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VISIBLE EMISSIONS FIELD MANUAL

EPA Methods 9 and 22

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Visible Emissions Field Manual EPA Methods 9 and 22

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Contents

Introduction

The Federal opacity standards for various industries are found in 40CFR Part 60 (Standards of Performance for New and Modified Stationary Sources) and 40 CFR Part 61 and 62 (Emission Standards for Hazardous Air Pollutants). These standards require the use of Reference Method 9 or Reference Method 22, contained in Appendix A of Part 60, for the determination of the level or frequency of visible emissions by trained observers.

In addition to the plume observation procedures, Method 9 also contains data reduction and reporting procedures as well as procedures and specifications for training and certifying qualified visible emission (VE) observers.

State Implementation Plans (SIPs) also typically include several types of opacity regulations, which in some cases may differ from the federal opacity standards in terms of the opacity limits, the measurement method or test procedure, or the data evaluation technique. For example, some SIP opacity rules limit visible emissions to a specified number of minutes per hour or other time period (time exemption); some limit opacity to a certain level averaged over a specified number of minutes (time averaged); some set opacity limits where no single reading can exceed the standard (instantanous or "cap"). Regardless of the exact format of the SIP opacity regulations, nearly all use the procedures in Method 9 for conducting VE field observations and for training and certifying VE observers. The observation procedures contain instructions on how to read the plume and record the values, including where to stand to observe the plume and what information must be gathered to support the visible emission determinations. The validity of the VE determinations used for compliance or noncompliance demonstration purposes depends to a great extent on how well the field observations are documented on the VE Observation Form. This field manual will stress the type and extent of documentation needed to satisfy Method 9 requirements.

FEDERAL AND STATE OPACITY STANDARDS ARE INDEPENDENTLY ENFORCEABLE AND SERVE AS A PRIMARY COMPLIANCE SURVEILLANCE TOOL

Federal opacity standards and most SIP opacity regulations are independently enforceable, i.e., a source may be cited for an opacity violation even when it is in compliance with the particulate mass standard. Thus, visible emission observations by qualified agency observers serve as a primary compliance surveillance tool for enforcement of emission control standards. In addition, many federal and SIP regulations and construction and operating permits also require owners/operators of affected facilities to assess and report opacity data during the initial compliance tests and at specified intervals over the long term.

A NSPS OR SIP OPACITY VIOLATION CAN RESULT IN A FINE OF $10,000 TO $25,000

Regulated sources may be subject to stiff penalties for failure to comply with federal and state emission standards, including opacity standards. Civil and administrative penalties of up to $25,000 per day per violation can be assessed under the Clean Air Act (CAA). States and local agencies are encouraged under Title V of the CAA to have program authority to levy fines up to $10,000 per day per violation. Therefore, visible emission determinations for compliance demonstration or enforcement purposes must be made accurately and must be sufficiently well documented to withstand rigorous examination in potential enforcement proceedings, administrative or legal hearings, or eventual court litigation.

Procedural errors or omissions on the visible emission evaluation forms or data sheets can invalidate the data or otherwise provide a basis for questioning the evaluation. Only by carefully following the procedures set forth in Method 9 (or any other reference method) and by paying close attention to proper completion of the VE Observation Form can you be assured of acceptance of the evaluation data.

The purpose of this simplified manual is to present a step-by-step field guide for inexperienced VE observers who have recently completed the VE training and certification tests on how to conduct VE observations in accordance with the published opacity methods. The basic steps of a well-planned and properly performed VE inspection are illustrated in the inspection flow chart (see Figure 1). This manual is organized to follow the inspection flow chart. Sections of the reference methods that must be carefully observed or followed during the inspection are highlighted. Method 9 and Method 22 are reprinted in full in Appendix B and Appendix C respectively. A recommended field VE Observation Form, included in Appendix A, may be copied or modified for field use.

It should be noted that much of the information presented in this simplified field manual has been derived from a number of previously published technical guides, manuals, and reports on Method 9 and related opacity

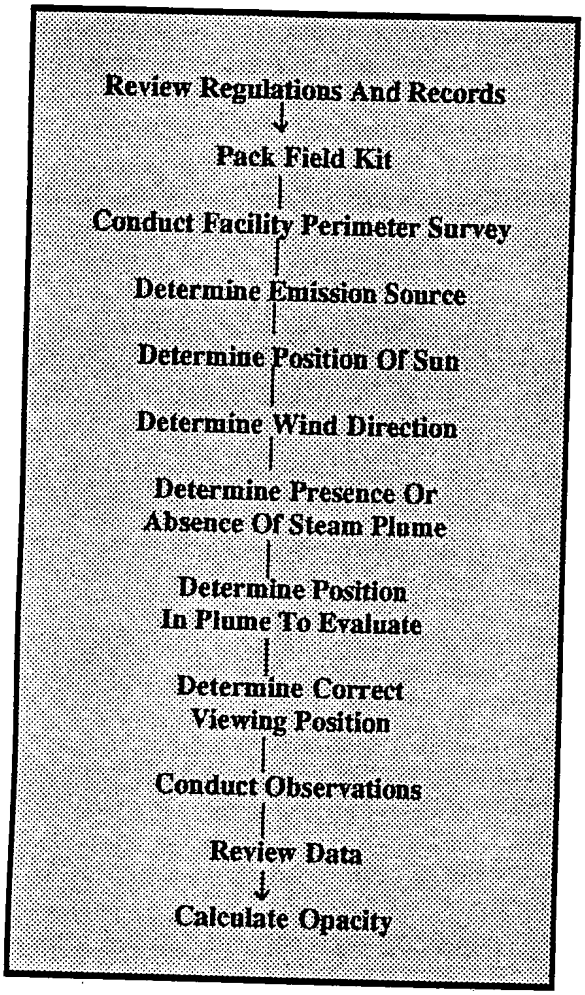


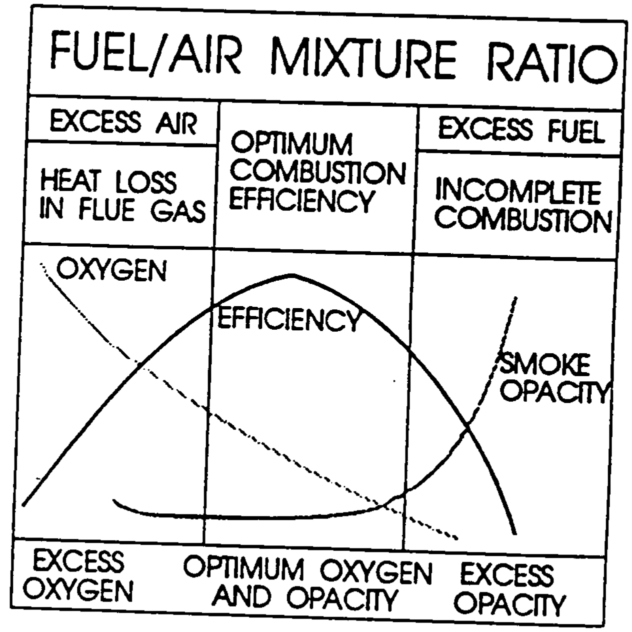
Figure 1. VE Inspection Flow Chart

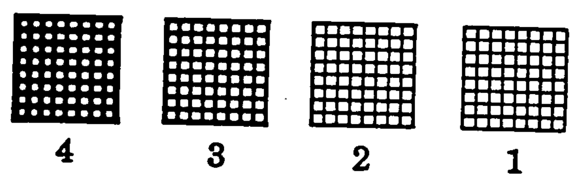
methods. For more detailed information on Method 9 and the application of Method 9, please consult the list of publications at the end of this manual.

A Brief History Of Opacity

Early History

The first smoke evaluation system evolved from a concept developed by Maximillian Ringelmann in the late 1800s. Ringelmann realized that black smoke from coal-fired boilers was the result of poor combustion efficiency. Darker smoke meant poorer efficiency, and to measure the darkness of the smoke, Ringelmann devised a chart with four different black grids on a white background. At a distance of at least 50 feet, the grids on the chart appear as shades of gray. By matching the shade of a smoke plume with the apparent shade of a grid on the chart, Ringelmann was able to classify emissions. With this information, he could adjust the fuel-to-air ratio of a furnace to increase efficiency and decrease the smoke. The Ringelmann Chart was adopted and promoted by the U.S. Bureau of Mines in the early 1900s in their efforts to improve coal combustion practices. It has been used extensively ever since by industry and control agencies to assess and control emissions.





Ringelmann Chart

Ringelmann Period

By 1910, many larger municipalities had adopted the Ringelmann Chart into their health and safety regulations in an attempt to control smoke as a nuisance. To prove a violation of a nuisance code, it was necessary to prove that:

- The smoke was dense
- The smoke was a nuisance

Between 1914 and the 1940s, the courts recognized that smoke could be regulated under the police power of the state, and a regulatory agency no longer had to prove that the smoke was a nuisance. The U.S. Surgeon General declared that smoke and other air pollutants were not only a nuisance but a health hazard in 1948 after a series of air-pollution-related deaths in Donora, Pennsylvania. This set the stage for federal regulations and the control of air pollution to protect the public health.

Equivalent Opacity

In the 1950s and 1960s Los Angeles added two major refinements to the use of visible emissions as a tool for controlling particulate emissions. The Ringelmann method was expanded to white and other colors of smoke by the introduction of "equivalent opacity." Equivalent opacity meant that the white smoke was equivalent to a Ringelmann number in its ability to obscure the view of a background. In some states, equivalent opacity is still measured in Ringelmann numbers, whereas in others the 0-to 100-percent scale is used. Also, by training and certifying inspectors using a smoke generator equipped with an opacity meter, regulatory agencies ensured that certified inspectors did not have to carry and use Ringelmann cards.

In 1968, the Federal Air Pollution Control Office published AP-30, Optical Properties and Visual Effects of Smoke-Stack Plumes, describing the accuracy of a smoke reader's observations compared to a transmissometer. AP-30 also discussed the effect on opacity observations when a plume is viewed with the sun in the wrong place relative to the source.

Method 9

The Environmental Protection Agency (EPA) stopped using Ringelmann numbers in the New Source Performance Standards when the revised EPA Method 9 was promulgated in 1974. All NSPS visible emission limits are stated in percent opacity units. Although some state regulations (notably California's) still specify the use of the Ringelmann system for black and gray plumes, the national trend is to read all emissions in percent opacity.

EPA conducted extensive field studies on the accuracy and reliability of the Method 9 opacity evaluation technique when the method was revised and repromulgated in response to industry challenges concerning certain NSPS opacity standards and methods. The studies showed that visible emissions can be assessed accurately by properly trained and certified observers. Two central features of Method 9 involve taking opacity readings of plumes at 15-second intervals and averaging 24 consecutive readings (6 minutes) unless some other time period is specified in the emission standard (some NSPS specify a 3-minute averaging period).

