. Guidelines for use of Molecular Fog Fluid in Le Maitre G150 smoke machine at a full volume setting.

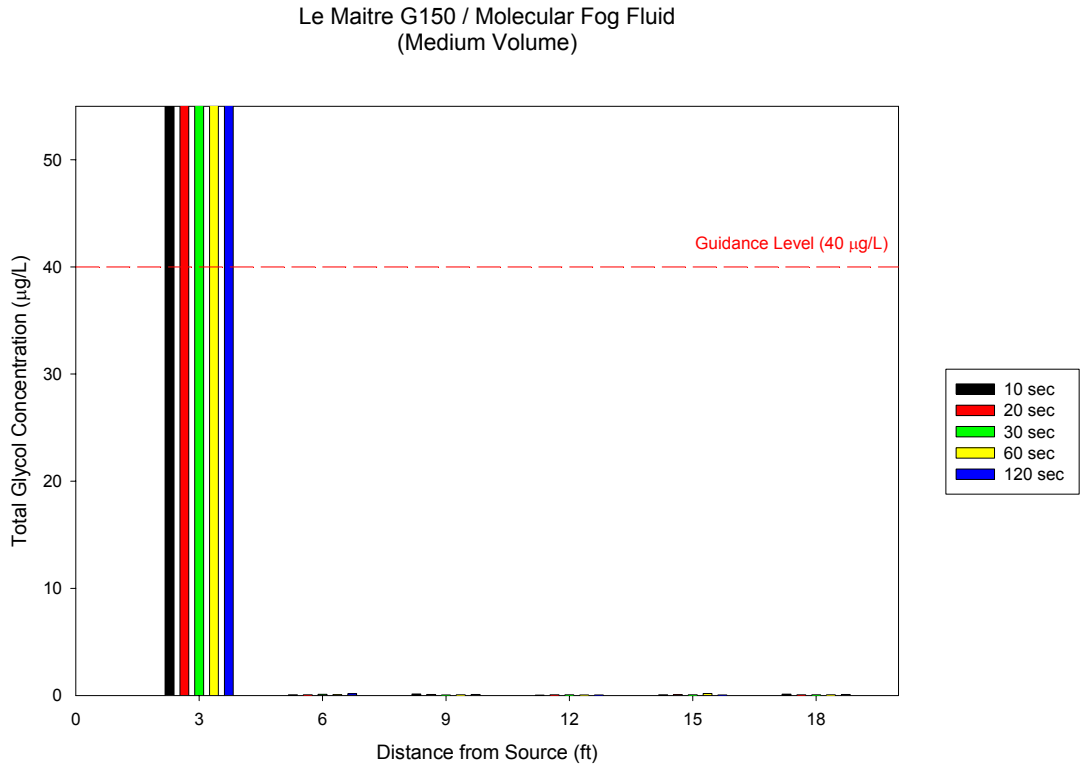

Figure 29. Guidelines for use of Molecular Fog Fluid in Le Maitre G150 smoke machine at a medium volume setting.

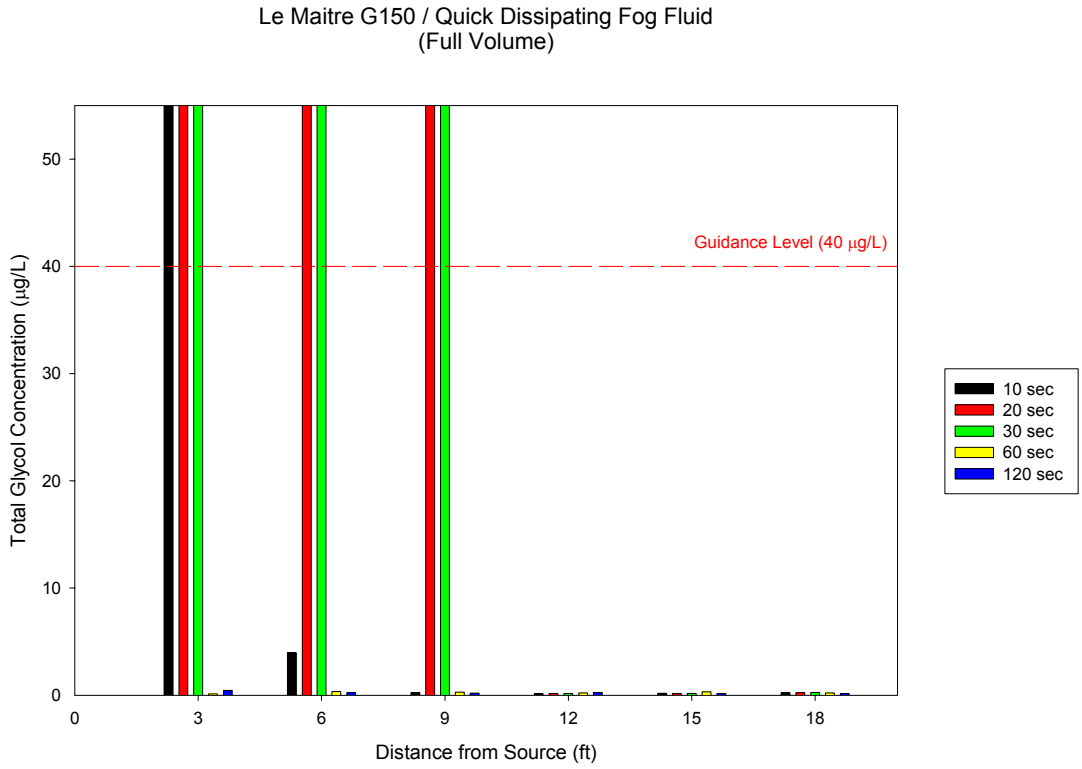

Figure 30. Guidelines for use of Quick Dissipating Fog Fluid in Le Maitre G150 smoke machine at a full volume setting.

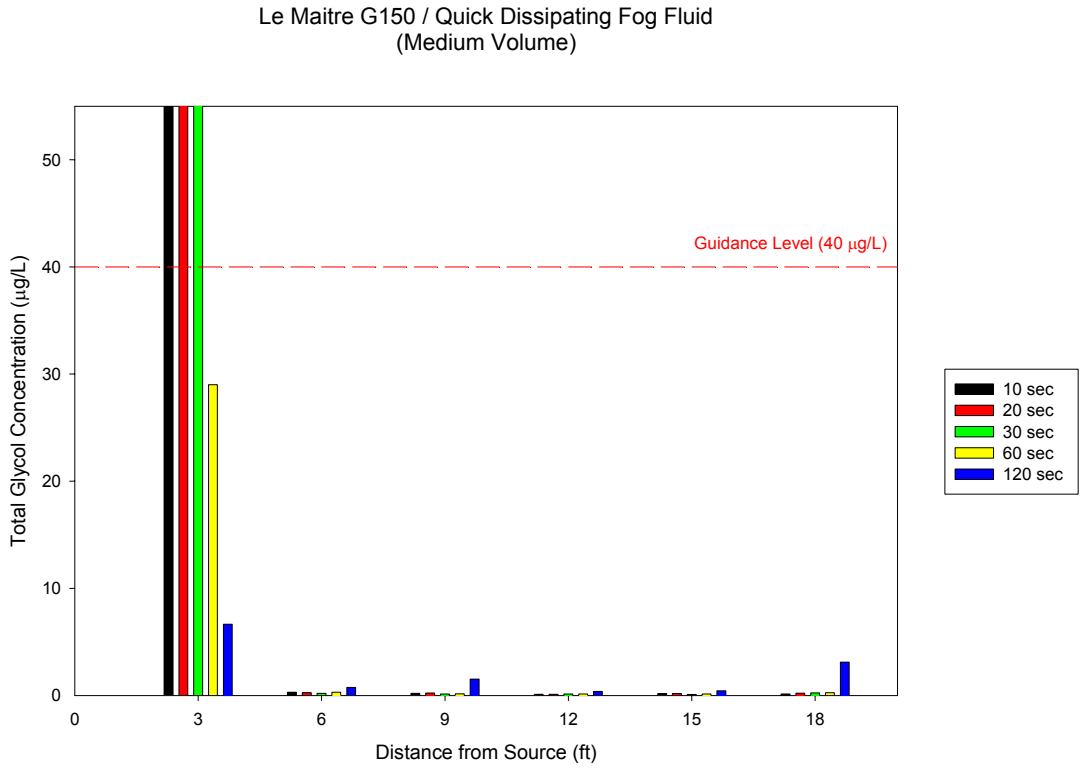

Figure 31. Guidelines for use of Quick Dissipating Fog Fluid in Le Maitre G150 smoke machine at a medium volume setting.

