Visible Emission Evaluation Procedures Course

Student Manual

APTI Course 325
Final Review Draft

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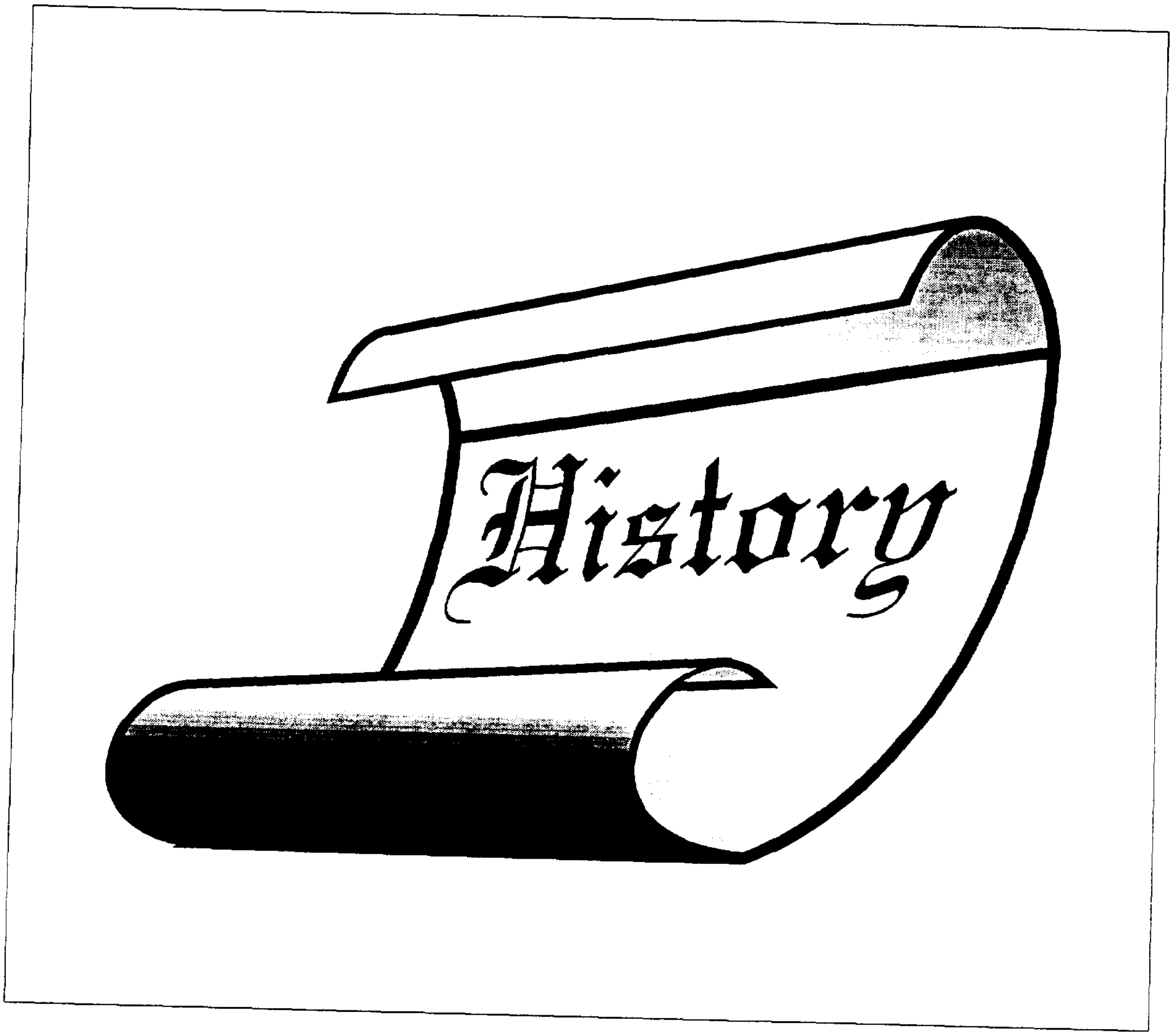
Contents

Lesson 1

History



History

Early History

Notes

Most early U.S. and English case law concerning air contamination fell under a part of the law commonly referred to as nuisance law. In the absence of specific regulations or laws against air pollutants, someone wanting to stop pollution (for example, smoke from factories) had to bring a tort (or injury) case against the offender. Smoke in general was not necessarily considered a nuisance, however. Each case had to stand on its own merit and prove that smoke was a nuisance. An early example of a successful court case in which air pollution was ruled a nuisance was an English case in which a lead smelter produced fumes that killed a neighbor's corn.

Probably the earliest case upholding a municipal smoke-control ordinance was the 1859 case *City of New Orleans v. Lambert*. The Louisiana Supreme Court upheld an injunction against a blacksmith shop because, in violation of a city ordinance, it emitted offensive odors and smoke and was a nuisance. The court upheld the police powers of the municipal government.

The problem of proving that smoke is an annoyance or is injurious to health in every case was well stated by Lord Romilly in *Crump v. Lambert* in 1867: "The real question in all of these cases is the question of fact, namely, whether the annoyance is such as to materially interfere with the ordinary comforts of human existence."

Industrial development increased toward the end of the 19th century. With increased industry came increased awareness of the health, social, and physical costs of industrialization and city crowding. Communities passed regulations that sought to control air pollution itself rather than to control nuisances caused by air pollution. In 1881 the first smoke control ordinances were adopted in Chicago and Cincinnati. Court records from the late 19th and early 20th centuries contain many examples of city and state prosecutions of smoke ordinance violations.

Notes

The proliferation of smoke ordinances set the stage for the introduction of measurement science into the smoke-control mechanism. Maximillian Ringelmann, a Belgian-born, German-trained engineer working in France, developed a method to quantify emissions according to the density of the observed smoke. He developed the method, known as the Ringelmann Chart, to assist in his studies of combustion efficiency. Using a set of cards with patterns of black ink, he was able to categorize the density of black smoke into four shades of darkness (see Figure 1-1).

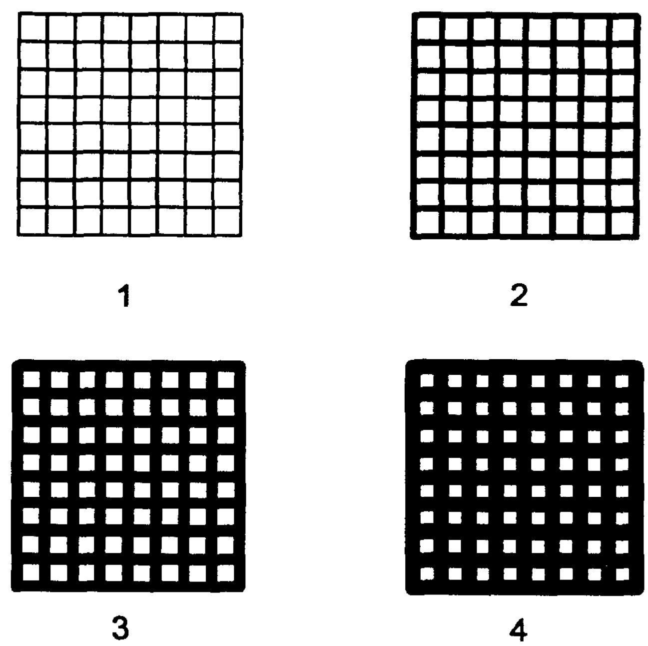


Figure 1-1. Ringelmann Cards

In 1899 the American Society of Mechanical Engineers recognized the Ringelmann Chart as its official scale for determining smoke density. In 1904 the U.S. Geological Survey used the Ringelmann Chart in combustion studies for coal-fired sources, giving it further credibility. Agencies and municipalities seeking to improve the quality of the air quickly picked up the Ringelmann system. By 1912, 23 of the 28 cities in the United States with populations of over 200,000 had adopted smoke ordinances.

Ruling bodies soon recognized that the law of nuisance alone was not adequate to prevent air contamination. What was needed was a shift of emphasis away from individual complaints toward community-wide concerns. In 1905 in the case of *Glucose Refining Company v. City of Chicago*, the court upheld the view that "the emission of dense smoke in populous communities is a public nuisance." In *Field v. Chicago* the court found that "smoke emitted from a tall chimney is carried over a wide territory and that when dense, it deposits soot to such an extent so to injure property and health wherever it spreads."

Notes

At this point, the relationship between legislation and common law becomes important:

- Legislation is all the statutes, laws, rules, regulations, etc. passed by ruling bodies. Legislation is also called statutory law.
- Common law is the body of court interpretations and rulings that enhance, modify, and temper these legislative actions.
- Until statutory law has had its day in court and withstood the challenge, it is not fully established.

The need for enlarging the scope of the public nuisance definition was formally recognized in the Missouri case of *State v. Tower* in 1904:

> "It was entirely competent for the Legislature to take cognizance of the fact, known to all men, that the emission and discharge of dense smoke in the atmosphere of a large and populous city is of itself a nuisance . . . and one calculated to interfere with the health and comfort of the inhabitants thereof, and to declare it a nuisance per se . . . . We have no hesitancy in holding that it was entirely competent for the Legislature to declare the emission of dense smoke in the open air in a city of 100,000 inhabitants a nuisance per se."

Refinement In Law

Other specific problems regarding regulations of air pollutants had to be addressed in the courts. One problem was how liberal a view the courts had toward air pollution regulations. Several cases speak to that issue. In *Penn Dixie Cement Corp. v. City of Kingsport* in 1949 the court found that public health

Notes

is the responsibility of the government. To that end, all reasonable ordinances to protect public health have been sustained.

Legislators have wide discretion in determining what is a nuisance and also what is regulated under police power. The courts do not interfere unless the law results in unnecessary hardship. The courts can look behind the law to determine whether the law is reasonable. In *Moses v. United States* the court agreed that adapting regulations to meet specific conditions is within the province of legislatures. The courts can interfere only when regulation is not within police power and only when private rights have been violated. This case raised the issue of reasonableness. Any statute or ordinance must be reasonable and must regulate something injurious to health, safety, and welfare. "Reasonable" is a word subject to various interpretations and this latitude of interpretation has generated many cases. The following case review illustrates the courts' general interpretation of "reasonable."

What is reasonable depends on the circumstances. In the 1884 case of *Harmon v. Chicago* in the Illinois Supreme Court, the defendant argued that it was unreasonable to require the burning of expensive, clean fuel, such as anthracite coal, in place of locally available bituminous coal. "Not so," said the court. Although the holding in this case recognized that regulations could be inconvenient or costly, the court's place is not to address such issues. Cities have the authority to regulate.

Other decisions have held the following messages:

- In 1851 it was stated that the inconvenience must be real, not imaginary, and must interfere with ordinary comfort.

- In 1937 the courts found that the loss of even one night's sleep is not a trivial matter (*Andreae v. Selfridge*).

After the parameters of "reasonable" had been determined, courts upheld regulations, as in the following examples:

- In *People v. Lewis* (Michigan, 1891) it was found not unreasonable to exempt certain classes (residences and steamboats) from regulations.

- In 1899 in the case of *City of Brooklyn v. Nassau Elect RR* a penalty of $100 for burning soft coal was collected from Nassau Elect RR because of their violation of a statute.

- *Cincinnati v. Burkhardt* (1908) upheld the use of a color scale to measure smoke.

- In 1910 a Rochester, New York, statute upheld the use of the Ringelmann scale. This statute prohibited smoke from 5 a.m. to 7:30 a.m., presumably to protect commuters, and allowed dense smoke for only 5 minutes in every four-consecutive-hour period.

Notes

In the early 1900s legislatures and municipalities were still wrestling with the problem of air pollution. In 1916 a much-cited case—*Northwestern Laundry v. Des Moines*—was filed in the U.S. District Court in Iowa. This case, against the city smoke inspectors and the smoke abatement board, sought to enjoin or block the enforcement of a Des Moines regulation that declared dense smoke in portions of the city a public nuisance. The plaintiff claimed that the ordinance was void for the following reasons:

- Due process was guaranteed under the 14th Amendment.

- The Ringelmann Chart was arbitrary.

- The standard required the remodeling of almost all the plaintiff's furnaces.

- In the permitting requirements for new construction, inspectors and abatement commissioners had discretion to require and prescribe requirements.

The court dismissed the case, saying:

> So far as the federal Constitution is concerned, we have no doubt the state may by itself, or through authorized municipalities, declare the emission of dense smoke in cities or populous neighborhoods a nuisance and subject to restraint as such; and that the harshness of such legislation, or its effect upon business interests, short of a merely arbitrary enactment, are not valid constitution-

Notes

> al objections. Nor is there any valid federal constitutional objection in the fact that the regulation may require the discontinuance of the use of property, or subject the occupant to large expense in complying with the terms of the law or ordinance.

This landmark decision has been cited as a precedent in numerous cases. The courts consider the problem settled. For example, in 1950 in the *Board of Health of Weehawken Township, Hudson County (NJ) v. New York Central Railroad* the court referred to the Des Moines case and stated that there were no constitutional restraints against the state's regulating dense smoke injurious to the common welfare.

Historic Events 1945 To 1970

1945: Air pollution control began in the city of Los Angeles. In the same year, Los Angeles developed the equivalent opacity concept that extended smoke density measurements to white smoke, allowing for control of a larger number of air pollution sources.

1950: California passed California Rule 50A, which was based on the Ringelmann system, to limit smoke. This rule eventually was copied by almost all states and found its way into federal new source performance standards (NSPS) promulgated 20 years later.

1953: Los Angeles County started its smoke-school program for black smoke. The program was the beginning of standardization of visible emission observation programs nationwide.

1955: The federal government enacted the 1955 Air Pollution Control Act, the first of a series of air pollution control acts to be passed by the federal government.

1963: Momentum increased with the passage by Congress of the first Clean Air Act. Part of the Act provided grants to air pollution control agencies.

1965: The Clean Air Act was amended to include Title 2, Motor Vehicle Emissions Standards. This legislation recognized that automobiles presented a pollution problem in many areas of the country.

Notes

1967: The Federal Air Quality Act was passed, moving the responsibility for automobile emission controls to the federal government. The Act also required states to establish Air Quality Regions and to adopt Ambient Air Quality Standards, a precursor to the modern State Implementation Plans (SIPs).

1968: The federal government published AP-30, a joint industry and government study of opacity, leading the way for strong emphasis on opacity as a federal regulatory tool.

1970 (Earth Year): A new wave of environmental activity swept the country. Intensive media attention heralded the increase of public support for pollution control agencies and their efforts to protect the public. The National Environmental Policy Act was passed on January 1, 1970. It signified a federal commitment to use all practical means to promote the general welfare and to attain harmony with the environment. A new set of Clean Air Act Amendments also was established in 1970.

Creation Of EPA

EPA was created in 1970 out of federal agencies that included the National Air Pollution Control Administration from the Public Health Service, Water Pollution Control from the Department of Agriculture, and Solid Waste and Radiation from the Public Health Service. EPA was created to consolidate environmental activities at the federal level and to support state and local control and research efforts.

In 1971 EPA promulgated national ambient air quality standards for the following pollutants:

- Sulfur dioxide
- Nitrogen dioxide
- Particulate matter
- Photochemical oxidants
- Carbon monoxide

Selected Cases

The cases described below either set important precedents or serve as examples of key legal principles.

Notes

In 1973 EPA proposed a new Portland cement standard of 10-percent opacity for emissions from Portland cement plants. The Portland Cement Association sued the EPA Administration on the grounds that the accuracy of the opacity method was not adequate to support the standard. EPA spent the next year conducting field studies on the method. As a result of those field studies, EPA:

- Raised the opacity limit for Portland cement plants from 10 to 20 percent.
- Revised the data reduction scheme of Method 9 to averaging.
- Established more specific observation and training requirements.

These revisions resulted in the first modern version of Method 9. Since its promulgation, the method has undergone only one minor change: it now requires a sketch that indicates the relative positions of the observer, the sun, and the source.

The concept of free and open fields was settled in the Western Alfalfa case (1976). This case is important because it established the right of an inspector to go onto the property of a company as long as the inspector stays in areas that are accessible to the public and does not cross a barrier or go through a gate.

Inspectors who were denied entry to a plant in New York filed a court case (known as the Donner Hanna case) that ended in a landmark decision. Its implications were serious. The source was a coke oven battery being regulated under rules in the state implementation plan (SIP), and both EPA and the state were involved in the case. The source was being regulated under a time aggregation rule patterned after California Rule 50A. Emissions from the battery were timed with a stopwatch in accordance with historical precedents in New York and Pennsylvania.

Inspectors were denied entry by the source on the following grounds:

- In the absence of a promulgated state measurement method, the method of measurement must be Federal

Reference Method 9 as found in the new source performance standards (NSPS).

Notes

- Because the inspectors intended to use a time aggregation technique rather than Method 9, they had no usable method.

The court upheld the company position and denied entry to EPA inspectors. This case focused attention on the differences between Federal Reference Methods and SIP methods that were used by states and EPA without being officially promulgated within the agencies.

Typical Regulation

A typical regulation might read as follows:

> *No source shall suffer or permit to emit into the atmosphere an emission with an opacity equal to or greater than 20 percent for 3 minutes in any 1 hour.*

It is important to analyze the elements of the regulation to ensure that the full meaning of the rule is understood.

No source shall suffer or permit

The source cannot purposely or accidentally create an emission.

to emit into the atmosphere an emission

Emission into the atmosphere includes emissions into the air inside a building if all the inside air is not captured by hoods or ductwork and processed by control equipment. Thus, even fugitive emissions from building leaks are included in emissions.

with an opacity equal to or greater than 20 percent

The most common opacity standard is 20 percent (in other words, the opacity reading must be less than 20 percent). Some SIPs still have 40-percent regulations. Some of the NSPS are down to 3 percent or less.

for 3 minutes in any 1 hour.

Notes

This is the time exemption allowing for startup, etc. Even if the regulation is for 3 minutes, a 6-minute average is necessary to prove a violation unless an alternative method is clearly specific and has been through formal promulgation.

Review Questions

1. In early U.S. and English case law, smoke was dealt with as a __________.

2. Who developed the first method used to quantify emissions according to the density of the smoke?

3. A 1949 court case determined that public health is the responsibility of __________.

4. In 1937 in *Andreae v. Selfridge* the courts found that the loss of even __________ was not a trivial matter.

5. In the landmark __________ case, the court ruled that the state can declare the emission of black smoke a public nuisance.

6. In what year did the federal government pass the first Air Pollution Control Act?

7. What Act in what year first included automobile emission regulations?

8. In 1970 what federal agency was formed from the National Air Pollution Control Administration from the Public Health Service, Water Pollution Control from the Department of Agriculture, and Solid Waste and Radiation from the Public Health Service?

9. The Donner Hanna case established the right of an inspector to enter the property of a company as long as the inspector ______________________________.

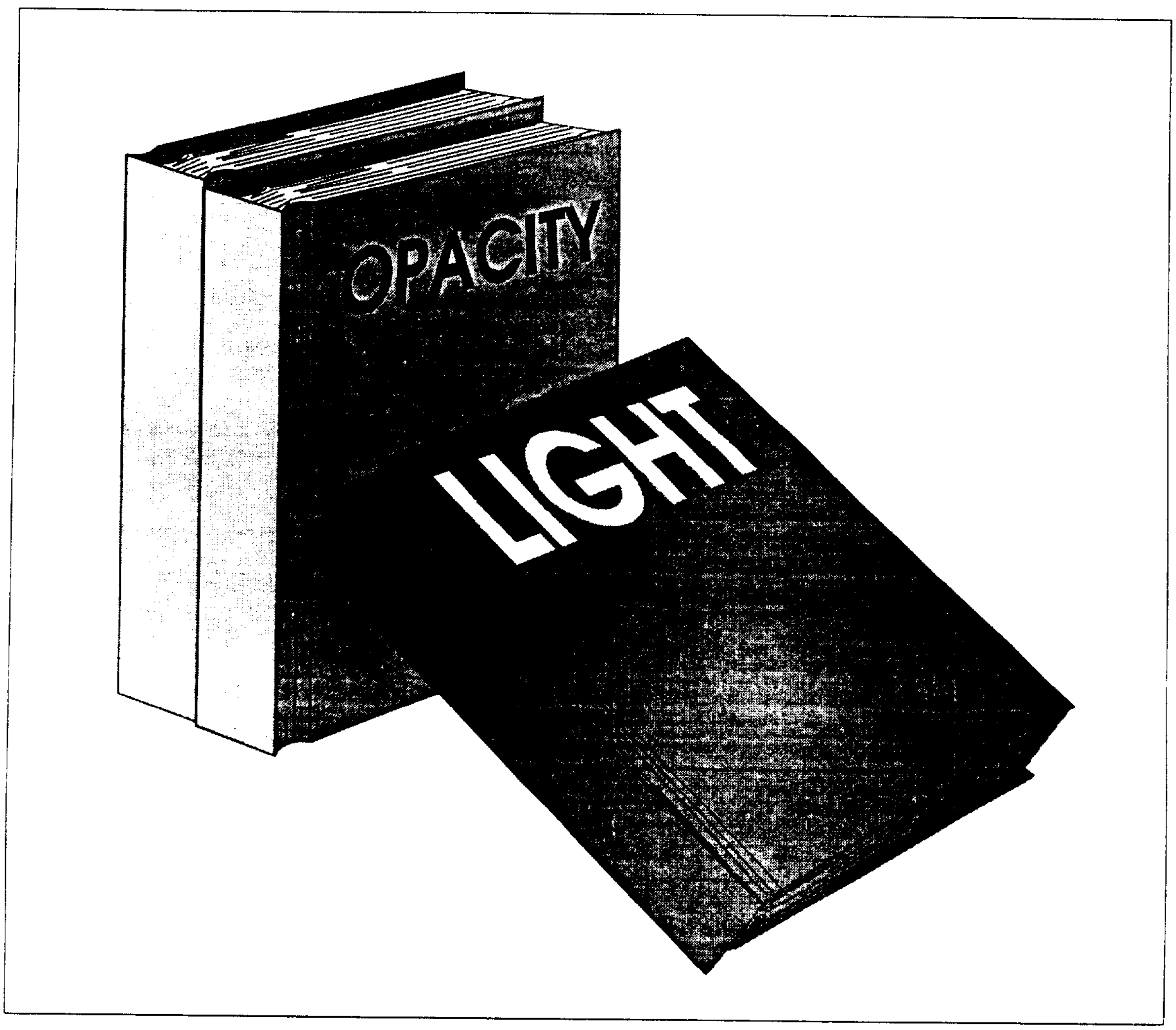
10. The Donner Hanna case focused attention on the differences between Federal Reference Methods and ______________________________.

11. Match the following:

A) Ruling bodies	1) Until it has had its day in court and withstood the challenge, it is not fully established.
B) Common law	2) Pass statutes, laws, rules, regulations, etc.
C) Statutory law	3) Body of court interpretations and rulings that enhance, modify, and temper laws.

Lesson 2

Principles Of Visual Emissions Measurement



Principles Of Visual Emissions Measurement

This lesson defines basic concepts related to opacity and discusses the scientific principles associated with measuring opacity and the practical application of those principles.

Notes

Ringelmann Method

As outlined in Lesson 1, the system of visible emissions evaluation evolved from a concept developed by Maximillian Ringelmann in the late 1800s. Ringelmann used a chart of calibrated black grids on a white background to measure dark or black smoke emissions from coal-fired boilers. The grids ranged from approximately 20-percent ink coverage for a Ringelmann #1 through 100-percent ink coverage, or solid black, for a Ringelmann #5 (see Figure 2.1). The observer simply compared the shade of the smoke with the shade of the card.

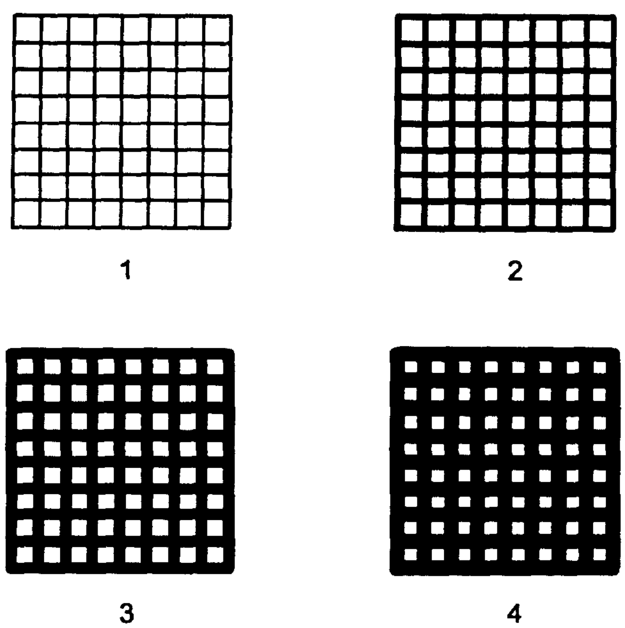


Figure 2-1. Ringelmann Chart

Notes

Equivalent Opacity

In the early 1950s, the Ringelmann concept was expanded to include colors of smoke other than black by introducing "equivalent opacity." Equivalent opacity is the opacity equivalent to the obscuring power of black smoke characterized by a specific Ringelmann grid. Thus, a Ringelmann #1 was equivalent to 20-percent opacity. The major difficulty in the equivalent opacity system was not the scientific basis of the system but that opacity witnesses frequently could not explain to a court how white was equivalent to black.