Plume opacity emission standards and requirements remain the mainstay of federal, state, and local enforcement efforts. Today, more visible emission observers are certified annually than at any time in the past. This certification rate will continue to increase with the increase of federal and state regulations on industrial processes and combustion sources such as municipal, medical, and hazardous waste incinerators. Visible emissions standards are also applied extensively in controlling fugitive emissions from both industrial processes and non-process dust sources such as roads and bulk materials storage and handling areas. Often there are no convenient accurate stack testing methods for measurement of emissions from unconfined sources other than opacity methods.

METHOD 22 IS A QUALITATIVE TECHNIQUE CONCERNED ONLY WITH THE PRESENCE OR ABSENCE OF AN EMISSION

Method 22

Since EPA promulgated Method 22 in 1982, it has become an important tool in the control of visible emissions. Method 22 is a qualitative technique that checks only the presence or absence of visible emissions. Method 22 or a similar method is often used in the regulation of fugitive emissions of toxic materials. Unlike with Method 9, Method 22 users don't have to be certified. However, a knowledge of observation techniques is essential for correct use of the method. Therefore, Method 22 requires the observer to be trained by attending the lecture and field practice session of the Method 9 smoke school.

Opacity Measurement Principles

The relationships between light transmittance, plume opacity, and Ringelmann numbers are presented in Table 1.

Ringelmann	Opacity	Transmittance
1	20	80
2	40	60
3	60	40
4	80	20
5	100	0

Table 1. Comparison of Ringelmann Number, Plume Opacity, and Light Transmittance

A literal definition of plume opacity is the degree to which the transmission of light is reduced or the degree to which the visibility of a background as viewed through the diameter of a plume is reduced. In simpler terms, opacity is the obscuring power of the plume, expressed in percent. In physical terms, opacity is dependent upon transmittance (I/I_o) through the plume, where I_o is the incident light flux and I is the light flux leaving the plume along the same light path. Percent opacity can be calculated using the following equation:

Percent opacity = $(1-I/(I_o) \times 100$.

Variables Influencing Opacity Observations

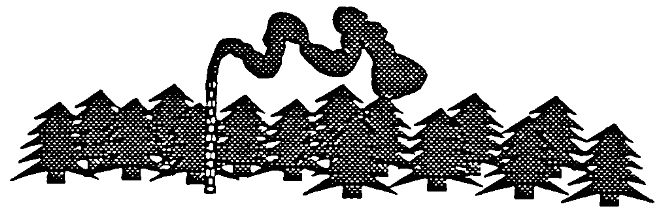
Method 9 advises:

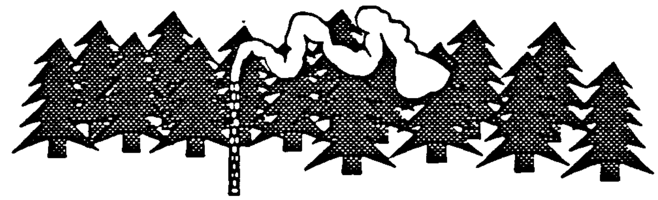
> The appearance of a plume as viewed by an observer depends upon a number of variables, some of which might be controllable and some of which might not be controllable in the field.
>
> The factors that influence plume opacity readings include particle density, particle refractive index, particle size distribution, particle color, plume background, pathlength, distance and relative elevation to stack exit, sun angle, and lighting conditions.

Particle size is particularly significant; particles decrease light transmission by both scattering and direct absorption. Particles with diameters approximately equal to the wavelength of visible light (0.4 to 0.7 μm) have the greatest scattering effect and cause the highest opacity. For a given mass emission rate, smaller particles will cause a higher opacity effect than larger particles. You should note that particles in the size range of 0.5 μm to 8 μm which typically cause most of the plume opacity, are also in the respirable range and are designated as PM_{10} particles.

Variables that might be controllable in the field are luminous contrast and color contrast between the plume and the background against which the plume is viewed. These variables exert an influence on the appearance of a plume and can affect an observer's ability to assign opacity values accurately. For example, when either contrast is high, the effect of the plume on the background is more evident and opacity values can be assigned with greater accuracy. When both contrasts are low, such as in the case of a gray plume on an overcast cloudy day, the effect is low and negative errors will occur. A negative error is when the observer under-estimates the true opacity of the plume.

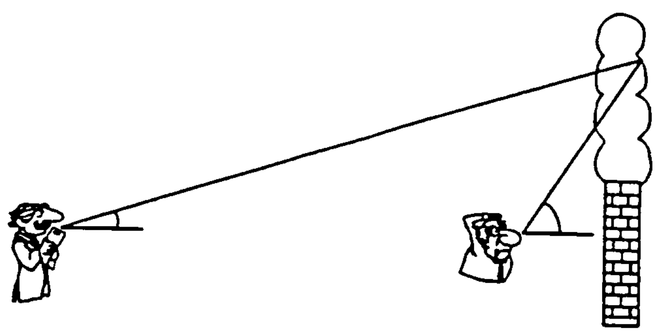
An example of high luminous contrast is a black plume against a light sky. Two objects of the same color could show up against each other because of differences in lighting levels or light direction. This effect is particularly important when the sun is behind a plume, thereby making the plume more luminous than the background and creating a high bias (positive error) in opacity readings. On the other hand, when the sun is properly oriented in relation to the plume and the plume color is identical with the background color, observers will generally have difficulty distinguishing between the plume and the background.



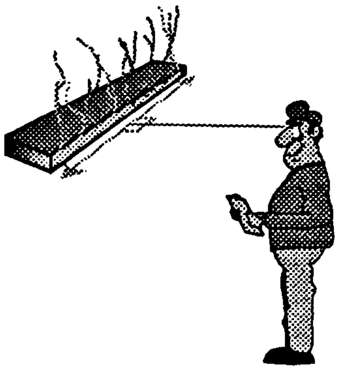


The line-of-sight pathlength through the plume is of particular concern. Method 9 states:

> ...the observer shall, as much as possible, make his observations from a position such that his line of vision is approximately perpendicular to the plume direction, and when observing opacity of emissions from rectangular outlets (e.g., roof monitors, open baghouses, noncircular stacks), approximately perpendicular to the longer axis of the outlet.



If the line of sight varies more than 18° from the perpendicular, a positive error greater than 1 percent occurs. As the angle increases, the error increases. When observing plumes from conventional sources, observers should stand at least three stack distances away from a vertically rising plume to meet this requirement. When observing plumes from fugitive sources, which are rarely perfectly round and are strongly affected by the wind, observers must take care to meet this requirement.



Measurement Error

All measurement systems have an associated error, and Method 9 is no exception. As a result of field trials conducted at the time Method 9 was promulgated, the error levels at two confidence intervals for white and black smoke using Method 9 were determined. The method states:

> For black plumes (133 sets at a smoke generator) 100 percent of the sets [average of 25 readings] were read with a positive error of less than 7.5 percent opacity; 99 percent were read with a positive error of less than 5 percent opacity.
>
> For white plumes (170 sets at a smoke generator, 168 sets at a coal-fired power plant, 298 sets at a sulfuric acid plant), 99 percent of the sets were read with a positive error of less than 7.5 percent opacity; 95 percent were read with a positive error of less than 5 percent opacity.

This means that during these field trials 100 percent of the black plumes and 99 percent of the white plumes were not overread by more than 7.5 percent opacity. In other words, there is only a 1-percent chance that an observer will exceed the error on a white plume and no chance that an observer will exceed the error on a black plume. Negative biases due to low-contrast observation conditions will often further offset the observational error.

Ninety-nine percent of the black plumes and 95 percent of the white plumes were read within 5 percent opacity. This means that an overreading occurs only about once in 20 readings. Again, negative biases that result from poor observation conditions (low plume-to-background contrast) reduce the positive observational error.

Later field studies have shown slightly higher observation errors, but they are still within the 7.5-percent opacity measurement error at two confidence intervals. These studies also showed that positive error is reduced by increasing the number of observations in either averaging time or in number of averages. Both techniques improve the accuracy of the method.

Method 22

Method 22 is used in conjunction with emission standards or work practices in which no visible emissions is the stated goal. This is frequently the case with fugitive emission sources or sources with toxic emissions. Method 22 differs from Method 9 in that it is qualitative rather than quantitative. Method 22 indicates only the presence or absence of an emission rather than the opacity value. Thus, many of the provisions of Method 9 that enhance the accuracy of the opacity measurement are not necessary in Method 22 determinations. Method 22 does not require that the sun be the light source or that you stand with the sun at your back. In fact, for reading asbestos emissions regulated under NESHAP Subpart *M*, you are directed to look toward the light source to improve your ability to see the emission. Under Method 22, the duration of the emission is accurately measured using a stopwatch. Table 2 on the following page compares major features of Method 9 and Method 22.

Table 2. Comparison Of Methods 9 & 22

	Method 9	Method 22
Applicability	Any NSPS and SIP sources with an opacity standard, such as 20 percent.	NSPS and SIP fugitive and specified flare sources with a "no visible emission" standard. No opacity level can be specified.
Measurement	The method determines the value of the opacity measured.	The method determines the existence of a plume but not the opacity.
Certification	Observer must demonstrate the ability to measure plumes in the field every six months.	Observer is not required to participate in field certification.
Lecture	Observer is not required to attend a lecture program.	Observer must be able to demonstrate knowledge. A lecture is advised, but reading material is acceptable.
Distance From Source	No distance is specified, but the observer must have a clear view of the emissions.	From 15 feet to 0.25 mile.
Viewing Angle	Observer views the plume from a position that minimizes the line of sight through the plume to minimize positive bias.	Observer simply observes the plume.
Light Source	The sun is implied as the light source and it is required to be at the observer's back.	Light sources other than the sun are acceptable but must be documented. The light must be at least 100 lux, but, it is not required to be at the observer's back.
Viewing Times	Momentary observation every 15 seconds for a period determined by the standard. Each observation is recorded.	Continuous viewing with observer rest breaks every 15 to 20 minutes. The observer times the emissions with a stopwatch and records the duration of emissions.

Records Review

Standard Visible Emission Inspection

The standard VE observation starts with a review of the source records on the emission point of interest. This initial review of the records can prevent considerable confusion and lost time in the field. You might not have the opportunity to make the review before the inspection, in which case the documentation should be completed after the review. The following paragraphs describe the items that should be checked.

The regulatory requirements and compliance status of the emission point are critical. To use the correct measurement method and the correct data-reduction technique, you must know which regulations apply.

> **SOURCES ARE REGULATED UNDER:**
>
> **NSPS**
> **SIPs**
> **Compliance agreements**
> **Permit conditions**
> **Enforcement decrees**

You must determine whether the emission point is regulated under federal New Source Performance Standards (NSPS), the State Implementation Plan (SIP), special permit conditions, or compliance order/agreement conditions. You must check each potentially applicable regulation; if you do not, you might use the wrong test method or data-reduction method. You cannot rely entirely on the Method 9 procedure in Appendix A of 40CFR Part 60. If the source is NSPS- regulated, special procedures or other modifications could be included in the emission standard for a specific source category.

