United States
Environmental Protection
Agency

Environmental Sciences
Research Laboratory
Research Triangle Park NC 27711

Research and Development

EPA-600/S3-84-093 Nov. 1984

EPA

Project Summary

Evaluation of Trained Visible Emission Observers for Fugitive Emission Opacity Measurement

Thomas H. Rose

The stack of a visible emission training school smoke generator was modified to emit white or black smoke in a horizontal direction near ground-level to simulate fugitive emissions. Trained smoke observers measured the opacity of these simulated fugitive emissions against a dark terrestrial background and under clear sky lighting conditions. They measured both black and white emissions generated at four different opacities--15, 20, 30, and 40%. The observers also measured the same opacity of smoke plumes emitted from an unmodified training school smoke generator. These vertical-flow smokestack plumes were evaluated against a sky background to provide reference data on the observers ability to measure the opacity of conventional stack plumes under the same clear sky lighting conditions used for the fugitive plume tests.

The observers measured opacities of white fugitive emissions with accuracies similar to the conventional stack emissions when opacities were in the range of 15 to 20%. As opacity increased, however, the observers increasingly underestimated opacity. At 40% opacity, observer measurements were lower on average by about 8% opacity. The opacities of black fugitive emissions were underestimated at all opacity levels. Opacity was lower on average by 5% opacity at the 15% opacity level and by 11% opacity at the 40% opacity level. It was also observed that for both black and white simulated fugitive emission plumes, the observers sensitivity to changes in opacity levels declined relative to the conventional vertical stack plumes.

This Project Summary was developed by EPA's Environmental Sciences Research Laboratory, Research Triangle Park, NC, to announce key findings of the research project that is fully documented in a separate report of the same title (see Project Report ordering information at back).

Introduction

Many types of airborne particulates and aerosols are not emitted from conventional vertical stacks. Instead, these emissions may come from windows, roof monitors, vents, conveyor belts, hoppers, storage piles, construction sites, roads, and a variety of other sources. Often these unconfined emissions originate close to the ground and move with the wind in a horizontal direction. Unlike conventional smokestack plumes that are viewed against the sky, these emissions are usually viewed against a darker terrestrial background. This study was designed to determine the biases, if any, introduced when certified Method 9 smoke observers measure opacities of horizontal-flow, ground-level emissions

Experimental Design

Smoke Generators

Two smoke generators were used Both generators were originally designed for training smoke observers, however, for the study one was modified to provide horizontal emissions near ground level This was achieved by raising the stack only partially to a horizontal position and

placing an elbow between the lower vertical stack element and the upper horizontal stack element The elbow was caulked and shimmed to prevent leaks. This method of generating horizontal emissions was selected after it was determined that the plume would remain uniform in both vertical and horizontal axes through the transmissometer and at the emission point. The determination consisted of viewing the white plume against a black velvet background at close range and the black plume against a white background The appearances of both plumes were uniform along both axes To further simulate the fugitive nature of horizontal emissions, a 12-inch-wide board was used to block an observer's view of the stack end

The other smoke generator was set up in the conventional manner, with the stack upright to emit a vertical plume

Observers

The observers selected for the study were six inspectors from a state agency and two air pollution personnel from local contractors Each participant possessed a current Method 9 certification and a past record of accurate smoke reading, as evidenced by his ability to certify promptly at a smoke school. The Method 9 certification procedure is described in the Federal Register. The participants ranged in age from 26 to 38 years old, with an average age of 31. Three possessed college degrees, three had associate degrees, and the other two had some education beyond high school. Their experience at reading visible emissions ranged from one to eight years, with an average of 4.1 years.

Observer Tests

Both black and white simulated (horizontal-flow) fugitive emissions were measured under clear sky conditions. Black and white conventional (vertical-flow) plumes were also measured under clear sky conditions to confirm the observers' abilities to assign unbiased opacity values to conventional plumes.

The opacity levels selected for the study were 40, 30, 20, and 15 percent. For each opacity level, the observers were required to read for 12 minutes. Within that 12-minute period there was a period of just over six minutes of steady opacity smoke. The average of 24 consecutive readings by an observer during this six-minute period was the EPA Method 9 evaluation of the smoke opacity. The observers were shown the same opacity levels from each generator but in random order. They were given no review of emission opacities prior to testing and were given no instructions except how to complete the test form and to read on signal. Smoke opacity measurements were recorded on computer compatible data forms in bound books. The observers were instructed by a pre-recorded tape to read at 15-second intervals to assure Method 9 compatibility and standardization of the time reference. At the same time, the data logger made a reference mark on the transmissometer strip chart record.