The federal government has discontinued using the Ringelmann numbers in EPA Method 9 procedures for new source performance standards (NSPS). Although current procedures are based solely on opacity, some state regulations (notably California's) still specify the use of the Ringelmann Chart to evaluate black and gray plumes. The general trend, however, is toward reading all visible emissions in percent opacity.

Opacity And Transmission Of Light

Plume opacity is defined as one of the following:

- The degree to which light transmission through the diameter of a plume is reduced.
- The degree to which the visibility of a background viewed through the diameter of a plume is obscured.

When light strikes an object or substance, the light is either reflected, absorbed, or transmitted. The amount of light that is reflected and absorbed determines the opacity of the substance. Simply put, in the observation of a pollutant plume, opacity is the obscuring power of the plume.

In terms of physical optics, opacity is related to transmittance (I/I_0) through the plume. Percent opacity and percent transmittance always total 100 percent. Percent opacity is defined by the following equation:

Percent opacity = $(1 - I/I_0) \times 100$

Notes

in which: I_0 = the incident light flux (the light that enters the plume)

I = the light flux leaving the plume along the same path

Many factors influence plume opacity readings: 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.

Light And Particles

The wavelengths of visible light in the electromagnetic spectrum range from 400 nanometers (nm) for blue light to 700 nm for red light. Below 400 nm is the ultraviolet (UV) frequency, and above 700 nm is the infrared (IR) frequency (see Figure 2.2). Human vision peaks in the middle of the visible range, at 550 nm, a yellowish-green color. This color is seen the best, and not coincidentally, it is also the best background for light-colored plumes.

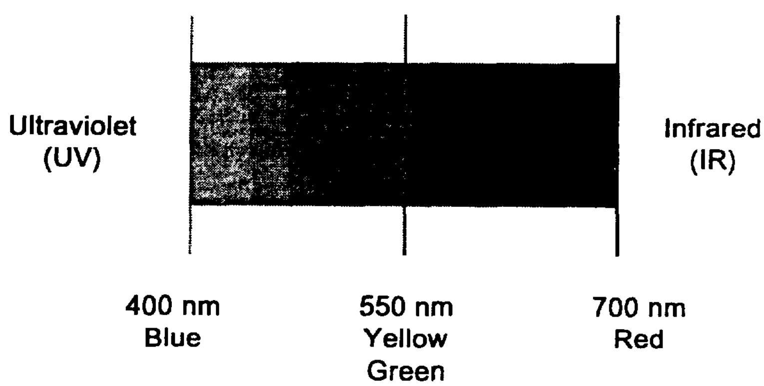


Figure 2-2. Electromagnetic Spectrum

Opacity is a function of the interaction between light over this visible spectrum and particles. This interaction is affected by properties of both the particles and the light that include:

- Number and size of the particles
- Particle shape
- Particle color
- Index of refraction of the particles

Notes

- Spectral characteristics of the light
- Light direction
- Amount of light

When light hits a particle, one of two things can happen: the light can either be transmitted through the particle, or it can be affected by the particle. Mechanisms by which the particles affect light include absorption and scattering. Light scattering mechanisms include reflection, refraction, Rayleigh scattering, and Mie scattering. These mechanisms are affected in turn by the particle and light properties defined above.

Transmission

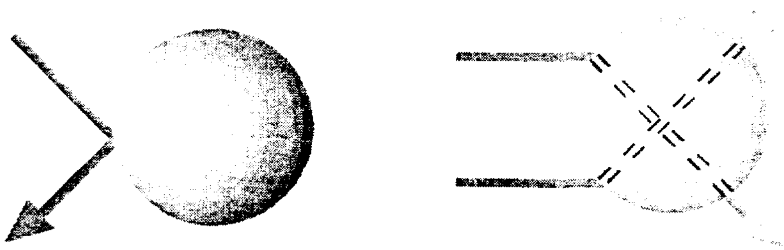
The least likely but simplest interaction of a particle and light is transmission, which involves light passing completely through the particle in its initial direction. For light to be transmitted through a particle, the light must hit the front and back surfaces of the particle exactly perpendicular and the particle must be clear. Even in the rare cases that meet these conditions, light will be attenuated (weakened) as a consequence of absorption.

Absorption

If a particle has any color or is black, it will absorb a certain amount of light as the light enters the particle. The energy of the light is converted to heat in the particle. The energy simply warms the particle, just as a black seat cover in a car is heated by the summer sun. Black particles absorb all colors of light, whereas colored particles absorb only specific wavelengths of light.

Scattered Light

Scattered light is light diverted from its original path of transmission. The two main light-scattering mechanisms for large particles are reflection and refraction (see Figure 2-3). For smaller particles, the main light-scattering mechanisms are Rayleigh and Mie scattering. The observed opacity of colored particles depends strongly on the light-scattering properties of those particles, not on the absorption of light entering the particles.



Reflection   Refraction

Figure 2-3. Large-Particle Light-Scattering

Notes

Reflection

Reflection occurs when light "bounces off" a surface rather than passing through it. The surface color and texture of a particle determine its reflective quality. A white particle reflects light more readily than does a black particle. Even a black particle can reflect light if the surface is smooth, however. An everyday example of reflection from black materials is the mirror effect of well-polished black marble.

Refraction

Simple refraction is the bending of light as it goes through a transparent medium. Lenses, such as those used in eyeglasses, work by refraction. When a light wave hits the curved surface of a particle, the light wave turns toward the particle center. Subsequently, the light leaves the particle along a different line than that of its entrance.

Rayleigh Scattering

When particle size is significantly smaller than the wavelength of light, the light is widely scattered (see Figure 2-4a). Rayleigh scattering is important for extremely small particles because they scatter much of the light away at large angles from the forward direction. Rayleigh scattering is responsible for the typically blue color of the sky: blue light is scattered out from the light coming directly from the sun. Extremely small particles create a bluish plume even if the individual particles are actually colorless. Fine particles are often referred to as blue smoke in the control-equipment industry.

Notes

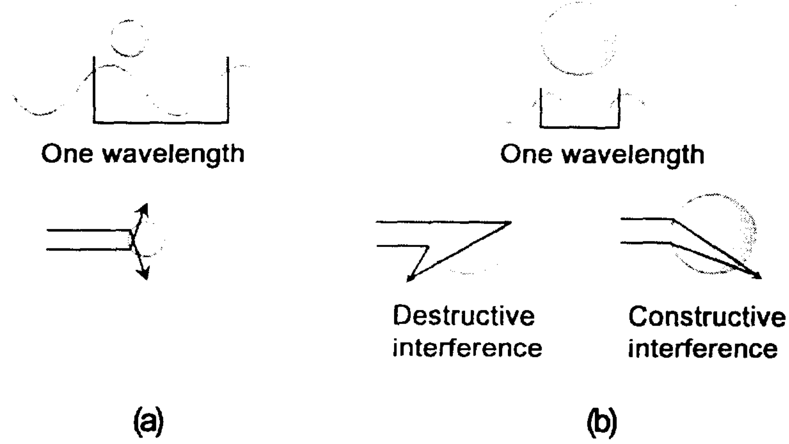


Figure 2-4. Small-Particle Light-Scattering: Rayleigh (a) and Mie (b)

Mie Scattering

When particle size and the wavelength of light are approximately the same, Mie scattering occurs (see Figure 2-4b). Light waves reflecting off the inside surfaces of a particle can either add together constructively or subtract destructively as they move from the separate locations within the particle. Light can also be refracted from the edges of the particle and contribute to the scattering interference patterns. Visible light scattering from emission particles below 1 μm falls within the Mie scattering range.

Particle Size

Given that particles decrease light transmission by both scattering and direct absorption, particle size plays a significant role in opacity. Particles with diameters approximately equal to the wavelength of visible light (0.4 to 0.7 microns) have the greatest scattering effect and cause the highest opacity. These particles, PM_{10} particles, are in the respirable range.

Variables Influencing Opacity Observations

The appearance of a plume as viewed by an observer depends on a number of variables, some of which might be controllable and some of which might not be controllable in the field. Variables that might not 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 influence the appearance of a plume as viewed by an observer and can affect the ability of the observer to assign accurate opacity values to the 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 it is viewed against a contrasting background.

Notes

Color contrast is the difference in color between two objects. For instance, red and orange are different colors but the difference between them is not nearly as great as that between red and blue. If the plume color is identical to the background color, the visible emissions observer will have difficulty distinguishing between the plume and the background. One manufacturer reportedly used this principle to lower its apparent opacity by painting its facility the same color as its particulate emissions. This tactic deprived the observers of backgrounds of a contrasting color. To the degree possible, the observer should maximize the color contrast between the plume and the background to get the most accurate readings.

Luminous contrast is the difference in light emanating from two objects, for example, a black plume against a light sky. Two objects that have the same color can show up against each other because of these differences in lighting levels. This effect is important in the case of forward scatter, in which plumes become more luminous than their background. Luminous contrast is vital to a color-blind observer. Also, luminous contrast is the primary tool for observing a light-colored plume against a light-colored sky.

When reading light-colored plumes, it is useful to have a patterned background as a target. The degree to which the pattern is obscured is another tool to assist in determining the opacity. Patterned backgrounds can include trees, buildings, towers, power poles, mountains, or even other stacks at the source.

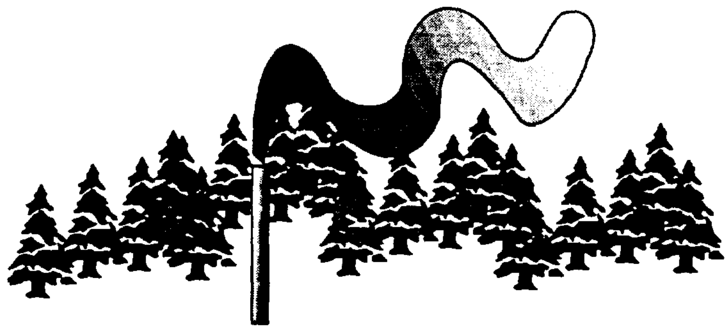
Selecting The Background

All the factors discussed above are important in selecting the proper background for an opacity determination.

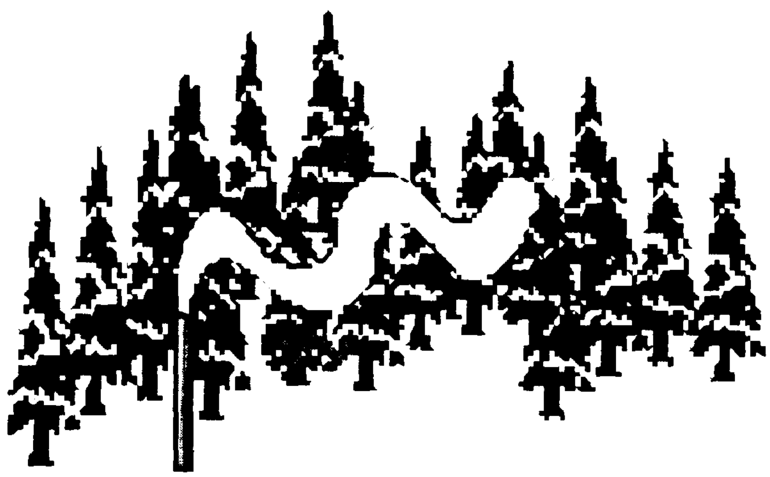
Notes

For black smoke, a light-colored background is best and light-blue sky is excellent (see Figure 2-5). Because the black smoke does not scatter the light, it is not necessary or desirable to use a textured or patterned background.

For white smoke, a dark-colored background with texture or a pattern is best (see Figure 2-5). The observer is often faced with only a blue sky background because of stack height. Generally, the deeper the blue, the more accurate the observations.



A black plume should be read against a light background.



A white plume should be read against a dark, textured background.

Figure 2-5. Plume Background

During all observations, it is important that the observer look through the smoke at the background and also at the background without the smoke. The observer should compare the *background* appearances under both conditions and not focus only on the appearance of the background through the emissions. The observer should remember that the goal in determining opacity values is to judge how much the unobscured background is changed by the emissions.

Notes

Mass Emissions/Opacity Relationship

Generally, denser plumes have more particles and, consequently, higher mass emissions. When Method 9 was promulgated, the relationship between opacity and mass emissions was not well developed. Today, opacity can be predicted if sufficient information about the emissions is available. Factors that affect the mass emissions/opacity relationship include:

- The number of particles
- The particle size distribution
- The pathlength through the plume
- The density of the particles
- The spectral characteristics of the light
- The index of refraction of the particle
- The opacity of the plume in terms of transmission

The relationship can be described by the following equation:

$$C = \frac{K\,R\,\ln(T)}{P}$$

in which:
C = mass concentration
K = particle size distribution
R = particle density
T = equivalent transmittance
P = pathlength through the plume

As the pathlength through the plume increases, the opacity increases because the number of particles between the source of light and the detector or observer has increased.

The natural log, ln, of the equivalent transmittance, which is referred to as optical density, is also directly proportional to particle concentration. All other factors being equal, opacity is a function of the number of particles in a specified size distribution per unit volume of gas. Particle density is used to convert particle concentration to mass concentration.

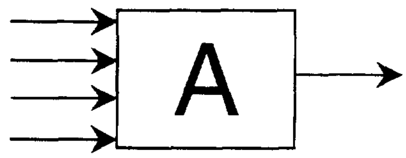
Review Questions

1. A Ringelmann #2 would have what percent ink coverage?

2. What was the major difficulty with the concept of equivalent opacity?

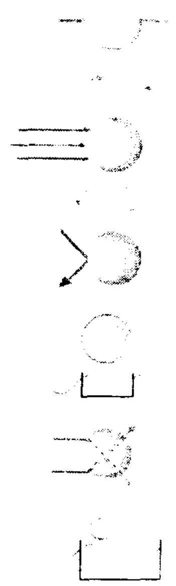
3. Define opacity.

4. In the following picture, what is the opacity of substance A?



5. Name four properties that affect opacity.

6. Match the following.



A) Absorption	1)	
B) Refraction	2)	
C) Transmission	3)	
D) Rayleigh scattering	4)	
E) Reflection	5)	
F) Mie scattering	6)	

7. The difference between the color of two objects is the ____________________.

   The difference in the light emanating from two objects is the ______________.

8. An observer should (maximize/minimize) the luminous contrast and color contrast between plume and background.

9. An excellent background for black smoke is ___________________________.
   An excellent background for white smoke is ___________________________.

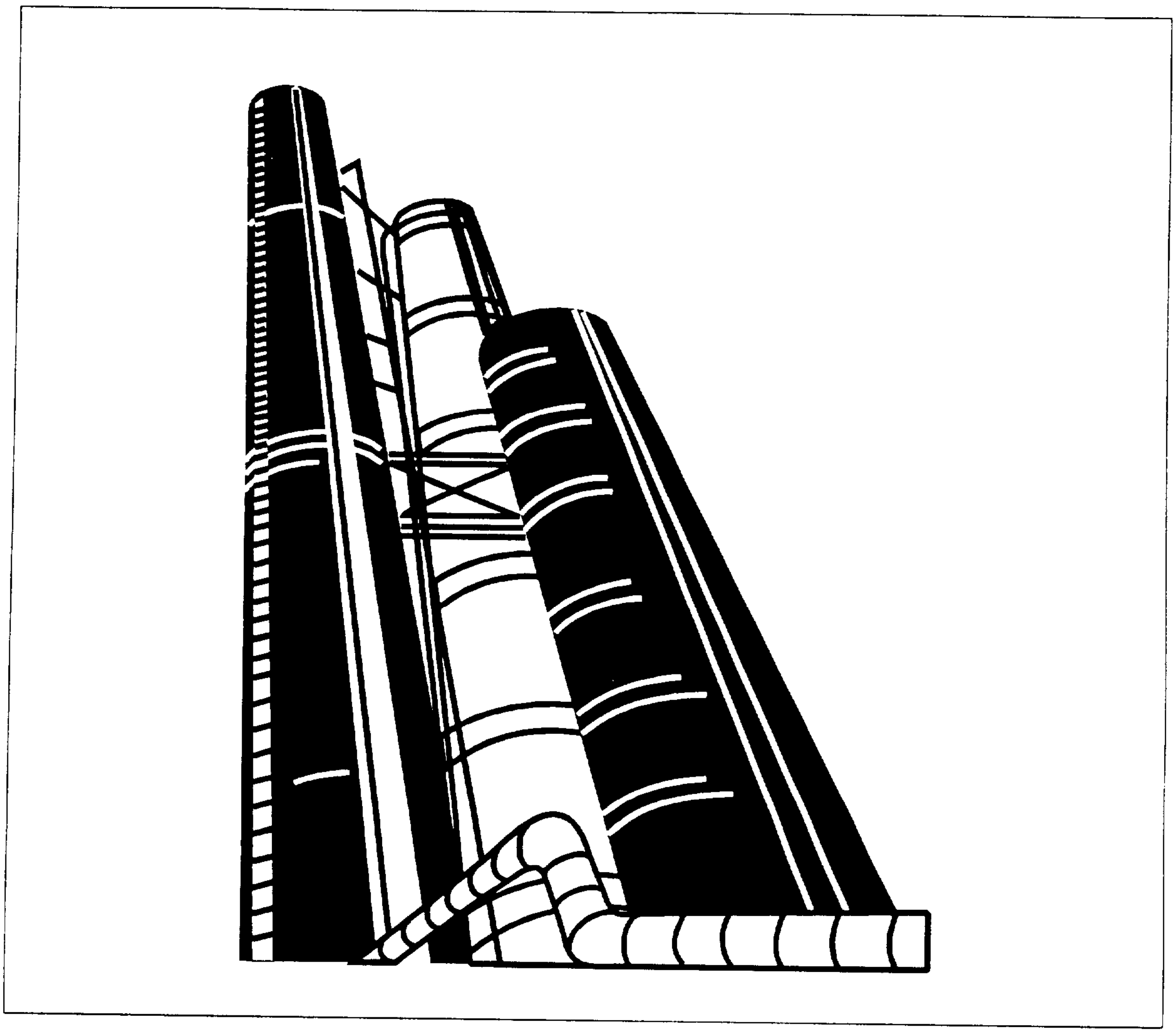
Review Questions

10. If one has sufficient information (such as number and size of particles, plume pathlength, etc.) one can predict ______________________________.

11. If the pathlength increases, the opacity ____________________________.

Lesson 3

Sources Of Visible Emissions



Sources Of Visible Emissions

A wide range of industries produce visible emissions. This lesson discusses the types of emissions and their causes, emission sources, emission components, plumes, and visible emissions control equipment.

Notes

Emissions

Visible emissions come in many shades, but they are usually categorized as either black or white (non-black) emissions. Black particles absorb visible light; white, or non-black, particles scatter visible light.

Black emissions are produced when solid fuels or residual oils are burned under poor combustion conditions in an oxygen-deficient environment. Unburned carbon particles cause a visible black plume, as do magnesium dioxide, hematite, and some material-handling processes.

White (non-black) emissions are produced as a by-product of combustion, either as the result of hydrocarbon vaporization, excess combustion air, or loss of flame. Also, white emissions occur as a result of a condensation reaction or as fine dust from material handling.

Emission Sources

Visible emissions are introduced into the atmosphere by stacks, vents, conveyor lines, and other non-point sources, such as storage piles and unpaved roads.

Stacks

Many sources send their emissions into the atmosphere through smokestacks. A stack is a pipe or funnel through which smoke and gases are discharged. Stacks vary in

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height and diameter; the opacity of the plume can be influenced by these characteristics.

Tall stacks influence readings by increasing the sun/slant angle and by eliminating the possibility of a high-contrast background. When a white plume is observed, a contrasting background, such as trees or a hillside, is desirable. Sometimes, however, the sky is the only background for a tall stack. If the sky is overcast, this can cause a negative bias of readings, especially with light-colored plumes.

Wide stacks or large-diameter stacks can cause a higher-than-expected opacity ratio because of the increased pathlength through the plume.

Emissions from non-circular stacks, including oval, rectangular, and square stacks, should be read across the narrowest axis of the plume. The observer should pre-select the time of day and pay close attention to wind conditions at the time of the observation, because these factors can severely limit the observer's ability to read the stacks correctly from the best position.

Readings of emissions exhausted horizontally are strongly limited by wind direction, which could cause difficulty in making accurate readings. For example, an emission port facing west would be unreadable with a west wind, and the plume could be sheared off by either a north or south wind. Sun angle also might be difficult to reconcile, depending on the direction of the emission port and on the visual interference presented by the stack itself. The observer should ascertain the appropriate meteorological conditions, as well as the proper time of day for acceptable sun angle, before performing visible emissions observations.

Fugitive Emissions

Fugitive emissions come from non-specific point or area sources that include:

- Roof monitors
- Unpaved roads
- Gaps in duct work
- Doors
- Storage piles
- Conveyors

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Particles that comprise fugitive emissions are often larger than those found in a stack gas stream and, therefore, tend to settle out of the cloud more rapidly.

Studies have shown, however, that fugitive dust plumes also have a significant PM-10 dust-particle component. Fugitive emissions are caused by many mechanical processes, such as:

- Crushing
- Drilling
- Sanding
- Vehicle movement
- Grinding
- Sweeping
- Demolishing
- Material handling

Visible Emission Components

Visible emissions contain a variety of particles in sizes ranging from 0.1 micrometer (µm) to 200 µm. Particles are categorized as:

- Smoke
- Soot
- Fly ash
- Dust
- Fumes
- Mist
- Gas
- Condensed vapor

Smoke is a visible effluent resulting from incomplete combustion. Smoke consists mostly of soot, fly ash, and other solid or liquid particles.

Soot consists principally of carbon particles that contain attached or absorbed tars and other hydrocarbons. Soot is formed by the incomplete combustion of carbonaceous material and is the principal cause of the blackness of a smoke plume. Soot particles are generally quite fine (1µm or less).

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Fly ash, which is unburned material from fuel combustion, consists of particles small enough to remain suspended in the air. A pure fly ash plume is light-brown or cream colored. If a system achieves nearly complete combustion, fly ash is primarily inorganic material. The quantity of inorganic fly ash emitted depends on the fuel's ash content. Distillate fuels do not contain appreciable amounts of ash. Residual oils can have an ash content of up to 0.3 percent by weight, but the ash content for oil grades 4 and 5 cannot exceed 0.1 percent.

Dust consists of solid particles, generally greater than 1 μm in diameter, released into the air by processes such as drilling, crushing, and grinding. Because these particles are larger than smoke or fume particles, they tend to settle to the ground more quickly.

Fumes consist of metal or metal oxide particles less than 1 μm in diameter. These minute particles are created when vapors generated by high-temperature metallurgical processes condense. Fumes are common in metallurgical industries such as steel and aluminum production.

Mist consists of liquid droplets. A pollutant could be the primary material that forms the droplet, or it could be suspended or dissolved in droplets of a different material. Typical droplets have diameters of about 10 μm and range from 2 to 200 μm in diameter. It can be difficult to distinguish pollutant-containing mists from innocuous water droplets that are generated from steam condensation.

Gas is a fluid, like air, that has neither specific shape nor volume but tends to expand indefinitely. Two visible pollutant gases are nitrogen dioxide (NO_2), which is brown to yellow, and chlorine, which is greenish yellow.

Vapor is the gaseous phase of a substance that, at normal temperature and pressure, is a liquid or solid, such as vapor from gasoline. Most vapors have no color, but they can refract light. In doing so, they alter the image of a background pattern.

Condensing And Reacting Plumes

Notes

Plumes that form in the atmosphere are generally called condensing plumes. The visible material in a condensing plume could be particles or droplets generated either by homogeneous condensation of gases or as products of chemical reactions. In some cases, both mechanisms are involved.

Condensing Steam Plumes

The classic condensing plume is the steam plume. Sources of water that can cause steam plumes include:

- Drying operations that remove water by evaporation from foods, chemicals, detergents, paper, pharmaceuticals, ores, etc.

- Combustion of hydrogen or hydrocarbon fuels, particularly natural gas. If wet organic material is burned, water vapor is generated by both evaporation and combustion reactions.

- Air pollution control devices that use water to suppress dust generation or to remove gases or particles from the gas stream (e.g., spray chambers, spray towers, venturi scrubbers).

- Evaporation of water to remove combustion or chemical-reaction heat from a process (e.g., forced- and natural-draft cooling towers, operations for cooling hot gases to protect pollution control equipment, removal of the heat generated in the thermal process of producing phosphoric acid).

- Thermal processes that break down and release chemically bonded water, such as cement production.

Reacting Plumes

Some gases can be mixed under dry conditions without reacting with one another, but when these same gases are mixed with water droplets, they react and generate a reaction product that dissolves in the droplet. When the water evaporates, the reaction product remains as a solid particle. For example, when

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sulfur oxides, ammonia gases, and water vapor mix in the same gas stream, the sulfur dioxide and ammonia react on the surface of the water droplets and an aqueous solution with dissolved ammonium sulfate is generated. The water evaporates back into the atmosphere, leaving an ammonium bisulfate particle. This reaction can occur in kilns at cement plants and brick-manufacturing plants.