SIP regulations often stipulate procedures that vary from Method 9, even though Method 9 or a similiar method is referenced in the SIP regulation. These variances could be in the observation procedures, in certification requirements, or in the data-reduction technique. The 15-second opacity values could be reported as time duration (time aggregation), or as shorter or longer averages than 6 minutes, or as the number of individual values above a "cap" (not to exceed rules). You should check the applicability of the standard to the specific process unit, and you should also check for exempt operating conditions, such as start-up, malfunction, and shut-down.

Another source of information regarding the applicable standards as well as observation and data reduction procedures for a source is the operating permit. Special conditions are often placed in the permit. Also, any negotiated compliance orders or agreements pertaining to the source may contain references to opacity standards and compliance methods or other written procedures.

Previous observations that have been made by the source, your agency, or another agency should be reviewed. Check for photographs of the source, and make copies to take on the evaluation to help in identifying emission points, performing observations in a consistent manner, and documenting changes in plant equipment.

> **EACH SOURCE AT A FACILITY CAN HAVE A DIFFERENT COMPLIANCE STATUS, A DIFFERENT RULE, A DIFFERENT OBSERVATION METHODOLOGY, AND A DIFFERENT DATA REDUCTION METHOD. ALSO, THE STATUS OF A SOURCE CAN CHANGE OVER TIME.**

Review any available videotape to get a feel for the site and the emissions. VE Observation Forms from previous inspections should be evaluated to determine whether steam plumes or other unusual conditions exist. Check inspection reports for viewing conditions or locations.

Maps and plot plans are often found in the agency source file, which will help you in determining good observation positions and their access. Time can be saved by using the maps and plot plans and calculating the sun's position at different times of the day.

Emission test reports are a good source of data on the stack height, source type, and compliance status with other regulations such as mass emissions regulations. Stack temperature and moisture content can be used to determine whether a steam plume could potentially be present on the day of your observation using the technique described in the EPA Quality Assurance Handbook, Volume III, Section 3.12.

Some emission reports have data on particle size distribution. This information is useful when observing a plume. Small particles impart a bluish haze to a plume, because the particles scatter blue light preferentially. The test data might reveal whether there are condensable emissions in the gas stream. This information is helpful in determining whether any residual plume is due to water or to a complex plume reaction.

Stack test reports usually contain descriptions of control equipment and their operating conditions. This information is useful in determining whether there is potential for a water condensation plume to form

CARRY THE FILLED-IN FORM WITH YOU IN THE FIELD

Lastly, fill in a sample VE Observation Form with the data that you have collected so that you have a ready reference when you go into the field. It is also useful to copy a map onto the back of the field forms you plan to use to help locate or verify the exact observation point.

Reverse Observations

Sometimes, you must make VE observations before a formal record review. Impromptu observations are often necessary when an opacity event is discovered. In this case, you will not have time for an extensive pre-inspection data review. Document what you can determine accurately in the field and complete the documentation as soon as possible after the observation. Visible emissions records used in court are treated as evidence under the principle of past recollection recorded. This means that you wrote it down while it was still fresh in your mind. If you must change an entry due to new knowledge obtained in the file review:

1. Draw a thin line through the error WITHOUT OBLITERATING IT.
2. Write the correction above it in ink.
3. Initial and date the change.

Equipment

Method 9 does not contain any special requirements or specifications for equipment or supplies; however, certain equipment is necessary to conduct a valid observation that will withstand the rigors of litigation. Other equipment, though optional, can make the collection of high-quality data easier. This section gives specifications, criteria, or design features for the recommended basic VE equipment.

Clipboard And Accessories

You should have a clipboard, several black ballpoint pens (medium point), several large rubber bands, and a sufficient number of VE Observation Forms to document any expected and unexpected observations. Use black ballpoint pens so that completed forms can be copied and still remain legible over several reproduction generations. Rubber bands hold the data form flat on the clipboard under windy conditions and hold other papers and blank forms on the back of the clipboard. Use observation forms that meet EPA Method 9 requirements. Sample forms that have been extensively field tested are provided in Appendix A.

Timer

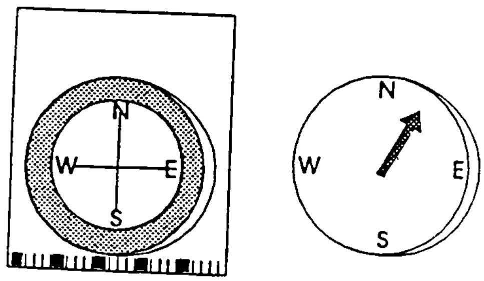
During a VE observation, it is necessary to time the 15-second intervals between opacity readings. You have a choice between using a watch or dedicated timer. The best practice is to attach two dedicated timers to your clipboard. Liquid-crystal-display timers are preferred because of their accuracy and readability. Use one timer to determine the start and stop times of the observation and the other timer to provide a continuous display of time to the nearest second. You can set most stick-on timers to run from 1 to 60 seconds repeatedly. A timer with a beeper that sounds every 15 seconds is recommended for use in some industrial locations, because you can then pay attention to your surroundings and your safety and not the timer.

CHECKLIST

- **Clipboard**
- **Ballpoint pens**
- **VE forms**
- **Rubber bands**
- **Timers (2)**
- **Compass**
- **Topographic map**
- **Rangefinder**
- **Clinometer**
- **Sling psychrometer**
  - **Water**
- **Binoculars**
- **Camera**
  - **Film**
  - **Tripod**
  - **Telephoto lens**
  - **Macro lens**
- **Video camera**
  - **Tape**
  - **Batteries**
  - **Tripod**

Compass

A compass is needed to determine the direction of the emission point from the spot where you stand to observe the plume and to determine the wind direction at the source. Select a compass that you can read to the nearest 2°. The compass should be jewel-mounted and liquid-filled to dampen the needle's swing. Map-reading compasses are excellent for this purpose. Because you must take the magnetic declination for your area into account when you take the reading, you should consider investing in a compass that allows presetting the declination.



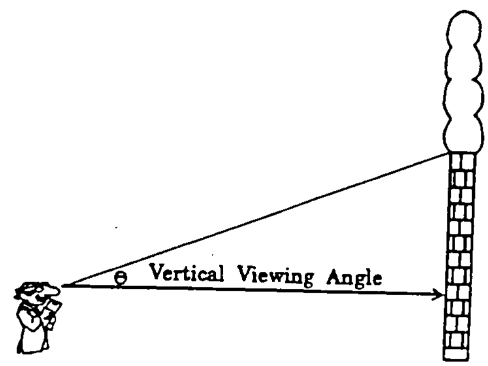
Topographic Maps

United States Geological Survey (USGS) 7.5-minute topological maps are a practical necessity for serious opacity work. From these maps you can determine your exact location, true north, distances, access roads, latitude, longitude, magnetic declination, relative ground height, and background features. You also can use these maps to calibrate rangefinders. If you are planning an inspection, photocopy the section of the map that shows the facility on the back of your observation form. Laminate the full-sized map for field use and to allow for temporary marking with dry erasable pens.

Rangefinder

If you do not have a topographic map of the area, you will need a rangefinder. Even with a map, a rangefinder is useful in field work. The two types in general use are the split-image and the stadiometric rangefinders. The split-image type uses the technique of superimposing one image over another to determine the distance. The most useful models for most opacity work have a maximum range of about 1,000 yards. To use the stadiometric rangefinder, you must know the height or width of an object at the same distance as the object of interest. Stadiometric rangefinders are lighter and more compact than split-image rangefinders. Split-image rangefinders, although inherently more accurate, are more likely to become uncalibrated if bumped during transport. The accuracy of either type of rangefinder should be checked on receipt and periodically thereafter with targets at known distances of approximately 100 meters and 1,000 meters. Any rangefinder must be accurate to within 10 percent of the measurement distance.

Clinometer

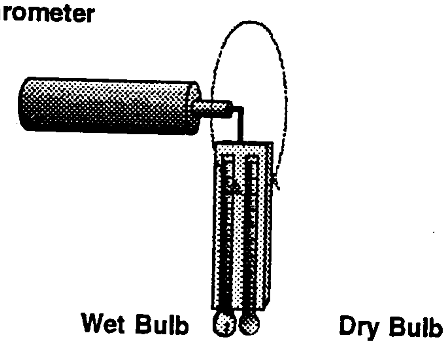


You will need a clinometric device for determining the vertical viewing angle. For visible emission observation purposes, it should be accurate within 3°. Many suitable devices are available in a wide range of prices, including Abbney levels, pendulum clinometers, and sextants. Abbney levels use a bubble in a curved tube to determine the angle with an accuracy of 1° to 2°. The pendulum clinometer is the cheapest and has an accuracy of about 2° when used properly. It consists of a protractor and a plum bob. A sextant is very accurate but more expensive, and you will need to know the position of the actual horizon.

Sling Psychrometer

If there is a potential for the formation of a condensed water droplet "steam" plume, you will need a sling psychrometer to determine the temperature and relative humidity of the atmosphere. The sling psychrometer consists of two thermometers, accurate to 0.5°C, mounted on a sturdy assembly attached to a chain or strap. One thermometer has a wettable cotton wick surrounding the bulb. Thermometer accuracy should be checked by placing the bulbs in a deionized ice water bath at 0°C. Electronic models that use newly developed solid state sensors are also available and do not have to be slung. Electronic models are simpler to use but require tedious periodic calibration using standard salt solutions.

Sling Psychrometer



Binoculars

Binoculars are helpful for identifying stacks, searching the area for emissions and interferences, and helping to characterize the behavior and composition of the plume. Binoculars are designated by two numbers, such as 7 x 35. The first number is the magnification and the second is the field of view. Select binoculars with a magnification of 8 or 10 (8 x 50 and 10 x 50 are standard designations). The binoculars should have color-corrected coated lenses and a rectilinear field of view. Check the color correction by viewing a black and white pattern, such as a Ringelmann card, at a distance greater than 50 feet. You should see only black and white: no color rings or bands should be evident. Test for rectilinear field of view by viewing a brick wall at a distance greater than 50 feet. There should be no pincushion or barrel distortion of the brick pattern. Plume observations for compliance purposes should not be made through binoculars unless you are certified with binoculars.

35 MM Camera And Accessories

Use a camera to document the presence of emissions before, during, and after the actual opacity determination and to document the presence or lack of interferences. Photographs document the specific stack that is under observation but do not document the exact opacity. Select a 35-mm camera with through-the-lens light metering, a "macro" lens or a 250 to 350-mm telephoto lens, and a 6-diopter closeup lens (for photographing the photo logbook). A photo logbook is necessary for proper documentation. An example of a photo log is provided in Appendix A of this manual. Use only fresh color negative film with an ASA of approximately 100. You can get first-generation slides or prints from negatives. The first photograph is of the log, identifying the time, date, and source. Log each photograph when you take it. The last photograph is of the completed log. Instruct the processor not to cut the film or print roll so that you can refer to the photo log at the end of the roll to identify each photograph.