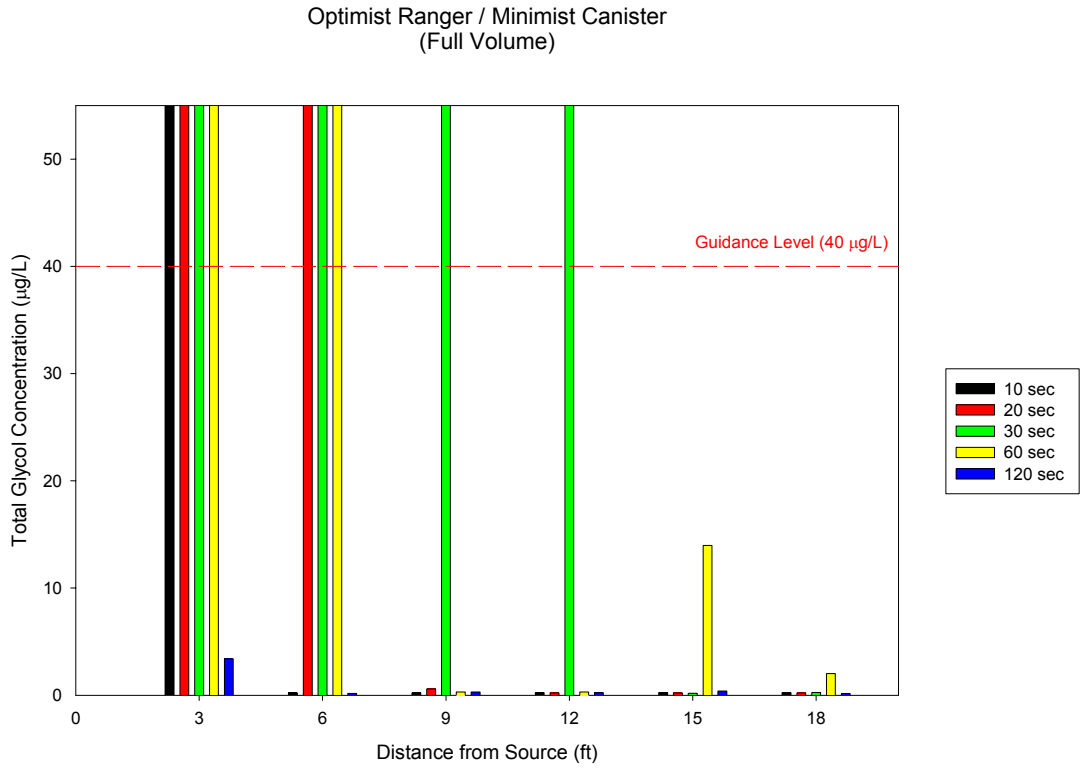

Figure 32. Guidelines for use of Minimist Canisters in Le Maitre Opti Mist Ranger smoke machine at a full volume setting.

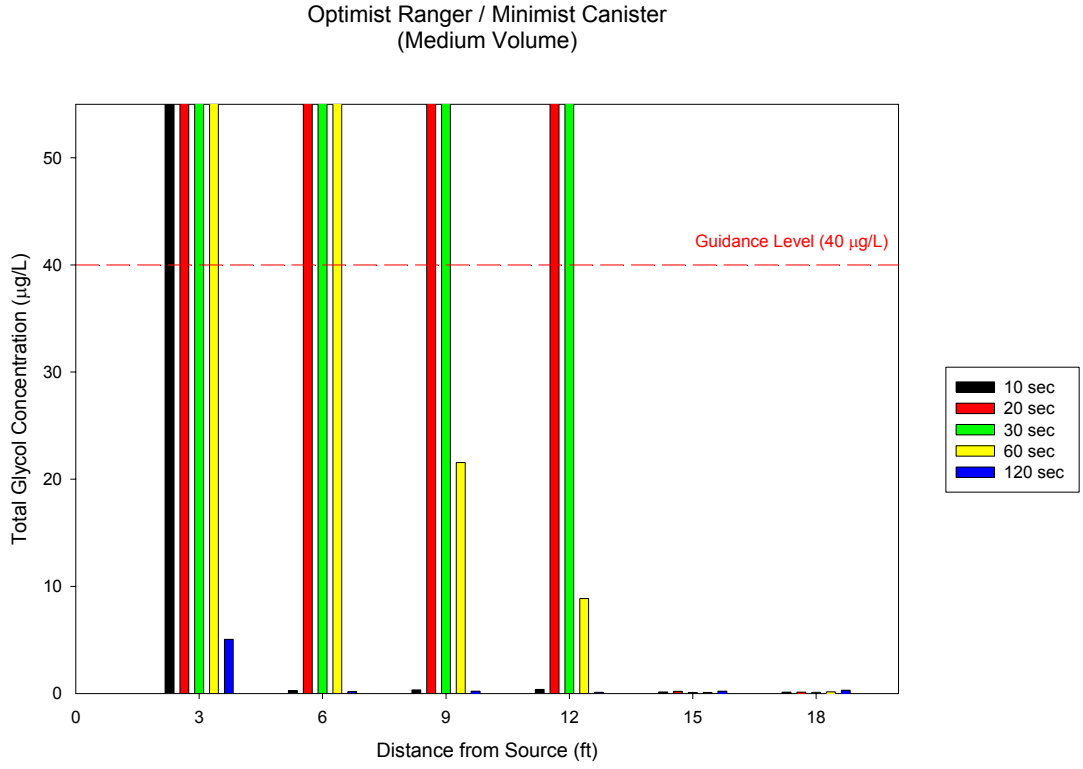

Figure 33. Guidelines for use of Minimist Canisters in Le Maitre Opti Mist Ranger smoke machine at a medium volume setting.

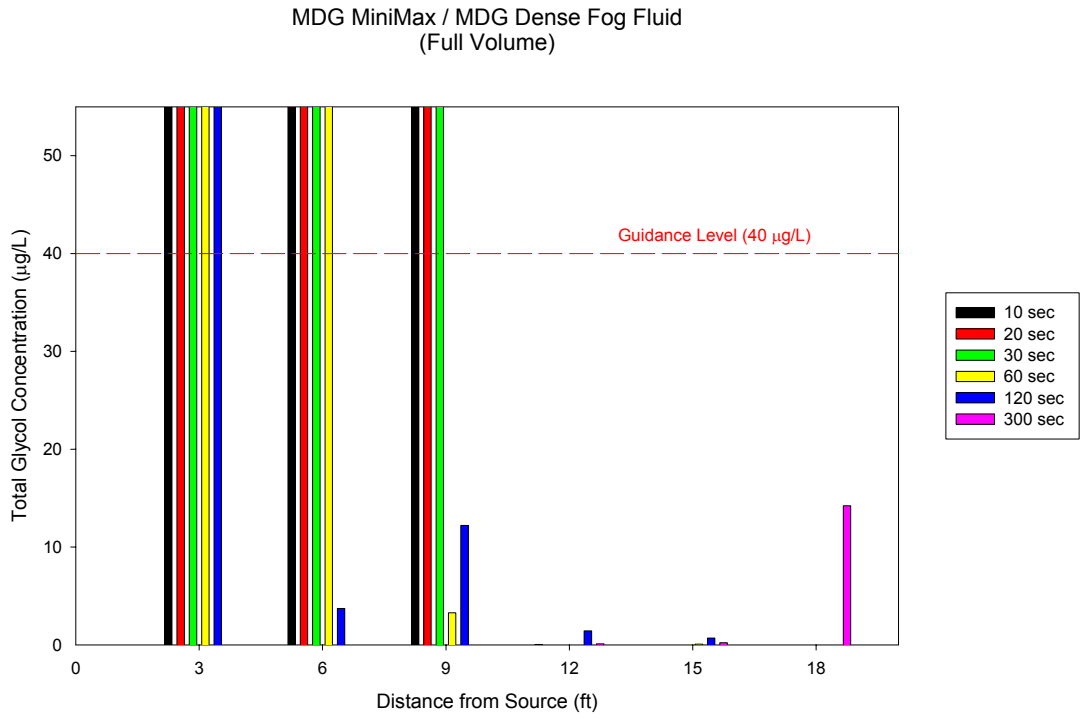

Figure 34. Guidelines for use of Dense Fog Fluid in MDG MiniMax smoke machine at a full volume setting.