Control Equipment

The basic control devices for particulate emissions are classified as:

- Mechanical collectors
- Wet scrubbers
- Fabric filters
- Electrostatic precipitators
- Afterburners

Mechanical Collectors

Settling chambers and cyclones are mechanical particulate-matter collectors. In settling chambers, the gas stream is slowed down through a chamber so that particles can settle out. Although their design is simple, collection chambers require large spaces and have low collection efficiencies for small particles. A cyclone separates the particulate matter from the gas stream via inertial force. The gas stream containing the particles is forced in a circular path. The denser particles migrate to the outside walls and then slide down the walls into a collection bin. Water is used on the walls of some cyclones to wet down the particles and help them slide to the bottom. Neither settling chambers nor cyclones efficiently collect the smaller particles responsible for most visible plumes.

A more efficient version of the cyclone is the centrifugal washer or scrubber. In the centrifugal scrubber, the particle-laden air stream is impinged on a stream of water droplets, which trap the particles. The water droplets containing the particles are then denser and larger than the particles and can be more easily collected by cyclonic action. Because the centrifugal scrubber adds moisture to the air stream, there is often a condensing plume of water droplets (steam plume) at or beyond the lip of the stack.

Wet Scrubbers

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Wet scrubbers operate by trapping particles and gases and washing them away. Gases are absorbed by the liquid and can form corrosive compounds. Collection efficiencies of wet scrubbers can be high for larger particles, but normally are lower for smaller particles. Again, the presence of moisture often leads to the creation of a steam plume. Wet scrubbers often are followed by mist eliminators.

Fabric Filters

Fabric filtration is one of the most widely used methods for removing fine particles in gas. When particle-laden gas passes through a filter, the particles are retained on the dirty-gas side of the filter, while the gas passes through the filter and the filter cake that builds up on the filter surface. Accumulated dust particles are removed from the filter by a shaking motion, a pulse-jet motion, or reverse air flow. The filters are usually in the shape of long tubes suspended from the ceiling of a room, giving the buildings that hold them the name "baghouses." The baghouse is more efficient than any of the mechanical devices for collecting small, high-opacity particles. Some sources have dry injection systems before the baghouse to coat the fabric with agents that will absorb, adsorb, or "react out" gas stream components. When a visible emission is observed from a fabric-filter-controlled source, it is usually a result of either broken bags or a secondary reaction in the plume.

Electrostatic Precipitators

The electrostatic precipitator works by electrically charging the suspended particles in a gas stream, collecting the matter on a plate that has been grounded or has an opposite charge, and removing the matter to an external hopper by rappers or by flushing with liquids. The precipitation rate depends on:

- The electrical properties of the particles
- The electrical properties of the gas stream
- The velocity of the gas stream
- The voltage
- The design of the charging and collection plates

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High collection efficiencies, up to 99.9 percent, can be achieved with the electrostatic precipitator over a wide range of particle sizes. Actual collection efficiency, however, depends on design and process conditions.

Afterburners

Afterburners remove combustion process products that can still be oxidized. Afterburners dispose of fumes, vapors, odors, and low amounts of combustible materials remaining in the gas stream. The two basic types of afterburners are direct-flame and catalytic burners.

Direct-flame burners are used to complete the combustion process. They can be inefficient unless some secondary heat recovery system is used. Catalytic units are unsuitable for particles because the particles can clog or poison the catalyst. Many of the wood stoves currently sold in the United States contain a catalytic afterburner, as do most automobiles.

Review Questions

1. How do black particles and white particles react with visible light?

2. Emissions from burning solid fuels or residual oils in an oxygen-deficient environment are:

   a. Black
   b. White

3. How do the majority of sources send emissions into the atmosphere?

4. Viewing a light-colored plume against an overcast sky can cause readings that are biased:

   a. Higher than actual opacity (positive)
   b. Lower than actual opacity (negative)

5. Horizontally emitted emissions readings are limited by:

   a. Wind direction
   b. A west wind
   c. Sun angle
   d. All the above

6. Visible emissions contain a variety of particles. What are they?

7. True or false? Dust particles are smaller than smoke or fume particles and, therefore, settle to the ground more slowly.

8. What are two visible pollutant gases?

9. What is the visible material in a condensing plume and how is it generated?

10. What are the types of control devices for particulate pollutant emissions?

Lesson 4

Meteorology

Meteorology

Visible emissions observers need to understand the basic principles and terminology used in meteorology to fill out observation forms. This knowledge will also promote effective communication in meetings and courtrooms.

Notes

Wind

Meteorologists usually consider two factors in describing wind: speed and direction. It is important to use standard terminology in describing these factors. The information recorded on visible emissions forms can be confusing if the observer fails to use standard terminology to describe wind conditions. The following discussion describes how wind affects visible emissions readings and presents the terminology that observers should use to describe wind conditions.

Wind speed has several direct effects on smoke plumes:

- Wind speed determines the height that a plume will attain before it bends horizontally. If the wind speed is high enough, the plume could even shear off at the stack and re-form downwind.
- Wind speed affects opacity measurements by diluting the plume.

Wind speed is usually measured in miles per hour. If an anemometer is not available to make a direct measurement of wind speed, the modified Beaufort scale can be used (See Table 4-1 on the next page).

Wind direction specifies the direction from which the wind blows. Thus, a north wind comes from the north and blows to the south. Wind directions might vary, especially with light winds. The observer should be positioned at an angle of approximately 90 degrees (perpendicular) to the direction of the

Wind direction is specified by the direction <u>from</u> which the wind blows.

plume. Wind direction and wind speed help determine the exact position of the observer, as stated in Method 9.

Table 4-1. Beaufort Wind Scale (Modified)

General wind classification	Description of effects	Limits of velocity 33 ft (10 m) above the ground, mph
Calm	Smoke rises vertically	Below 1
	Direction of wind shown by smoke drift but not by wind vanes	1 to 3
Light	Wind felt on face; leaves rustle; ordinary vane moved by wind	4 to 7
Gentle	Leaves and small twigs in constant motion; wind extends light flag	8 to 12
Moderate	Raises dust and loose paper; moves small branches	13 to 18
Fresh	Small trees in leaf begin to sway; crested wavelets form on inland waters	19 to 24
	Large branches in motion; whistling heard in telegraph wires; umbrellas used with difficulty	25 to 31
Strong	Whole trees in motion; inconvenience felt in walking against the wind	32 to 38
	Twigs broken off trees; progress against wind generally impeded	39 to 46
Gale	Slight structural damage occurs (e.g., chimney pots and slates removed)	47 to 54
	Trees uprooted; considerable structural damage occurs	55 to 63
Whole gale	Rarely experienced; accompanied by widespread damage	64 to 75
Hurricane	Most rare; accompanied by severe, widespread damage	Above 75

Plume Types

Notes

When a smoke plume is emitted into the atmosphere, its shape is determined by the following factors:

- Plume temperature
- Vertical temperature profile of the atmosphere
- Wind speed
- Emission velocity

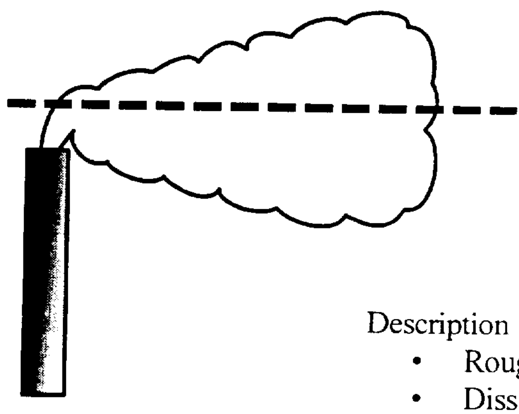
A plume rises if it is more buoyant than the surrounding air. Generally, such conditions occur when the plume is hotter than the atmosphere. If the air above a plume is more buoyant than the plume, the plume cannot rise.

The change in air temperature at increasing altitude is called the lapse rate. Normally, the lapse rate is about 5°F for each 1,000 feet of altitude. This means that the air will be 5°F cooler at 1,000 feet than at the surface of the earth. The interaction between the temperature of the plume and the temperature of the surrounding air strongly affects the shape of the plume. Plumes can be categorized into the following five types:

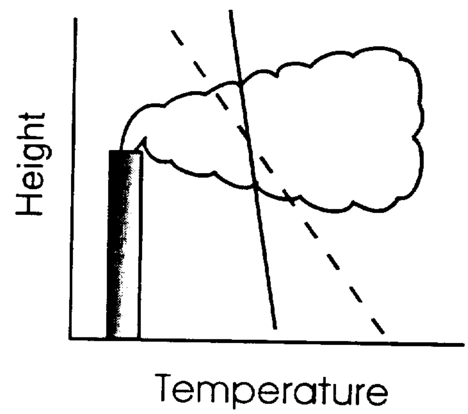
- Coning
- Lofting
- Looping
- Fanning
- Fumigating

These plume types and the conditions involved in their formation are described and illustrated on the following pages.

Coning



Description
- Roughly cone-shaped with horizontal axis
- Dissipates farther downwind than looping plume

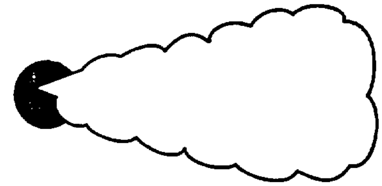


Temperature Profile—Stability
- Lapse rate between dry adiabatic and isothermal-neutral or stable

Typical Occurrence
- During windy conditions, day or night
- Layer-type cloudiness favored in day
- Might also occur briefly in a gust during looping

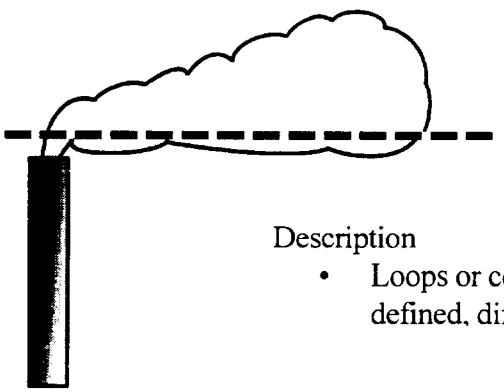
Associated Wind and Turbulence
- Moderate to strong winds
- Turbulence largely mechanical rather than thermal

Dispersion and Ground Contact
- Disperses less rapidly with distance than does looping plume
- Large probability of ground contact some distance down wind
- Concentration less but persisting longer than that of looping

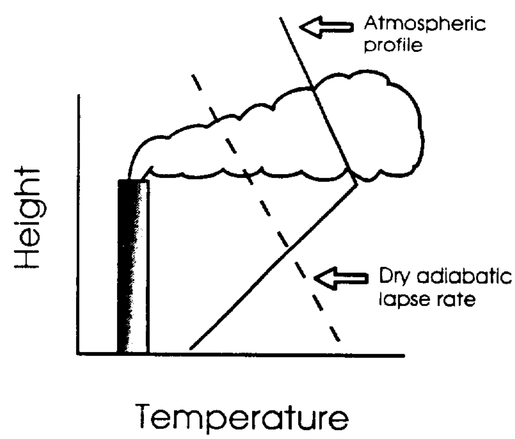


Ground-level Patterns
- Top view of stack

Lofting



Description
- Loops or cone with well-defined bottom and poorly defined, diffuse top



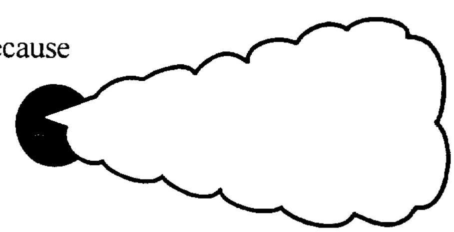
Temperature Profile—Stability
- Adiabatic lapse rate at stack top and above
- Inverted below stack layer—lower layer is stable, upper layer is neutral or unstable

Typical Occurrence
- During change from lapse to inversion condition
- Usually near sunset on fair days
- Lasts about an hour but could persist through night

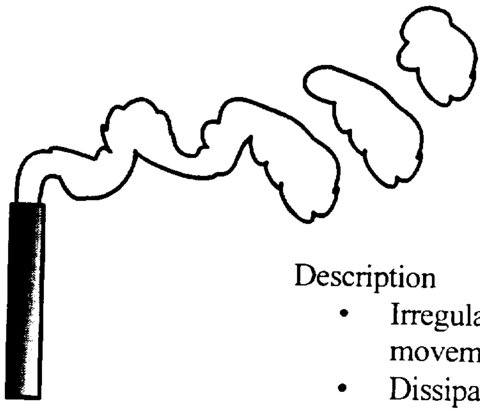
Associated Wind and Turbulence
- Moderate winds and considerable turbulence aloft
- Light winds and little or no turbulence in the layers below

Dispersion and Ground Contact
- Probability of ground contact small unless inversion layer is shallow and stack is short
- Concentration high with contact, but contact usual ly prevented by stability of inversion layer
- Considered best condition for dispersion because pollutants are dispersed in upper air with small probability of ground contact

Ground-level Patterns
- Top view of stack



Looping

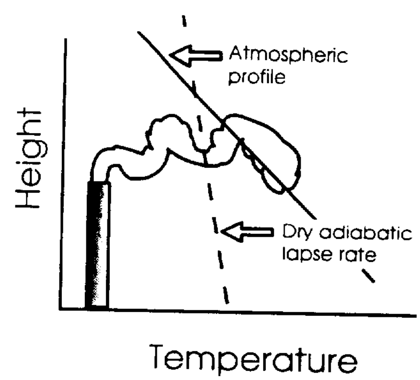


Description

- Irregular loops and waves with random, sinuous movements
- Dissipates in patches, relatively rapidly

Temperature Profile—Stability

- Adiabatic or super-adiabatic lapse rate—unstable



Typical Occurrence

- During daytime with clear or partly cloudy skies and intense solar heating
- Not favored by layer-type cloudiness, snow cover, or strong winds

Associated Wind and Turbulence

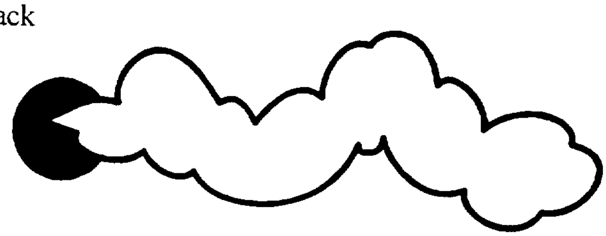
- Light winds and intense thermal turbulence

Dispersion and Ground Contact

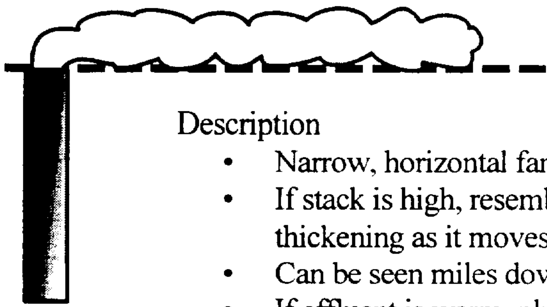
- Disperses rapidly with distance
- Large probability of high concentrations sporadically at ground relatively close to stack

Ground-level Patterns

- Top view of stack



Fanning

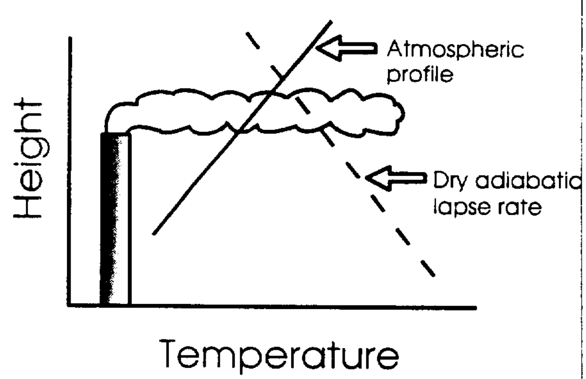


Description

- Narrow, horizontal fan; little if any vertical spread
- If stack is high, resembles a meandering river, widening but not thickening as it moves
- Can be seen miles downwind
- If effluent is warm, plume rises slowly and drifts horizontally

Temperature Profile—Stability

- Inverted or isothermal lapse rate—stable



Typical Occurrence

- At night and in early morning, any season
- Usually associated with inversion layer(s)
- Favored by light winds, clear skies, and snow cover

Associated Wind and Turbulence

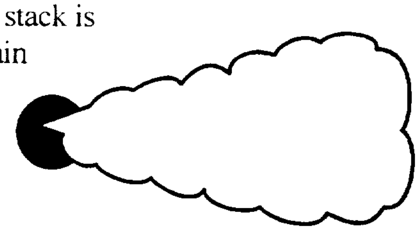
- Light winds
- Little turbulence

Dispersion and Ground Contact

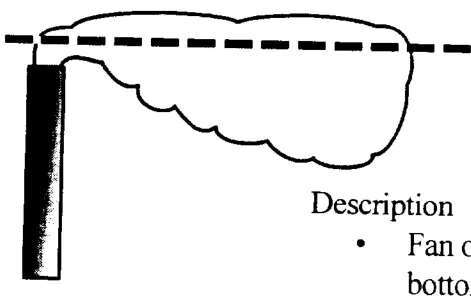
- Disperses slowly
- Concentration aloft is high at relatively great distances downwind
- Small probability of ground contact, though increases in turbulence can result in ground contact
- High ground-level concentrations can occur if stack is short or if plume moves to more irregular terrain

Ground-level Patterns

- Top view of stack



Fumigating

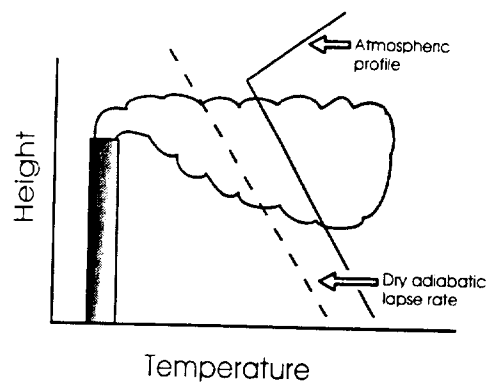


Description

- Fan or cone with well-defined top and ragged or diffuse bottom

Temperature Profile—Stability

- Adiabatic or super-adiabatic lapse rate at stack top and below
- Isothermal or inverted lapse rate above—lower layer unstable or neutral, upper layer stable



Typical Occurrence

- During change from inversion to lapse condition
- Usually nocturnal inversion is being broken up through warming of ground and surface layers by morning sun
- Breakup commonly begins near ground and works upward, less rapidly in winter than in summer
- Can also occur with sea breeze in late morning and early afternoon

Associated Wind and Turbulence

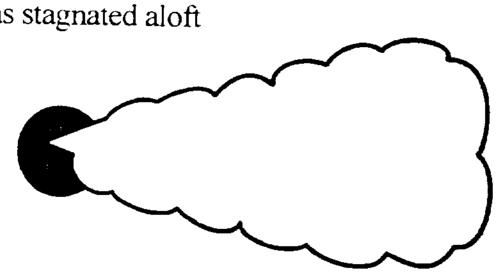
- Winds light to moderate aloft and light below
- Thermal turbulence in lower layer, little turbulence in upper layer

Dispersion and Ground Contact

- Large probability of ground contact in relatively high concentration, especially after plume has stagnated aloft

Ground-level Patterns

- Top view of stack



Sky Condition

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Sky condition is another important meteorological parameter. Reporting sky condition can make the total visible emission observation records more complete and credible. Sky condition includes the presence of clouds and other obscuring phenomena, such as haze or rain. These conditions can seriously affect the contrast between the plume and the background. Contrast is also affected by the elevation of the sun and the location of the observer with respect to the plume.

Sky cover affects the observation in at least three ways:

- Sky cover determines whether the plume is in shadow or in bright sunlight. When the plume is in shadow, the sun's position has less effect on the apparent opacity than it might have when the plume is in direct sunlight. This difference can be readily observed on overcast days.

- The background against which the plume is observed might be the sky. The color of the sky, along with the presence or absence of clouds, will affect the contrast and the apparent opacity of the plume.

- Clouds might cover the sun intermittently during the observation. These changes in lighting can have a detrimental effect on emissions observations if the observer is not evaluating how the plume alters the view of a background.

Relative Humidity

Relative humidity is the amount of moisture in the air compared with the amount of moisture that could be in the air (i.e., saturation). Relative humidity is affected by:

- The temperature of the air
- The amount of moisture in the air

At higher temperatures, the air can hold more water vapor. When the temperature drops below the dew point, however, the relative humidity reaches 100 percent and moisture is forced

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out of the air in the form of mist, fog, haze, rain, sleet, snow, or dew.

The relative humidity affects several aspects of visible emissions determinations:

- It can create mist, fog, or haze
- It can create rain
- It affects the formation and persistence of steam plumes

If the humidity is high enough to cause mist, fog, or haze to form, the contrast between the plume and the background can be diminished. This lower contrast can lead to a negative bias in the observation. The same problem occurs when rain is falling and the background is some distance from the source.

If the temperature of the air is cool enough and the humidity is high enough, the moisture exiting the stack cannot enter the air. Under these conditions, a steam plume will form in the atmosphere. The higher the humidity and the lower the temperature, the longer a steam plume persists. If the relative humidity is 70 percent or above, steam plumes will persist for long periods of time and will travel correspondingly long distances.

Review Questions

1. What are the two factors meteorologists use to describe wind?

2. List two ways in which wind speed directly affects smoke plume formation.

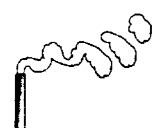
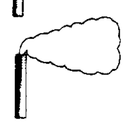
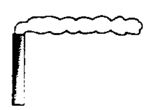
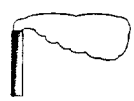
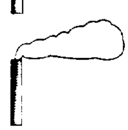
3. List four factors that determine plume shape.

4. Define relative humidity.

5. At higher temperatures, air can hold (more/less)_______water.

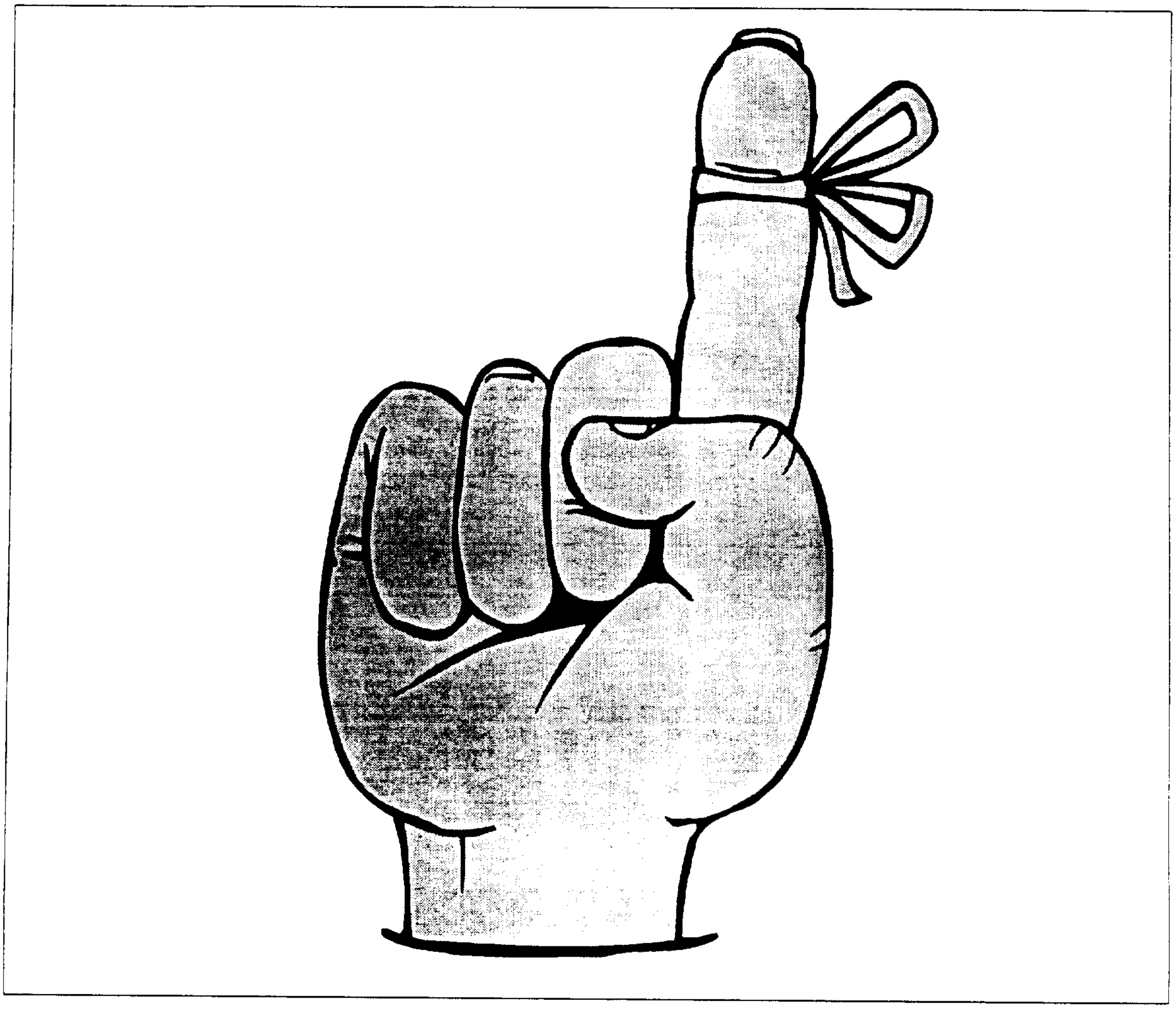
6. The higher the humidity and the lower the temperature, the (longer/ shorter)___________ the steam plume will last.

