PROCEDURES MANUAL FOR AIR POLLUTION CONTROL

SECTION II - EVALUATION OF VISIBLE EMISSIONS MANUAL

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Preface

This document specifies those procedures and protocols required in order for sources of air pollution in Idaho subject to IDAPA 16.01.1000 et seq. (Rules and Regulations for the Control of Air Pollution in Idaho), the Idaho Environmental Protection and Health Act 39-100 et seq. and the applicable permits, orders, and decrees to determine compliance with Idaho air quality regulations. In addition, it details the mechanisms used by the state to determine ambient air quality. For the convenience of the user, this Manual is divided and bound into three sections:

Section I.......................... Source Test Methods

Section II......................... Evaluation of Visible Emissions Manual

Section III........................ Ambient Methods - Quality Assurance Manual

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SECTION II

EVALUATION OF VISIBLE EMISSIONS MANUAL

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SECTION II

EVALUATION OF VISIBLE EMISSIONS MANUAL

1.0 SECTION PREFACE

This manual provides guidance and procedures for making visual opacity readings on air pollution sources subject to IDAPA 16.01.1000 et seq. (Rules and Regulations for the Control of Air Pollution in Idaho), Idaho Code Section 39-101 et seq., or Federal New Source Performance Standards (NSPS, 40 CFR 60) operating in Idaho.

In this manual, the methods for making opacity determinations are in nearly all respects identical to those contained in 40 CFR 60 Appendix A, Method 9. The actual Method 9 text has been used as much as possible with only the method of calculating opacity exceedances being altered so as to make the method usable with and applicable to IDAPA 16.01.1201 and .1203. The forms printed in 40 CFR 60 Appendix A Method 9 have also been replaced with forms more applicable to Idaho regulations. The actual means of conducting observations and certifying observers is intended to be identical with Method 9.

Sources subject to (NSPS) must calculate opacity as detailed in this manual <u>and</u> as specified in 40 CFR 60 Appendix A, Method 9.

The Appendix to this manual is intended to provide guidance and explanation to the actual method. Many of the protocols are of general procedural value. Some would be rarely used, but are included as reference material. Opacity determinations conforming to the actual method are to be considered valid. The Appendix is largely based on, and in many cases copied from, EPA's "Quality Assurance Handbook for Pollution Measurement Systems: Volume III Stationary Source Specific Methods" U.S. EPA-600/4-77-0276, February 1984. Some modifications have been made in order to make the forms and mathematical computations more applicable to Idaho regulations and procedures.

Reference Method

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

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. 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.

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. 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. 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.

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:

(1) For black plumes (133 sets at a smoke generator), 100 percent of the sets were read with a positive error[1] of less than 7.5 percent opacity; 99 percent were read with a positive error of less than 5 percent opacity.

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

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

1. Principle and applicability.

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

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

[1]For a set, positive error = average opacity determined by observers' 25 observations — average opacity determined from transmissometer's 25 recordings.

2. Procedures.

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

2.1 Position. The qualified observer shall stand at a distance sufficient to provide a clear view of the emissions with the sun oriented in the 140° sector to his back. Consistent with maintaining the above requirement, the observer shall, as much as possible, make his observations from a position such that his line of vision is approximately perpendicular to the plume direction, and when observing opacity of emissions from rectangular outlets (e.g. roof monitors, open baghouses, noncircular stacks), approximately perpendicular to the longer axis of the outlet. The observer's line of sight should not include more than one plume at a time when multiple stacks are involved, and in any case the observer should make his observations with his line of sight perpendicular to the longer axis of such a set of multiple stacks (e.g. stub-stacks on baghouses).

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

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

2.3.1. Attached steam plumes. When condensed water vapor is present within the plume as it emerges from the emission outlet, opacity observations shall be made beyond the point in the plume at which

*or a similar form or document containing the required information.