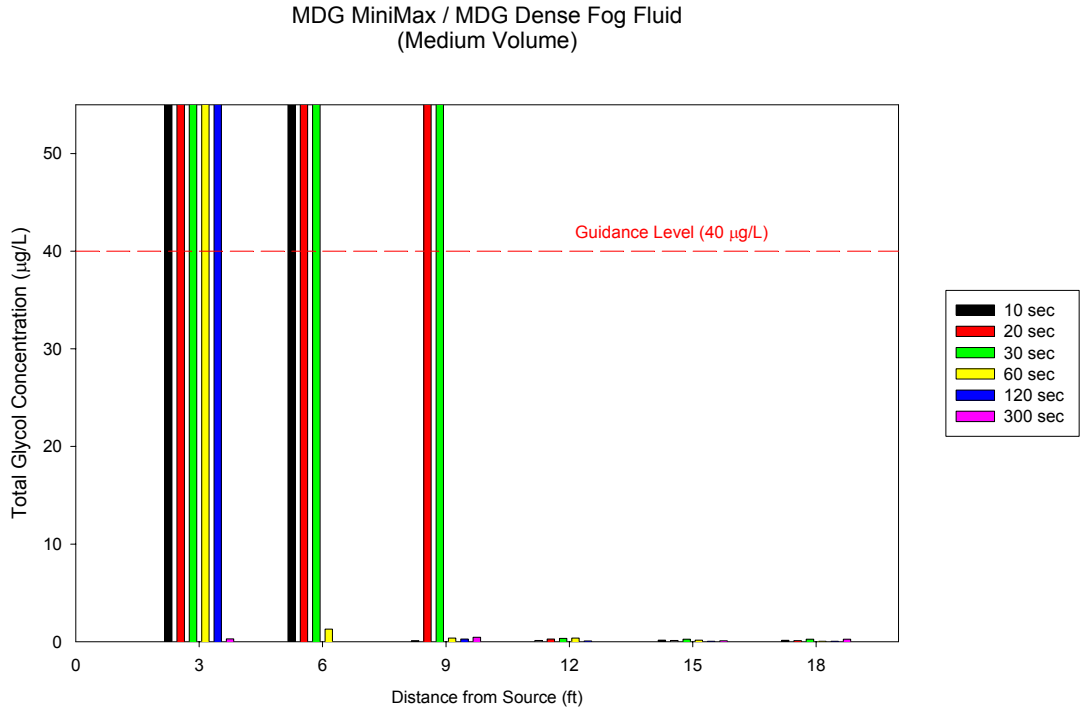

Figure 35. Guidelines for use of Dense Fog Fluid in MDG MiniMax smoke machine at a medium volume setting.

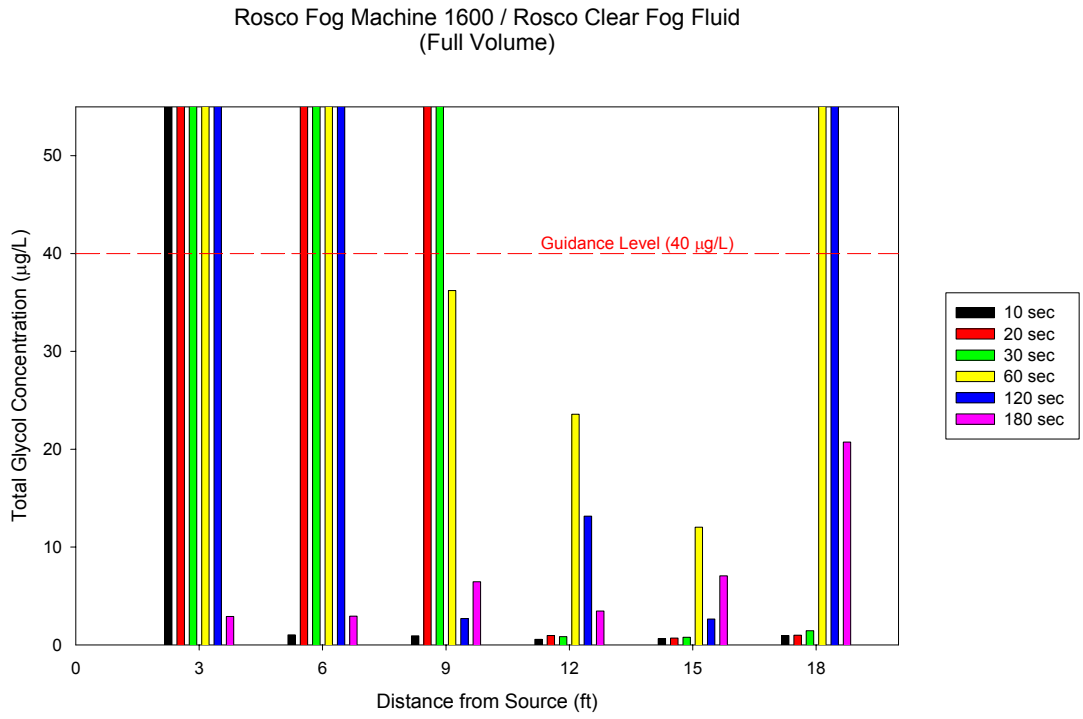

Figure 36. Guidelines for use of Clear Fog Fluid in Rosco 1600 smoke machine at a full volume setting.

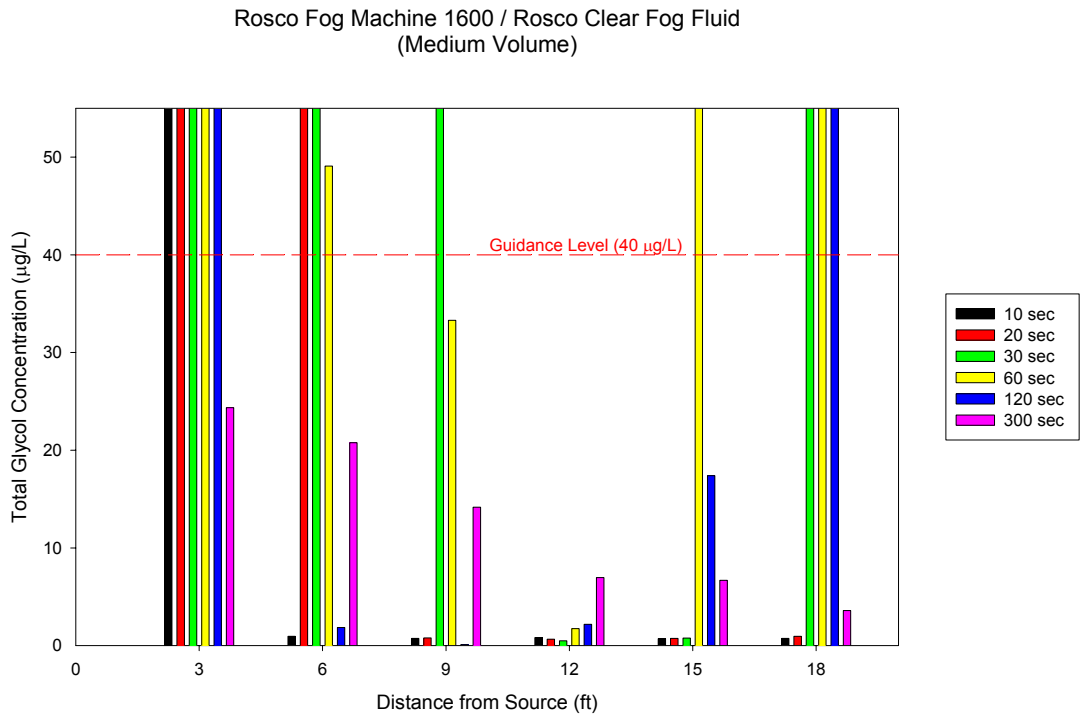

Figure 37. Guidelines for use of Clear Fog Fluid in Rosco 1600 smoke machine at a medium volume setting.