7. Match the plume type with its name.

1. Looping	A. 
2. Lofting	B. 
3. Coning	C. 
4. Fumigating	D. 
5. Fanning	E. 

Lesson 5

Method 9 Requirements



Method 9 Requirements

Method 9

Notes

EPA Reference Method 9 (or Method 9) is the visible emissions inspection method most frequently used by visible emissions observers. It has been tested in the courts and in practice and has wide acceptance within the regulatory community. The purpose of this lesson is to acquaint students with the details of the method as they are described in the method itself. The students must know and understand the method to apply it.

When EPA promulgated Method 9, the text of the method was preceded by a preamble that explains EPA's rationale in developing the method. The preamble also provides some historical perspective on the method:

> On June 29, 1973, the United States Court of Appeals for the District of Columbia remanded to EPA the standard of performance for Portland cement plants (40 CFR 60.60 et seq.) promulgated by EPA under section 111 of the Clean Air Act. (*Portland Cement Association* v. *Ruckelshaus*, 486 F.2d 375 [1973].) In the remand, the court directed EPA to reconsider, among other things, the use of the opacity standards.

All other versions of Method 9 are based on the EPA promulgation remanded in this historic case.

The Reference Method Is One Of Observation

EPA established that Method 9-type observations take precedence even when transmissometers are used:

> "EPA will accept as probative evidence in certain situations and under certain conditions the results of continuous monitoring by transmissometer to determine whether a violation has in fact occurred."

Notes

The revision makes clear that even in such situations the results of opacity readings by Method 9 remain presumptively valid and correct. In other words, human observers collect the best evidence.

EPA recognized that because transmissometers and CEMs are located within the stack, often well before the actual point at which the emissions enter the atmosphere, the readings from these instruments might not represent the opacity at or above the emission point. Aerosols can form after the transmissometer within the stack or above the stack by gas-phase reactions, condensation, or accumulation. Consequently, the best measure of opacity at the stack is presumed to be the visible emissions readings obtained by applying Method 9.

Opacity Variances

EPA recognized that in some limited cases, opacity can be an unfair measure of emissions:

> The provisions in paragraph (e) provide a mechanism for an owner or operator to petition the Administrator to establish an opacity standard for an affected facility where such facility meets all applicable standards for which a performance test is conducted under 60.8 but fails to meet an applicable opacity standard. The intent of this provision is primarily applied to cases where a source installs a very large diameter stack that causes the opacity of the emissions to be greater than if a stack of the diameter ordinarily used in the industry were installed (see Figure 5-1).

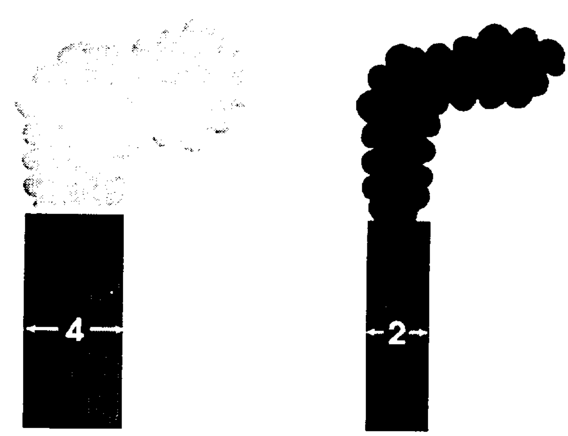


Figure 5-1. Opacity Varies With Stack Diameter

Notes

The effect of stack diameter on opacity is not inconsequential. Transmission (and, consequently, opacity) is directly proportional to the square of the pathlength. A plume with an opacity of 20 percent will have an opacity of 36 percent if the stack diameter is doubled.

A few industries have seized upon this provision, ignoring the condition about "very large diameter stack," to justify their requests for an alternate opacity provision. A high opacity relative to measured mass emissions, however, can result from small particles (PM_{10}) in the gas stream, reactions that occur in or above the stack downstream from the particulate test, and condensation of particulate that occurs downstream from the particulate test. More-sophisticated mass emissions testing techniques often will detect the additional mass that an observer would record during a Method 9 observation.

Portland Cement Standard Set At 20 Percent

After reviewing the data from field tests and the opacity of Portland cement plant tests, EPA revised the 10 percent standard originally proposed. As noted in the preamble:

> A revision to the opacity standard for Portland cement plants is promulgated herein. The revision changes the opacity limit for kilns from 10 percent to 20 percent. This revision is based on EPA's policy on opacity standards and the new emission data from Portland cement plants evaluated by EPA during its reconsideration.

Standards of around 20 percent are common in existing NSPS, and state and local agency regulations. Today, however, regulations often contain lower opacity standards. Values of 10 percent, or even 3 percent, are being applied to industry.

EPA Policy On Opacity

The preamble to the standards of performance for Portland cement plants, which were proposed on March 8, 1974 (39 FR 9308), sets EPA's policy on opacity standards. This policy has three elements:

Notes

- Opacity limits are independently enforceable standards.
- When opacity and mass/concentration standards apply to the same source, they are established at a level that will result in the design, installation, and operation of the best, adequately demonstrated system of emission reduction (taking costs into account).
- Opacity standards are established at a level that requires proper operation and maintenance of such control systems.

The first element clearly shows EPA's thinking that an opacity violation does not have to have a corresponding mass emissions standard violation. As previously noted, a violation of a mass emissions standard can go undetected because of the measurement limitations in conventional mass emissions testing.

The second element addresses setting standards in terms of mass. The intent is to ensure that emissions are minimized by installing state-of-the-art control system designs.

The last element illustrates one of the roles of opacity standards. If an opacity standard is set at a level the facility can meet when it is properly maintained and operated, then an opacity violation would indicate that the facility is not being operated properly or has not been adequately maintained. A facility can be fined for exceeding the opacity standard without additional evidence that the mass emission limit was violated.

Revising The Opacity Limits For Portland Cement Plants

The preamble to the Portland cement plant standards of performance states:

> The new data indicate that increasing the opacity limit for kilns from 10 percent to 20 percent is justified, because such a standard will still require the design, installation, and operation of the best adequately demonstrated system of emission reduction (taking costs into account) while eliminating or minimizing the situations where it will be necessary to promulgate a new opacity standard under 60.11 (e).

EPA recognized that the 10-percent standard was not always approachable in 1974. As a result, the Agency was willing to raise the standard at that time (but only for the 1974 Portland cement plant standard).

Notes

Changes In EPA Procedures

After a series of extensive field tests, EPA determined that some revisions and clarifications in applying Method 9 were in order. In evaluating the accuracy of results from qualified observers following the newly revised Method 9 procedures, EPA determined that observers trained and certified in accordance with the procedures prescribed under Method 9 are consistently able to read opacity with positive errors not exceeding 7.5 percent based on single sets of an average of 24 readings.

Analysis Of Error

The preamble states:

> An introductory section was added. This included a discussion of the concept of visible emission reading and described the effect of variable viewing conditions. Information was also presented concerning the accuracy of the method, noting that the accuracy of the method must be taken into account when determining possible violations of applicable opacity standards.

This accuracy information has been widely misinterpreted and misquoted by defense attorneys and regulatory officials. Knowledgeable observers have no problems with the issue of error analysis, however.

Averaging Was Introduced To Increase Accuracy

At the time Method 9 was proposed, a commonly used standard technique for reducing data was to count the number of observations at or above the standard and to multiply by 15 seconds to determine the amount of violation time (15 seconds represents the lapse of time during an observation). This violation time was compared to the time exemption in the rule. At the time of the Portland cement remand, EPA had not determined the accuracy of this approach. Consequently, EPA modi-

Notes

fied the method to use an averaging approach to ensure the accuracy of the observations.

The preamble states:

> Provisions were added which specify that the determination of opacity requires averaging 24 readings taken at 15-second intervals. The purpose for taking 24 readings is both to extend the averaging time over which the observations are made and to take sufficient readings to insure acceptable accuracy.

After taking an average of 20 or more values, statistical accuracy is not greatly enhanced by adding more data. Thus, 24 readings over a 6-minute period produces a statistically significant average and demonstrates that the plume is not a momentary puff of excess emissions.

This change of method indirectly had an immense impact on the states that were using the time-aggregation technique. In accordance with regulatory provisions later promulgated in CFR part 52.12.(c), federal enforcement required states that do not clearly specify a method in their State Implementation Plans (SIPs) to use averaging as the data-reduction technique.

Sun Position Became An Issue

The preamble states:

> More specific criteria concerning observer position with respect to the sun were added. Specifically, the sun must be within a 140° sector to the observer's back.

Of all the changes in the method, this one increased the accuracy of the observations the most.

Slant-Angle Considerations Were Introduced

The preamble states:

> Criteria concerning an observer's position with respect to the plume were added. Specific guidance was also provided for reading emissions from rectangular emission points with

> large length-to-width ratios, and for reading emissions from multiple stacks. In each of these cases, emissions are to be read across the shortest pathlength.

Notes

This section was included to minimize positive bias inherent to the effect of pathlength on visible emissions observations.

Slant-angle effects occur when the observation pathlength is longer than it should be. The pathlength is lengthened when an observer either gets too close to a tall stack or observes a plume along its line of travel. The best rule of thumb for observing tall stacks with vertical plumes is to be positioned at least 3 stack heights away, where the slant-angle is 18° or less.

The Issue Of Steam Source Plumes Was Introduced

The preamble states:

> Provisions were added to make clear that opacity of contaminated water or steam plumes is to be read at a point when water does not exist in condensed form. Two specific instructions are provided: one for the case where opacity can be observed prior to the formation of the condensed water plume, and one for the case where opacity is to be observed after the condensed water plume has dissipated.

For the first time, standardized approaches were included to eliminate the problems of observing plumes formed by the condensation of steam or steam plumes.

Smoke Generators Were Standardized

The preamble states:

> Specifications were added for the smoke generator used for qualification of observers so that state or local air pollution control agency . . .

EPA wanted to standardize the certification procedure by establishing criteria for the generators and opacity-measuring equipment used in training and certifying observers.

Notes

Minor Changes To The Method

The current version of Method 9 can be found in the Federal Standards of Performance for New and Modified Stationary Sources—Code of Federal Regulations (CFR) Part 60, Appendix A—Reference Methods. Some minor variations to the basic method are found in specific standards. The method has essentially been unchanged since its promulgation in 1974, except for two minor changes in 1987. The following discussion reflects the 1987 version of the method.

The method states:

> 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 method includes procedures for the training and certification of observers, and procedures to be used in the field for determination of plume opacity.

Appearance And Controllable Observational Variables

The method states:

> The appearance of a plume as viewed by an observer depends upon a number of variables, some of which may be controllable and some of which may not 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.

These variables are discussed in the next few pages. It is interesting to note that the controllable variables generally give a positive bias to any observations if the specific criteria in the method are not followed. Thus, it is imperative that any observer collecting data for regulatory action follow these requirements or be prepared to evaluate the effect of not doing so.

Notes

Appearance And Uncontrollable Observational Variables

The method states:

> 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 accurately assign opacity values to the observed plume.

Generally speaking, the uncontrollable errors lead to negative bias in observations. In other words, these errors tend to result in Method 9 opacity readings that are lower than the actual opacity of the plume. Although any documented violation that is influenced by such errors could probably be sustained in court, the errors also result in "under-enforcement" of opacity regulations.

High-Contrast Backgrounds

The method states:

> 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. It follows from this, and is confirmed by field trials, that 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.

Defense attorneys often turn the last sentence against observers. The key word is *potential.* "Potential for positive error" does not mean that observations always or even often will be higher than the actual opacity. An additional series of tests sponsored

Notes

by EPA determined that the most likely outcome is for observers to estimate opacity correctly or to underestimate opacity.

Low-Contrast Backgrounds

The method states:

> 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 cited for a violation of opacity standards due to observer error.

Simply put, as the amount of visual information to help determine plume opacity decreases, negative bias increases. It is hard to distinguish a black cat at night; likewise, it is hard to distinguish a white plume against an overcast sky. In the real world, it is most likely that the observer will encounter factors that tend to result in negative bias because of low contrast between the plume and the background. Plumes from tall stacks must always be evaluated against a blue or cloudy sky in which the color contrast is low and the luminous contrast is poor.

Positive Error Defined

EPA has on several occasions quantified the errors associated with Method 9. In the original promulgation, data were presented from a series of field studies conducted by the Agency.

The method states:

> Studies have been undertaken to determine the magnitude of positive errors which can be 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:

Notes

- 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.

- For white plumes (170 sets at a smoke generator, 168 sets at a coal-fired power plant, and 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.

Note that black smoke was only slightly easier to evaluate. Note also that two levels of error are addressed in each set of results. For black smoke, the reported levels of confidence were 100 and 99 percent. For white smoke, the levels were 99 and 95 percent. These data indicate that there is no *single* level of error for Method 9. In addition, note that the method does not address negative error at all. EPA is simply addressing the issue of wrongfully identifying a compliant source as a violator.

Positive Observational Error

The method states:

> 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.

The Agency does not define a specific positive observational error but warns that accuracy must be taken into account. Any potential negative biases associated with observations should also be taken into account. A source should not be given a percentage above the standard as a routine practice, however. From a practical standpoint, the extent that an observation is above a standard will go to the weight of the evidence. Other factors that might be considered in cases in which the opacity reading is only marginally above the standard are the frequency and duration of excess emissions and a pattern of degradation of control-equipment performances.

Notes

Principle

The method states:

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

Again, this is a method that involves human observation. The observer must be certified before completing observations for record.

Applicability

The method states:

> This method is applicable for the determination of the opacity of emissions from stationary sources pursuant to 60.11 (b) and for qualifying observers for visually determining opacity of emissions.

In addition to sources subject to NSPS, other sources are evaluated using Method 9. Often, states incorporate Method 9 into their SIP rules and regulations by reference. If a state SIP is unclear as to an exact method or if the cited method has not gone through formal rulemaking, Section 52.12(c) of CFR Part 52 allows EPA to apply Method 9 in making a compliance determination. Thus, the observer should be careful to check the standard to which a source is subject and to determine whether any other methods apply for observations.

Procedures

The method states:

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

An observer must follow specific procedures to complete a valid visible emission evaluation. These procedures are described below.

Observer Position Relative To The Sun

Notes

One of the most important aspects of visible emissions evaluation is the relative positions of the observer, the sun, and the plume (see Figure 5-2). If the observer looks toward the sun, the appearance of the plume is enhanced, resulting in a high bias.

The method 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.

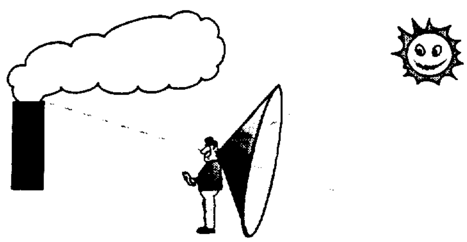


Figure 5-2. Observer Relationship To The Sun

Adherence to this rule prevents forward scattering of the light by the plume from interfering with the observation. On an overcast day when no shadows are observed and the lighting is diffuse or flat, this rule might not be as important from a scientific standpoint as on a bright, sunny day. Observers might have trouble defending their positions in court if they disregard the rule. The best practice for an observer is always to have the sun at his or her back, even if it is not visible and no shadows are cast.

Observer Line Of Sight

The method states:

> 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, non-circular stacks), approximately perpendicular to the longer axis of the outlet.

Notes

Recognizing that sun angle is the most important factor, the method gives guidance to limit slant-angle effects. Slant-angle effects occur when the observation pathlength through the plume is longer than it should be. Pathlength increases when the observer gets too close to a tall stack or observes a plume along its line of travel (see Figure 5-3).

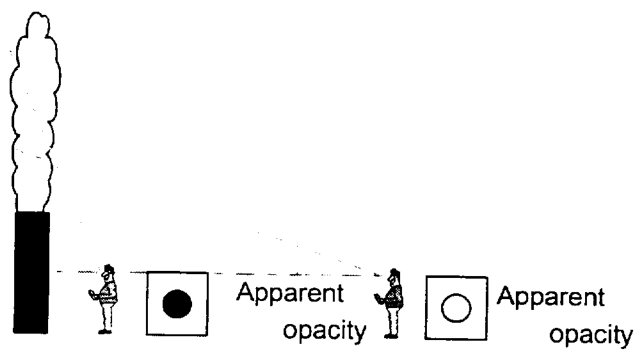


Figure 5-3. Effect Of Slant Angle On Pathlength And Apparent Opacity

The best rule for observing tall stacks with vertical plumes is to take a position at least three stack heights away, where the slant angle is 18° or less. Under these conditions, the positive error is less than 1 percent of the true opacity.

When the plume is horizontal, the same effect holds true. Because of slant angle, observers must take special care in observing plumes from ships' holds. If the slant angle cannot be minimized, calculations can be used to negate the effects and determine the corrected opacity.

Multiple Stacks

Multiple stacks can create plumes that intermingle. The method states:

> 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).

If the observer cannot get perpendicular to the line of stacks, he or she should make sure that no interfering plumes are present. Sometimes just viewing the plumes before they intermingle will achieve this goal.

Notes

Field Records

The method states:

> The observer shall record the name of the plant, emission location, type of facility, observer's name and affiliation and the date on a field data sheet. The time, estimated distance to the emission location, approximate wind direction, estimated wind speed, description of the sky conditions (presence and color of clouds), and plume background are recorded on a field data sheet at the time opacity readings are initiated and completed.

This section contains language not present in the 1974 promulgation. The method now requires a sketch of the relative positions of the sun, the source, and the observer. If the observer uses the form reproduced in this manual and completes all the entries and the sketch, all the required data will be collected.

Observation Point In The Plume

The method states:

> 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 provision ensures that the opacity is measured after particles and gas-phase reactions in the plume have formed. The provision could, however, cause problems if the plume is mushrooming in the atmosphere. Mushrooming occurs when the plume velocity cannot be maintained in the atmosphere and the pathlength increases faster than the natural dilution of the plume. Normally, this is not the case.

Notes

Attached Steam Plumes

When steam is emitted, cools, and condenses, it forms a steam plume. Steam is not defined as particulate matter by the Agency. To address the problem of steam plumes, several modifications to the rule of observing at the densest part of the plume are part of the method.

The method states:

> 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.

Detached Steam Plumes

The method states:

> 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 key words in those last three sections of the method that have been discussed. In the first two, the key word was *shall*, while in the third the key word was *should*. There is no option in the first two cases. In the last case, however, observations could be made before steam plume formation, as suggested, or they could be made after the steam plume re-evaporates. The key to this decision is to follow the first rule and observe at that point where the plume is the most dense.

Recording Observations

The method states:

> Opacity observations shall be recorded to the nearest 5 percent at 15-second intervals on an observational record sheet. A minimum of 24 observations shall be recorded.

> Each momentary observation recorded shall be deemed to represent the average opacity of emission for a 15-second period.

Notes

From a technical standpoint, the most important part of this section concerns making momentary observations. Staring at the plume reduces the ability of the observer to make an accurate assessment of the opacity.

Data Reduction

The method states:

> 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.

Taken out of context, this section has been used by defense attorneys to claim that the observer must take the first 6 minutes and average them, then the next 6 minutes and average them, and so on. This is not the case.

The method continues:

> 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 any set of observations in the total data set could contain a violation. A computer is useful in analyzing possible averages.

Calculation Of Opacity

The method states:

> 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.

Notes

For a 1-hour data set, there are 217 possible 6-minute averages that could be calculated using the "rolling average" calculation technique preferred by EPA.

Qualifications And Testing

General Certification Requirements

The method states:

> 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 an average error not to exceed 7.5 percent opacity in each category. Candidates shall be tested according to the procedures described in paragraph 3.2. Smoke generators used pursuant to paragraph 3.2 shall be equipped with a smoke meter which meets the requirements of paragraph 3.3.

Period Of Certification

The method states:

> The certification shall be valid for a period of 6 months, at which time the qualification procedure must be repeated for an observer to retain certification.

Certification Procedure

The method has specific instructions regarding the certification procedure. This portion of Method 9 will be covered in Lessons 10 and 12.

Review Questions

1. Which readings does EPA consider presumptively valid and correct?

   a. Transmissometer readings
   b. Opacity readings by Method 9

2. A larger diameter stack will (increase/decrease) observed opacity.

3. True or False? A facility can be fined for exceeding the opacity standard without additional evidence that the mass emission limit was violated.

4. What is the error that most Method 9-certified observers will not surpass in an average of a set of 24 readings?

5. Of all the changes in Method 9, which increased accuracy the most?

6. If a detached steam plume is present, at what two places could the opacity be read?

7. What are some variables that influence the appearance of the plume but are controllable by the observer?

8. Controllable variables usually give a (positive/negative)________ bias. Uncontrollable variables usually give a (positive/negative)______ bias.

9. EPA determined that the highest likelihood is that an observer will (over-estimate/underestimate) ________________ opacity.

10. Which type of smoke is slightly easier to evaluate, white or black?

11. The sun must be within a _________ degree angle to the observer's back.

12. At three stack heights away, the slant angle is ________ degrees or less, which gives a positive error of _________ percent or less.

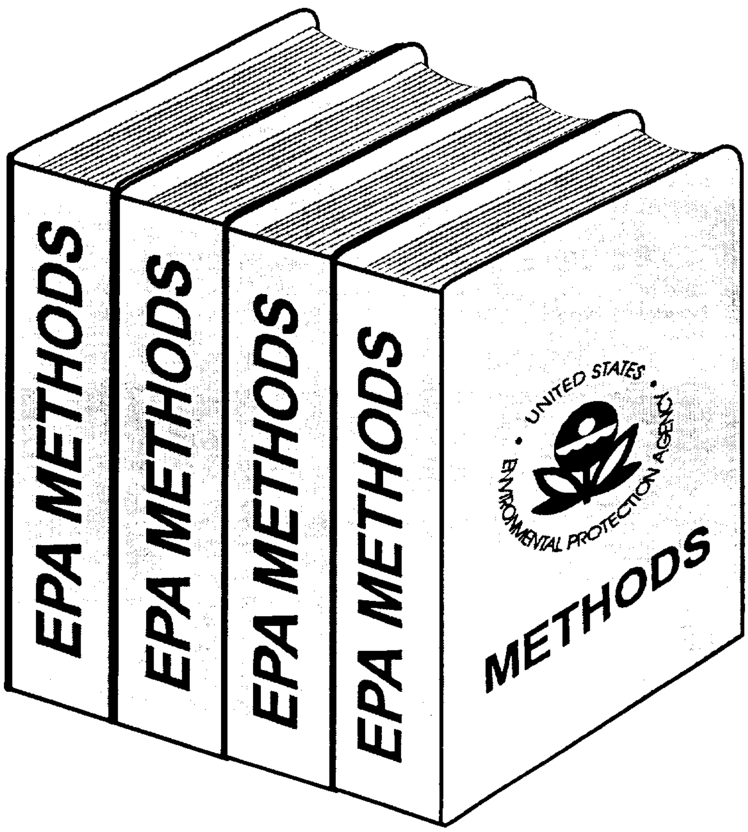
13. ______________ occurs when plume velocity cannot be maintained in the atmosphere.

14. What are the requirements to be certified in Method 9 as a qualified observer?

15. For how long is certification valid ?

Lesson 6

Other Methods



Other Methods

Method 22—Visual Determination of Fugitive Emissions From Material-Processing Sources

Notes

Method 22 differs from Method 9 in several ways. Method 22 is a qualitative method; Method 9 is quantitative. This means that whereas Method 22 determines the presence (and duration) or absence of visible emissions, Method 9 determines the opacity of the emissions. Method 22 is most often used to determine visually the presence and/or duration of fugitive emissions (i.e., emissions not emitted directly from a process stack or duct). Method 9 is also used to measure the opacity level of fugitive emissions.

Fugitive emissions include emissions that:

- Escape capture by process equipment exhaust hoods.
- Are emitted during material transfer.
- Are emitted from buildings housing material-processing or material-handling equipment.
- Are emitted directly from process equipment.

Method 22 is also used to determine the duration of visible smoke emissions from flares used to combust process waste gas. Method 22 has been used successfully in litigation concerning visible emissions that contained asbestos.

Method 22 determines the amount of time that any visible emissions occur during the observation period (i.e., the accumulated emissions time). Because the procedure requires determining only whether a visible emission occurs and does not require determining opacity levels, observer certification according to the procedures of Method 9 is not required. The observer must know the general procedures for determining the presence of visible emissions, however. At a minimum, the

Notes

observer must be trained and knowledgeable about how the visibility of emissions is affected by background contrast, ambient lighting, observer position relative to lighting, wind, and the presence of uncombined water (condensing water vapor). This training is available in written materials or from Method 9 certification course lectures.

Applicability And Principle

Section 2.1, Applicability, states:

> 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.
>
> This method also applies for determining the frequency of visible smoke emissions from flares.