FIGURE 9-1

IDAHO AIR QUALITY BUREAU
IDHW/DIVISION OF ENVIRONMENT

Visible Emission Observation Form

SOURCE NAME

ADDRESS

CITY | STATE | ZIP

PHONE | SOURCE ID NUMBER

PROCESS EQUIPMENT | OPERATING MODE

CONTROL EQUIPMENT | OPERATING MODE

DESCRIBE EMISSION POINT
START | STOP

HEIGHT ABOVE GROUND LEVEL
START | STOP

HEIGHT RELATIVE TO OBSERVER
START | STOP

DISTANCE FROM OBSERVER
START | STOP

DIRECTION FROM OBSERVER
START | STOP

DESCRIBE EMISSIONS
START | STOP

EMISSION COLOR
START | STOP

PLUME TYPE CONTINUOUS ☐ FUGITIVE ☐ INTERMITTENT ☐

WATER DROPLETS PRESENT
NO ☐ YES ☐

IF WATER DROPLET PLUME
ATTACHED ☐ DETACHED ☐

POINT IN THE PLUME AT WHICH OPACITY WAS DETERMINED
START | STOP

DESCRIBE BACKGROUND
START | STOP

BACKGROUND COLOR
START | STOP

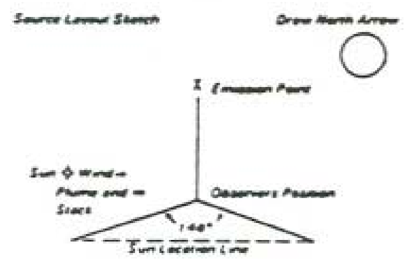
SKY CONDITIONS
START | STOP

WIND SPEED
START | STOP

WIND DIRECTION
START | STOP

AMBIENT TEMP
START | STOP

WET BULB TEMP | RH, percent



COMMENTS

I HAVE RECEIVED A COPY OF THESE OPACITY OBSERVATIONS
SIGNATURE

TITLE | DATE

OBSERVATION DATE | START TIME | STOP TIME

MIN \ SEC	0	15	30	45	MIN \ SEC	0	15	30	45
1					31				
2					32				
3					33				
4					34				
5					35				
6					36				
7					37				
8					38				
9					39				
10					40				
11					41				
12					42				
13					43				
14					44				
15					45				
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21					51				
22					52				
23					53				
24					54				
25					55				
26					56				
27					57				
28					58				
29					59				
30					60				

NUMBER OF READINGS ABOVE ___ % WAS | NUMBER OF MINUTES ABOVE ___ % WAS

AVERAGE OF READINGS ABOVE ___ % WAS | RANGE OF READINGS ABOVE ___ % WAS ___ to ___

OBSERVER'S NAME

OBSERVER'S SIGNATURE | DATE

CERTIFIED BY | DATE

VERIFIED BY | DATE

HWE 0072

condensed water vapor is no longer visible. The observer shall record the approximate distance from the emission outlet to the point in the plume at which the observations are made.

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

2.4 *Recording observations.* Opacity observations shall be recorded to the nearest 5 percent at 15-second intervals on an observational record

2.5 A minimum of 30 observations shall be recorded. Each momentary observation recorded shall be deemed to represent the average opacity of emissions for a 15-second period.

2.6 Data Reduction. Opacity shall be determined by counting the number of readings in excess of the percent opacity limitation (usually 20%), dividing this number by four (each reading is deemed to represent 15 seconds) to find the number of minutes in excess of the percent opacity limitation. The number of minutes in excess of the percent opacity limitations is compared to IDAPA 16.01.1201 and .1203 in order to determine if a violation has taken place.

3. Qualifications and testing.

3.1 Certification requirements. To receive certification as a qualified observer, a candidate must be tested and demonstrate the ability to assign opacity readings in 5 percent increments to 25 different black plumes and 25 different white plumes, with an error not to exceed 15 percent opacity on any one reading and 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.