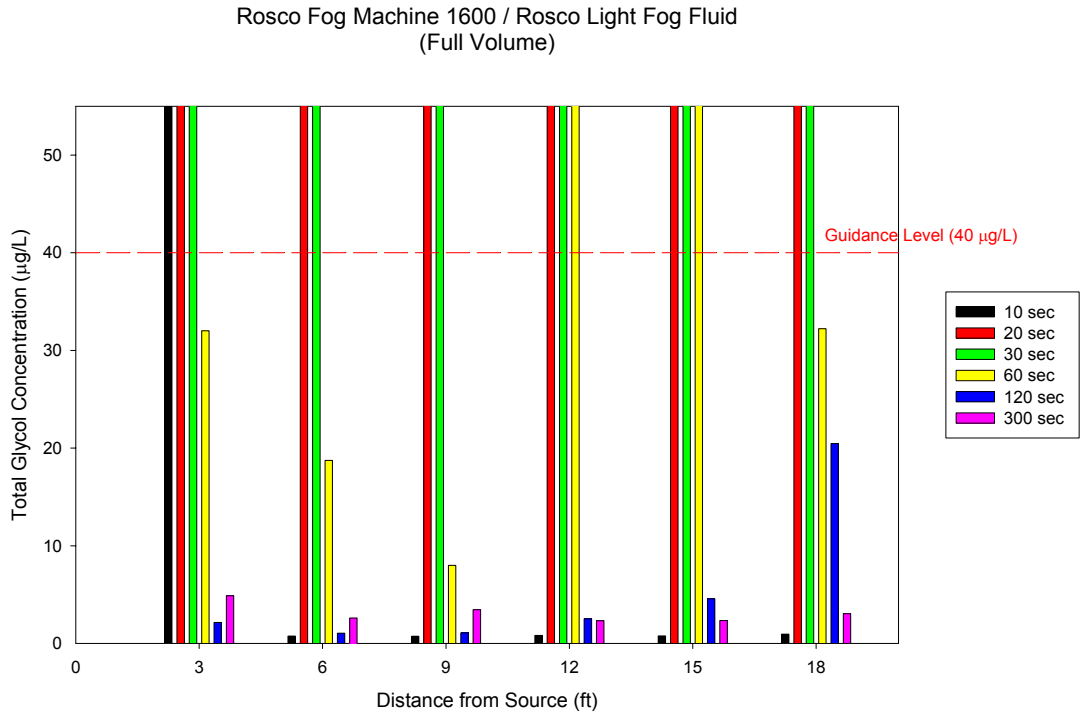

Figure 38. Guidelines for use of Light Fog Fluid in Rosco 1600 smoke machine at a full volume setting.

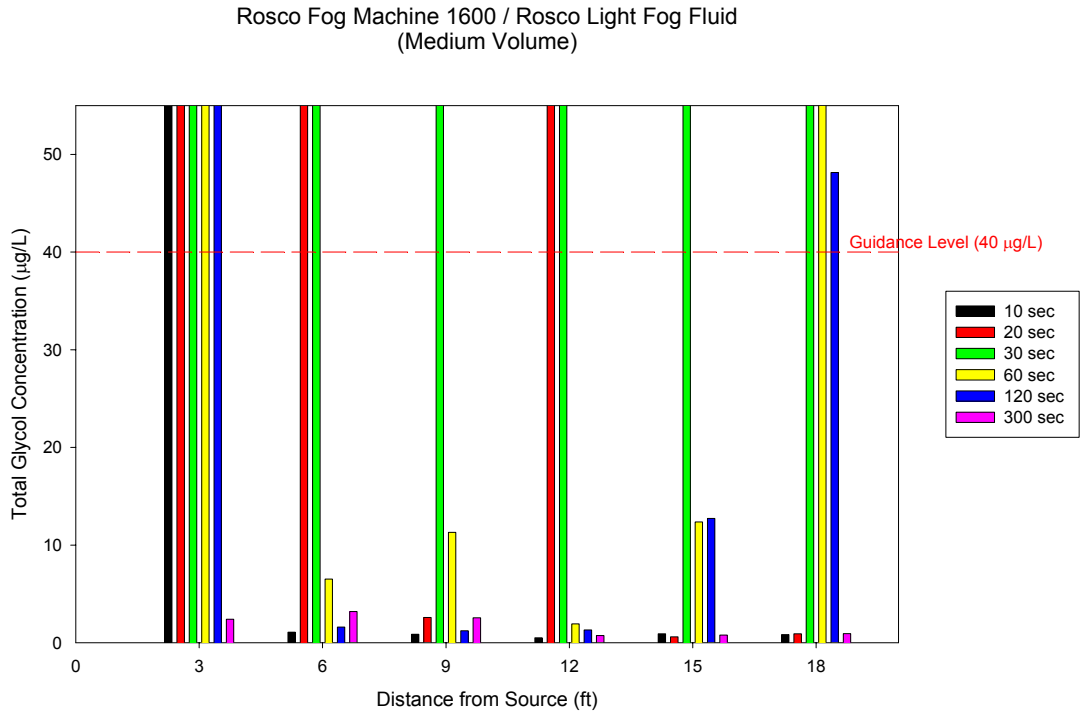

Figure 39. Guidelines for use of Light Fog Fluid in Rosco 1600 smoke machine at a medium volume setting.

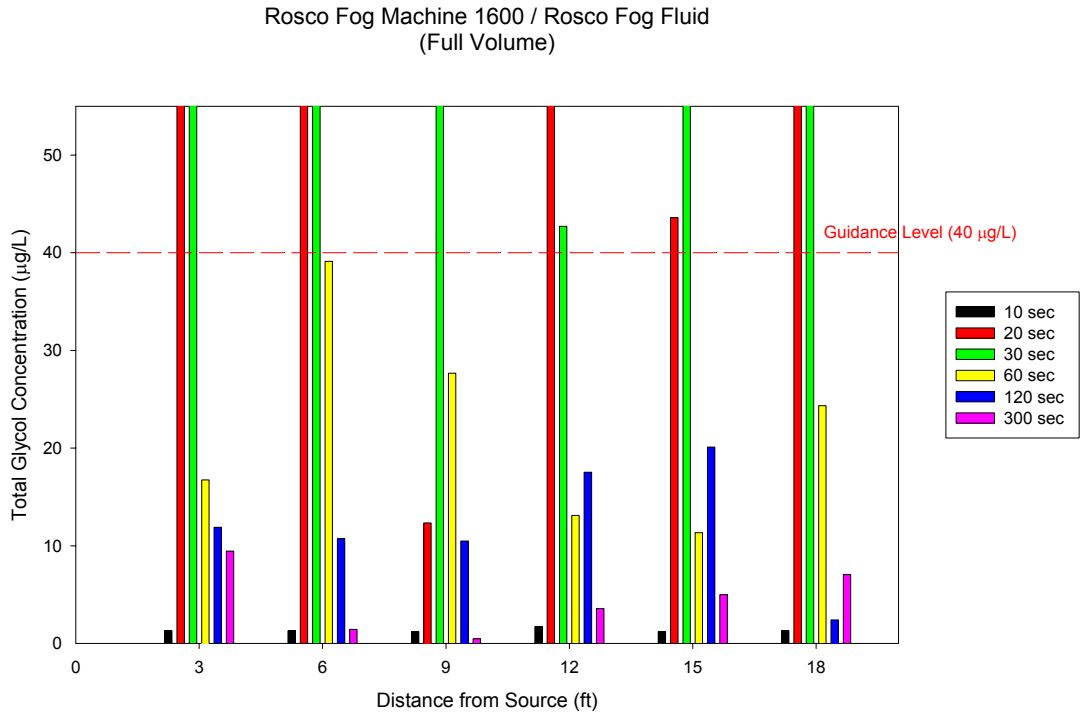

Figure 40. Guidelines for use of Rosco Fog Fluid in Rosco 1600 smoke machine at a full volume setting.