The method's principle is that fugitive emissions produced during material processing, handling, and transfer operations, or smoke emissions from flares, are visually determined by an observer without using instruments.

The method contains a series of definitions, including:

Emission frequency—the percentage of time that emissions are visible during the observation period.

Emission time—the accumulated amount of time that emissions are visible during the observation period.

Fugitive emissions—a pollutant that is generated by an affected facility, not collected by a capture system, and released to the atmosphere.

Smoke emissions—a pollutant generated by combustion in a flare and occurring immediately downstream of the flame. Smoke occurring in the flame, but not downstream of the flame, is not considered a smoke emission.

Observation period—an accumulated time period during which observations are conducted, not to be less than the period specified in the applicable regulation.

Equipment

Notes

Several pieces of equipment are required for Method 22, depending on the location of the source.

Section 4.1 Stopwatches, states:

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

Many liquid-crystal-type stopwatches do not have the time-accumulation function. Almost all mechanical stopwatches have this function. Mechanical stopwatches are suitable for Method 22 because great accuracy is not required.

The method states:

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

This type of light meter is available from industrial lighting companies, some photographic suppliers, and industrial safety equipment suppliers. These meters are incident light meters, not reflected light meters.

Procedure

The method states:

> 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 facility, as appropriate for the applicable subpart.

Notes

Several points and times might need to be selected for this observation if the building is large or if there are numerous process-emissions points.

The method states:

> 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.

This differs from Method 9 in that a specific requirement of distance is part of the method. Also, the Method 9 requirement of the sun at the observer's back has been relaxed. The sun must simply be kept from being directly in the observer's line of sight.

Field Records

Two sets of field-record forms are supplied with the method, one for outdoor locations and the other for indoor locations. The principal difference is the determination of minimum lighting in the indoor location.

The method states:

> 5.2.1 Outdoor Location. Record the following information on the field data sheet: 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: 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.

Notes

Indicate the potential and actual fugitive emission points on the sketch.

One of the most difficult problems in implementing Method 22 is determining whether lighting requirements are being met. It is important that the measured lighting be the lighting at the location of the emissions, not just the lighting at the observer's location.

The method states:

> 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 source(s) as is feasible. An illumination of greater than 100 lux (10 foot candles) is considered necessary for proper application of this method.

An illumination of 100 lux is a fair amount of light. The method is not designed to be used under dim lighting conditions.

The method states:

> 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.

Because the emissions are going to be observed continuously, the observer must rest his or her eyes. To maintain a complete record, record the times of the breaks on the field-record form.

The method states:

> Stop the stopwatch at the end of the observation period. The accumulated time indicated by this stopwatch is the duration of the observation period. When the observation period is completed, record the clock time.

During the observation period, continuously watch the emission source. When an emission begins (condensed water vapor is not considered an emission), start the second accumulative

Notes

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 that emissions were visible during the observation period (i.e., the emission time).

The method states:

> 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 can (optionally) be stopped after an emission time of 6 minutes is exceeded. At this point, a violation has occurred. Similarly, when the regulation is expressed as an emissions frequency and the regulation prohibits emissions for greater than 10 percent of the time in any hour, then observations can (optionally) be terminated after 6 minutes of emissions are observed, because 6 minutes is 10 percent of an hour. Again, this represents a violation. If an observer is proving compliance, however, the observation must continue for the full time length of the observation period implied or stated in the regulation.

In any case, the observation period shall not be less than 6 minutes. If the process operation is intermittent or cyclic, the best practice is for the observation period to coincide with the process cycle.

The method states:

> 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.

Notes

This requirement is important and cannot be over-stressed. Eye fatigue sets in quickly. Under subpart 000 of the Nonmetallic Mineral Regulations, lengthy observations might be needed to demonstrate compliance or to certify that the source is meeting the standards. The observer must consider the rest-break requirement when planning the observation period.

The method states:

> 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.

Generally, because the lighting requirements are more relaxed than those for Method 9, an experienced or creative observer can find a location that does not have this problem.

Recording Observations

The method states:

> 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.

Calculations For Emission Frequency Regulations

The method states:

> If the applicable subpart requires that the emission rate be expressed as an emission frequency (in percent), determine

Notes

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.

This calculation is not necessary if the regulation has specific time exemptions for specific observation periods, such as 3 minutes in 1 hour.

Method 9A

The LIDAR method is designated as Method 9A. This instrumental method uses a lidar, a device that emits pulsed laser light, to determine plume opacity. It has several advantages over the visible emissions observer method.

- It is not limited to daylight hours.
- It is not a subjective method.
- Under proper conditions, it can be slightly more accurate than Method 9.

Method Of Operation

The lidar projects a powerful red laser through the plume. Light is reflected back from particles in the air before the laser light hits the plume. This reflection gives the unattenuated signal that is recorded electronically. The light that has gone through the plume then bounces off particles in the ambient air on the other side of the plume and, on the way back to the receiver, is attenuated by the plume. A comparison is made between the signals coming back from the particles on the near side and on the far side of the plume. The comparison is corrected for the inverse square loss due to distance. Opacity is calculated from the transmission of light through the plume.

Disadvantages

As with any method, Method 9A has disadvantages as well as advantages. Some of the disadvantages are:

- The method requires much-more-expensive equipment than Method 9.

- Method 9A requires more staff to operate and a far higher level of training than does Method 9.
- Minimum distances are required between the lidar, the source, and background objects. Also, safety procedures must be followed carefully.
- The lidar assumes that particle density in the air is uniformly distributed. If additional particles are behind the plume reflecting light, the true opacity will be higher than the measured value.

Notes

SIP Methods

Many of the SIP rules predate the 1974 promulgation of Method 9. Additionally, because Method 9 introduced the concept of averaging over a 6-minute period, there are times when the SIP rule seems to be at variance with Method 9. EPA recognized this problem when it stated the following in the preamble:

> Many state and local air pollution control agencies use a different approach in enforcing opacity standards than the six-minute averaging period specified in this revision to Method 9. EPA recognizes that certain types of opacity violations that are intermittent in nature require a different approach in applying the opacity standards than this revision to Method 9.

EPA has completed extensive testing of the alternate procedures as promised in the preamble to Method 9, collecting 65,000 data points in field studies of observers reading against a smoke generator.

Many SIP regulations vary from Method 9 in that they:

- Count the number of violations of the standard.
- Multiply that number by 15 so that the total time of violation is accumulated or aggregated.
- Divide the result by 60 to determine the number of minutes.
- Compare the number of minutes of violation with the number of minutes allowable in the standard (the time exemption).

Notes

If a state has gone through formal rulemaking and promulgation of the test method, the above regulations would be used to enforce the SIP.

If the applicable test method is not clearly stated, or if the state has not gone through formal rulemaking, a common practice is to use Method 9 procedures. That means a minimum of a 6-minute average of 24 consecutive readings, even if the standard is for 3 minutes in 1 hour.

EPA is remedying this problem by promulgating methods 203A, 203B, and 203C, which provide for several different reduction techniques, including non-averaging. This will allow the regulator to choose the method implied by the regulation.

Review Questions

1. Whereas Method 9 is quantitative, Method 22 is ____________.
2. Observer certification (is/is not) __________ required for Method 22.
3. Define fugitive emissions.
4. How does Method 22 differ from Method 9 with respect to sun angle? How does it differ with respect to distance from source?
5. How great must the illumination be for proper use of Method 22?
6. An observer cannot observe emissions for a period greater than 15 to 20 minutes without taking a _______________.
7. The LIDAR method is designated as Method ________.
8. List three advantages Method 9A has over Method 9.
9. List three disadvantages of Method 9A compared with Method 9.

Lesson 7

Special Field Problems

Special Field Problems

Notes

During visible emissions evaluations, observers might encounter viewing problems that are not addressed by Method 9, or they might have difficulty determining whether the requirements are being met. The most common problems encountered by observers are:

- Predicting steam plume formation
- Line-of-sight problems (including slant angle)
- Complex plumes
- Extreme distances
- Nighttime observations

Predicting Steam Plume Formation

Visible steam plumes are caused by the condensation of water vapor in exhaust streams. Five primary factors affect the formation of steam plumes:

- Dry-bulb temperature
- Wet-bulb temperature
- Relative humidity
- Absolute humidity
- Specific volume

Dry-bulb temperature is the actual ambient temperature. This temperature is represented on the horizontal axis of the psychrometric chart (see Figure 7-1) on the next page.

Wet-bulb temperature is the temperature indicated by a "wet-bulb" thermometer (a regular thermometer that has its bulb covered with a wet wick and is exposed to a moving air stream). This temperature (saturation temperature) is represented by the curved axis on the left side of the psychrometric chart.

Notes

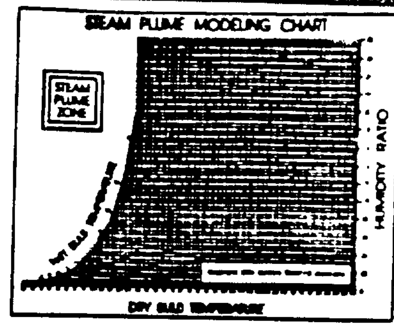


Figure 7-1. Psychrometric Chart

Relative humidity is the ratio of the amount of water vapor actually present in the air compared with the greatest amount possible at the same temperature. These values are represented by the set of curved lines originating in the lower left portion of the psychrometric chart.

Absolute humidity (humidity ratio) is the amount of water vapor present in a unit of air. This value, expressed as grains per pound or pound per pound, is represented on the vertical axis of the psychrometric chart.

Specific volume is the volume occupied by a unit mass of air, expressed as cubic feet per pound. This value is represented on the psychrometric chart by the diagonal lines running from lower right to upper left.

The relationships shown in the psychrometric chart differ with changes in barometric pressure. The chart included in this section is for a barometric pressure of 29.92 inches of mercury. Therefore, with use of the wet-bulb/dry-bulb technique, if the actual pressure is less than about 29.5 inches of mercury, the humidity ratio should be calculated from an equation (see below) and not from the chart.

The psychrometric chart shown in Figure 7-1 is a graphical representation of the five atmospheric conditions just discussed. This type of chart can be used in conjunction with the following simple equation to predict the formation of a steam plume.

$$HR = \frac{0.62\,(MC)}{1 - MC}$$

HR = Humidity ratio (pound water/pound dry air)
MC = Moisture content expressed as a decimal

Notes

Plotting the values for any two of the five atmospheric properties determines the values for the remaining three properties. For example, by measuring the wet-bulb and dry-bulb temperatures with a sling, the relative humidity, the absolute humidity, and the specific volume of the air can be determined. The point on the psychrometric chart where the plotted values fall is called the "state point" or "state condition." This describes the current condition of the ambient air or of the stack emission itself.

To predict the occurrence of a visible steam plume, both the ambient air conditions and the stack gas conditions must be known (or estimated), and the state conditions must be located or plotted on the psychrometric chart. The change of the exhaust gas from the stack state conditions to the ambient air state will be accompanied by a visible steam plume if any portion of the line connecting the two points on the chart lies to the left of the 100-percent relative humidity line. The visible steam plume will be caused by the condensation of the water vapor present in the exhaust stream.

It is relatively simple to obtain the state point for the ambient air conditions. The wet-bulb and dry-bulb temperatures, which will determine a unique state point, can be measured with a sling psychrometer. Often, the only data available for determining the state point of the stack gas are the dry-bulb temperature and moisture content of the exhaust gas stream. A relationship exists between the moisture content and the humidity ratio (or absolute humidity), however, as shown in the following equation:

$$HR = \frac{0.62(MC)}{1 - MC}$$

where:

HR = humidity ratio, in water vapor per pound of dry air

MC = percentage moisture content, expressed as a decimal

The following sample problem demonstrates the use of this equation.

Notes

Given:

Ambient conditions

Dry-bulb temperature	= 70°F
Wet-bulb temperature	= 60°F
Barometric pressure	= 29.92 in Hg

Effluent gas conditions

Dry-bulb temperature	= 160°F

$$\text{Moisture content} = \frac{16.8}{100} = 0.168$$

Find:

1. Ambient relative humidity
2. Exhaust gas humidity ratio

Determine whether or not water will condense (i.e., whether a steam plume will form).

Solution:

Plot ambient wet-bulb and dry-bulb temperatures.
Ambient relative humidity = 55%
Exhaust gas humidity ratio = *HR*

$$HR = \frac{0.62\,(MC)}{1 - MC}$$

$$= \frac{0.62\,(0.168)}{1 - 0.168}$$

$$= 0.125 \text{ pound water/pound dry air}$$

Plot humidity ratio and stack dry-bulb temperature. Connect the ambient state point and stack gas state point with a straight line. The line crosses the 100-percent relative humidity line; hence, a water vapor plume will be visible.

When the wet-bulb/dry-bulb technique is used and the barometric pressure is less than 29.5 inches of mercury, use the following equations to calculate the vapor pressure (*VP*) from the saturated vapor pressure (*SVP*) and then to determine the final moisture content (*MC*).

Notes

$$VP = SVP - (3.57 \times 10^{-4})(P_{abs})(T_d - T_w)$$

where:

SVP = Saturated vapor pressure (inches of mecury) at wet-bulb temperature

T_d = Dry-bulb temperature, °F

T_w = Wet-bulb temperature, °F

$$MC = \frac{VP}{P_{abs}}$$

where:

VP = Vapor pressure of H_2O

P_{abs} = Barometric pressure

Line-Of-Sight Problems

Method 9 requires that the plume be observed across the narrow axis:

> The observer shall, as much as possible, make his observations from a position so that his line of vision is approximately perpendicular to the plume direction. When observing opacity of emissions from rectangular outlets (e.g., roof monitors, open baghouses, noncircular stacks), the observer shall make his observations approximately perpendicular to the longer axis of the outlet. (See Figure 7-2(a).)

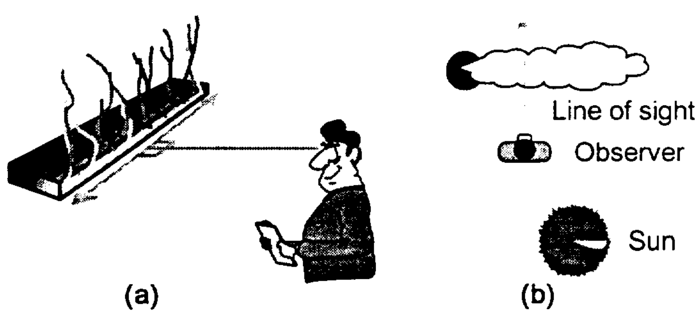


Figure 7-2. Line-Of-Sight Guidelines

Notes

The observer should be situated so that his sight line crosses only one plume diameter. (See Figure 7-2(b).) An observation will be positively biased if it is made through a longer visual pathlength than is appropriate. The usual guidance to eliminate this problem is to observe the plume from at least 3 stack lengths from the source. At 3 stack lengths, the view deviates about 18° from the line of sight and will make a 1-percent positive bias in the observation if the opacity is 20-percent. For angles less than 18°, the adjustment is relatively insignificant and can be ignored.

In rare cases, the observer has no choice but to be relatively close to the stack so that the sight line is up through the plume rather than across it. This extended sight pathlength through the plume should be acknowledged and the individual data values adjusted mathematically in the final data report to show the increase in opacity reading due to the longer pathlength. These adjusted opacity readings should be used in demonstrating that averages exceed the standard.

Figure 7-3 shows how the slant angle varies inversely with distance from an elevated source. As an observer moves closer to the base of the stack, the angle of sight and the visual pathlength through the plume both increase. An increased visual pathlength through the plume causes an increased opacity reading even though the actual cross-plume opacity remains constant. This situation applies only when the opacity is read through a vertically rising plume and the observer is on the same plane as the base of the stack.

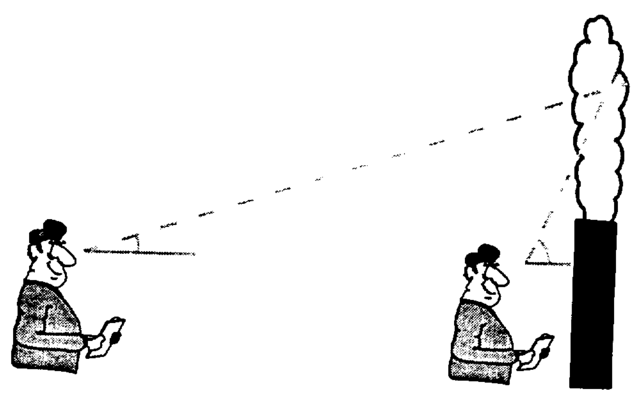


Figure 7-3. Slant Angle

The actual opacity can be calculated from the observed opacity if the slant angle is known or if the height of the stack and the distance from the observer to the base of the stack are known.

Notes

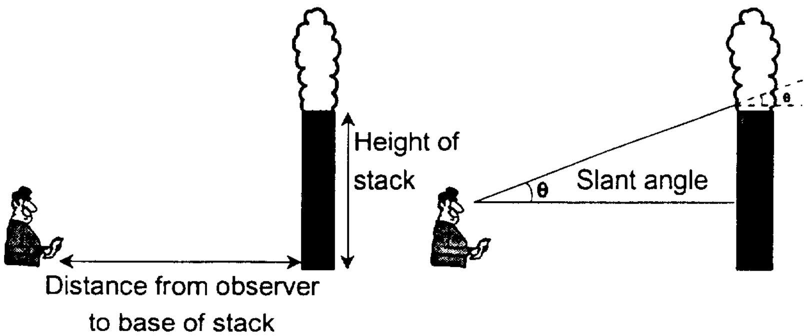


Figure 7-4. Information Needed To Calculate Actual Opacity From Observed Opacity

Method 1 (slant angle is known):

$$1 - \frac{(O_o)}{100} = T$$

$$(1 - T^F) \times 100 = O_c$$

where:

O_o = observed opacity in percent
T = observed transmittance
F = cosine of slant angle
O_c = corrected opacity in percent

Method 2 (distances are known):

$$F^2 = \frac{Y^2}{H^2 + Y^2}$$

where:

F = cosine of slant angle
Y = distance from observer to stack
H = height of stack

Notes

$$1 - \frac{(O_o)}{100} = T$$

$$(1 - T^F) \times 100 = O_c$$

where:

O_o = observed opacity in percent
T = observed transmittance
F = cosine of slant angle
O_c = corrected opacity in percent

Note: Because the correction is a power function, the correction must be made on each opacity reading before the value is used for calculations. The correction procedure should never be performed on the reduced (averaged) data.

Table 7-1 on the next page presents opacity data values corrected for various slant angles. To use the table, first locate the measured opacity value along the left side of the table. Follow this row across to the column under the slant angle recorded for the observation. The value of the intersection of the measured-opacity row and the slant-angle column is the actual opacity for that observation. For example, if the measured opacity were 75 and the slant angle were 40, the actual opacity would be 65.

Complex Plumes

Water Retention On Particles

At some facilities, observers are confronted with plumes of complex mixtures of contaminated water vapor and other condensable or reactive materials. Sometimes the condensed material seems to be attached to fine particles. When the plume is observed through binoculars, it is clear that the condensed water or "steam" does not simply dissipate sharply, as it does in many sources. Instead, the free water not attached to particles dissipates, as do classic steam plumes, but a large amount of water is retained on particles, giving the appearance of steam past the point of the "steam break." After viewing the source through binoculars periodically, observers will learn to recognize this problem without relying on binoculars. This situation can be observed from both the correct viewing angle in relation

Table 7-1. Opacity Values Adjusted For Increased Pathlength Due To Slant Angle

Measured Opacity	Slant Angle, degrees						
	0	10	20	30	40	50	60
95	95	95	94	93	90	85	78
90	90	90	89	86	83	77	68
85	85	85	83	81	77	71	62
80	80	80	78	75	71	65	55
75	75	75	73	70	65	59	50
70	70	70	68	65	60	54	45
65	65	64	63	60	55	49	41
60	60	59	58	55	50	45	37
55	55	55	53	50	46	40	33
50	50	50	48	45	41	36	29
45	45	45	43	40	37	32	26
40	40	40	38	36	32	28	23
35	35	35	33	31	28	24	19
30	30	30	29	27	24	21	16
25	25	25	24	22	20	17	13
20	20	20	19	18	16	13	11
15	15	15	14	13	12	10	8
10	10	10	9	9	8	7	5
5	5	5	4	4	3	3	3
0	0	0	0	0	0	0	0

Notes

to the sun and the incorrect viewing angle (facing into the sun). When the observer views the plume from the incorrect angle by facing into the sun, a more qualitative assessment of the plume can be made. The observer sees the first "steam" break more clearly and also sees the lingering plume of water and particles. The water and particulate matter plume will change in texture as the water evaporates until the plume becomes essentially all particles. Using relative plume heights along the plume to determine the appropriate viewing location, the observer should view the same location in the plume from the correct viewing position (sun at back). Observations should be made after the point of water evaporation in full accordance with Method 9.

Condensation And Reaction Plumes

Some gases can be mixed together under dry conditions without reacting, but when these same gases are mixed in the presence of water droplets, the two compounds can react to generate particulate matter. Usually these compounds react via ionic bonding, and the product dissolves in the water droplet. Subsequently, the water droplets evaporate, and a particulate matter plume remains. For example, when sulfur oxides, ammonia gases, and water vapor are in the same gas stream, the sulfur dioxide and ammonia react on water droplet surfaces and form dissolved ammonium sulfate. The water evaporates back into the atmosphere, leaving ammonium sulfate particles in the plume. This reaction can occur in exhaust gases from cement plant kilns.

Similar reactions occur in other industries, and plumes from these reactions can cause viewing problems. Normally, when observing a detached plume, the observer will make the observation between the stack outlet and the condensing plume, as suggested by Method 9. If the material condensing or reacting out is of interest, however, the observation should be made after the steam plume dissipates, as shown in Figure 7-5.

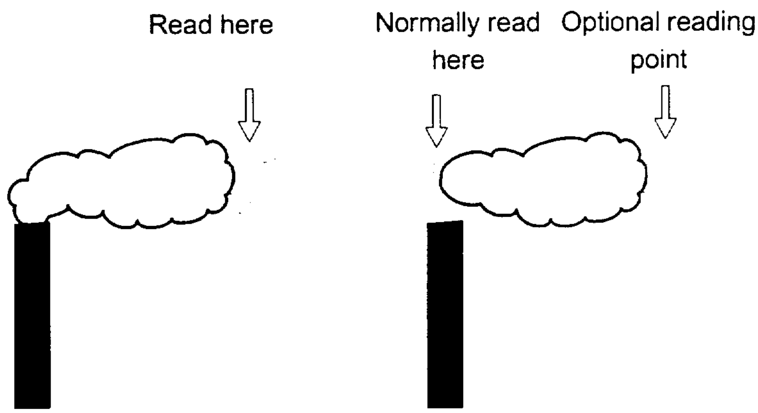


Figure 7-5. Reading Detached Steam Plumes

Notes

Extreme Distances

In some guidance documents, EPA has stated that a quarter of a mile is the maximum suggested viewing distance. In some cases, however, such as during the observation of tall stacks, that limit must be exceeded, particularly when the source layout is such that it is impossible to get correct sun positions at certain times of day or if access is difficult, unsafe, denied, or inadvisable because the observation must be candid.

The quarter-mile viewing distance prevents intervening haze from lowering the contrast between the observer and the source and background and consequently limits the corresponding negative bias in observations. Also, the quarter-mile viewing distance helps the observer get a clear view of the plume. Binoculars can shorten the apparent distance to the source, but this method should be used with care, and the general rule of certifying and observing with the same equipment should be followed.

Nighttime Observations

Little long-term use of visible emissions observations at night has been documented except in California. In certain areas of the country, however, regulatory personnel and in some cases industry personnel must be able to evaluate the opacity of nighttime visible emissions accurately, because:

Notes

- Areas in the more-northern parts of the United States, such as Alaska, Maine, and those states at the northern border, have short days during the winter months.

- Some industries, because of the nature of their operations, incinerate during the less-busy evening hours or second shift.

- Some industries might try to circumvent regulations by operating certain processes at night or under reduced controls. (Soot blowing is a common example.)

- In states where industries are required to submit opacity data from an opacity monitor, human observers are allowed during monitor downtime, which might be at night.

For years, California has routinely provided opportunities for readers to become certified in night viewing and to cite violations based on night observations. A number of other states are considering adoption of similar night observation and certification programs.

Several agencies have experimented with nighttime VE observations. In the early 1970s, EPA Region III certified an observer using a starlight scope. This instrument's method of operation actually distorts emission observations. The starlight scope amplifies light, and although this amplification helps the observer see the plume, it does not help judge opacity. Similar tests with infrared systems provided flawed results, because the exhaust gases were at an elevated temperature. Also, infrared devices can "see" through the smoke because of particle-size and wavelength-of-light considerations. Because visibility is not opacity, neither the starlight scope nor an infrared system is recommended.

Usually, there is enough natural light at night for an observer to see a plume. EPA has determined that an observer certified in Method 9 at night can estimate the opacity from a source at night with the same accuracy as in daylight. In fact, by using proper techniques, a trained and certified observer can assign an accurate value to the opacity of a source under many conditions.