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

3.2 Certification procedure.

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

3.3 Smoke generator specifications.

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

Table 9-1. *Smoke Meter Design and Performance Specifications*

Parameter:	*Specification*
a. Light source	*Incandescent lamp operated at nominal rated voltage.*
b. Spectral response of photocell.	*Photopic (daylight spectral response of the human eye—reference 4.3).*
c. Angle of view	*15° maximum total angle.*
d. Angle of projection	*15° maximum total angle.*
e. Calibration error	*±3% opacity, maximum*
f. Zero and span drift.	*±1% opacity, 30 minutes.*
g. Response time	*≤5 seconds.*

3.3.1 Calibration. The smoke meter is calibrated after allowing a minimum of 30 minutes warmup by alternately producing simulated opacity of 0 percent and 100 percent. When stable response at 0 percent or 100 percent is noted, the smoke meter is adjusted to produce an output of 0 percent or 100 percent, as appropriate. This calibration shall be repeated until stable 0 percent and 100 percent readings are produced without adjustment. Simulated 0 percent and 100 percent opacity values may be produced by alternately switching the power to the light source on and off while the smoke generator is not producing smoke.

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

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

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

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

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

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

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

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

4. References.

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

4.2 Weisburd, Melvin L. Field Operations and Enforcement Manual for Air, U.S. Environmental Protection Agency, Research Triangle Park, N.C., APTD-1100, August 1972, pp. 4.1-4.36.

4.3 Condon, E.U., and Odishaw, H., Handbook of Physics, McGraw-Hill Co., N.Y., N.Y., 1958, Table 3.1, p. 6-52.

1.0 Certification and Training of Observers

The purpose of this section is to summarize the content of the QA manual for VE training programs.[1] Since the observer must be properly certified or a qualified VE reader in order to have his/her opacity reading accepted, it is important that he/she fully understand this phase of his/her training.

1.1 Definition and Brief History of Opacity

The VE evaluation system evolved from the concept developed by Maximillian Ringelmann in the late 1800's, in which a chart with calibrated black grids on a white background was used to measure black smoke emissions from coal-fired boilers. The Ringelmann Chart was adopted by the U.S. Bureau of Mines in the early 1900's and was used extensively in efforts to assess and control emissions. In the early 1950's, the Ringelmann concept was expanded to other colors of smoke by the introduction of the concept of "equivalent opacity."

The Federal government has discontinued the use of Ringelmann numbers in EPA Method 9 procedures for New Source Performance Standards (NSPS). Current procedures are based solely on opacity. Although some State regulations still specify the use of the Ringelmann Chart to evaluate black and gray plumes, the general trend is toward reading all emissions in percent opacity.

In practice, the evaluation of opacity by the human eye is a complex phenomenon and is not completely understood. However, it is well documented that visible emissions can be assessed accurately and with good reproducibility by properly trained/certified observers.

The relationships between light transmittance, plume opacity, Ringlemann number, and optical density are presented in Table 1.1. A literal definition of plume opacity is the degree to which the transmission of light is reduced or the degree to which visibility of a background as viewed through the diameter of a plume is reduced. In terms of physical optics, opacity is dependent upon transmittance (I/I_o) through the plume, where I_o is the incident light flux and I is the light flux leaving the plume along the same light path. Percent opacity is defined as follows:

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

Many factors influence plume opacity readings: particle density, particle refractive index, particle size distribution, particle color, plume background, path length, distance and relative elevation to stack exit, sun angle, and lighting conditions. Particle size is particularly significant; particles decrease light transmission by both scattering and direct absorption. Thus, particles with diameters approximately equal to the wavelength of visible light (0.4 to 0.7 μm) have the greatest scattering effect and cause the highest opacity.

Table 1.1. Comparison of Light, Extinction Terms

Light transmission, %	Optical density units	Plume opacity, %	Ringelmann number
0	N/A[a]	100	5
20	0.70	80	4
40	0.40	60	3
60	0.22	40	2
80	0.10	20	1
100	0.00	0	0

[a]*N/A = not applicable.*

1.2 Training of Observer

Field inspectors and observers are required to maintain their opacity evaluation skills by periodically participating in a rigorous VE certification program. Accordingly, EPA's Stationary Source Compliance Division (SSCD) and Environmental Monitoring Systems Laboratory (EMSL) have provided the QA training document[1] to individuals who conduct VE training and certification programs. This section summarizes the training program.