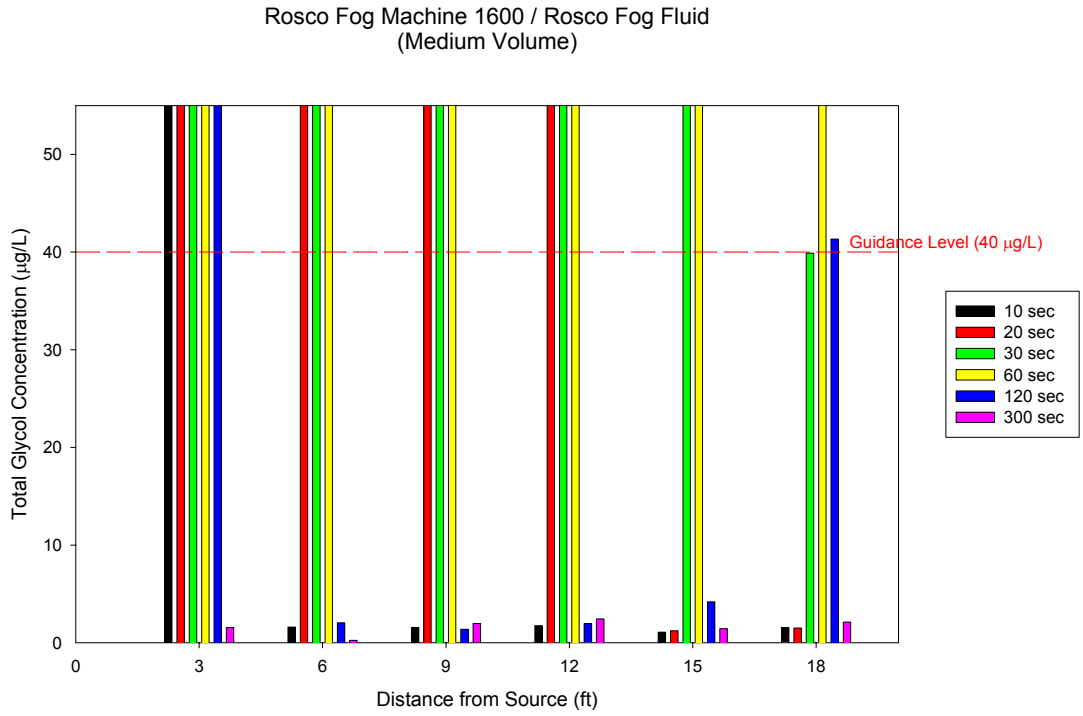

Figure 41. Guidelines for use of Rosco Fog Fluid in Rosco 1600 smoke machine at a medium volume setting.

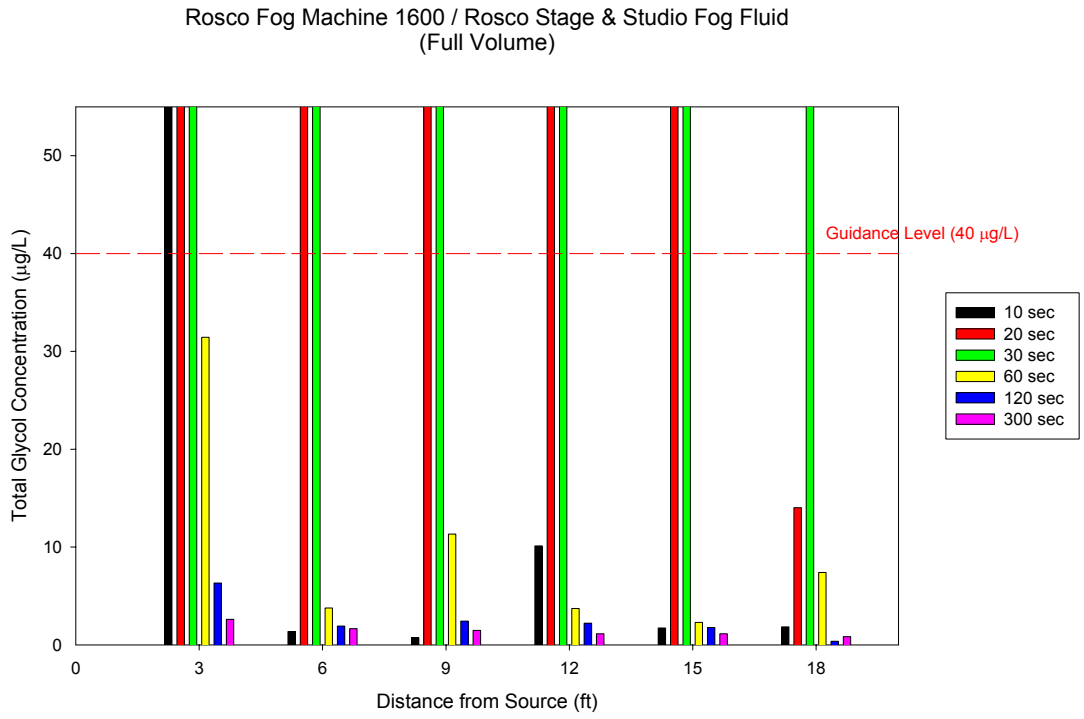

Figure 42. Guidelines for use of Stage and Studio Fog Fluid in Rosco 1600 smoke machine at a full volume setting.

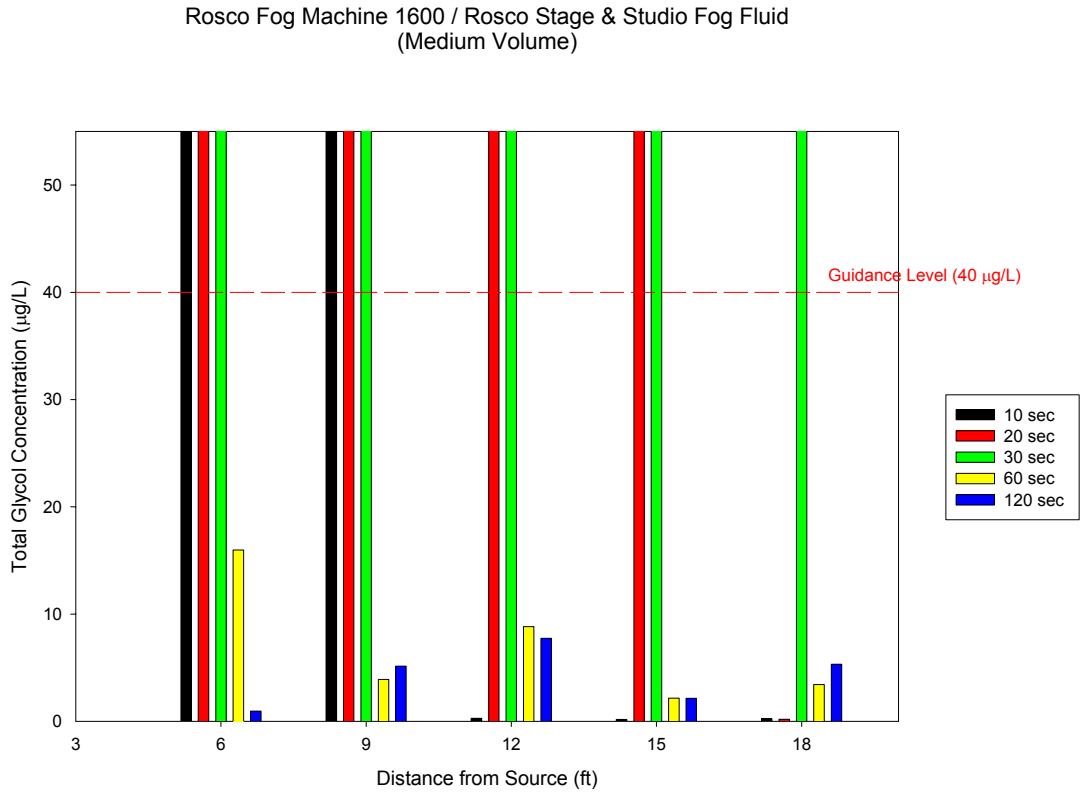

Figure 43. Guidelines for use of Stage and Studio Fog Fluid in Rosco 1600 smoke machine at a medium volume setting.