Notes

Observers must be trained and certified to observe plumes at night by taking and passing nighttime field tests before observing for record. The following guidelines are recommended for nighttime viewing:

- Conduct observations on a night clear of fog.
- Maintain night vision by avoiding light.
- Select a light behind the source:
  - A blue-white star is excellent
  - A low-power incandescent light is good
  - High-intensity lights should be avoided
  - Sodium or mercury arc lights should be avoided
  - Colored lights should be avoided
- View the light alternately through the plume and beside the plume.
- Determine opacity in the same way as during daylight hours.

Review Questions

1. The psychrometric chart is a graphical representation of what five variables?

2. Give a brief definition of the five variables from question 1.

3. What is the least number of these five properties that must be known in order to determine them all?

4. The ___________ is the point on the psychrometric chart that describes the current condition of the ambient air or stack emission.

5. The change of the exhaust gas from the stack state conditions to the ambient air conditions (will/will not) _____________ be accompanied by a visible steam plume if the line connecting the two points on the chart lies completely to the right of the 100-percent relative humidity line.

6. When observing a rectangular outlet, the observer should be perpendicular to the (long/short)_________ axis of the outlet.

7. Which observer would have a greater slant angle?
   a. An observer 40 feet away from a 10-foot stack.
   b. An observer 100 feet away from a 75-foot stack.

8. Given:

   Ambient Air Conditions:
   Dry-bulb temperature: 80°F
   Wet-bulb temperature: 70°F
   Barometric pressure : 29.90 in Hg

   Stack Emission Conditions
   Dry-bulb temperature: 170°F
   Moisture content: 16.2%

   Find:
   Ambient relative humidity ____________________
   Exhaust gas humidity ratio____________________
   Will a steam plume form?____________

9. If an observer is less than 3 stack lengths away, he or she will perceive an ~~opacity that is (greater than/less than)~~_______ ~~the actual opacity.~~

Review Questions (cont.)

10. Given:
    Slant angle = 30°
    Observed opacity = 25%
    Calculate the corrected opacity (use the chart on page 7-11).

11. Given:
    Observed opacity = 40%
    Height of stack = 100 feet
    Distance from observer to stack = 60 feet
    Calculate the corrected opacity.

12. What kind of bias is present if an observer is less than 3 stack lengths away?

13. A plume in which water attaches to fine particulate matter is a ____________________.

14. In what way can an observer determine where the steam break is in a complex plume?

15. What would happen if sulfur oxides and ammonia were present in a steam plume? What kind of plume is this?

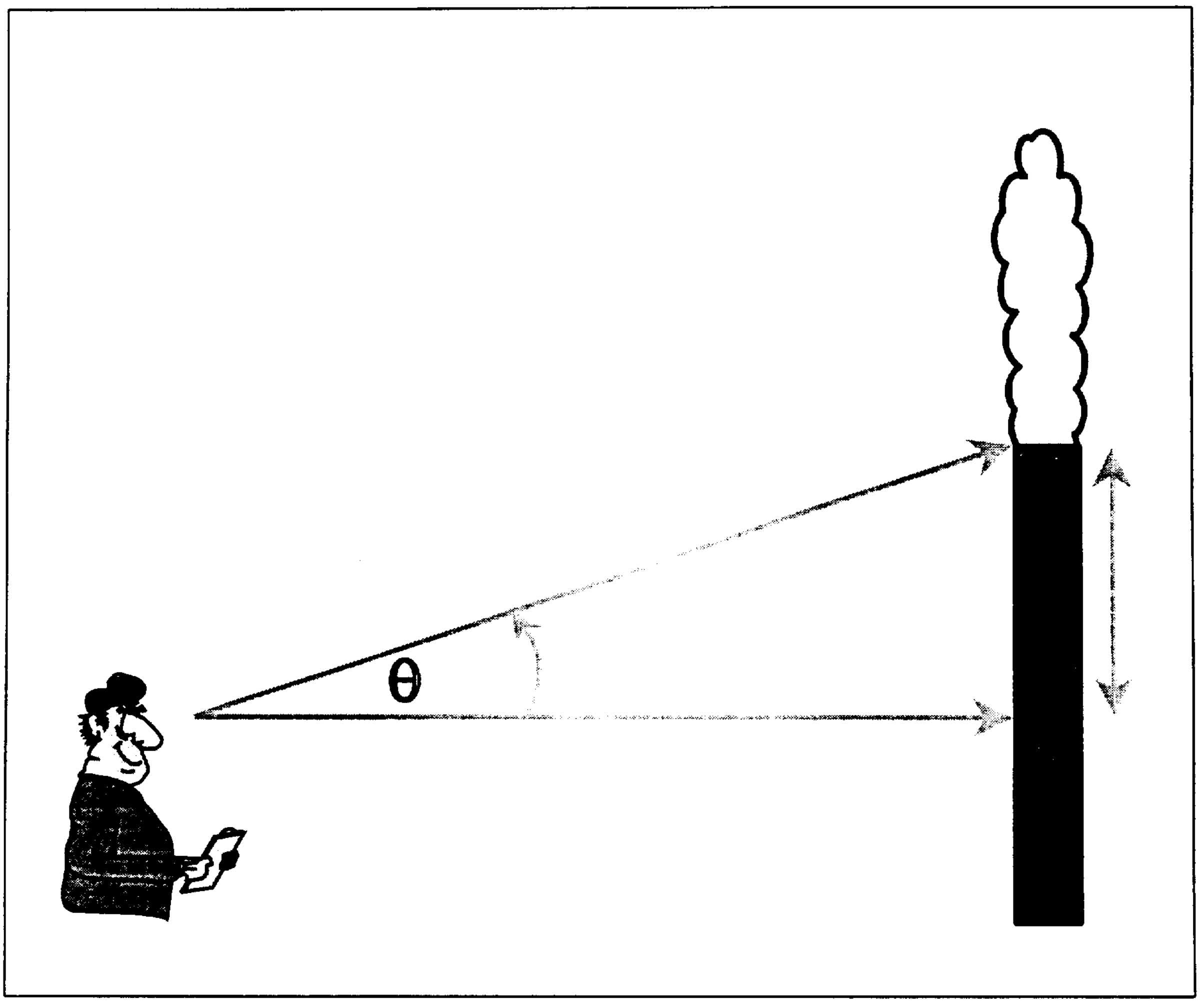
16. EPA has suggested that the maximum distance an observer should view from is ____________________.

17. An observer observing a stack from greater than 0.5 mile might have a (positive/negative) _______ bias because of intervening ________________.

18. List three reasons nighttime observation might be used.

Lesson 8

Documentation



Documentation

Notes

Under the Clean Air Act of 1970, violations of visible emission standards from either an NSPS or a SIP could result in a fine of up to $25,000. A violation can be compared to a speeding ticket. Someone who receives a speeding ticket might have a lawyer look at the ticket to determine if the documentation is correct. If it is not, they might have a chance to beat the ticket in court. The same concept holds true for opacity violations.

Industry is motivated to scrutinize the visible emissions data on a form for error because of the size of the fines. Court cases have been lost or dropped because of poor documentation of opacity violations. Observers in the field simply do not always pay enough attention to the details necessary for litigating a violation successfully. Observers can prevent possible challenges during deposition processes and in court by properly documenting the visible emissions they observe.

Initial use of Method 9 demonstrated that more documentation was needed. The example form and documentation included in the *Federal Register* with the Method 9 procedure are not always adequate to determine the compliance status of sources subject to opacity standards. A new visible emission observation (VEO) form was developed after a review of the opacity forms that had been used in EPA Regional Offices and in state and local air quality control agencies. The new form includes the data required by Method 9 plus additional descriptive information pertaining to observation conditions.

The VEO form is a three-part form with one original and two carbon copies. The form should be completed and signed on-site so that the observer can give the source immediate documentation of the inspection. The original goes to the observing agency's files, the first copy is for the VE observer's file, and the second copy is for the facility. Waterproof black ink should be used on these forms. Unless an item is specifically designated as optional, the observer must provide an entry in all sections.

Notes

The next section of this lesson discusses each of the 10 major parts of the VEO form and each data element found on the form. The discussion includes an explanation of each section's purpose and each data element. A description of the type of information being sought and, in some cases, examples of appropriate entries are included. An example of a completed VEO form is at the end of this lesson.

Company Identification

This section of the form provides information that identifies the company and gives the observer information on contacting the company.

Company name—Include the facility's complete name. To give positive identification of the facility, include the parent company name, division, or subsidiary name.

Street address—Indicate the street address of the facility (not the mailing address or the home office address) so that the exact physical location of the source is known. If necessary, the mailing address or home office address can be listed elsewhere.

Process And Control Equipment

This section of the form includes:

- A description of the process and control equipment.
- Indication of current process operating capacity or mode.
- Operational status of control equipment.

Note: This section includes information that can be obtained from a plant official. Because plant officials might consider production rate or other process information proprietary, the inspector should specifically inform them that they have a right to request that this information be submitted subject to the confidential business information (CBI) provisions of 40 CFR Part 2, Subpart B.

Notes

Process equipment—Enter a description that clearly identifies the process equipment. Also enter the type of facility that emits the plume or emissions to be read. The description should be brief but should include as much information as possible.

Operating mode—Depending on the type of process equipment used, this information can vary. Some examples of the types of entries include:

- Quantification of the current operating rate.
- Description of the portion of a batch-type process for which the emission opacity is being read.
- An explanation of how the equipment is currently operating, such as "upset conditions," "startup," or "shutdown."
- "90-percent capacity" for a boiler.
- "85-percent production rate" for the shakeout area of a grey iron foundry.

For a metallurgical furnace, entries should include the exact part of the process cycle for which readings are being taken, such as "charging" or "tapping." Usually, this information will have to be obtained from a plant official.

Control equipment—Specify the type(s) of control equipment used in the system after the process equipment (e.g., hot-side electrostatic precipitator).

Operating mode—Two items of information should be in this section.

- The manner in which the control equipment is being operated at the time of the opacity observations (e.g., one field of eight tripped on ESP, scrubber operating without water, shutdown, offline).
- The operating mode (e.g., automatic, manual, by-pass). This information should be obtained from a plant official.

Notes

Emission Point Identification

This section of the form identifies the emission point and its specific relationship to the observer's position. Use consistent units for distances and heights in this section of the form.

Describe emission point—Indicate the type of emission point and its physical characteristics. The description must be specific enough so that the emission outlet that was observed can be distinguished from all others at the source. The description of the type of emission point should address whether it is one of the following:

- A specifically designated outlet, such as a stack, a vent, or a roof monitor (with confined emissions).
- An emission source with unconfined emissions, such as a storage pile, a chemical tank, or a non-ducted material-handling operation.

The description of the physical characteristics of the emission point should include:

- The appearance (such as color, texture, etc.).
- The geometry (such as size, shape, etc.) of the stack or other outlet.
- The emission point's location in relation to other recognizable facility landmarks.

Note any special identification codes agency or plant operating personnel use to identify a particular stack or outlet with the description and record the source of the code. Do not use a special identification code by itself to describe the emission point, because the code could be incorrect or might require a secondary reference. Special identification codes, in addition to a description of the emission point, an identification of the process equipment, and a description of the control equipment will ensure proper identification of the stack or outlet.

Notes

Height above ground level—Indicate the vertical distance from the ground to the emission point. There are several ways to obtain this information.

- It can be found in agency files, engineering drawings, or computer printouts (such as National Emissions Data System [NEDS] printouts).

- It can be obtained by using a combination of a rangefinder and an Abney level or clinometer.

- It can be estimated.

The observer should record what method was used to determine the height.

Height relative to observer—Indicate a height estimate of the emission outlet above the observer's position. This measurement shows the observer's position in relation to the outlet's base (i.e., higher or lower than the base). This information is necessary if slant-angle calculations are performed. This parameter should be recorded in the same units as those used to indicate height above ground level.

Distance from observer—Record the distance from the point of observation to the emission outlet. The distance can be measured with a rangefinder, or a map can be used to estimate the distance. The observer should use the same units that were used to record the two height measurements.

This measurement of "distance from observer" must be reasonably accurate when the observer is close to the stack (within three stack heights). Accuracy is important because this measurement might be used in conjunction with the outlet height relative to the observer to determine the slant angle at which the observations were made (see Figure 8-1). A precise determination of the slant angle is needed to calculate the positive bias. This bias is inherent in opacity readings made when the observer is within three stack heights distance from the stack.

Direction from observer—Specify the direction of the emission point from the observer. This parameter should be

Notes

specified using one of the eight points of the compass (e.g., S, SE, NW, NE). A compass or map can be used to make this determination. If a plotting table is used with a high-quality compass, this determination is accurate to within 2°.

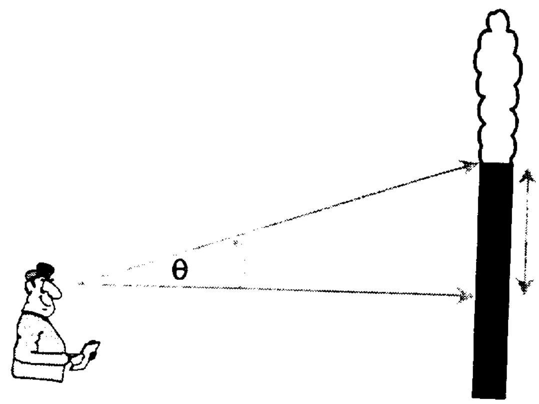


Figure 8-1. Slant-Angle Determination

Vertical angle to plume—Indicate the angle between the horizontal plane (ground) and the line from the observer to the point where the emissions were read.

Horizontal angle to plume—Indicate the angle between the observer north line and the horizontal line from the observer to the emission point.

Emissions Description

This section of the form includes information that definitely establishes what was observed while the visible emissions determination was being made.

Note: Information needed to complete this section might change many times during the observation period. These changes should be noted in the comment space beside the appropriate opacity readings. These comments should be referenced in the corresponding space in this section.

Describe emissions—Include descriptions of the physical characteristics and behavior of the plume (not addressed elsewhere on the form). Also, the observer should include the maximum distance at which the plume is visible. Physical descriptions could include such things as texture,

Notes

gradation, and contents. Examples of descriptions include "lacy," "fluffy," "copious," "mushrooming," "spreading over horizon," and "detached non-water vapor condensables." Standard plume terminology also can be used to characterize plume behavior. This behavior is generally used to determine the atmospheric stability on the day of the opacity observations.

Emission color—Note the emission color. The plume color can sometimes be useful in determining the composition of the emissions. Plume color also serves to document the color contrast between the plume and its background as seen by the opacity observer. If emissions (such as those from a basic oxygen furnace) change color during the observation period, the color changes should be noted in the comments space next to the opacity readings themselves.

If water droplet plume—This box is completed only if visible water droplets are present. Check "attached" if condensation of the moisture contained in the plume occurs within the stack. In this case the water droplet plume is visible at the stack exit. Check "detached" if condensation occurs some distance downwind from the stack exit. In this case the water droplet plume and the stack appear to be unconnected.

Plumes containing condensed water vapor ("water droplet plumes" or "steam plumes") are usually white and billowy, and they are wispy at the point of dissipation. At this point the opacity decreases rapidly from a high value (usually 100 percent) to zero if there is no residual opacity caused by contaminants in the plume.

To document the presence or absence of condensed water vapor in the plume, the following points must be addressed:

- Is sufficient moisture present (condensed or uncondensed) in the effluent to produce water droplets at in-stack or ambient conditions?

- If enough moisture is present, are the in-stack and ambient conditions such that water vapor will condense or form droplets before or after exiting the stack?

Notes

The first question can be answered by examining the process type and/or the treatment of the effluent gas after the process.

Some common sources of moisture in the plume are:

- Combustion
- Process loss
- Drying operations
- Chemical processes
- Control equipment (wet scrubbers)

If water is present in the plume, a prediction can be made about whether steam plume formation is probable. Data from a sling psychrometer in combination with the moisture content and temperature of the effluent gas can be used to make this prediction. These procedures were described in Lesson 7.

Point in the plume at which opacity was determined—Describe as accurately as possible the physical location in the plume where the observations were made (such as the distance from the emission point). This information is necessary to establish that nothing interfered with the observer's clear view of the contaminant plume. An example of this type of interference would be condensed water vapor. Knowing the point in the plume where the observations were made is also important in the case of secondary plume formation. Therefore, the observer must specify:

- If the readings were made before water droplet plume formation or after water droplet plume dissipation.

- The distance from the emissions point and/or water droplet plume. Descriptions such as "4 feet above outlet," "80 feet downstream from outlet," or "10 feet after steam dissipation" are appropriate.

Observation Conditions

This section of the form covers the background and ambient weather conditions during the observation period. These factors could affect observed opacity.

Describe plume background—Describe the background against which the opacity is being read. Include characteristics such as texture in the background description. Examples of background descriptions are "structure behind roof monitor," "stand of pine trees," "edge of jagged, stony hillside," "clear blue sky," "stack scaffolding," or "building obscured by haze."

Background color—Describe the background color, including the shade (e.g., new leaf green, conifer green, dark brick red, sky blue, light gray stone). The observer should try to choose a background that contrasts with the color of the plume.

Sky conditions—Indicate the percent cloud cover of the sky by using straight percentages (e.g., 10-percent overcast, 100-percent overcast) or by description (e.g., partly cloudy, mostly cloudy, clear).

Wind speed—Record the wind speed. Speed should be measured or estimated to ±5 miles per hour. The wind speed can be measured with a hand-held anemometer or wind speed can be estimated by using the Beaufort Scale of Wind Speed Equivalents. (See Table 4.1.)

Wind direction—Indicate the direction from which the wind is blowing. The direction should be estimated according to one of the eight direction points of the compass. Wind direction can be determined by observing which way the plume is blowing. If the wind direction is not readily discernible from the plume path, it can be determined by observing a blowing flag or by noting the direction in which a few blades of grass or a handful of dust is blown when tossed into the air. The observer should keep in mind that the wind direction at the observation point can be different from that at the emission point; the wind direction at the emission point is the one of interest.

Ambient temperature—Measure the outdoor temperature at the plant site with a thermometer and note which temperature scale is used (Fahrenheit or Celsius). The ambient temperature is used in conjunction with the wet-bulb temperature when there are indications of a condensing water droplet plume.

Notes

Notes

Wet-bulb temperature—Record the wet-bulb temperature from the sling psychrometer. This measure should be taken when there is the possibility of a condensing water droplet plume.

Relative humidity—Enter the relative humidity, which can be determined by using a sling psychrometer and a psychrometric chart. This information is used to determine whether water vapor in the plume will condense to form a steam plume.

Observer's Position And Source Layout

Use this section of the form to identify the observer's position in relation to the emission point, plant landmarks, topographic features, sun position, and wind direction. Method 9 currently requires a sketch that shows the relationship of the sun, the observer, and the source.

Source layout sketch—This sketch should be drawn as a rough plan view and should include as many landmarks as possible. The exact landmarks included on the sketch depend on the specific source, but they might include buildings, roads, ponds, and other permanent landmarks. At the very least, the sketch should show the relative positions of the observed outlet and associated buildings so that these landmarks will not be confused with others later. The sketch also should clearly indicate the position of the observer during the VE readings.

Include a sketch of the plume (indicating the direction of wind travel). This will assist in subsequent analysis of the reading conditions. The wind direction also must be indicated in the observation conditions section of the form that was discussed earlier.

Draw north arrow—To determine the direction of north, point the line of sight in the source layout sketch in the direction of the actual emission point. Place the compass next to the circle and draw an arrow in the circle parallel to the compass needle (which points north). Alternatively, a map can be used to determine the direction of north.

Notes

Sun's location—Verify the location of the sun before making any opacity readings. The sun's location should be within the 140° sector indicated in the layout sketch. This confirms that the sun is within the 140° sector to the observer's back.

To draw the sun's location, the observer should perform the following steps:

1. Point the line of sight in the source layout sketch in the direction of the actual emissions point.

2. Move a pen upright along the "sun location line" until the shadow of the pen falls across the observer's position.

3. Draw the sun at the point where the pen touches the "sun location line" and the pen's shadow remains across the observer's position.

Additional Information

This section of the form can be used to provide information on actual conditions and/or deviations. The information should pertain only to conditions that have a bearing on the opacity observations and that have not been addressed elsewhere on the form.

Additional information—Note actual conditions or deviations that cannot be addressed elsewhere on the form, such as in the comments section of the data set. These notes must be factual and specific to the particular source. Examples of information that can be included in this section are:

- Entry difficulties
- Interferences
- Presence of haze

Data Set

This section of the form is used for the opacity readings obtained during the observation period. The readings should

Notes

be organized by minute and second. This section also includes the actual observation date as well as start and end times for the observation period. There is space next to each minute of readings to note relevant comments.

Observation date—Here the observer should enter the date on which the opacity observations were made.

Start time and end time—Here the observer should indicate the times at the beginning and at the end of the actual observation period. The times can be expressed in 12-hour or 24-hour time (i.e., 8:35 a.m. or 0835), but 24-hour time tends to be less confusing and is strongly recommended. Time zone indication is also critical (e.g., EST, CST, EDT, PDT, or MST).

Data set—Spaces are provided on one form for entering an opacity reading every 15 seconds for up to a 30-minute observation period. If observations continue beyond 30 minutes, a second form (and a third, etc.) should be used to record additional readings. The readings should indicate percent opacity and should be made to the nearest 5 percent. The readings are entered from left to right for each numbered minute.

The minutes run from top to bottom. The first entry would be entered in the top left-hand box (MIN 1, SEC 0). The next entry would be entered in the top row second box from the left (MIN 1, SEC 15). The next readings are entered consecutively in the spaces labeled MIN 1, SEC 30; MIN 1, SEC 45; MIN 2, SEC 0; MIN 2, SEC 15; etc.

If for any reason a reading is not made for a particular 15-second period, a dash (–) should be placed in the space. A blank space might be taken for an oversight. The comment section beside that reading should be used to explain why the reading was missed.

Comments—Spaces for comments are provided next to the data for each minute of opacity readings. These spaces can be used to note changing observation conditions and/or reasons for missing readings. Items to be noted include wind shift, changing background, and interfering emissions.

Observer Data

Notes

This section of the form deals with the information required to validate the opacity data.

Observer's name—Print entire name.

Observer's signature—Self-explanatory.

Date—Enter the date on which the form was signed.

Organization—Enter the name of the agency or company employing the observer.

Certified by—Identify the agency, company, or organization that conducted the "smoke school" or VE training and certification course where the observer's current certification was obtained.

Date—Provide the date of the current certification.

Forms Interrelation

This section should be used if the observer has continued VE observations on additional forms that are related to the same observation.

Continued on VEO form number—Here the observer should fill in the five-digit number of the Observation Form, if any, where the observations from the form in use are continued. Each form of a series that is followed by another form will have the number of the next form noted in this section.

Review Questions

1. Violation of visible emissions standards from either an NSPS or a SIP can result in a fine of up to ________________.

2. Which of the following would be the best way to indicate the time of observation?

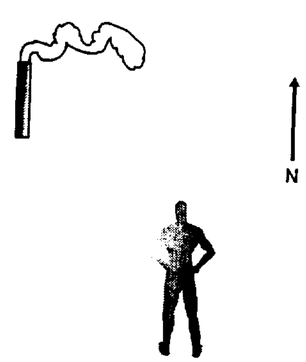
   a. 1:45
   b. 1345
   c. 1:45 EDT
   d. 1345 EDT

3. Where should an observer record events that affect the validity of the observation (such as interfering plumes)?

4. Where would the following entry be on the VEO form?
   "85-percent production rate"

5. Where would the following entry be on the VEO form?
   "Tallest of four stacks, directly south of a small pond"

6. What would an observer enter in "Direction From Observer" for the following?



7. To document the presence or absence of condensed water vapor in the plume, what two points must be addressed?

8. Where would the following be found on the VEO form?
   "Stand of pine trees"

Review Questions (cont.)