1.2.1 Frequency of Training Sessions — Certification schools should be scheduled at least twice per year since Method 9 requires a semiannual recertification. It is highly recommended that training be an integral part of the certification program. A spring/fall schedule is preferable because of weather considerations. Certifying previous graduates while the smoke school is in session is more efficient and less costly than scheduling a separate session.

1.2.2 Classroom Training — The training is accomplished most effectively by holding an intensive 1- or 2-day classroom lecture/discussion session. Although this training is not required, it is highly recommended for the following reasons:

1. Increases the VE observer's knowledge and confidence for the day-to-day field practice and application.
2. Reduces training time required to achieve certification.
3. Trains the smoke reader in the proper recording and presentation of data that will withstand the rigors of litigation and strengthens an agency's compliance and enforcement program.
4. Provides a forum for the periodic exchange of technical ideas and information.

Some states require classroom training for initial certification only. It is recommended, however, that observers attend the classroom training at 3-year intervals to review proper field observation techniques and method changes and to participate in the exchange of ideas and new information.

1.2.3 Lecture Material — Example lecture material for a thorough training program is presented in Section 3.1 and Appendix A of Reference 1. A typical six-lecture classroom training program consists of the following:

Lecture 1—Background, principles, and theory of opacity.

Lecture 2—Sources of VE's, presented by someone thoroughly familiar with source conditions, related particle characteristics, and opacity reading procedures and problems.

Lecture 3—Proper procedures for conducting field observations under a variety of conditions.

Lecture 4—Influence and impact of meteorology on plume behavior.

Lecture 5—Legal aspects of VE and opacity measurements.

Lecture 6—Actual observation/testing procedures.

1.2.4 Training Equipment — An integral part of the training program is the design and operation of the smoke generator and its associated transmissometer, as specified in Method 9 (reproduced in Section 3.12.8). Such a program is essential because proper observer certification cannot take place without the proper equipment. Section 4 of Reference 1 presents performance specifications and operating procedures for smoke generators which, if followed under a good QA program, will ensure nationwide uniformity and consistency with Method 9 criteria.

The design and operation of the smoke generator has evolved significantly since the mid-1960's. The basic components of the smoke generator now include:

1. Black and white smoke generating units,
2. Fan and stack,
3. Transmissometer system, and
4. Control panel and strip chart recorder.

Table 1.2 lists the design and performance specifications for the smoke generator. It must generate smoke with an opacity range of 0 to 100 percent and be sufficiently accurate to allow the operator to control and stabilize the opacity of the smoke. It is recommended that the generator also achieve and hold opacities in 5 percent increments at ±2 percent for a minimum of 5 s.

White smoke is produced by dispensing, at regulated rates, No. 2 fuel oil into the propane-heated vaporization chamber. The opacity varies in proportion to the volume of fuel oil vaporized and is regulated by adjusting the flow of fuel oil.

Black smoke is produced by the incomplete combustion of toluene in the double-wall combustion chamber. The toluene flowrate is also controlled by valves and flowmeters.

1.2.5 Equipment Calibration Procedures — Detailed calibration procedures are included in a QA procedures manual for VE training programs.[1] The generator transmissometers must be calibrated every six months or after each repair. The National Bureau of Standards (NBS) traceable standards (optical filters) for linearity response are available from Quality Assurance Division, Environmental Monitoring Systems Laboratory, U.S. EPA, Research Triangle Park, North Carolina 27711. It is strongly recommended that the calibration be performed before and after each certification course to ascertain whether any significant drift or deviation has occurred during the training period. The "zero and span" check must be repeated before and after each test run. If the drift exceeds 1 percent opacity after a typical 30-min test run, the instrument must be corrected to 0 and 100 percent of scale before resuming the testing.