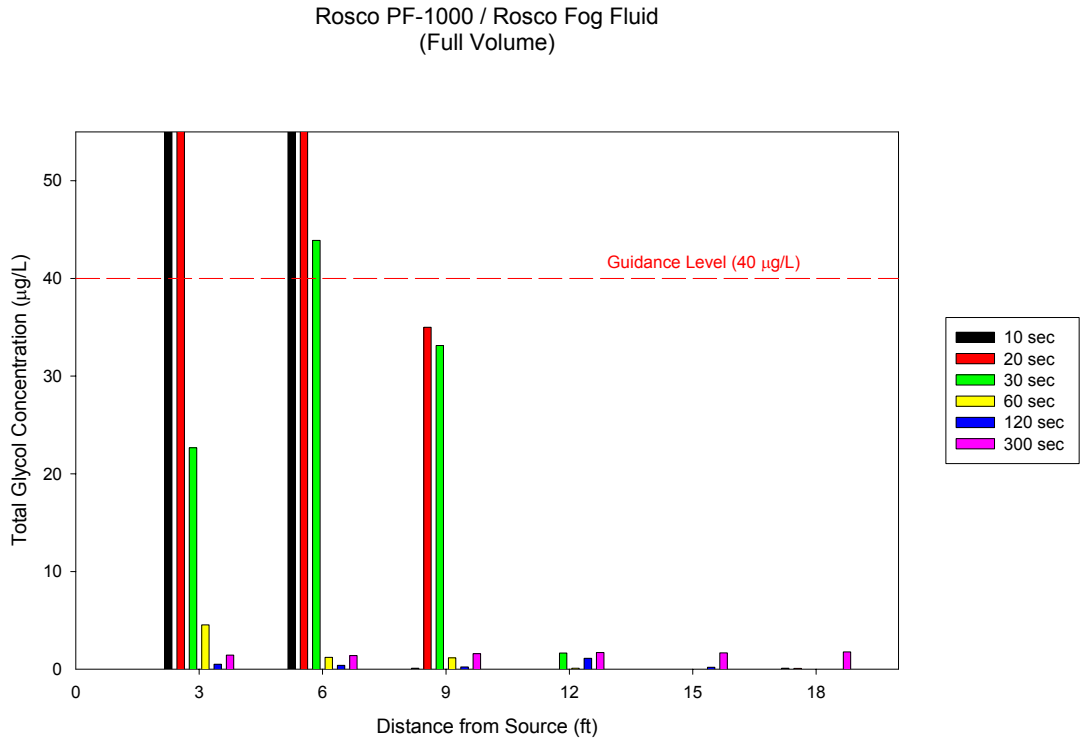

Figure 44. Guidelines for use of Rosco Fog Fluid in Rosco PF-1000 smoke machine at a full volume setting.

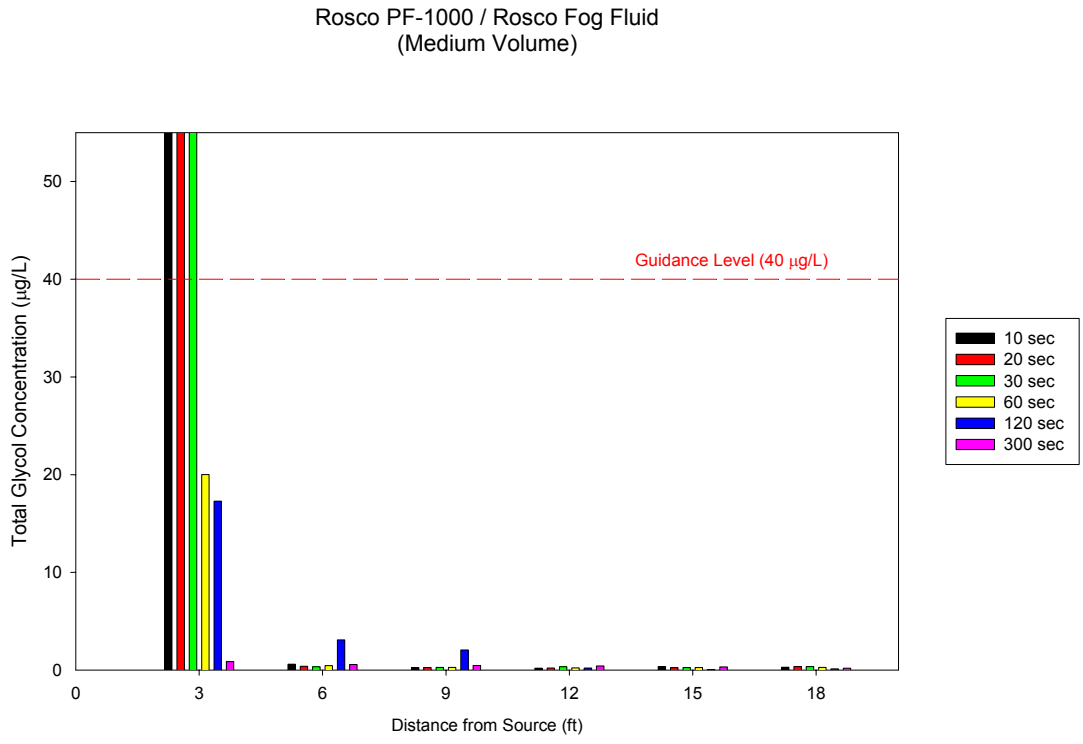

Figure 45. Guidelines for use of Rosco Fog Fluid in Rosco PF-1000 smoke machine at a medium volume setting.

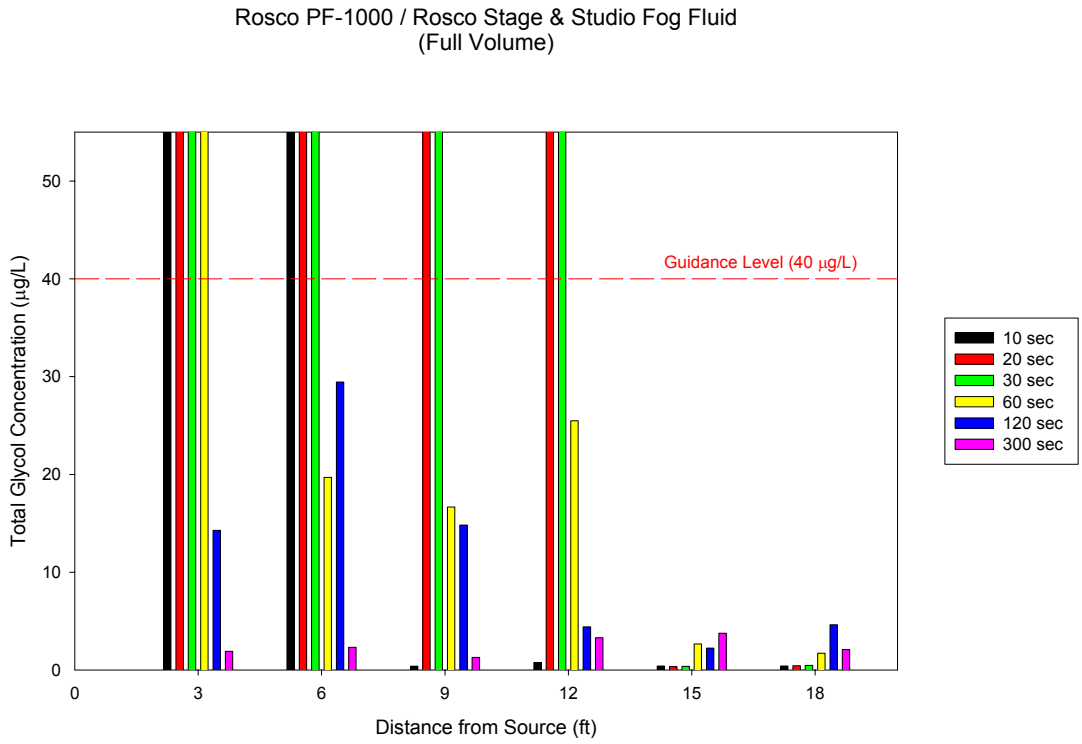

Figure 46. Guidelines for use of Stage and Studio Fog Fluid in Rosco PF-1000 smoke machine at a full volume setting.