CARRY EXTRA ROLLS OF FRESH FILM AND USE A PHOTO LOG

Video

Video is an excellent tool for opacity work. Because of the wider tonal range of video, it does a better job of reproducing the actual appearance of the plume than photography. In terms of resolution, video is poorer than film. The best video systems for opacity work include High 8 and Super VHS. Each gives 400 lines of resolution. Edited tapes have near broadcast quality and are excellent for research and court work. Regular VHS or regular 8 resolution is poor and duplicates are even worse. Select the highest quality videotape available for your system. Set and use the automatic date and time feature when taping, title each shot in the field, and narrate while taping. A sturdy tripod is as necessary as a good camera.

ALWAYS SHOOT EACH SCENE FOR AT LEAST 3 MINUTES TO MAKE EDITING EASIER.

Field Operations

Perimeter Survey

Before making your observations you need to determine the correct viewing position for the source being monitored, and you must also identify any potential interferences. You will need to select backgrounds, determine the wind direction, and determine the position of the sun relative to the source. You also should look for unlisted sources at this time. If you do not consider each of these items, the observation could be invalid.

Determine Sources

First, determine the sources of visible emissions at the facility and identify the specific source that you are going to observe. Record the source identification on the field data sheet. Next identify any potential interferences near the source for example, other visible emission plumes from nearby sources, fugitive dusts from work activities in the line of sight or obstructing buildings. Lastly, identify any other sources that are unlisted but visible.

Determine The Position Of The Sun

Method 9 states:
The qualified observer shall stand at a distance sufficient to provide a clear view of the emissions with the sun oriented in the 140 sector to his back.

This means that a line from the sun to the observer and a line from the observer to the observation point in the plume must form an angle of at least 110 degrees. This will place the sun in the required cone-shaped 140 degree sector. The purpose of this rule is to prevent forward scattering of light transmitted in the plume. Forward scattering enhances the plume visibility and creates a positive bias in measurement results. In fact, every viewing requirement of the method is designed to prevent positive bias.

METHOD 9 OBSERVATION RULES ARE DESIGNED TO ELIMINATE POSITIVE BIAS IN READINGS

Use a compass to determine the position of the sun in terms of true north. Remember to correct the compass for the magnetic declination at the site which might be different from that at your office location. When you position yourself initially you will position the sun in a 140 degree sector to your back when you face the source. Use the sun location line on the form for this initial check.

Now you must determine whether the vertical location of

METHOD 9 DOES NOT STATE THAT THE SUN MUST BE IN A 140° <u>HORIZONTAL</u> SECTOR

the sun is acceptable. This is especially true under one or more of the following conditions:

- You are observing a tall stack
- The sun is high overhead
- You are observing the plume high in the sky

In the summer the sun can be as high as or higher than 60° in the sky during the solar noon (1 p.m.) at most locations in the United States. If this is the case and the plume observation point is only 15° in the vertical, the combined vertical angle (from the observation point to the observer to the sun) will violate the vertical requirements because the total of the vertical plume angle and the vertical sun angle is at least 75° (which is less than the 110° specified minimum). Finally, the horizontal and vertical angles have a combined effect. If the sun is the sun is high overhead, or if the observation point is high, or if the observation point is high and the sun is close to the edge of the acceptable position, the final angle will probably be unacceptable.

Determine The Point In The Plume To Evaluate

Method 9 provides excellent guidance on the selection of the spot in the plume to observe. This guidance is presented in several sections and, unless the method is read in its entirety, the information can be confusing. The following extractions from Method 9 address what to consider in selecting the point in the plume for the observation.

Method 9 states:

2.3 OBSERVATIONS

Opacity observations shall be made at the point of greatest opacity in that portion of the plume where condensed water vapor is not present.

This is the first and most significant criterion. It has two elements that must be adhered to:

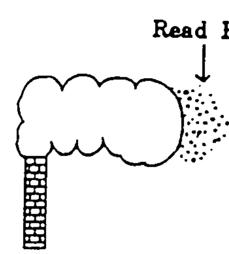
- You must read opacity at the densest portion of the plume
- There cannot be any condensed water vapor at the point of observation

If there is no condensed water droplet plume, you can read at the densest part of the plume. If there is a "steam" plume, sections 2.3.1 and 2.3.2 explain how to implement the rule.

Method 9 states:

2.3.1 ATTACHED STEAM PLUMES

When condensed water vapor is present within the plume as it emerges from the emission outlet, opacity observations shall be made beyond the point in the plume at which condensed water vapor is no longer visible. The observer shall record the approximate distance from the emission outlet to the point in the plume at which the observations are made.

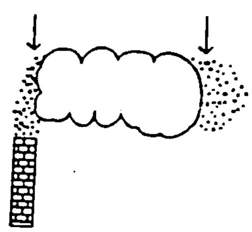


You must be sure that the condensed water aerosol has re-evaporated and is not enhancing the opacity of the particulate matter in the plume. If the relative humidity is high, water will hang on to particulate matter, and if the particulate matter is hygroscopic, the water could hang on at lower humidities. Either are unacceptable for a valid observation. You can observe the plume from the other side looking into the sun to determine where there is a real break point in the steam plume. Do not look into the sun when observing for record.

Method 9 states:

2.3.2 DETACHED STEAM PLUMES

When water vapor in the plume condenses and becomes visible at a distinct distance from the emission outlet, the opacity of emissions should be evaluated at the emission outlet prior to the condensation of water vapor and the formation of the steam plume.



(Note: The word "shall" has been changed to" should" in this subsection.)
If the steam plume is detached, you have two choices:

- Read before the steam forms
- Read after it evaporates

It is easy to choose between these options if you remember that "observations shall be made at the point of greatest opacity" is your primary rule. If the plume is denser before the steam plume forms, read there. If the plume is denser after the steam plume evaporates, read there, unless there are specific directives to the contrary.

Certain complex plumes--those with high condensable loadings or secondary reactive products--might present problems in determining where to read the plume and how to interpret the results. This is where your homework comes in. From the permits or emission test data you should have a good feel for the material being emitted. Some materials that have a strong affinity for water might retain water far longer than others. Also, if the ambient air humidity is high, there is less potential for water to evaporate from particles. In either of these cases, condensed water droplets containing particulate contaminates could mimic particulate matter. Other cases that require caution are those in which condensed hydrocarbons are the principle component of the visible plume.

Some opacity regulations might not be applicable to sources with consensing hydrocarbon plumes if the intent of the emission standard was only to control primary particulate emissions detected by the emission control system. An example is the case of "blue haze" plumes from asphalt concrete batch plants, which have been determined to be exempt from the NSPS opacity requirement.

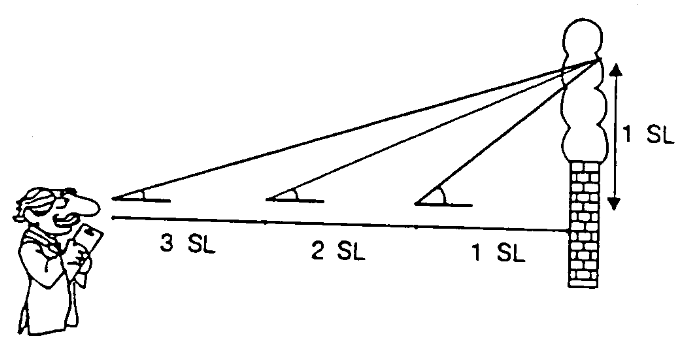
Document The Point In The Plume Where The Reading Was Taken

You must document on the data sheet the point in the plume that you selected for the opacity reading. This location should be documented in terms of distance from the stack and in relative terms to any condensed water or steam break. You can be sure that you will be challenged later on this issue if there is reason to suspect that the plume has a high moisture content or condensable emissions.

Check For Direction Of Plume Travel

Method 9 states:

[The VE observer should]...make his observations from a position such that his line of vision is approximately perpendicular to the plume direction.



If you are observing the plume, you should be at least three effective stack heights away from the plume. (The effective stack height is the vertical distance between the point where your horizontal line of sight intersects the stack and the point in the plume where the observation is to be made.) The intent is to keep within 18° of the perpendicular to the plume. If the plume is horizontal, make sure that your line of vision is approximately perpendicular to the plume at the point of observation. Again, the line of sight should be within 18° of a perpendicular to the plume line of travel. The reason for standing approximately perpendicular to the plume when making the VE determination is to use the shortest pathlength through the plume, which will result in the most conservative estimate of plume opacity.

Adjust Your Field Location If Necessary

After picking the point in the plume to observe, you must recheck that you are in the correct position relative to the sun and that point. If you are not, move. Recheck each of the same factors at the new field position and move again if necessary. Do not start observations until all the factors conform to the regulations. It might be necessary to come back at a different time of day to get all the observation conditions acceptable.

METHOD 9 IS A METHOD OF OPPORTUNITY. THE VE INSPECTION MIGHT HAVE TO BE DELAYED TO A DIFFERENT TIME OF DAY IF VIEWING LOCATION OR CONDITIONS ARE UNACCEPTABLE

Performing The Observations

Compared to the preliminary activities, observing the plume is easy. You will be filling out the upper left section of the form first. Fill in the observation date in the appropriate space on the form. Fill in the start time when you make the first observation. Use the 24-hour clock to avoid confusion with a.m. and p.m. and indicate the time zone. For example, 10:30 a.m. Eastern Daylight Time should be recorded as 1030 EDT; 2:30 p.m. Eastern Daylight Time should be recorded as 1430 EDT.

Method 9 states:

The observer shall not look continuously at the plume, but instead shall observe the plume momentarily at 15-second intervals.

Watch your timer and look up at the plume only momentarily at the 0-, 15-, 30-, and 45-second intervals. It takes only a few seconds to record your observation on the form. Record your observations in 5-percent opacity intervals unless the permit or regulation specifies otherwise. Continue until you have made the required number of observations. Method 9 usually requires at least 24 observations for a complete data set. Good measurement practice is to take more than the bare minimum required, and it might be necessary to take more than one data set to defend the observations against litigation in some courts.

IF CONDITIONS CHANGE DURING THE OBSERVATION, DOCUMENT ALL CHANGES IN THE COMMENT SECTION

There is a comment section for each minute of observation. Use these comment sections to document events that affect the validity of the observation, such as interferences or reasons for missing readings. Document changes in your position or plume color.
When you conclude your observation session, record the stop time in the appropriate section. Fill in the section on observer and affiliation. Sign and date the form. Enter the requested information concerning your last certification. A completed VE Observation Form is found on the next page.

Calculations

Method 9 Data Reduction

Method 9 states:

Opacity shall be determined as an average of 24 consecutive observations...