Results

To observe the effect smoke color and mode of emission had upon the observers, opacity measurements were plotted against actual transmissometer values. A slope of 1.00 would show equal sensitivity between observer and transmissometer to opacity changes.

Panel (averaged observer) opa measurements of conventional s plumes (white and black), under blue conditions and observed against a background, agreed closely w transmissometer opacity measureme over the range of opacity levels. Slope 1.17 and 1.01 were calculated for white and black smoke, respectiv Thus, the observers showed on aver an ability to correctly measure the opa of normal plumes with little bias.

Measurements of simulated (horiz tal-flow) fugitive emissions for wl plumes on a clear day (Figure 1) revea no systematic difference (bias) betwe observers and transmissometer readi for opacities around 15-20%. At hig opacities, however, an increas negative observer bias was seen (Fig 1). At 40% opacity, this bias resultec observer panel readings around opacity lower than transmissome values. For black emission lower obser

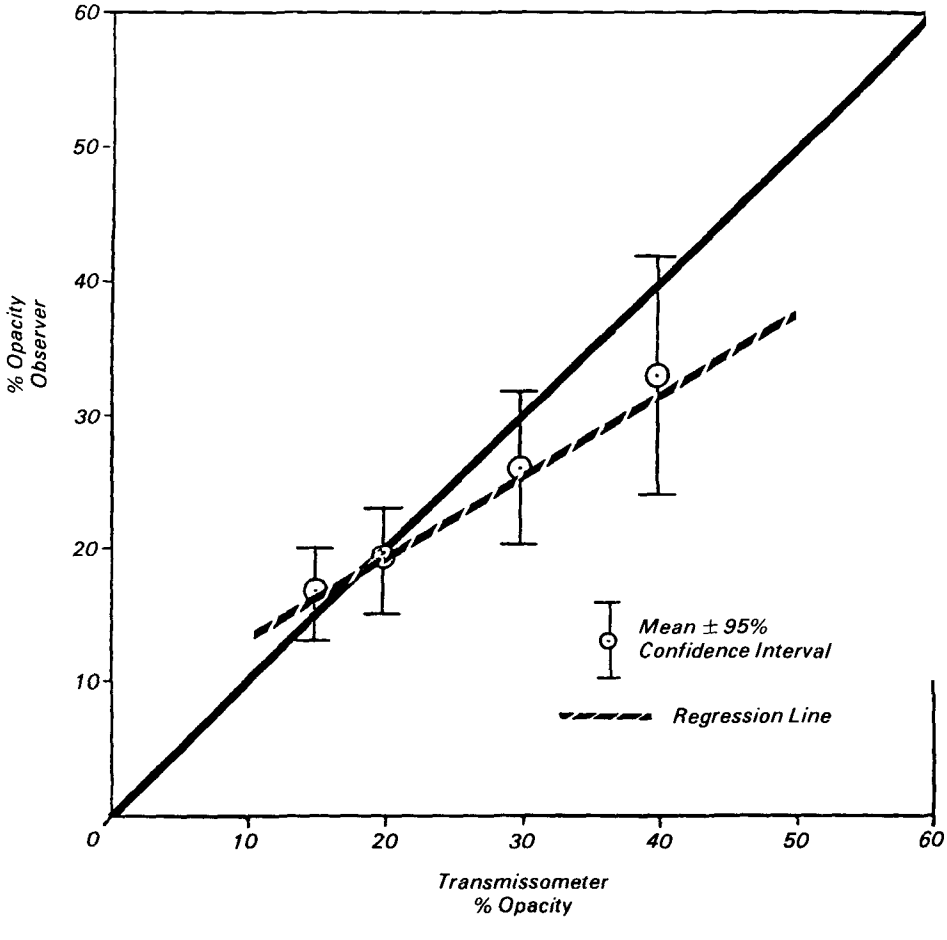

Figure 1. *Observer opacity evaluations versus transmissometer measured opacities o simulated white fugitive plumes viewed against a terrestrial background on a clea day.*

panel measurements were seen at all opacity levels (Figure 2). At 15% opacity, measurements were 5% opacity low; at 40% opacity, they were 11% opacity low. Overall, observer sensitivity to opacity changes, as evidenced by the slopes of the curves, declined for both the white and black (horizontal-flow) fugitive plumes. The change in observer measured per change in transmissometer measured opacities declined from near 1.0 for the conventional (vertical-flow) plume measurements to 0.62 and 0.77 for the white and black simulated (horizontal-flow) fugitive plume measurements, respectively.

Conclusions and Recommendations

The panel of smoke observers measured the opacities of simulated white (horizontal-flow) fugitive emissions with accuracies similar to (vertical-flow) plume opacity measurements when opacity levels were around 15-20%. As opacities increased, however, the panel increasingly underestimated them. They were lower on average by about 8% opacity at the 40% opacity level.