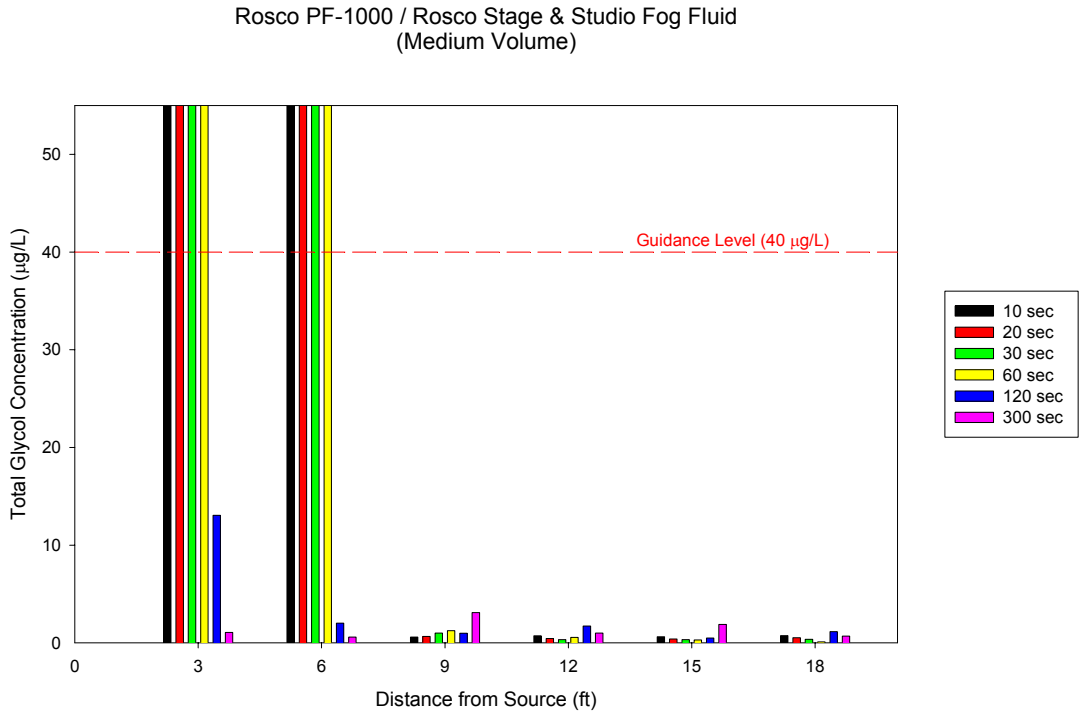

Figure 47. Guidelines for use of Stage and Studio Fog Fluid in Rosco PF-1000 smoke machine at a full volume setting.

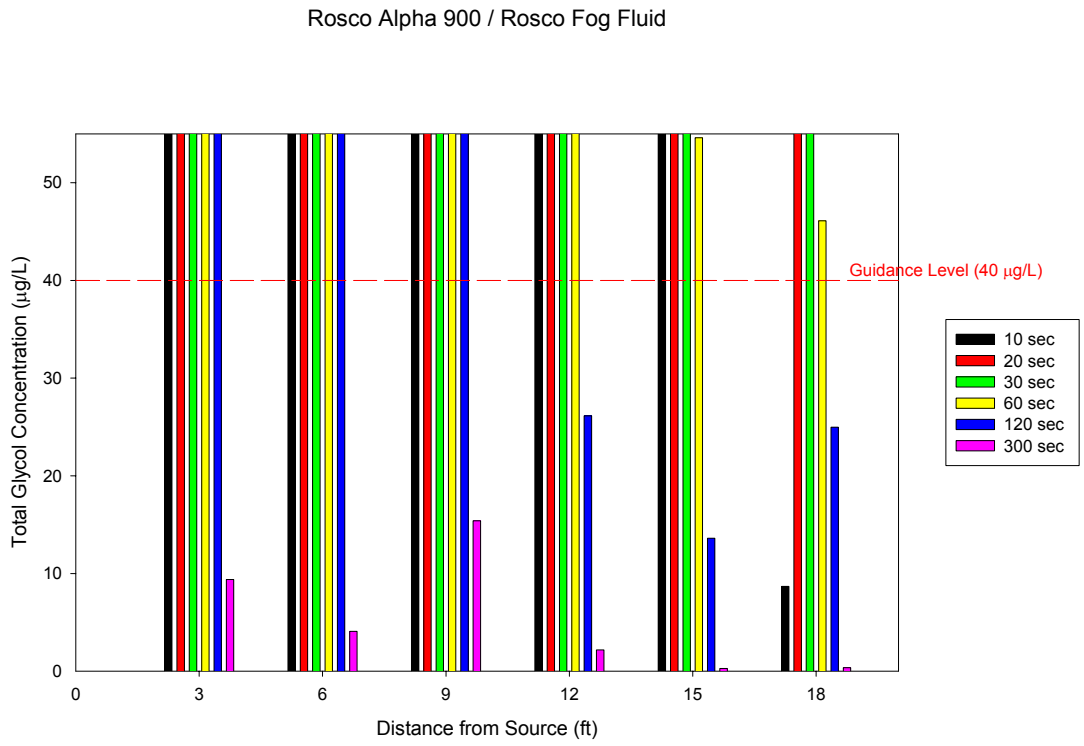

Figure 48. Guidelines for use of Rosco Fog Fluid in Rosco Alpha 900 smoke machine.

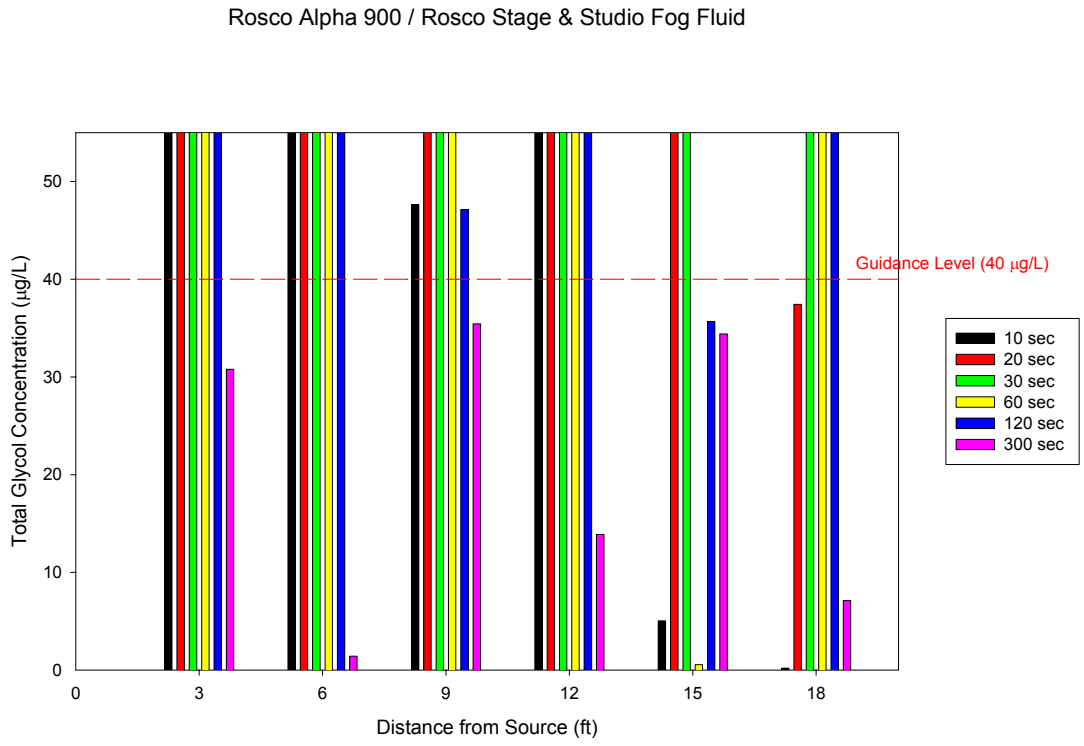

Figure 49. Guidelines for use of Stage and Studio Fog Fluid in Rosco Alpha 900 smoke machine.