Divide the observations recorded on the record sheet into sets of 24 consecutive observations. A set is composed of any 24 consecutive observations. Sets need not be consecutive in time and in no case shall two sets overlap.

This means that you can select any set of 24 sequential values to construct your final average. The best practice is to construct a screening average (rolling average) of each possible average in the data set and then select the data combinations that you want to calculate. In an hour of observations with no data gaps there are 227 potential averages. Computer programs are available for this calculation or you can construct a spreadsheet with a rolling average to perform the calculation. If you are simply determining noncompliance, you can often scan the data to determine a data set that appears to violate the standard.

A SET DOES NOT HAVE TO START AT THE BEGINNING OF A MINUTE

The set does not have to start at the beginning of a minute; it can start at any point in the observation data. Often this is the difference between compliance and noncompliance.

VISIBLE EMISSION OBSERVATION FORM

COMPANY NAME: GORTON INDUSTRIES

LOCATION: 4242 AIKI ROAD

LOCATION:

CITY: SUSQUEHANNA **STATE:** PA **ZIP:** 18847

PROCESS EQUIPMENT: BOILER **OPERATING MODE:** 90 PERCENT CAPACITY

CONTROL EQUIPMENT: ELECTROSTATIC PRECIPITATOR **OPERATING MODE:** RAPPING

DESCRIBE EMISSION POINT: TALLEST OF THREE STACKS, SECOND FROM LEFT FACING NORTH DIAMETER OF 8 FT.

HEIGHT ABOVE GROUND LEVEL: 75 FT.

HEIGHT RELATIVE TO OBSERVER: START 50 FT. END SAME

DISTANCE FROM OBSERVER: START 300 ft. END SAME

DIRECTION FROM OBSERVER: START N END SAME

VERTICAL ANGLE TO PLUME: 9 DEGREES

HORIZONTAL ANGLE TO PLUME: 0 DEGREES

DESCRIBE EMISSIONS: START LOFTING PLUME END SAME

EMISSION COLOR: START WHITE END SAME

IF WATER DROPLET PLUME: ATTACHED ☐ DETACHED ☒ NA ☐

POINT IN THE PLUME AT WHICH OPACITY WAS DETERMINED: START ONE STACK WIDTH ABOVE OUTLET END SAME

DESCRIBE PLUME BACKGROUND: START MOUNTAIN END SAME

BACKGROUND COLOR: START DARK GREEN END SAME

SKY CONDITIONS: START CLEAR END SCATTERED

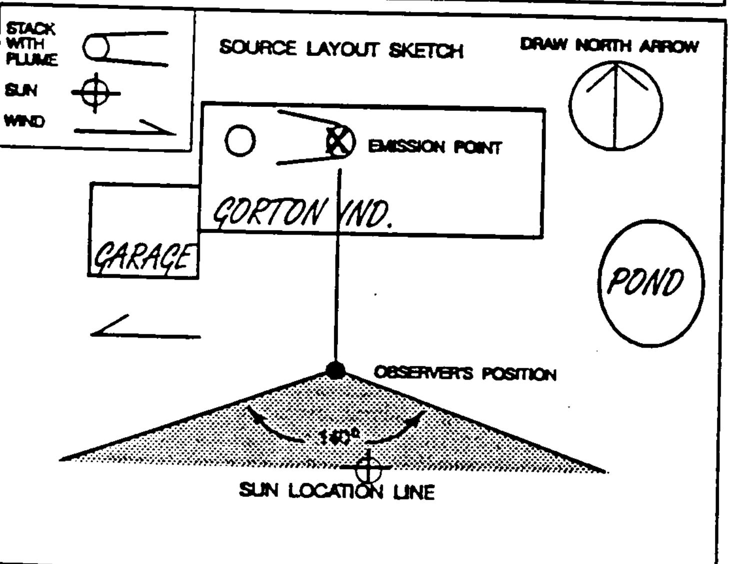
WIND SPEED: START 5-7 MPH END 7-9 MPH

WIND DIRECTION: START E END SAME

AMBIENT TEMP: START 65 END 60

WET BULB TEMP: 53

RH percent: 50



ADDITIONAL INFORMATION:

OBSERVATION DATE: FEB 21, 1991 **START TIME:** 1100 EST **END TIME:** 1125 EST

MIN \ SEC	0	15	30	45	COMMENTS
1	30	35	40	30	
2	25	20	15	30	
3	40	35	40	35	
4	30	30	30	35	
5	30	25	20	30	
6	25	20	15	15	
7	20	35	25	35	
8	30	30	30	25	
9	30	35	40	30	
10	25	20	15	30	
11	40	35	40	35	
12	30	30	30	35	
13	30	25	20	30	
14	25	20	15	15	
15	—	—	25	35	INTERFERING PLUME
16	30	30	30	25	
17	25	20	15	15	
18	20	35	25	35	
19	35	30	30	25	
20	30	35	40	30	
21	25	20	15	30	
22	40	35	40	35	
23	25	20	15	15	
24	20	35	25	35	
25	30	30	30	25	
26					
27					
28					
29					
30					

OBSERVER'S NAME (PRINT): THOMAS ROSE

OBSERVER'S SIGNATURE: Thomas H. Rose **DATE:** FEB 21, 1991

ORGANIZATION: HADLEY ENGINEERING

CERTIFIED BY: EASTERN TECHNICAL ASSOCIATE **DATE:** NOV 1, 1990

CONTINUED ON VEO FORM NUMBER:

Method 9 states:

For each set of 24 observations, calculate the average by summing the opacity of the 24 observations and dividing this sum by 24.

WHEN THE SIP DOESN'T ADDRESS THE ISSUE, METHOD 9 DATA REDUCTION IS USED

A simple mean is calculated for each data set and each mean is compared to the standard. If any correction is made for pathlength, it must be made before calculating the average.

Method 9 states:

If an applicable standard specifies an averaging time requiring more than 24 observations, calculate the average for all observations made during the specified time period.

Federal standards and SIP opacity regulations sometimes contain averaging times other than 6 minutes. EPA's policy is that if the SIP regulation does not clearly specify an averaging time or other data-reduction technique, the 6-minute average calculations should be used. EPA is currently in the process of providing additional methods to cover alternative averaging times.

Time-Aggregation Standards

Time-aggregation standards are generaly stated in terms of an opacity limit that is not to be exceeded for more than a given time limit, such as 3 minutes, over a total period, such as 1 hour. The usual technique is to count the number of observations that violate the standard during the observation period. Multiply the number of violations by 15 seconds to get the total number of seconds in violation and divide by 60 to get the number of minutes of violation. Compare the answer to the standard. EPA is in the process of promulgating methods that will allow for time-aggregation calculations.

Data Review

Field Data Check

Before you leave the field, look over the form carefully. Start at the bottom right-hand section and work your way up, following the form backwards. Make sure that each section is either filled out correctly or is left blank on purpose. All entries should be legible. Remember, this is the first-generation copy and all subsequent copies will be of lower print quality. As stated earlier in this manual, the visible emission observation form is usually introduced as evidence in enforcement litigation under the principle of "past recollection recorded." This means that you made entries on the form while they were fresh in your mind. A five-minute review at this time can save hours later.

Complete The Form

As soon as possible, gather the missing information and complete the form. Do not sign the form until you have completed all entries you intend to complete.

Method 9 warns:

....are recorded on a field data sheet at the time opacity readings are initiated and completed.

Any additional entries made after you sign the form must be dated and initialed. Failure to document changes properly makes the observations subject to challenge. Even the markout might have to be explained in a deposition or in court.

DESCRIBE EMISSION POINT TALLEST OF THREE STACKS, ~~SECOND~~ THIRD FROM LEFT FACING NORTH T.H.R. 12/15/91 DIAMETER OF ~~8~~ 6 FT. T.H.R. 12/15/91	
HEIGHT ABOVE GROUND LEVEL 75 FT.	HEIGHT RELATIVE TO OBSERVER START 50 FT. END SAME
DISTANCE FROM OBSERVER START 300 ft. END SAME	DIRECTION FROM OBSERVER START N END SAME
VERTICAL ANGLE TO PLUME 9 DEGREES	HORIZONTAL ANGLE TO PLUME 0 DEGREES

Quality Assurance Audit

If the form is used as proof of compliance or of violation in a permit application or of agency enforcement action, a third party should review the document in detail. The following sections describe the elements of a minimal audit.

After each item on the form is checked, you should compare related data items for consistency. For example, check if:

- The wind direction arrow in the sketch agrees with the wind direction recorded in the text section of the form.
- The final signature date is consistent with the observation date.
- The time of day is consistent with the sun position.

CERTIFICATION WITHIN 6 MONTHS OF OBSERVATION

Compare the date of the observation at the top of the form with the date of the certification at the bottom of the form. The observation date must be after the certification but no more than 6 months after.

ALL REQUIRED DOCUMENTATION SUPPLIED

Method 9 has specific requirements for recording information regarding the emission source or point observed and the field conditions at the time of the observation. Check to see whether the following information is provided on the VE Observation Form:

- Name of the plant.
- Facility and emission point location.
- Type of facility.
- Observer's name and affiliation.
- Date and time of observation.
- Estimated distance to the emission location.
- Approximate wind direction.
- Estimated wind speed.
- Description of the sky conditions (presence and color of clouds).
- Plume background.
- Sketch of sun, source, and observer positions.
- Distance from the emission outlet to the point in the plume at which the observations are made.
- 24 observations (unless other criteria exist).

If any of these items is missing, it will be pointed out in a deposition, or in a motion before the court, or to the judge when you are on the witness stand.

SUN ANGLE REQUIREMENTS MET

Compliance with sun angle regulations is one of the most difficult items to audit accurately because of inadequate documentation. The angle created by the line of sight of the observer and the line from the sun to the observer must be at least 110°. This places the sun in the 140° cone-shaped sector to the observer's back. Sun angle has both horizontal and vertical components, and both must be reviewed.

Horizontal sun angle is the easiest to check. Compare the direction to the measurement point with the position of the sun at that time of day. If the sun location line on the suggested form is used, this should be easy. If the line looks right, you must still check it against the north arrow in the sketch. You can check the sun location for accuracy using the US Naval Observatory ICE program or solar tables. If all these records are reasonable, you can calculate the horizontal angle. The angle must be at least 110°. Next, check the vertical sun angle. Add the vertical angle of the observer's line of sight to the vertical line of sight to the sun. The total of these two angles must be less than 70°.

VERTICAL, HORIZONTAL, AND COMBINATION SUN ANGLES MUST BE ACCEPTABLE

Lastly, both horizontal and vertical angles must be combined to get the resultant angle. This requires solid trigonometry. Commercial computer programs exist that perform the task. As a general rule, if the total vertical angle is less than 60° and the horizontal angle is above 130°, the resultant angle should be acceptable. Otherwise, the observation is suspect.