All of the smoke generator performance verification procedures (e.g., repair and maintenance work, spectral response checks, calibration check, and response time checks) should be documented in writing and dated; a bound logbook is highly recommended. These records become part of the permanent files on the VE training program.

1.2.6 Setup, Operating, and Shutdown Procedures — Detailed procedures and a parts list are given in Section 4.4 of Reference 1.

1.2.7 Storage and Maintenance of the Smoke Generator — Proper storage and maintenance procedures are essential for smoke generators to increase their useful operating life and to provide reliability.

1.2.8 Common Problems, Hazards, and Corrective Actions — The generator has hot surfaces that can cause serious burns. It is recommended that attendees be advised to stay away from the generator during training and test runs. It is also recommended that gas and fuel lines be correctly checked for leaks prior to each use of the generator to prevent fire and explosive hazards to the operator and nearby attendees.

Occasional breakdowns or malfunctions of the generator usually occur at the most inopportune times. The problem must be diagnosed and repairs made expeditiously to provide the proper training and maintain the interest of the course attendees. Some common malfunctions are listed in Section 4 of the QA training manual.[1]

Table 1.2. Smoke Generator Design and Performance Specifications

Parameter	*Performance*
Light source	*Incandescent lamp operated at ±5% of nominal rated voltage*
Photocell spectral response	*Photopic (daylight spectral response of the human eye)*
Angle of view	*15° maximum total angle*
Angle of projection	*15° maximum total angle*
Calibration error	*±3% opacity, maximum*
Zero and span drift	*±1% opacity, 30 min*
Response time	*5 s, maximum*

1.3 Certification of Observer

This section summarizes the certification part of the training program. The first part of the certification program is to acclimate the smoke readers. The following procedure is recommended. Both black and white plumes are produced at certain levels, and during this production, the opacity values are announced. After some standards exposure, four plumes are presented to the trainee for evaluation. The correct values of the four plumes are announced to provide the trainee with immediate feedback. The majority of the trainees should be ready to take the test after a few sets. Certification runs are made in blocks of 50 readings (25 black smoke and 25 white smoke). The trainees who successfully meet the criteria receive a letter of certification and a copy of their qualification form. The school retains the original of the qualification form for a minimum of three years, to be available for any legal proceedings that might occur. According to Method 9, certification is valid for a period of *only six months*. Neither certification or recertification procedures require the observer to attend the lecture program; however, it is recommended that the observer attend the series during initial certification and thereafter every three years. It is also recommended that all persons unable to pass after 10 qualification runs, be provided additional training before allowing qualification runs to be made.

Test forms vary greatly because of the specific needs and experiences of each agency. Figure 1.1 illustrates one suggested form. The form should be printed on two-copy paper, the original for the official file and the carbon copy for the trainee to grade after each certification run. The test

FIGURE 1.1

PLUME EVALUATION

STUDENT OBSERVATION RECORD

	BLACK	WHITE
NUMBER OF EXACT RDGS.		
NUMBER OF 15% DIV.		
TOTAL % DEVIATION		
NUMBER OF READINGS		
AVERAGE DEVIATION		

NAME ______________

DATE ______________

CERTIFICATION RUN NO. ______________

VALIDATED ______________

BLACK				WHITE			
NO.	OBS.	MET.	DEV.	NO.	OBS	MET	DEV
1				1			
2				2			
3				3			
4				4			
5				5			
6				6			
7				7			
8				8			
9				9			
10				10			
11				11			
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25				25			

form must be filled in completely. Certification requires that *both* of the following criteria be satisfied:

1. No reading may be in error by more than 15 percent opacity.
2. The average [absolute] error must not exceed 7.5 percent for either set of 25 white or 25 black smoke readings. The certification runs may be repeated as often as necessary. However, it is recommended that all persons who have not passed after ten certification runs be given additional training prior to conducting additional certification runs.