9. **Which of the following would be appropriate for the "Source layout sketch"? (You may select more than one.)**

   a. **Buildings**
   b. **Other emission outlets**
   c. **A crane**
   d. **A pond**
   e. **A delivery truck**

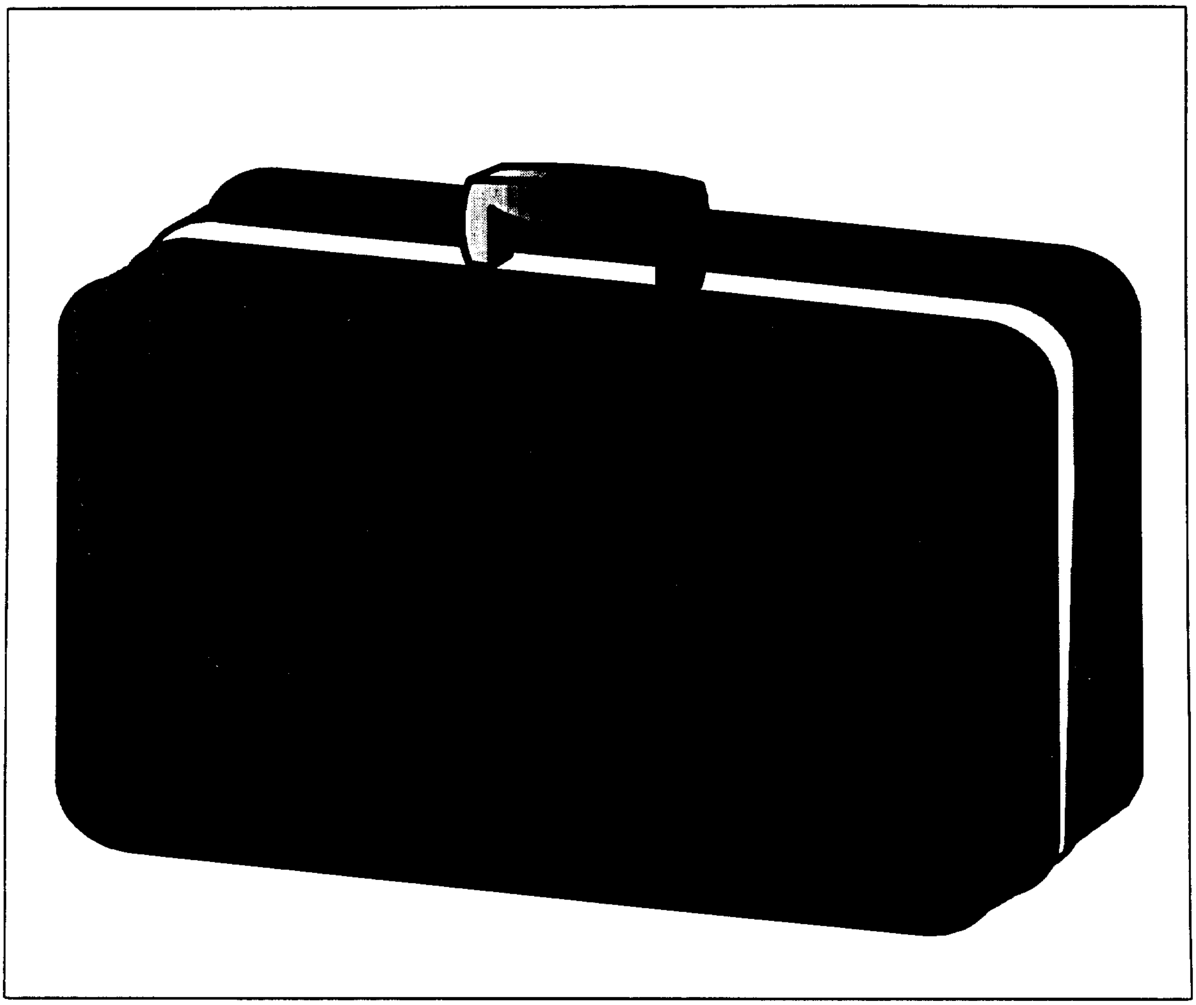
10. **The sun must be within a _________degree sector to the observer's back.**

11. **If a reading is missed, how should an observer indicate this?**

12. **If all the observations will not fit on one form, where should additional information be recorded?**

Lesson 9

Equipment



Equipment

Introduction

Method 9 does not require unique equipment or supplies—just a few general items. This section provides specification criteria or design features to help select equipment that will be useful in collecting VE data. These specifications are based on observer experience observing plumes and plume conditions.

Notes

Supplies

The observer should have a clipboard, several black ballpoint pens (medium point), several large rubber bands, and a sufficient number of VE observation (VEO) forms. The clipboard should be dark, with a black plastic or other nonreflective paper clip that will not reflect the glare of the sun while the observer is making observations on bright days. One or two rubber bands around the bottom of the clipboard are useful for holding down forms.

The observer should use high-quality reproductions of the VE forms because they will probably be reproduced numerous times during the litigation process. Using a high-quality, black, medium ballpoint pen to fill out the forms will enhance the quality of subsequent copies. If there is a chance that the forms will get wet during the observations, the observer should reproduce the forms on plastic paper available from office supply stores. It is also useful to copy the forms onto light-blue or green paper if glare is a problem.

Equipment

Timer/Watch

The observer should use a watch to time the 15-second intervals between opacity readings. Liquid-crystal-display watches are good because they are easy to read. The observer

Notes

can even mount two stick-on timers on the clipboard, one set to alternate between time and date and the other to count seconds. These timers are available with displays ½ inch or larger. A watch with a beeper that sounds every 15 seconds allows the observer to focus on the surroundings, which is especially important in busy industrial areas.

Compass

The observer uses a compass to determine the direction of the emissions point from where the observer stands and to determine the wind direction at the source. For accurate readings, the compass should have a resolution better than 5°. The compass should be jewel-mounted and liquid-filled to dampen the needle swing. Map-reading compasses are excellent for this purpose and come in two types:

- Card
- Needle

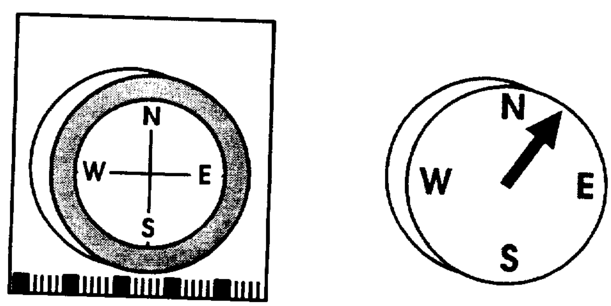


Figure 9-1. Card-Type and Needle-Type Compasses

The card-type compass has a circular disk, marked in degrees, that rotates on a pivot. The needle-type compass has a needle with a north marker that indicates magnetic north. The observer should keep the compass level and away from ferrous metals. Even a small amount of ferrous metal, such as the clip on a clipboard, can influence the reading on a compass. This makes the hood of a car an unsuitable place to take a compass reading. It is also important to know the magnetic declination from true north at the observation location. Sizeable documentation errors can be generated when an observer relies on a compass alone for determining direction. For this reason, a map should be used in conjunction with a compass to ensure accuracy.

Maps, Plans, And Aerial Photographs

Notes

The best maps to use for opacity work are U.S. Geological Survey maps. Quadrangle maps are available in a large enough scale to allow individual buildings to be identified. These maps give the magnetic declination as well as the relative heights of the topography. Company plans are not useful if they do not reflect the final construction configuration. Current aerial photographs are extremely useful and are usually available from a map service or an aerial photographer at a nominal cost. The stack height can be calculated from these aerial photographs by using the length of the shadow from the stack and the time of day and time of year that the photograph was taken.

Rangefinder

A rangefinder measures the observer's distance from the emissions point and should be capable of determining distances to 1,000 meters with an accuracy of ±10 percent. The accuracy of the rangefinder should be checked on receipt and periodically thereafter with targets at known distances of approximately 100 meters and 1,000 meters. The two common types of rangefinders are stadiometric and split image. For ease of use and portability, most observers prefer the stadiometric rangefinder, but either type is acceptable.

Clinometric Devices

Clinometric devices determine the vertical viewing angle. For VE observation purposes, a clinometric device should measure within 5°. Clinometric devices include:

- Abney level
- Clinometer
- Sextant

The Abney level was designed for forestry work and is the most practical clinometric device for determining opacity because of its portability and field ruggedness. An Abney level costs about $100. Clinometers can be somewhat cheaper, but they are not as well suited for opacity work. The sextant is the most accurate of the clinometric devices. It can determine the vertical angle within minutes of an arc. The

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sextant is harder to use, and it is not as durable as either the Abney level or the clinometer unless an expensive model is purchased. Sextants are not as compact as either of the other devices.

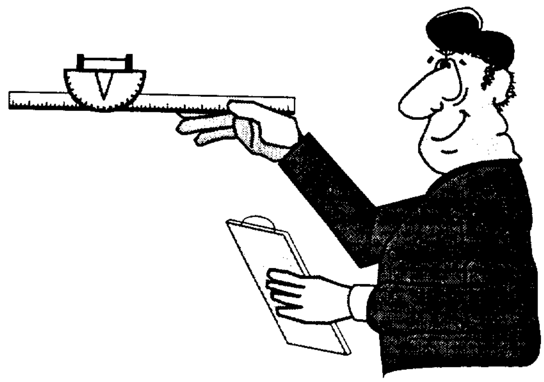


Figure 9-2. An Abney Level—A Type Of Clinometric Device

Drawing Tools

An invaluable accessory is a template that has basic shapes cut out to help draw the sketch required by Method 9. One of the best templates is a small computer-programming template available at office supply stores.

Anemometers

Anemometers are devices that determine wind speed. The three basic types are:

- Mechanical
- Electronic
- Pressure

Mechanical anemometers measure the wind with a rotating turbine. The rate of rotation depends on the wind speed. The rate of rotation is electrically determined and translated into wind speed on a meter or display.

Electronic anemometers usually consist of a hot wire that is cooled by the air flowing past. The faster the air flow, the more cooling occurs. The amount of current required to reheat the wire is then translated to wind speed. These electric (or hot-wire) anemometers are the most expensive of the wind-speed instruments.

Notes

The simplest anemometer and the most popular among field personnel is the pressure type. It consists of either a hinged pressure plate that rises with wind speed or a variable orifice flow meter (rotameter) with an indicator that rises proportionally to wind speed.

Sling Psychrometer

A sling psychrometer is used when the atmospheric conditions might promote steam plume formation. The psychrometer consists of two thermometers, accurate to 0.5°C, mounted on a sturdy assembly that allows the thermometers to be swung rapidly in the air. One thermometer is fitted with a wettable cotton wick tube on the bulb. If for some reason the wick is missing, a cotton shoelace can be substituted. Thermometer accuracy should be checked by placing the bulbs in a fresh-water/ice-water bath and checking to see that they read 0°C.

A person uses a sling psychrometer by wetting the cotton wick and swinging the assembly through the air until the temperatures of both thermometers stabilize. Because of evaporative cooling, the wet-bulb temperature will be lower than the dry-bulb temperature if the relative humidity is below 100 percent. The difference between the two temperatures indicates relative humidity. The relative humidity can be calculated from these two values by using either a psychrometric chart or a slide rule that has the necessary scales.

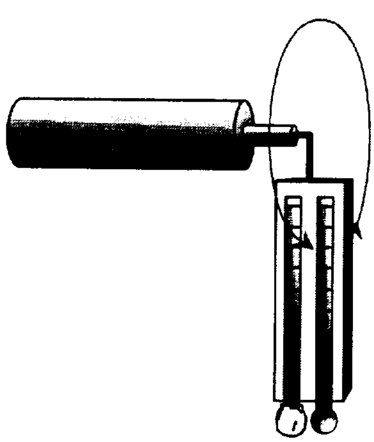


Figure 9-3. Sling Psychrometer

Notes

Binoculars

Binoculars are helpful for identifying stacks, searching the area for emissions, and helping to characterize the behavior and composition of the plume. Method 9 neither prohibits nor endorses the use of binoculars for opacity observations, but if binoculars are used they should have a magnification of at least 10 x 50; color-corrected, coated lenses; and a rectilinear field of view. Color correction can be checked by viewing a black and white pattern, such as a Ringelmann card, at a distance greater than 50 feet. No color rings or bands should be evident; the observer should see only black and white. The rectilinear field of view can be tested by viewing a brick wall at a distance greater than 50 feet. There should be no distortion of the brick pattern as the field of view is changed.

Camera And Accessories

A camera should be used to document the emissions before, during, and after the actual opacity determination. A 35-mm camera with through-the-lens light metering is recommended. Useful accessories include a macro lens, or a 250- to 350-mm telephoto lens, and a 6-diopter close-up lens (for photographing the logbook and evidence of particulate matter deposition). A photo logbook is necessary for proper documentation, and the observer should use fresh, color- negative film (ASA 100 is recommended). It is important to save the last two or three exposures on each roll to photograph the logbook.

Video

Most video equipment on the market is unsuitable for documenting opacity because of the poor resolution and tonal registration of the recording system. When a duplicate is made, the situation is even worse. Avoid VHS and regular 8mm, and if a plume must be videotaped, use one of the following formats:

- ¾ inch or greater
- Super VHS
- High-resolution 8-mm

One advantage of video is the automatic date and time function in most modern cameras that can support the testimony concerning changes in opacity. Another advantage of using video is the ability to document intermittent plumes from cyclic processes.

Notes

Computers And Software

Several MS DOS programs are useful, although not necessary, for an observer preparing reports on VE observations. Particularly helpful software includes:

- Spreadsheets
- U.S. Naval Observatory Industrial Combustion Emissions (ICE) Model
- Instack
- Opacicalc

Spreadsheets can be used for data analysis, graphing, and statistical calculations. The ICE program is used to determine the actual position of the sun at the time of the observation. Instack can be used to calculate mass/opacity relationships. Opacicalc is a commercial program that calculates:

- Rolling averages
- Time aggregation
- Slant-angle effects
- Duct-size differences

Review Questions

1. Why should an observer use high-quality reproductions of the VEO form?
2. What kind of maps are the best for opacity work?
3. What does a rangefinder do?
4. What does a clinometric device do?
5. What does an anemometer do?
6. How are the two thermometers on a sling psychrometer different?

   What do their two temperatures indicate?
7. If an observer is going to use binoculars, what two qualities should he or she look for in the binoculars?
8. Why is most of the video equipment on the market today unsuitable for opacity documentation?

Lesson 10

Field Training And Certification

Field Training And Certification

The field training and certification program is presented after the completion of the VE enforcement procedures classroom session. The field training and certification program is held outdoors using a smoke generator to present black or white smoke plumes and a measuring device that determines opacities from 0 to 100 percent.

Notes

Because this session is conducted outdoors, it is important to wear appropriate clothing. The student should bring the following items to the field session:

- Two medium, black ballpoint pens
- Clipboard
- Two rubber bands

Optional items include:

- A folding chair
- Beverage or snack
- Golf umbrella
- Sunscreen
- Hat

The field certification process has five elements:

- Demonstration of standards
- Practice plumes
- Testing for black and white
- Grading
- Retesting, if necessary

Standards And Practice Plumes

First, the generator operator demonstrates the standard plume values of 25, 50, and 75 percent. This demonstration helps orient the observer to the scale used in the testing program. Next, each observer is issued a practice form. This form is used be-

Notes

fore actual certification runs. Four practice plumes are generated, and the trainees estimate the opacity of each plume, basing the estimate on the given standards. The opacity estimate should be expressed in 5-percent increments. The trainer then calls out the correct answers to the four practice plumes. The trainees write down the correct answers beside the estimates and compare the answers. Only after a significant number of trainees are ready will actual certification testing begin.

Testing Requirements

To receive certification as a qualified observer, a candidate must 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 an average error not to exceed 7.5-percent opacity in each category (black and white).

Testing Form

After the practice session, a two-part form is handed out. An example of this form is given at the end of this lesson. Trainees fill in this form as follows:

1. Last name, first name, middle initial
2. Affiliation (employer)
3. Run number (announced by trainer)
4. Course location (city)
5. Date
6. Trainees indicate whether or not they are wearing sunglasses and, if so, the type (Polaroid, Photogray, etc.)
7. Description of cloud conditions under the "sky" heading
8. Wind speed and direction (announced by trainer)
9. Estimated distance to the stack

10. The affirmation is signed when the form is handed in.

Notes

11. The trainer announces whether the smoke will be black or white, and the appropriate circle must be marked on the form.

When all these steps have been completed, trainees are ready to take the test. The test consists of a set of 25 black plumes and a set of 25 white plumes. The plumes are generated at random levels of opacity within each test set. The standards are shown again before the test.

Field Testing For Black And White Plumes

Trainers will announce when the plumes should be read and when the papers should be marked. The following procedure is used during the test:

Note: The following presentation of proper field test protocol is given in the second person voice for clarity; the statements are addressed to *you* as trainee.

Before reading the plume, do not observe the stack but, instead, look at the ground or at your paper. The generator operator will announce:

"Reading Number 1"

Look up and make your determination of the opacity. Approximately 1 to 3 seconds will be allowed. The generator operator will then announce:

"Mark"

At the word "mark," immediately look away from the plume and mark your paper. Simply circle the answer that best matches the observation. Do not look back at the plume until the next reading number is announced.

This process continues for the entire first set. Check your paper for missing observations or for observations made on the wrong line. If you need to change an answer, cross out the one to change and circle the new answer.

Notes

If the wind makes the plume unreadable by blowing it towards or away from you, yell "scratch" loud enough for the generator operator to hear. The operator will then repeat that reading, because the goal is to give the best possible test plumes.

If the generator operator interrupts the reading with the word "scratch," do not mark the paper. The plume will be repeated at the same opacity value.

The process will then be repeated for the set of plumes of the other color.

Grading

At the conclusion of the test, the white copies of the certification test form will be collected. After they are all collected, the actual values from the run will be announced. Mark the yellow copy with a slash on each value that the operator announces.

After all 50 values are announced, compare your answers to the correct answers. For each value, count the number of spaces (if any) between the two answers. Remember, it does not matter whether your value is higher or lower than the correct answer—just count the number of spaces.

For example, if 20 had been circled and the operator announced, 25, the error would be one space:

(20) ~~25~~ 30 35 40

20 circled and 30 announced would be an error of two.

(20) 25 ~~30~~ 35 40

20 circled and 35 announced would be an error of three.

(20) 25 30 ~~35~~ 40

20 circled and 40 announced would be an error of four.

(20) 25 30 35 ~~40~~

Record the errors on the right-hand side of the paper. When you finish marking errors, you can determine whether you passed. The two criteria are:

- No error of 4 or greater anywhere on the page
- Total error of less than 38 on *each* of the sets

The white plumes and black plumes can each have a total error of up to 37.

Notes

If your paper meets both of the criteria stated above, the yellow sheet should be passed to the graders, who will then grade the original for record.

If you are sure that there are no grading errors, and if you have passed, you have completed the certification process. A certificate will be sent to the address on the registration form within two weeks.

Retesting

If an error of 4 or greater appears anywhere on the page, or if the total error on either of the sets is more than 37, retesting is necessary.

Common Errors

The most common error in making smoke observations is staring at the plume. As demonstrated in earlier lessons, it takes less than 20 seconds of staring to bias your vision and make accurate observations nearly impossible. The second most common error made during certification is reading the plume at the wrong time. To prevent these problems, trainees must listen carefully to the generator operator and follow instructions.

Certification Period

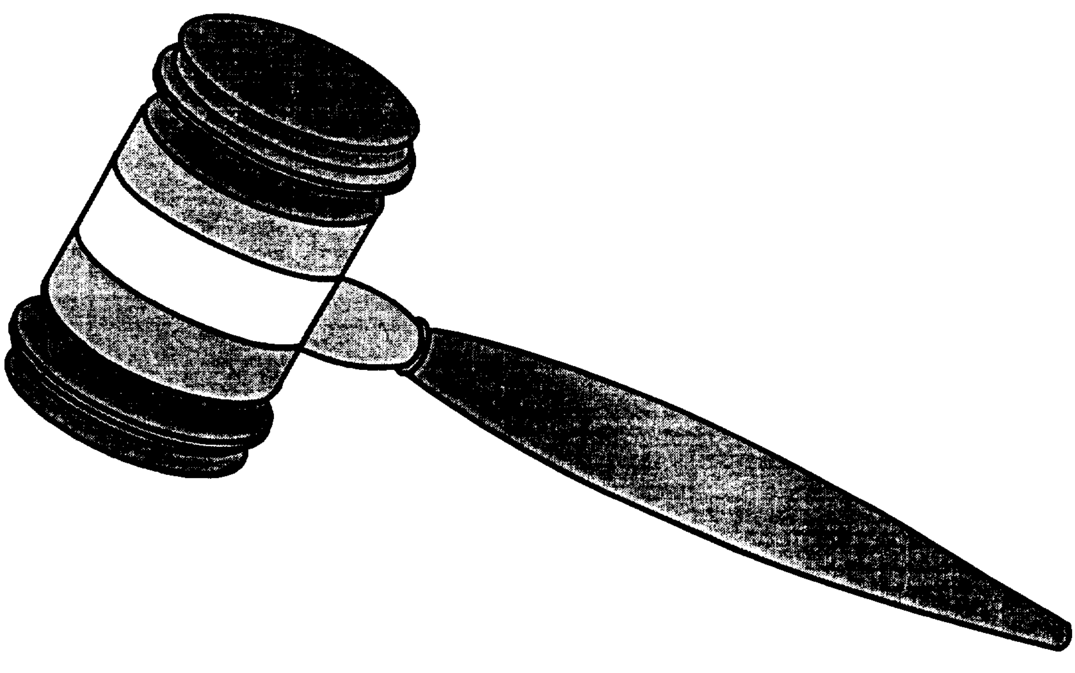
The certification is valid for 6 months, at which time the qualification procedure must be repeated to retain certification.

Review Questions

1. What items should the student definitely bring to the field session?
2. Will practice plumes be shown before the test? If so, what percentages will they be?
3. What should the observer do when the generator operator says, "Reading Number 1"?
4. What should the observer do when the generator operator says, "Mark"?
5. If the plume becomes unreadable, what should the students yell?
6. If a student marked a 30 and the actual value was 50, this would be an error of ________.
7. What are the two criteria for passing a test?
8. What is the most common error in making smoke observations?
9. How long is the certification valid?

Lesson 11

Presentation Of Opacity Data In Court Cases



Presentation Of Opacity Data In Court Cases

Types Of Evidence

Notes

Types of evidence that the visible emissions (VE) observer might be required to present include:

- Visible Emissions Observation (VEO) forms
- Certification records
- Notebooks, field logs, etc.
- Photographs and videotapes

The observer's testimony will serve to substantiate the evidence, showing that it was collected, maintained, and analyzed correctly.

Types Of Witnesses

The following types of witnesses are generally recognized:

- Fact witness
- Trained witness
- Expert witness

Fact Witness

Fact witnesses have direct knowledge of a fact because they have seen it, smelled it, heard it, tasted it, felt it, or done it. They testify in court to the facts. Many observers can be used as fact witnesses. They testify that they saw visible emissions or other opacity evidence. This is the simplest witness situation, because the only qualification is that the witness observed the fact of emissions.

Notes

Trained Witness

Generally, VE observers are introduced as trained witnesses. The observer's training could become an issue. After the observer's credentials are verified, he or she testifies to the measurements made and the procedures followed. It is not necessary for the trained witness to explain why the measurements were made in a specified manner if clear procedures, such as those in Method 9, are available. Such explanations are left to an expert witness.

Expert Witness

An expert witness is anyone who has specialized knowledge of issues and principles in an area pertinent to the case. An expert witness can testify to facts in the case and will often be asked to give an expert opinion as to their meaning. Because an expert witness is expressing an opinion, the court must be satisfied with his or her credentials. Establishing these credentials can be difficult, and if the defense attorney can keep an expert witness from being regarded as an authority, the prosecution's case will be damaged. Once credibility is established, however, the expert witness is often asked to explain the regulations, procedures, and documentation to the court. Expert witnesses are often asked hypothetical ("What if . . . ?") questions.

Depositions

A witness will receive a notice of deposition, which is an order to attend. In the deposition, the defense attorney probes to determine what the witness will say on the stand. Defense attorneys take depositions for several reasons:

- They are looking for flaws in the prosecution's case.
- They want to see what kind of witnesses they are up against.
- They want to see what the witness knows and/or does not know.

Notes

- They want to see whether the witness can defend his or her data and whether the witness has data of which he or she is not aware.

- They want to intimidate the prosecuting team.

In the deposition, the observer will be represented by the prosecuting attorney, who will "defend the deposition" and protect the witness' rights.

Documents

The deposition is often taken *duces tecum*, which means that the witness is required to bring certain documents to the deposition. These documents will be listed in the notice of deposition. The witness should consult with the prosecuting attorney before bringing any documents to the deposition.

Preparation For The Deposition

The witness should review the deposition process with the prosecuting attorney before attending the actual deposition. This briefing is not to set up testimony but to make sure that the witness understands the "rules of the game" at the deposition.

A deposition is not as structured as a court case. Often the attorneys use the deposition as a forum to iron out matters between themselves and to test each other. It could be the first time they meet face to face. The witness should ignore any theatrics that occur between the attorneys.

Attendance

The following persons can attend the deposition:

- Attorney for the plaintiff, along with legal assistants and/or additional attorneys.

- Attorney for the defendant, along with legal assistants and/or additional attorneys.

- The court reporter.

Notes

- Experts for either side (to advise the attorneys and to help prepare questions).

- The witness.

Procedure

At the beginning of the deposition, the witness is sworn in. The deposition becomes a part of the court records, and the witness is subject to the laws of perjury. Witnesses do not have to swear to God; they can affirm.

The attorneys will make a few opening remarks and then turn their attention to the witness. The following, which is a transcript from a deposition, is a typical series of questions:

Q: You understand that the format is that I will ask you questions, you will be answering those questions, you are sworn under oath, and the questions will be transcribed by the court reporter?
If you have any questions regarding the questions that I am posing to you or if it is not clear to you what I am asking, then I would be glad to rephrase it.

Q: I would like to start with some background, educational background. Could you describe for me your education since high school?

These questions set the tone of the deposition and serve to relax the witness. After these preliminaries involving the witness' education and experience, the defense attorney will begin to question the witness. How the questions are answered and how much information is given are extremely important issues.

Rules By Which To Testify

For the first-time witness, it is important to know the following rules for testimony:

- The witness should always tell the truth.

- The witness should listen carefully to the questions.