SIGHT LINE PERPENDICULAR TO DIRECTION OF PLUME TRAVEL

In order to assure that the sight line was approximately perpendicular to the direction of plume travel, the slant angle should be less than 18°. Use the distance from the stack and the effective stack height to determine the angle. If the plume was horizontal at the point of observation, check the sketch for the direction of plume travel. Then check to see if the plume direction and wind direction are reasonable.

NON-CIRCULAR VENTS READ ACROSS SHORTEST AXIS

Check to see that the plume was observed along a line of sight perpendicular to the long axis of the vent if the vent is not circular. This is important when observing fugitive emissions. Sources such as storage piles, dusty roads, roof monitors, and ships' holds are difficult to observe properly because of this requirement. In many cases you must reach a compromise between the axis of the source and the axis of the plume. If the reading is not made from a position nearly perpendicular to the plume, you should look at the final opacity and determine whether correcting the data for pathlength will still give the same final result in terms of compliance status.

OBSERVATIONAL INTERVALS

Were observations made at 15-second intervals or in compliance with the applicable regulations?

DATA GAPS EXPLAINED

Were a minimum number of observations made with no data gaps? If data gaps exist, are they explained? If an average was calculated with a data gap, what value was assigned to the data gap? What is the reason for selecting the value?

INTERFERENCES CHECKED AND NOTED ON FORM

Check for possible interferences. Obstacles in the line of sight or other emission plumes in front of or behind the plume being monitored create interferences that must be avoided or noted on the data form. Review the sketch for other vents, stacks, or sources of fugitive emissions that might cross the line of sight or co-mingle with the plume being evaluated and create a positive bias in the observations. Compare any photographs to the sketch. The sketch should indicate the backgrounds and their relative distances. If mountains or other distant objects are used as a reading background, check if haze is indicated in the background section. This will potentially create a negative bias in the opacity readings. Also, note in the comments section beside the observation whether interferences were reported. Lastly, check the additional information section and the data section for comments regarding haze or other interferences.

STEAM PLUMES NOTED AND PROPER PROCEDURES FOLLOWED

Was the emission observed at a point where there was no condensed water? If the form indicates the presence of a steam plume, pay special attention to the point in the plume where the observation was made. Does it make sense in relation to instructions given in sections 2.3, 2.3.1, and 2.3.2 of the Method 9? Check the ambient temperature and relative humidity, if available. If the temperature is low or if the relative humidity is high (over 70 percent), consider the possibility of a steam plume that does not evaporate easily. If the data are available, model the steam plume using the technique in EPA Quality Assurance Handbook, Volume III, Section 3.12. When you use this model you must recognize that:

- The charts were developed from steam tables to represent the conditions in an ideal closed system, and the atmosphere is not an ideal closed system.
- The tables do not consider the presence of particulate matter or condensation nuclei.
- The temperature of the emission gases is an average of at least a one-hour emission test and does not necessarily represent a steady-state condition in the stack.
- The moisture content entered into the calculation is an average of at least one hour and might not be representative of the plume conditions over a shorter time frame. The chart does not recognize that the plume might not be uniform in moisture concentration and that some portions of the plume might be at supersaturation.
- The tables do not consider the presence of hygroscopic particulate matter that could attract and hold onto water by lowering its vapor pressure.

The chart is best used by constructing a line with an error band that recognizes the associated error in measurement of each of the input parameters. It should be assumed that no water plume forms only if the error band does not approach the dewpoint.

DATA REDUCTION AND REPORTING PREFORMED IN ACCORDANCE WITH REGULATION

Are the calculations in compliance with the regulation? Does the regulation require averaging over a time period other than 6 minutes? Does it require time aggregation? Is the math correct? Was the highest average determined? Is there data showing noncompliance in excess of the regulation in terms of opacity and time?

OPACITY READINGS REPRESENTATIVE OF ACTUAL CONDITIONS

Verify that no interferences or extenuating circumstances existed during the observation that would make the opacity values not representative of actual conditions or otherwise invalidate the observation.

REPEAT THE AUDIT

Depending upon the potential use of the form, it may be wise to have an additional third party audit the form. After completing the second audit, compare the results of the two independent audits and resolve any outstanding difficulties.

Further Readings

Field Observation Procedures:

Quality Assurance Handbook for Air Pollution Measurement Systems: Vol. III Stationary source Specific Methods, Section 3.12 — Method 9 Visible Determination of Opacity of Emissions from Stationary Sources, EPA 600/4-77-027b, February 1984.

Guidelines for Evaluation of Visible Emissions: Certification, Field Procedures, Legal Aspects and Background Materials, EPA 340/1-75-007, April 1975.

Guide to Effective Inspection Reports for Air Pollution Violations, EPA 340/1-85-019, September 1985.

Instructions for Use of the VE Observations Form, EPA 340/1-86-017.

Observer Training and Certification:

Self-Audit Guide for Visible Emission Training and Certification Programs, EPA 455/R-92-005.

Technical Assistance Document: Quality Assurance Guideline for Visible Emission Training Schools, EPA 600/4-83-011.

Course 325 — Visible Emission Evaluation: Student Manual, EPA 455/B-93-011a, January 1994.

Opacity Evaluation Methods:

Optical Properties and Visual Effects of Smoke-Stack Plumes, AP-30, Revised May 1972.

Evaluation and Collaborative Study of Method for Visual Determination of Opacity of Emissions from Stationary Sources, EPA 650/4-75-009, January 1975.

Measurement of the Opacity and Mass Concentration of Particulate Emissions by Transmissometry, EPA 650/2-74-128, November 1974.

Appendix A

Forms

VISIBLE EMISSION OBSERVATION FORM

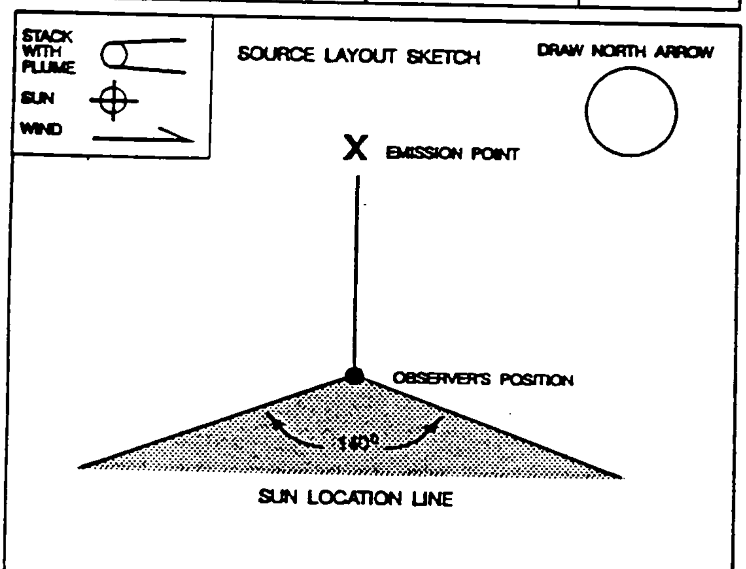
COMPANY NAME		
LOCATION		
LOCATION		
CITY	STATE	ZIP

PROCESS EQUIPMENT	OPERATING MODE
CONTROL EQUIPMENT	OPERATING MODE

DESCRIBE EMISSION POINT	
HEIGHT ABOVE GROUND LEVEL	HEIGHT RELATIVE TO OBSERVER START END
DISTANCE FROM OBSERVER START END	DIRECTION FROM OBSERVER START END
VERTICAL ANGLE TO PLUME	HORIZONTAL ANGLE TO PLUME

DESCRIBE EMISSIONS START END		
EMISSION COLOR START END	IF WATER DROPLET PLUME ATTACHED☐ DETACHED☐ NA☐	
POINT IN THE PLUME AT WHICH OPACITY WAS DETERMINED START END		

DESCRIBE PLUME BACKGROUND START END		
BACKGROUND COLOR START END	SKY CONDITIONS START END	
WIND SPEED START END	WIND DIRECTION START END	
AMBEINT TEMP START END	WET BULB TEMP	RH percent



ADDITIONAL INFORMATION

OBSERVATION DATE	START TIME	END TIME	

SEC / MIN	0	15	30	45	COMMENTS
1					
2					
3					
4					
5					
6					
7					
8					
9					
10					
11					
12					
13					
14					
15					
16					
17					
18					
19					
20					
21					
22					
23					
24					
25					
26					
27					
28					
29					
30					

OBSERVER'S NAME (PRINT)	
OBSERVER'S SIGNATURE	DATE
ORGANIZATION	
CERTIFIED BY	DATE

CONTINUED ON VEO FORM NUMBER					

FUGITIVE OR SMOKE EMISSION INSPECTION OUTDOOR LOCATION

Company ____________ Location ____________ Company Rep. ____________	Observer ____________ Affiliation ____________ Date ____________
Sky Conditions ____________ Precipitation ____________	Wind Direction ____________ Wind Speed ____________
Industry ____________	Process Unit ____________

Sketch process unit: indicate observer position relative to source and sun, indicate potential emission points and/or actual emission points.

OBSERVATIONS

	Clock time	Observation period duration, min:sec	Accumulated emission time, min:sec
Begin Observation	______		
	______	______	______
	______	______	______
	______	______	______
	______	______	______
	______	______	______
	______	______	______
	______	______	______
	______	______	______
End Observation	______	______	______

Figure 22-1

FUGITIVE EMISSION INSPECTION
INDOOR LOCATION

Company ____________________ Observer ____________________

Location ____________________ Affiliation ____________________

Company Rep. ____________________ Date ____________________

Industry ____________________ Process Unit ____________________

Light type(fluorescent,incandescent,natural) ____________________

Light location(overhead,behind observr etc) ____________________

Illuminance(lux or footcandles) ____________________

Sketch process unit: Indicate observer position relative to source; indicate potential emission points and/or actual emission points.

OBSERVATIONS

	Clock time	Observation period duration, min:sec	Accumulated emission time, min:sec
Begin Observation			
End Observation			

Figure 22-2

Photo Log

Roll # ______________________________

#	Time/Date	Subject

1. ______________________________
2. ______________________________
3. ______________________________
4. ______________________________
5. ______________________________
6. ______________________________
7. ______________________________
8. ______________________________
9. ______________________________
10. ______________________________
11. ______________________________
12. ______________________________

Appendix B

Method 9 - Visual Determination of the Opacity of Emissions from Stationary Sources

Introduction

(a) Many stationary sources discharge visible emissions into the atmosphere; these emissions are usually in the shape of a plume. This method involves the determination of plume opacity by qualified observers. The methods includes procedures for the training and certification of observers and procedures to be used in the field for determination of plume opacity.

(b) The appearance of a plume as viewed by an observer depends upon a number of variables, some of which may be controllable in the field. Variables which can be controlled to an extent to which they no longer exert a significant influence upon plume appearance include: angle of the observer with respect to the plume; angle of the observer with respect to the sun; point of observation of attached and detached steam plume; and angle of the observer with respect to a plume emitted from a rectangular stack with a large length to width ratio. The method includes specific criteria applicable to these variables.