Opacity measurements for black fugitive emissions were underestimated at all opacity levels. At 15% opacity, the observers measured the simulated fugitive emissions 5% opacity low, and at 40% opacity they measured them 11% opacity low.

Observer panel sensitivity to opacity changes was less for simulated (horizontal-flow) fugitive emissions than for conventional smokestack plumes. The change in panel opacity measurement per change in transmissometer opacity measurement declined from near 1.00 for the conventional smokestack plumes to 0.62 and 0.77 for the white and black (horizontal-flow) fugitive plumes, respectively.

It is recommended that controlled tests of observer and transmissometer opacity measurements of simulated black and white fugitive emissions be conducted for other environmental lighting conditions, e.g., on an overcast day. It is also recommended that a lower opacity level around 5 or 10% be included in the tests.

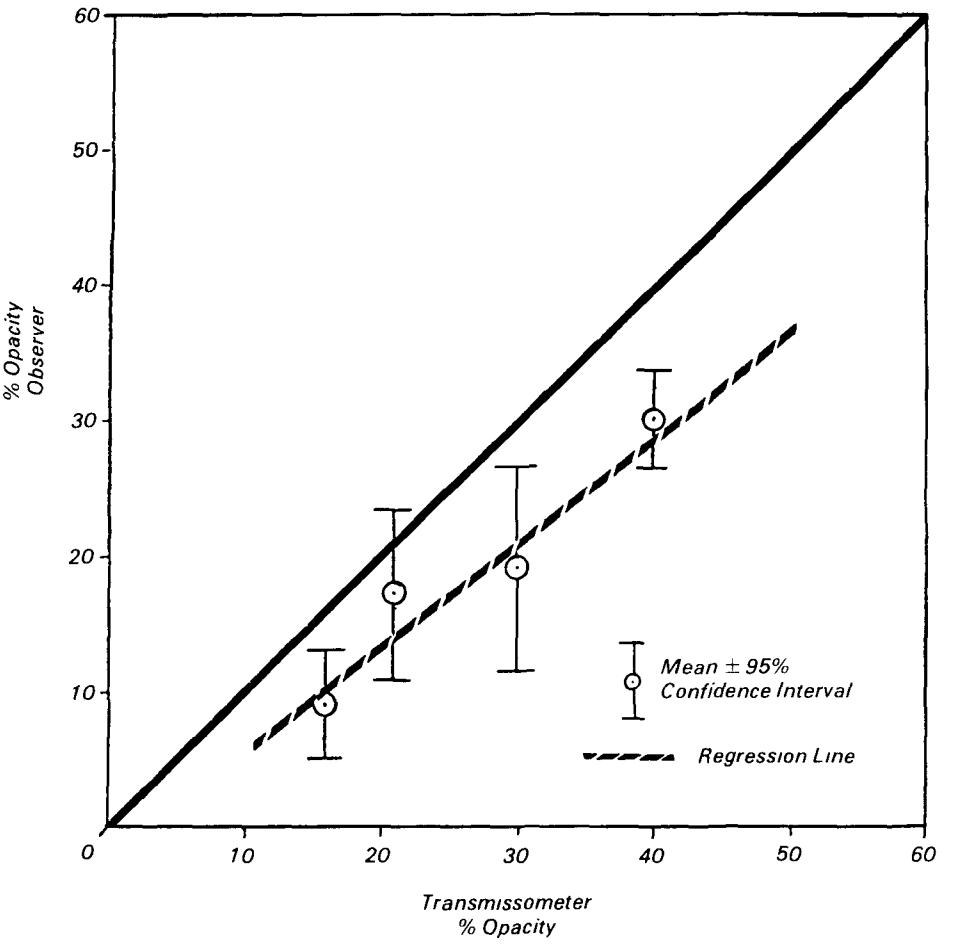

Figure 2. Observer opacity evaluations versus transmissometer measured opacities of simulated black fugitive plumes viewed against a terrestrial background on a clear day.

Thomas H. Rose is with Eastern Technical Associates, Raleigh, NC 27658.
***William D. Conner** is the EPA Project Officer (see below).*
The complete report, entitled "Evaluation of Trained Visible Emission Observers for Fugitive Emission Opacity Measurement," (Order No. PB 85-115 152, Cost: $8.50, subject to change) will be available only from:
National Technical Information Service
5285 Port Royal Road
Springfield, VA 22161
Telephone: 703-487-4650
The EPA Project Officer can be contacted at:
Environmental Sciences Research Laboratory
U.S. Environmental Protection Agency
Research Triangle Park, NC 27711

☆ U.S GOVERNMENT PRINTING OFFICE, 1984 — 559-016/7860