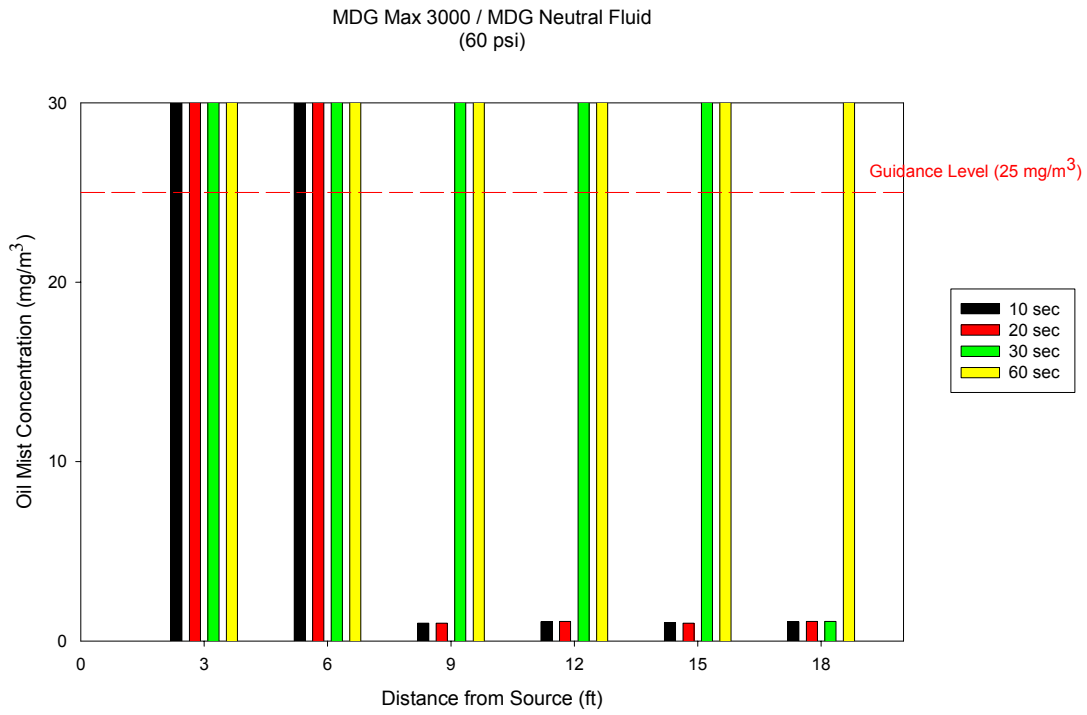

Figure 50. Guidelines for use of Neutral Fluid in MDG MAX 3000 haze machine.

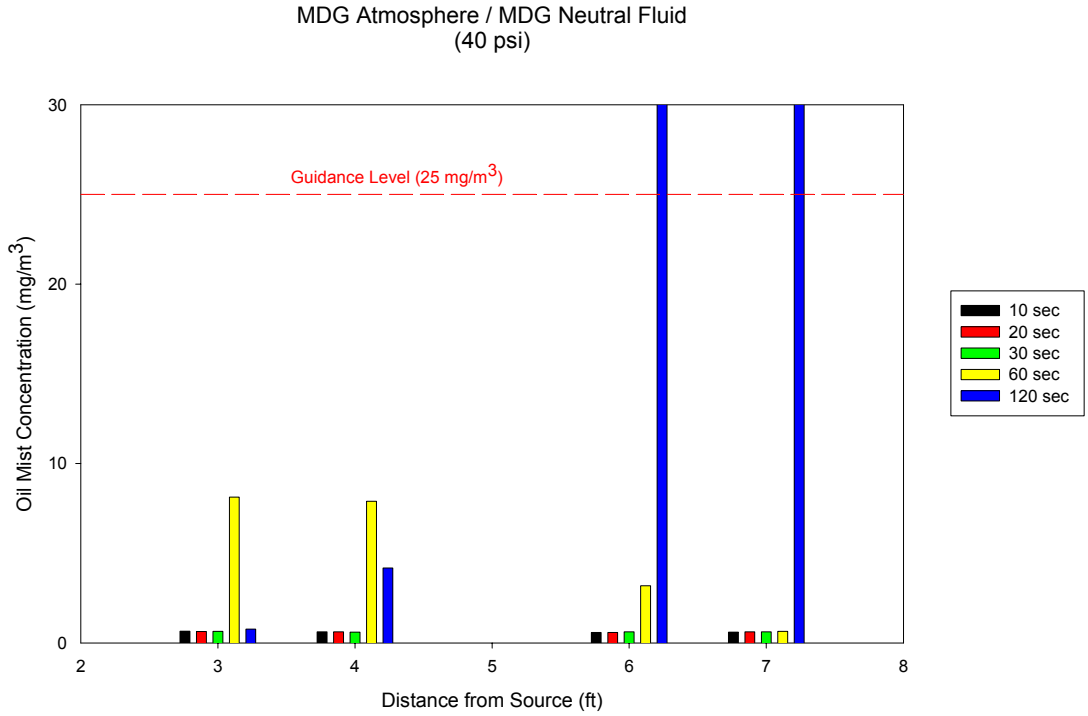

Figure 51. Guidelines for use of Neutral Fluid in MDG Atmosphere haze machine.

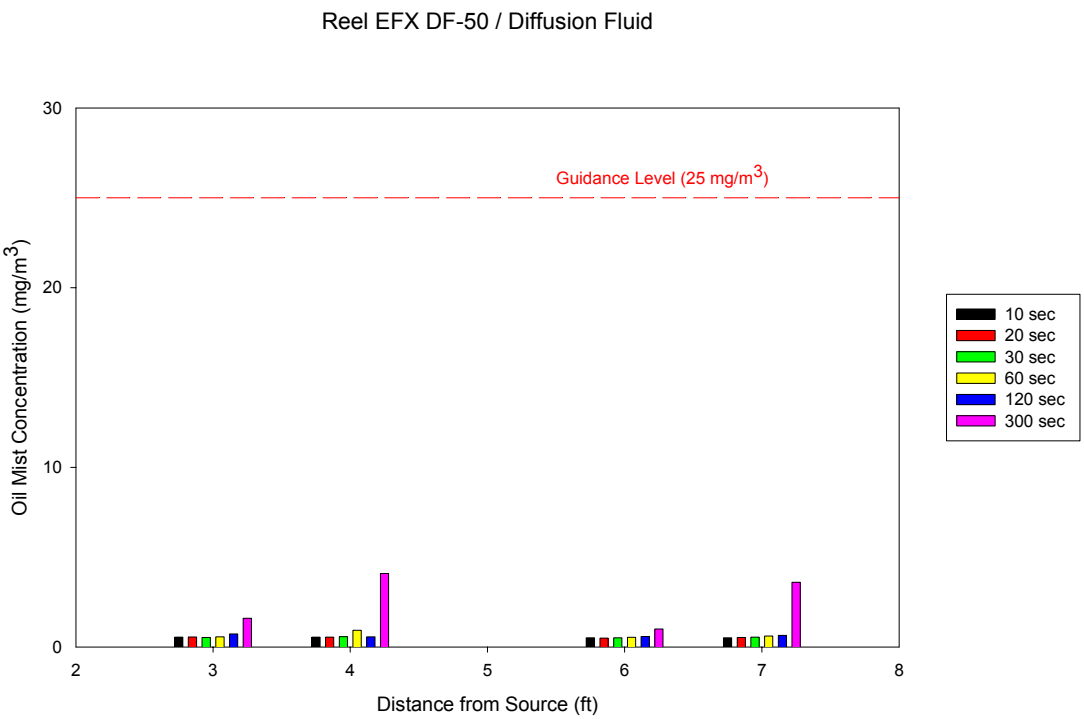

Figure 52. Guidelines for use of Diffusion Fluid in Reel EFX DF-50 haze machine.

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