(c) Other variables which may not be controllable in the field are luminescence and color contrast between the plume and the background against which the plume is viewed. These variables exert an influence upon the appearance of a plume as viewed by an observer and can affect the ability of the observer to assign accurately opacity values to the observed plume. Studies of the theory of plume opacity and field studies have demonstrated that a plume is most visible and presents the greatest apparent opacity when viewed against a contrasting background. Accordingly, the opacity of a plume viewed under conditions where a contrasting background is present can be assigned with the greatest degree of accuracy. However, the potential for a positive error is also the greatest when a plume is viewed under such contrasting conditions. Under conditions presenting a less contrasting background, the apparent opacity of a plume is less and approaches zero as the color and luminescence contrast decrease toward zero. As a result, significant negative bias and negative errors can be made when a plume is viewed under less contrasting conditions. A negative bias decreases rather than increases the possibility that a plant operator will be incorrectly cited for a violation of opacity standards as a result of observer error.

(d) Studies have been undertaken to determine the magnitude of positive errors made by qualified observers while reading plumes under contrasting conditions and using the procedures set forth in this method. The results of these studies (field trials) which involve a total of 769 sets of 25 readings each are as follows:
(1) For black plumes (133 sets at a smoke generator), 100 percent of the sets were read with a positive error of less than 7.5 percent opacity; 99 percent were read with a positive error of less than 5 percent opacity. (Note: For a set, positive error = average opacity determined by observers' 25 observations -average opacity determined from transmissometer's 25 recordings.)

(2) For white plumes (170 sets at a smoke generator, 168 sets at a coal-fired power plant, 298 sets at a sulfuric acid plant), 99 percent of the sets were read with a positive error of less than 7.5 percent opacity; 95 percent were read with a positive error of less than 5 percent opacity.

(e) The positive observational error associated with an average of twenty-five readings is therefore established. The accuracy of the method must be taken into account when determining possible violations of applicable opacity standards.

1. Principle And Applicability

1.1 Principle. The opacity of emissions from stationary sources is determined visually by a qualified observer.

1.2 Applicability. This method is applicable for the determination of the opacity of emissions from stationary sources pursuant to § 60.11(b) and for visually determining opacity of emissions.

2. Procedures

The observer qualified in accordance with Section 3 of this method shall use the following procedures for visually determining the opacity of emissions.

2.1 Position. The qualified observer shall stand at a distance sufficient to provide a clear view of the emissions with the sun oriented in the 140° sector to his back. Consistent with maintaining the above requirement, the observer shall, as much as possible, make his observations from a position such that his line of vision is approximately perpendicular to the plume direction and, when observing opacity of emissions

from rectangular outlets (e.g., roof monitors, open baghouses, noncircular stacks), approximately perpendicular to the longer axis of the outlet. The observer's line of sight should not include more than one plume at a time when multiple stacks are involved, and in any case the observer should make his observations with his line of sight perpendicular to the longer axis of such a set of multiple stacks (e.g., stub stacks on baghouses).

2.2 Field Records. The observer shall record the name of the plant, emission location, facility type, observer's name and affiliation, a sketch of the observer's position relative to the source, and the date on a field data sheet (Figure 9-1). The time, estimated distance to the emission location, approximate wind direction, estimated wind speed, description of the sky condition (presence and color of clouds), and plume background are recorded on a field data sheet at the time opacity readings are initiated and completed.

2.3 Observations. Opacity observations shall be made at the point of greatest opacity in that portion of the plume where condensed water vapor is not present. The observer shall not look continuously at the plume but instead shall observe the plume momentarily at 15-second intervals.

2.3.1 Attached Steam Plumes. When condensed water vapor is present within the plume as it emerges from the emission outlet, opacity observations shall be made beyond the point in the plume at which condensed water vapor is no longer visible. The observer shall record the approximate distance from the emission outlet to the point in the plume at which the observations are made.

2.3.2 Detached Steam Plume. When water vapor in the plume condenses and becomes visible at a distinct distance from the emission outlet, the opacity of emissions should be evaluated at the emission outlet prior to the condensation of water vapor and the formation of the steam plume.

2.4 Recording Observations. Opacity observations shall be recorded to the nearest 5 percent at 15-second intervals on an observational record sheet. (See Figure 9-2 for an example.) A minimum of 24 observations shall be recorded. Each momentary observation recorded shall be deemed to represent the average opacity of emissions for a 15-second period.

2.5 Data Reduction. Opacity shall be determined as an average of 24 consecutive observations recorded at 15-second intervals. Divide the observations recorded on the record sheet into sets of 24 consecutive observations. A set is composed of any 24 consecutive observations. Sets need not be consecutive in time and in no case shall two sets overlap. For each set of 24 observations, calculate the average by summing the opacity of the 24 observations and dividing this sum by 24. If an applicable standard specifies an averaging time requiring more than 24 observations, calculate the average for all observations made during the specified time period. Record the average opacity on a record sheet. (See Figure 9-1 for an example.)

3. Qualification and Testing

3.1 Certification Requirements. To receive certification as a qualified observer, a candidate must be tested and demonstrate the ability to assign opacity readings in 5 percent increments to 25 different black plumes and 25 different white plumes, with an error not to exceed 15 percent opacity on any one reading and average error not to exceed 7.5 percent opacity in each category. Candidates shall be tested according to the procedures described in Section 3.2. Smoke generators used pursuant to Section 3.2 shall be equipped with a smoke meter which meets the requirements of Section 3.3. The certification shall be valid for a period of 6 months, at which time the qualification procedure must be repeated by any observer in order to retain certification.

3.2 Certification Procedure. The certification test consists of showing the candidate a complete run of 50 plumes--25 black plumes and 25 white plumes-generated by a smoke generator. Plumes within each set of 25 black and 25 white runs shall be presented in random order. The candidate assigns an opacity value to each plume and records his observation on a suitable form. At the completion of each run of 50 readings, the score of the candidate is determined. If a candidate fails to qualify, the complete run of 50 readings must be repeated in any retest. The smoke test may be administered as part of a smoke school or training program and may be preceded by training or familiarization runs of the smoke generator during which candidates are shown black and white plumes of known opacity.

3.3 Smoke Generator Specifications. Any smoke generator used for the purposes of Section 3.2 shall be equipped with a smoke meter installed to measure opacity across the diameter of the smoke generator stack. The smoke meter output shall display in-stack opacity based upon a pathlength equal to the stack exit diameter, on a full 0 to 100 percent chart recorder scale. The smoke meter optical design and performance shall meet the specifications shown in Table 9-1. The smoke meter shall be calibrated as prescribed in Section 3.3.1 prior to the conduct of each smoke reading test. At the completion of each test, the zero and span drift shall be checked and if the drift exceeds ±1 percent opacity, the condition shall be corrected prior to conducting any subsequent test runs. The smoke meter shall be demonstrated, at the time of installation, to meet the specifications listed in Table 9-1. This demonstration shall be repeated following any subsequent repair or replacement of the photocell or associated electronic circuitry including the chart recorder or output meter, or every 6 months, whichever occurs first.

3.3.1 Calibration. The smoke meter is calibrated after allowing a minimum of 30 minutes warmup by alternately producing simulated opacity of 0 percent and 100 percent. When stable response at 0 percent or 100 percent is noted, the smoke meter is adjusted to produce an output of 0 percent or 100 percent, as appropriate. This calibration shall be repeated until stable 0 percent and 100 percent opacity values may be produced by alternately switching the power to the light source on and off while the smoke generator is not producing smoke.

3.3.2 Smoke Meter Evaluation. The smoke meter design and performance are to be evaluated as follows:

3.3.2.1 Light Source. Verify from manufacturer's data and from voltage measurements made at the lamp, as installed, that the lamp is operated within ±5 percent of the nominal rated voltage.

3.3.2.2 Spectral Response of Photocell. Verify from manufacturer's data that the photocell has a photopic response; i.e., the spectral sensitivity of the cell shall closely approximate the standard spectral-luminosity in (b) of Table 9-1.

3.3.2.3 Angle of View. Check construction geometry to ensure that the total angle of view of the smoke plume, as seen by the photocell, does not exceed 15°. The total angle of view may be calculated from: $È = 2 \tan^{-1} (d/2L)$, where È = total angle of view; d = the sum of the photocell diameter + the diameter of the limiting aperture; and L = the distance from the photocell to the limiting aperture. The limiting aperture is the point in the path between the photocell and the smoke plume where the angle of view is most restricted. In smoke generator smoke meters this is normally an orifice plate.

3.3.2.4 Angle of Projection. Check construction geometry to ensure that the total angle of projection of the lamp on the smoke plume does not exceed 15°. The total angle of projection may be calculated from: $È = 2 \tan^{-1} (d/2L)$, where È = total angle of projection; d = the sum of the length of the lamp filament + the diameter of the limiting aperture; and L = the distance from the lamp to the limiting aperture.

3.3.2.5 Calibration Error. Using neutral-density filters of known opacity, check the error between the actual response and the theoretical linear response of the smoke meter. This check is accomplished by first calibrating the smoke meter according to Section 3.3.1 and then inserting a series of three neutral-density filters of nominal opacity of 20, 50, and 75 percent in the smoke meter pathlength. Filters calibrated within 2 percent shall be used. Care should be taken when inserting the filters to prevent stray light from affecting the meter. Make a total of five nonconsecutive readings for each filter. The maximum error on any one reading shall be 3 percent opacity.

3.3.2.6 Zero and Span Drift. Determine the zero and span drift by calibrating and operating the smoke generator in a normal manner over a 1-hour period. The drift is measured by checking the zero and span at the end of this period.

3.3.2.7 Response Time. Determine the response time by producing the series of five simulated 0 percent and 100 percent opacity values and observing the time required to reach stable response. Opacity values of 0 percent and 100 percent may be simulated by alternately switching the power to the light source off and on while the smoke generator is not operating.

Table 9-1. Smoke Generator Design And Performance Specifications

	Parameter	Specification
a.	Light source	Incandescant lamp operated at nominal rated voltage
b.	Spectral response of photocell	Photopic (daylight spectral response of the human eye --Citation 3)
c.	Angle of view	15 1/2 maximum total angle
d.	Angle of projection	15 1/2 maximum total angle
e.	Calibration error	± 3 % opacity, maximum
f.	Zero and span drift	± 1 % opacity, 30 minutes
g.	Response time	± 5 seconds

Bibliography

1. Air Pollution Control District Rules and Regulations, Los Angeles County Air Pollution Control District, Regulation IV, Prohibitions, Rule 50.

2. Weisburd, Melvin I., Field Operations and Enforcement Manual for Air, U.S. Environmental Protection Agency, Research Triangle Park, NC, APTD-1100, August 1972, pp. 4.1-4.36.