Notes

- The witness should wait a few seconds after each question before answering. The purpose of the pause is:
    - To give the witness' attorney time to object.
    - To give the witness time to think about the question.
    - To allow the witness to pace the questioning and keep from getting flustered.
- The witness should speak clearly and slowly enough for the court reporter to get an accurate record. The witness should spell names and special terms for the reporter.
- The witness should answer any sensible question that is not a compound question and should ask for clarification if a question does not make sense. The witness should not answer compound questions. Instead, the witness should ask the attorney to rephrase the question as two questions.
- The witness should not argue with the opposing attorney; that is the job of the witness' attorney.
- If the witness' attorney objects to a question, the witness should let things settle down between the attorneys before answering. Then the witness should ask that the question (if it stands) be read by the court reporter before answering it.
- The witness should answer questions with the shortestpossible answers. The witness should use a simple "yes" or "no" if possible. A witness who says, "Let me explain that answer," is getting into trouble.
- The witness should ask to take a break if necessary; the witness is not obligated to endure any physical discomfort.

Remember that the opposing attorney's job is to probe and find flaws in the witness' case so that his or her client can be acquitted. Almost any area is fair game.

Notes

During the deposition, the witness might be asked to review documents or create drawings or other exhibits, and sign them. If in doubt as to what to do, the witness should seek the advice of the prosecuting attorney, who is there to assist the witness.

At some time after the deposition, the witness should receive a printed copy of the text of the deposition. The witness needs to check the text carefully to see that the court reporter transcribed the testimony correctly. The witness should also fill out the revision sheet and return it promptly.

Affidavits

In the filing or counter-filing of a case, the witness might be required to prepare an affidavit. An affidavit is a court document, signed under penalty of perjury, that describes the witness' background and the assertions that he or she will make in court. The witness should follow these steps when preparing an affidavit:

1. Discuss the specific requirements of the judicial jurisdiction in which the affidavit is being filed with the prosecuting attorney. In addition, they should discuss the specific items that the attorney wants covered.
2. Prepare a draft copy of the affidavit for the attorney.
3. Revise the document according to the attorney's needs.
4. Finally, sign, notarize (often not required), and date the final affidavit.

Testimony

In a visible emissions enforcement case, the observer will usually testify about the opacity levels observed at a facility during an inspection or surveillance activity. This testimony will be used to substantiate evidence in the VEO form. The observer will not be asked to remember the actual values observed, because they are on the form. The observer is often asked about methods and procedures used and whether this information is included on the form.

Notes

When the observer is on the witness stand, the same rules apply as those that applied during the deposition. There are three additional guidelines to keep in mind:

- The witness should "dress the part." Usually, a conservative suit is best; people (i.e., the judge and jury members) are confused when a person does not dress appropriately.

- The observer should smile naturally at the judge and jury when taking the stand. He or she should relax; a relaxed witness is more credible than one who is nervous.

- The observer should not become angry with the opposing attorney; that is the job of the observer's attorney. This rule is far more important during the trial than in the deposition. The observer should remember that the defense attorney is evaluating evidence based on his or her perceived trustworthiness of and personal feelings toward the witness.

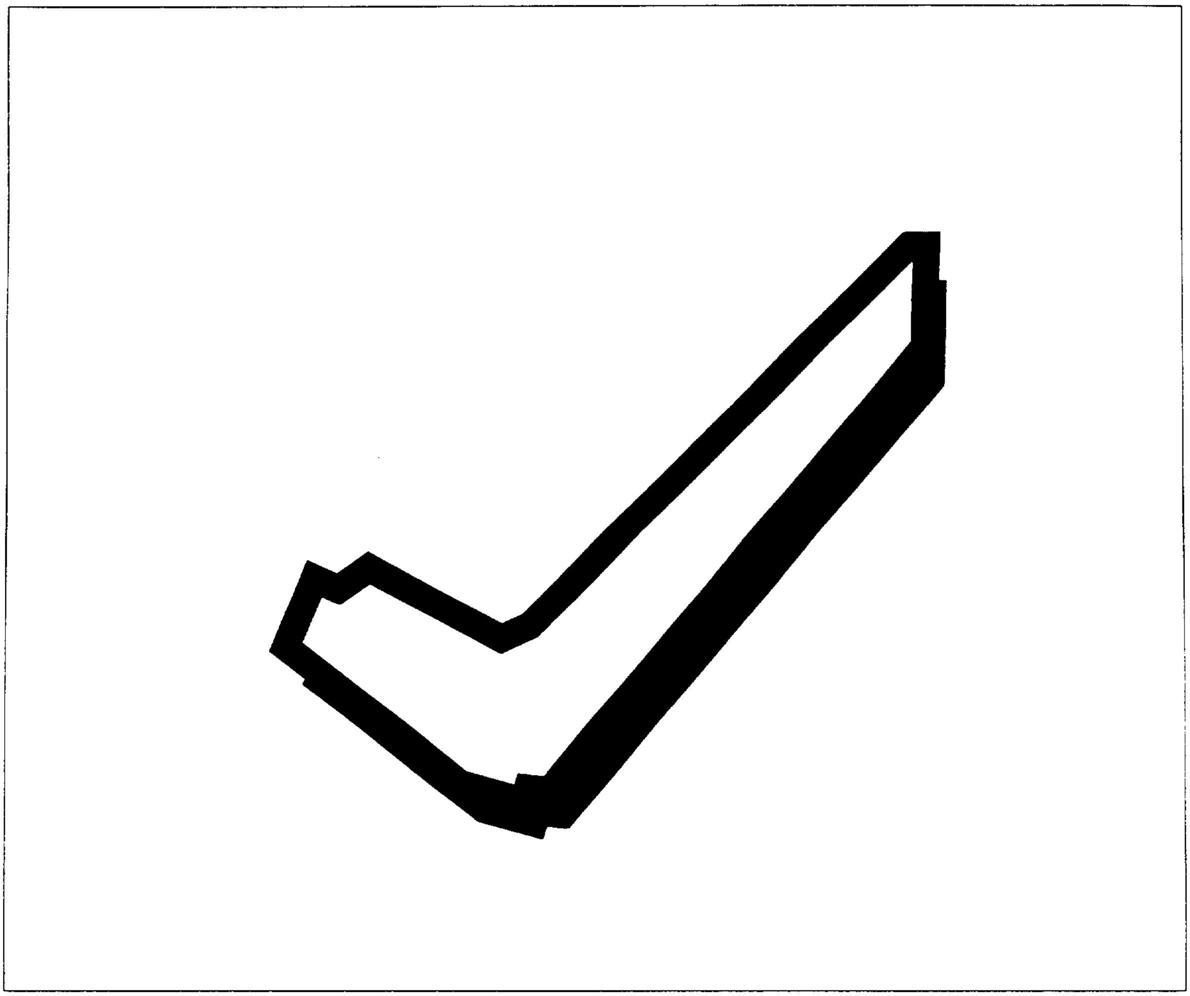
Finally, it is most important that the observer should always tell the truth.

Review Questions

1. List four types of evidence an observer might be required to present in court.
2. What is the difference between a fact witness and a trained witness?
3. What does the opposing attorney try to find out in a deposition?
4. List five people who might attend a deposition.
5. List three or more of the rules by which to testify.
6. A court document signed under penalty of perjury that describes the witness' background and what the witness intends to say in court is an ____________________.
7. Will an observer be asked to remember actual observed values? Will an observer be asked about methods and procedures used?

Lesson 12

Quality Assurance And Auditing



Quality Assurance And Auditing

As a part of the preparation for litigation, the observer should audit the data that he or she plans to introduce and defend in court. The following two sections are designed to assist the observer or supervisor in auditing the VEO form and the certifying VE training program. If a VEO form is worth $25,000 in a civil fine, it is assured that a defense attorney is going to examine the form closely.

Notes

Auditing The VEO Form

The following discussion presents a systematic process for auditing the VEO form. This process uses a standard audit form, which is found at the end of this chapter on pages 12 - 12a, b, and c. Before the audit is initiated, the information on the VEO form that concerns the source and observer should be copied onto the audit form to help keep the records straight.

Certification date?

Check the section on the VEO form for the certification date. Compare this date to the observation date. The certification is valid for a period of six months. Therefore, if the certification date predates the observation date by more than 6 months, the observations are invalid.

Checking for Horizontal Sun Angle

Three areas on the VEO form can be used to indicate horizontal sun angle:

- The source layout sketch. Is the sun location marked on the sun location line?
- The section that deals with the direction from the observer to source section.
- The block showing the observation date and observation period start/stop times.

Notes

A means of information corroboration is built into these three sections if the north directional arrow is given correctly in the source layout sketch. Look at the north arrow's relationship to the source and determine whether there are any discrepancies when compared to emission point "Direction from Observer" line on the VEO form. If the observer was contradictory about direction of source, he or she was probably mistaken about sun location, also.

After using the sketch to determine if the horizontal sun angle is correct, the relationship of the reported direction from the observer and the source and the time of day must be considered to see if it is reasonable. For example, if the time of the observation is noon and the observer's sketch shows the sun over the left shoulder, the observer must be southeast of the source. Sketching the relative positions on polar graph paper is a useful technique to establish that the observations were performed and documented correctly.

Checking for Vertical Sun Angle

The vertical sun angle problem is similar to the horizonal sun angle problem. The line from the height of the sun in the sky to the observer and the line from the observer up to the emission point should be 110 degrees. To audit for vertical sun angle, it is necessary to note the time of day, year, and location of the facility in terms of latitude and longitude. Given this information, solar tables or the US Naval Observatory ICE program may be utilized to get the sun location.

Using the ICE Program for Verification

The US Naval Observatory ICE program can confirm the horizontal and vertical sun angles. This program will quickly calculate both sun angles at any location and time on a MS-DOS computer with a minimum memory of 512K.

The sun observation source (SOS) angle is created by the intersection of the sun observation line and the source observation line. If either vertical or horizontal angles are nearly out of compliance, the SOS angle may be out of compliance. If the SOS angle is less than 110 degrees, the observer will not meet Method 9 criteria for sun angle. The 140 degree sector described in Method 9 is more than a horizontal measurement of the sun rotating about a horizontal plain from an eastern point (south of center if located in the northern hemisphere) through to a western point. The angle also has a vertical element in that the sun moves vertically towards an apex during the day. Therefore, both vertical and horizontal sun angles need to be addressed to determine if Method 9 criteria have been met.

Notes

3. Background viewed along narrow axis of vent? If not, what is the effect: This question refers to a rectangular vent. Plume opacity from such a vent should be read through the narrow axis. The observer should be standing approximately perpendicular to the longer axis of the vent. The rectangular stack should be noted on the VEO form under "describe emission point" and on the sketch.

4. Background viewed along narrow axis of plume? Is it acceptable? The plume should run approximately perpendicular to the observer's line of sight. Information pertaining to this subject can be found in sections of the VEO form that contain information on the source layout, height relative to observer, distance to stack, and point in the plume at which opacity was determined. If the source layout sketch indicated that the plume was observed at a point where it was traveling perpendicular (or nearly so) to the observer's line of sight, the viewing angle is acceptable.

During plume rise? If the sketch indicates that the plume is not traveling perpendicular to the observer's line of sight and if the plume was evaluated during plume rise before the plume travelled horizontally, there needs to be a description or additional supporting sketch documenting that plume travel is not a factor.

Slant angle? If the observation was made at a location where the plume appeared as a vertical column, slant-angle effects should be considered. As described in Lesson 7, the slant angle is based on the distance from the observer to the stack and the height relative to the observer of the point in the plume at which opacity was observed. If the observation angle deviates from looking perpendicular through the plume column by more than 18° degrees, corrections for slant angle are needed.

Slant-angle effect? If slant-angle problems are indicated, the auditor should determine whether those effects have been reported and whether appropriate corrections have been made.

Notes

5. Plume evaluated against contrasting background? If the plume is reported as a dark color, the background of greatest contrast is blue sky, white clouds, or white structures. If the plume is reported as a light color, the background should be a dark color and have a great deal of structural texture.

6. Plume continuous? A plume is continuous if the duration of emissions is greater than 6 minutes. A plume is 'intermittent' if the opacity cycle is less than 6 minutes.

7. Six-minute average complete? (___ consecutive values). Twenty-four consecutive 15-second readings are needed to perform the 6-minute average required by Method 9. Count the opacity readings and make sure that there are 24 consecutive readings between the start and end and that gaps are separated by 24 consecutive readings. Short gaps within the data block may be acceptable if explained on the data forms.

8. Positive observational error taken into account? Observations are 5%, 7.5%, 10% above the standard. This information will go to the weight of the evidence. If a summary judgement is being sought, observations of 7.5 percent or 10 percent above the standard are preferred. Lower margins can be used in actual court cases.

9. Sunglasses used? Type? Used during certification? If sunglasses are worn during a VE observation, a note should be made of it on the VEO form. The observer should be certified with the same glasses, and the certification form should so indicate.

The sunglasses should have gray or green lenses, because other colors will change the response curve of the observer's vision and affect the view of small particles in the plume.

The type of sunglasses frequently will be indicated on the certification form but will not be identified on the VEO form. Photo-gray lenses should be avoided, especially on partly cloudy days. As the sun appears from behind a cloud, a plume may lose its visibility because the lenses darken.

10. Data gaps explained? If a data gap occurs, that gap should be explained fully in the "comments" section. A data gap should be indicated with a "G" or a "-" to document that it is not just an oversight.

11. Source dimensions - roadway length, etc.? Is the information on plant dimensions and source location sufficient to define clearly the point at which the emissions originate?

Notes

12. Distance of observer from emissions source? If the distance from observer is not known exactly but is estimated (or approximated), it should be prefixed with a tilde mark (~). If an exact value is presented with no documentation of landmarks or other known dimensions, the presentation may damage the credibility of the observer if this information is later proven to be slightly in error.

13. Height above source that readings were made? The location of the plume reading is given in the section of the VEO form that specifies "point in the plume at which opacity was determined." The opacity should be read at approximately one stack diameter above the stack exit, if possible. Dilution can occur if the reading is taken too far from the stack exit; this dilution will decrease apparent opacity and result in readings that are biased low. In high wind situations, the plume may be sheared off; consequently opacity is difficult to read. Check "wind speed" and other factors to see whether shearing might have been a problem. Another factor that affects the validity of the location of the readings is the presence of water droplets in the plume. The plume should be read at the point of greatest opacity where water droplets are not present. Check "If water droplet plume" section of the VEO form to ensure that the plume was read after water droplets dissipated.

14. Wind speed available? Check the wind speed estimate for reasonableness. Wind is rarely one speed, and a range should be given (e.g., 4-7 mph). If wind speeds are very high (greater than 20 mph), there is a strong likelihood that the opacity values recorded have a negative bias introduced by intense dilution of the plume.

Wind direction available? Check for contradictions between the wind direction arrow presented in the sketch and the "wind direction" section in the VEO form. Wind direction should always be stated in terms of the direction from which the wind is blowing. The auditor should document any contradictions.

Notes

15. Collaborative readings taken? Did anyone else perform a VE observation at the same time as the observer in question? Other data could serve to substantiate or repudiate the data in the VEO form or record. If other data were taken, the auditor should examine those data for consistency with the data that are being used to establish the case.

16. Description of sky conditions provided? A description of sky conditions is a helpful indication that the observer was aware of surrounding weather conditions. This description also provides information on the amount and type of lighting available (i.e., constant lighting, fluctuating lighting, bright lighting, low lighting). Terms such as overcast, broken, partly cloudy, scattered, clear, rainy, or foggy should be found in the section of the VEO form marked "Sky Conditions."

17. Interferences present? Interferences can include other plumes in the background and foreground. Fugitive emissions also can create interferences. A piece of equipment that moves through the observer's viewing field to block the view totally also can interfere with VE readings. The apparent opacity could increase or decrease. Interferences also include fog or other meteorological activities.

Regardless of the interference, the opacity should not be read during this time and the 15-second interval should be marked with a data gap. The auditor should provide a brief written summary of how the interferences affected the readings.

18. Steam plume present? - Confirmation visual? In the "if water droplet plume" section on the VEO form, "attached" or "detached" should be checked if a water droplet plume exists. If neither applies, the NA notation should be placed into the section as an indicator that the issue was considered. A steam plume is very white and billowy, and visible emissions should be read after the steam dissipates or before the steam forms. If emissions are described using these words in the sections of the VEO form that describe emissions and emission color, the observer may have been observing a water droplet plume without realizing it. Also, the "point in the plume opacity was determined" section is important if steam plumes were present. The auditor should review that section of the VEO form in concert with the evaluation described here.

Notes

Confirmation modeled? It is important that the VE observer understand the process and whether it provides a source of moisture in the plume. The auditor should check "wet bulb" and "dry bulb" temperatures to ensure that they were recorded. These data can be used in conjunction with information on stack gas moisture content and temperature, if known, to derive a gas stream humidity temperature dilution line (GHTD line) on a psychometric chart. This line can be evaluated as to its position to the 100 percent relative humidity curve on the psychometric chart to predict plume moisture condensation. Equations presented in Lesson 7 of this manual can be used as an aid in modeling.

19. Were observations recorded to the nearest 5%? Opacity data are to be reported in 5% increments.

20. Sketch complete? For the sketch to be complete, it must provide the following minimal pieces of information: sun location, observer location, emission point, wind direction relative to the observer, direction of the plume's travel at the point in the plume where observations were made, and a north directional arrow. Other items that can be helpful in establishing viewer prospective in the layout sketch are the inclusion of surrounding landmarks (i.e., buildings, roads, parking lots, rivers, etc).

21. Data calculations verified? The observer's data calculations should be checked to determine if the proper data evaluation techniques were used and to verify that the correct results were obtained for the resulting agency conclusions and/or actions.

22. General comments. The auditor should use this section to state his or her findings with respect to the form evaluation.

Review Questions

1. Find the errors in the VEO form on the following page.

   (Hint: Use the audit form included in this lesson.)

Answers To Review Questions

Lesson 1

1. Nuisance
2. Maximillian Ringelmann
3. The government
4. One night's sleep
5. Northwestern Laundry v. Des Moines
6. 1955
7. The Clean Air Act of 1965
8. EPA
9. Stays on areas that are accessible to the public and does not cross a barrier or go through a gate.
10. SIPs (state implementation plans)
11. A:2, B:3, C:1

Lesson 2

1. 40%
2. Can a shade of black *really* be used to describe white?
3. The obscuring power of a plume
4. 75%
5. a. number and size of particles
   b. shapes of particles
   c. color of particles
   d. index of refraction of particles
6. A:2, B:5, C:1, D:6, E:3, F:4
7. Color contrast; luminous contrast
8. Maximize
9. Blue sky or white, cloudy sky; trees or a dark, textured background
10. Opacity
11. Increases

Lesson 3

1. Black particles absorb visible light, and white, or non-black, particles scatter visible light
2. a, black
3. Through smokestacks
4. b, negative
5. d, all the above (wind direction, a west wind, sun angle)
6. Smoke, soot, fly ash, dust, fumes, mist, gases, vapor
7. False. Dust particles are larger than smoke or fume particles and settle to the ground more quickly
8. NO_2, chlorine
9. Particles or droplets; generated either by homogeneous condensation of gases or as products of chemical reactions
10. Mechanical collectors, wet scrubbers, fabric filters, electrostatic precipitators, afterburners

Lesson 4

1. Speed and direction
2. Determines the height the plume will attain before bending horizontally; dilutes the plume
3. Temperature of plume; temperature profile of atmosphere; wind speed; emission velocity
4. The amount of moisture present in the air compared to the amount of moisture that could be in the air
5. More
6. Longer
7. 1:A, 2:E, 3:B, 4:D, 5:C

Lesson 5

1. b, opacity readings by Method 9
2. Increase
3. True
4. 7.5%
5. Sun position
6. Before steam plume formation or after "steam break"
7. Slant angle, sun position, point of observation in steam plume, and observer position relative to rectangular stack
8. Positive; negative
9. Underestimate
10. Black

11. 140
12. 18,1
13. Mushrooming
14. The observer must demonstrate ability to assign opacity reading in 5% increments to 25 different black and white plumes with an error not to exceed 15% on any one reading and an average error not to exceed 7.5% in each category.
15. 6 months

Lesson 6

1. Qualitative
2. Is not
3. Pollutants not collected by a capture system that seep into the atmosphere
4. Method 22 is more relaxed; the sun need only be out of the observer's eyes. Method 22 specifies a distance (15 feet to 0.25 miles).
5. 100 lux
6. A rest break
7. 9A
8. Not limited to daylight hours, not subjective, slightly more accurate than Method 9 under good conditions
9. More expensive, more staff and training needed, minimum distances required, LIDAR assumes that the density of particles is evenly distributed

Lesson 7

1. Wet-bulb temperature, dry-bulb temperature, relative humidity, absolute humidity, and specific volume
2. WBT is the temperature on a wet-bulb thermometer.
   DBT is the actual ambient temperature.
   RH is the ratio of the amount of water vapor actually in the air compared with the greatest amount there could be at the given temperature.
   AH is the amount of water vapor in a unit of air (expressed as grains/lb or lb/lb).
   SV is the volume occupied by a unit mass of air, expressed as ft^3/lb.
3. Two
4. State point or state condition

5. Will not
6. Long
7. b, an observer 100 feet away from a 75-foot stack
8. Ambient relative humidity = 60, exhaust gas humidity ratio = 0.120, no steam plume will form
9. Greater than
10. 22%
11. 23%
12. Positive bias
13. Complex plume
14. Observe the plume while looking into the sun to find the "steam break." Then with the sun at the observer's back (proper sun position), observe the plume after the steam break in accordance with Method 9.
15. The ammonia and sulphur oxides will react on the surface of the water droplets and form dissolved ammonium sulfate; then the water will evaporate into the atmosphere, leaving ammonium sulfate particles.
16. 0.25 miles
17. Negative, haze
18. Short daylight hours, late-night incineration, opacity monitor downtime

Lesson 8

1. $25,000
2. d, 1345 EDT
3. Comments section
4. Operating mode
5. Describe emission point
6. NW
7. Is sufficient moisture present in the effluent to produce water droplets at in-stack or ambient conditions? If enough moisture is present, will water vapor condense to form droplets before or after leaving the stack?
8. Describe plume background
9. a, b, d, (buildings, other emission outlets, a pond)
10. 140
11. Place a dash (-) in the space and explain in the comment section.
12. Forms interrelation

Lesson 9

1. They could be reproduced many times.
2. U.S. Geological Survey maps
3. Measures distance from emission point
4. Determines vertical viewing angle
5. Measures wind speed
6. One has a wet cotton wick covering the bulb; relative humidity
7. Color-corrected, coated lenses and a rectilinear field of view
8. Poor resolution and tonal registration of the recording system

Lesson 10

1. Two medium-point, black pens; a clipboard
2. Yes; 25 percent, 50 percent, 75 percent
3. Look at the plume and determine its opacity.
4. Immediately look away from the plume and mark the correct opacity
5. "Scratch!"
6. 4
7. No error of 4 or greater on the page and a total error less than 38 for each type of smoke
8. Staring at the plume
9. 6 months

Lesson 11

1. VEO forms; certification records; notebooks, field logs, etc.; photographs and videotapes
2. A fact witness needs no training.
3. What a witness will say and do on the stand
4. Attorney for plaintiff, attorney for defendant, court reporter, experts for either side, the witness
5. Tell the truth, dress the part, relax, don't become angry, answer as briefly as possible, do not answer compound questions
6. Affidavit
7. No; yes

Lesson 12

Mistakes on VEO form:

1. No north arrow drawn on source layout sketch
2. Shouldn't read an attached steam plume one stack-width above opening (reading steam)
3. All reading 100% because he or she was reading smoke
4. Expired certification
5. No explanation for missed reading during minute 25

Additional Readings

These documents contain guidance on visible emission determinations by trained observers (Reference Method 9):

Method 9 Field Observation Procedures

Visible Emissions Field Manual: EPA Methods 9 and 22, EPA 340/1-92-004, 12/93.

Guidelines for Evaluation of Visible Emissions:
Certification, Field Procedures, Legal Aspects and Background Materials, EPA 340/1-75-007, 4/75.

EPA Visible Emission Inspection Procedures, S. 24, 8/75.

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, 2/84.

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

Guide to Effective Inspection Reports for Air Pollution Violations, EPA 340/1-85-019, 9/85.

VE Observer Training and Certification (Method 9)

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

APTI Course 439: Visible Emission Evaluation Instructor/Student Manuals.

Method 9 Policy Memorandum and Other Background Information

Opacity Guidelines File: Policy Memoranda and Background Information (compiled and updated annually for Course # 539 APTI Visible Emissions Instructors Workshop).

Public Comment Survey: Opacity Provisions Under Standards of Performance of New Stationary Sources of Air Pollution, 8/75.

EPA Response to Remand Ordered by U.S. Court of Appeals for the District of Columbia in *Portland Cement Association v. Ruckelshaus*, EPA 450/2-74-023, 11/74.

Method 9 Technical Basis and Performance Evaluation

Optical Properties and Visual Effects of Smokestack Plumes, AP-30, 5/72.

Measurement of the Opacity and Mass Concentration of Particulate Emissions by Transmissometry, EPA 650/2-74-128, 11/74.

Evaluation and Collaborative Study of Method for Visual Determination of Opacity of Emissions from Stationary Sources, EPA 650/4-75-009, 1/75.