3. Condon. E.U., and Odishaw, H., Handbook of Physics, McGraw-Hill Co., New York, NY, 1958, Table 3.1, p. 6-52.

Figure 9-1. Record of Visual Determination of Opacity

Company ______________________

Location ______________________

Test No. ______________________

Date ______________________

Type Facility ______________________

Control Device ______________________

Hours of Observation ______________________

Observer ______________________

Observer Certification Date ______________________

Observer Affiliation ______________________

Point of Emissions ______________________

Height of Discharge Point ______________________

Clock Time	Initial			Final
Observer Location Distance to Discharge				
Direction from Discharge				
Height of Observation Point				
Background Description				
Weather Description Wind Direction				
Wind Speed				
Ambient Temperature				
Sky Conditions (clear, overcast, % clouds, etc.)				
Plume Description Color				
Distance Visible				
Other Information				

SUMMARY OF AVERAGE OPACITY

Set Number	Time	Opacity	
	Start - End	Sum	Average

Figure 9-2. Observation Record

Page ______ of ______

Company ____________________ Observer ____________________
Location ____________________ Type Facility ____________________
Test Number ____________________ Point of Emissions ____________________

		Seconds				Steam Plume (Check if applicable)		Comments
Hr	Min	0	15	30	45	Attached	Detached	
	0							
	1							
	2							
	3							
	4							
	5							
	6							
	7							
	8							
	9							
	10							
	11							
	12							
	13							
	14							
	15							
	16							
	17							
	18							
	19							
	20							
	21							
	22							
	23							
	24							
	25							
	26							
	27							
	28							
	29							

Figure 9-2. Observation Record (continued)

Page ______ of ______

Company ______________________ Observer ______________________
Location ______________________ Type Facility ______________________
Test Number ______________________ Point of Emissions ______________________

Seconds						Steam Plume (Check if applicable)		Comments
Hr	Min	0	15	30	45	Attached	Detached	
	30							
	31							
	32							
	33							
	34							
	35							
	36							
	37							
	38							
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Appendix C

Method 22 - Visual Determination of Fugitive Emissions from Material Sources and Smoke Emissions from Flares

1. Introduction

1.1 This method involves the visual determination of fugitive emissions, i.e., emissions not emitted directly from a process stack or duct. Fugitive emissions include emissions that (1) escape capture by process equipment exhaust hoods; (2) are emitted during material transfer; (3) are emitted from buildings housing material processing or handling equipment; and (4) are emitted directly from process equipment. this method is used also to determine visible smoke emissions from flares used for combustion of waste process materials.

1.2 This method determines the amount of time that any visible emissions occur during the observation period, i.e., the accumulated emission time. This method does not require that the opacity of emissions be determined. Since this procedure requires only the determination of whether a visible emission occurs and does not require the determination of opacity levels, observer certification according to the procedures of Method 9 are not required. However, it is necessary that the observer is educated on the general procedures for determining the presence of visible emissions. As a minimum, the observer must be trained and knowledgeable regarding the effects on the visibility of emissions caused by background contrast, ambient lighting, observer position relative to lighting, wind, and the presence of uncombined water (condensing water vapor). This training is to be obtained from written materials found in Citations 1 and 2 in the Bibliography or from the lecture portion of the Method 9 certification course.

2. Applicability And Principle

2.1 Applicability.

2.1.1 This method applies to the determination of the frequency of fugitive emissions from stationary sources (located indoors or outdoors) when specified as the test method for determining compliance with new source performance standards.

2.1.2 This method also is applicable for the determination of the frequency of visible smoke emissions from flares.

2.2 Principle. Fugitive emissions produced during material processing, handling, and transfer operations or smoke emissions from flares are visually determined by an observer without the aid of instruments.

3. Definitions

3.1 Emission Frequency. Percentage of time that emissions are visible during the observation period.

3.2 Emission Time. Accumulated amount of time that emissions are visible during the observation period.

3.3 Fugitive Emissions. Pollutant generated by an affected facility which is not collected by a capture system and is released to the atmosphere.

3.4 Smoke Emissions. Pollutant generated by combustion in a flare and occurring immediately downstream of the flame. Smoke occurring within the flame, but not downstream of the flame, is not considered a smoke emission.

3.5 Observation Period. Accumulated time period during which observations are conducted, not to be less than the period specified in the applicable regulation.

4. Equipment

4.1 Stopwatches. Accumulative type with unit divisions of at least 0.5 seconds; two required.

4.2 Light Meter. Light meter capable of measuring illuminance in the 50 to 200-lux range, required for indoor observations only.

5. Procedure

5.1 Position. Survey the affected facility or building or structure housing the process to be observed and determine the locations of potential emissions. If the affected facility is located inside a building, determine an observation location that is consistent with the requirements of the applicable regulation (i.e., outside observation of emissions escaping the building/structure or inside observation of emissions directly emitted from the affected facility process unit). Then select a position that enables a clear view of the potential emission point(s) of the affected facility or of the building or structure housing the affected, as appropriate for the

applicable subpart. A position at least 15 feet, but not more than 0.25 miles, from the emission source is recommended. For outdoor locations, select a position where the sun is not directly in the observer's eyes.

5.2 Field Records.

5.2.1 Outdoor Location. Record the following information on the field data sheet (Figure 22-1): Company name, industry, process unit, observer's name, observer's affiliation, and date. Record also the estimated wind speed, wind direction, and sky condition. Sketch the process unit being observed, and note the observer location relative to the source and the sun. Indicate the potential and actual emission points on the sketch.

5.2.2 Indoor Location. Record the following information on the field data sheet (Figure 22-2): Company name, industry, process unit, observer's name, observer's affiliation, and date. Record as appropriate the type, location, and intensity of lighting on the data sheet. Sketch the process unit being observed, and note observer location relative to the source. Indicate the potential and actual fugitive emission points on the sketch.

5.3 Indoor Lighting Requirements. for indoor locations, use a light meter to measure the level of illumination at a location as close to the emission sources(s) as is feasible. An illumination of greater than 100 lux (10 foot candles) is considered necessary for proper application of this method.

5.4 Observations. Record the clock time when observations begin. Use one stopwatch to monitor the duration of the observation period; start this stopwatch when the observation period begins. If the observation period is divided into two or more segments by process shutdowns or observer rest breaks, stop the stopwatch when a break begins and restart it without resetting when the break ends. Stop the stopwatch at the end of the observation period. The accumulated time indicated by this stopwatch is the duration of observation period. When the observation period is completed, record the clock time. During the observation period, continuously watch the emission source. Upon observing an emission (condensed water vapor is not considered an emission), start the second accumulative stopwatch; stop the watch when the emission stops. Continue this procedure for the entire observation period. The accumulated elapsed time on this stopwatch is the total time emissions were visible during the observation period, i.e., the emission time.

5.4.1 Observation Period. Choose an observation period of sufficient length to meet the requirements for determining compliance with the emission regulation in the applicable subpart. When the length of the observation period is specifically stated in the applicable subpart, it may not be necessary to observe the source for this entire period if the emission time required to indicate noncompliance (based on the specified observation period) is observed in a shorter time period. In other words, if the regulation prohibits emissions for more than 6 minutes in any hour, then observations may (optional) be stopped after an emission time of 6 minutes is exceeded. Similarly, when the regulation is expressed as an emission frequency and the regulation prohibits emissions for greater than 10 percent of the time in any hour, then observations may (optional) be terminated after 6 minutes of emission are observed since 6 minutes is 10 percent of an hour. In any case, the observation period shall not be less than 6 minutes in duration. In some cases, the process operation may be intermittent or cyclic. In such cases, it may be convenient for the observation period to coincide with the length of the process cycle.

5.4.2 Observer Rest Breaks. Do not observe emissions continuously for a period of more than 15 to 20 minutes without taking a rest break. For sources requiring observation periods of greater than 20 minutes, the observer shall take a break of not less than 5 minutes and not more than 10 minutes after every 15 to 20 minutes of observation. If continuous observations are desired for extended time periods, two observers can alternate between making observations and taking breaks.

5.4.3 Visual Interference. Occasionally, fugitive emissions from sources other than the affected facility (e.g., road dust) may prevent a clear view of the affected facility. This may particularly be a problem during periods of high wind. If the view of the potential emission points is obscured to such a degree that the observer questions the validity of continuing observations, then the observations are terminated, and the observer clearly notes this fact on the data form.

5.5 Recording Observations. Record the accumulated time of the observation period on the data sheet as the observation period duration. Record the accumulated time emissions were observed on the data sheet as the emission time. Record the clock time the observation period began and ended, as well as the clock time any observer breaks began and ended.

6. Calculations

If the applicable subpart requires that the emission rate be expressed as an emission frequency (in percent), determine this value as follows: Divide the accumulated emission time (in seconds) by the duration of the observation period (in seconds) or by any minimum observation period required in the applicable subpart, if the actual observation period is less than the required period, and multiply this quotient by 100.

Bibliography

1. Missan, Robert and Arnold Stein. Guidelines for Evaluation of Visible Emissions Certification, Field Procedures, Legal Aspects, and Background Material. EPA Publication No. EPA-340/1-75-007. April 1975.

2. Wohlschlegel, P., and D.E. Wagoner. Guideline for Development of a Quality Assurance Program: Volume IX--Visual Determination of Opacity Emissions from Stationary Sources. EPA Publication No. EPA-650/4-74-005i. November 1975.

FUGITIVE OR SMOKE EMISSION INSPECTION OUTDOOR LOCATION

Company ______ Location ______ Company Rep. ______	Observer ______ Affiliation ______ Date ______
Sky Conditions ______ Precipitation ______	Wind Direction ______ Wind Speed ______
Industry ______	Process Unit ______

Sketch process unit: indicate observer position relative to source and sun, indicate potential emission points and/or actual emission points.

OBSERVATIONS

	Clock time	Observation period duration, min:sec	Accumulated emission time, min:sec
Begin Observation	______		
	______	______	______
	______	______	______
	______	______	______
	______	______	______
	______	______	______
	______	______	______
	______	______	______
	______	______	______
		______	______
End Observation	______		

Figure 22-1

FUGITIVE EMISSION INSPECTION
INDOOR LOCATION

Company ______________________ Observer ______________________

Location ______________________ Affiliation ______________________

Company Rep. ______________________ Date ______________________

Industry ______________________ Process Unit ______________________

Light type(fluorescent,incandescent,natural) ______________________

Light location(overhead,behind observr etc) ______________________

Illuminance(lux or footcandles) ______________________

Sketch process unit: Indicate observer position relative to source; indicate potential emission points and/or actual emission points.

OBSERVATIONS

	Clock time	Observation period duration, min:sec	Accumulated emission time, min:sec
Begin Observation	________		
	________	________	________
	________	________	________
	________	________	________
	________	________	________
	________	________	________
	________	________	________
	________	________	________
	________	________	________
End Observation	________	________	________

Figure 22-2