The detailed testing and grading procedures required to ensure a valid test are outlined in Section 5 of the QA training manual.[1] The Agency should maintain a bound logbook, arranged by training session, for at least three years, as evidence that the observer has been certified as a qualified VE evaluator by a recognized smoke training and certification group. Each trainee who successfully meets the Method 9 criteria receives a letter of certification and a copy of his/her qualification form. This letter includes the date of expiration.

1.4 Recertification

Method 9 requires an individual to be recertified every six months.

TABLE 1.2

Activity Matrix for Certification and Training of Observers

Activity	Acceptance limits	Frequency and method of measurement	Action if requirements are not met
Classroom training of observer	*Classroom training per Ref. 1 (suggested)*	*Initially and every 3 years*	*Review training procedures per Ref. 1*
Smoke generator	*Should be able to generate smoke with an opacity range of 0 to 100%; hold opacities ±2% for at least 5 s*	*Before each certification test run; use method in Ref. 1*	*Adjust and make repeat check of operation*
Setup, operating, and shutdown procedures	*Adherence to procedures in Ref. 1*	*Each test run*	*Review procedures*
Storage and maintenance	*As above*	*As above*	*As above*
Transmissometer			
Design and performance specifications	*Specifications in Table 1.2*	*Upon receipt, repair, and at 6-mo intervals use method in Ref. 1*	*Adjust and repeat specification check until specifications are met*
Calibration	*±3% opacity maximum*	*Every 6 mo or after repair, before and after each certification course is recommended; use method in Ref. 1*	*Adjust and recalibrate until acceptance limits are met*
Zero and span	*Opacity drift <1% after a typical 30-min test run*	*As above*	*Instruments must be corrected to 0 and 100% before testing is resumed*
Certification of observer	*No reading must be in error by more than 15% and average absolute error must not exceed 7.5% for either white or black smoke readings*	*Take smoke reading test until a successful test has been completed*	*Retake test until successful completion*
Recertification	*As above*	*Every 6 mo take a smoke reading test until a successful test has been completed*	*As above*
In-the-field training	*No reading in error by more than 20% difference and average absolute error should not exceed 10% difference during the field observation*	*Checks are made on the first two field observations subsequent to the initial certification; comparison is made between new certified observer and an experienced observer*	*Continue comparisons until acceptance limits are met during two field observations*

2.0 (RESERVED)

3.0 Preobservation Operations

The following procedures are not required by Method 9 but are recommended in order to provide more consistent data collection and better data documentation and verification of representative plume viewing conditions. Not all procedures are needed for every observation.

Before making on-site VE determinations, the observer should gather the necessary facility data, provide prior notifications when applicable, establish an observation protocol, and check for availability of supplies and properly maintained equipment. Table 3.1 at the end of this section summarizes the quality assurance activities for preobservation operations.

3.1 Gather Facility Information

The observer should be thoroughly familiar with the source facility, operation, emissions, and applicable regulations. In preparation for the on-site visit, the observer should review the Agency's information (in the official source file) on the source in question. The observer should:

1. Determine the pertinent people to be contacted.
2. Become familiar with the processes and operations at the facility and identify those facilities to be observed.
3. Review the permit conditions, requirements, and recent applications.
4. Determine applicable emission regulations.
5. Identify all operating air pollution control equipment, emission points, and types and quantities of emissions.
6. Review history of previous inspections, source test results, and complaints.
7. Check the file to become familiar with (or review) plant layout and possible observation sites.
8. Determine normal production and operation rates.
9. Identify unique problems and conditions that may be encountered (e.g., steam plume).
10. Discuss with attorney if case development is expected.
11. Obtain a copy of the facility map with labeled emission points, profile drawings, and photographs, if available. A facility map is very helpful during inspection and should be a required item for every Agency source file. The map makes it easier for the observer to identify point sources and activities, and it may be used to mark any emission points that have been added or modified.
12. If an operating permit exists, obtain a copy because it may contain the VE limits for each point source and any special operating requirements.
13. Determine the status of the source with respect to any variance or exemption from the Agency's rules and regulations. Observation may not be required if the source has a variance or is exempt from the regulations.
14. Review plant terminology.
15. Use references such as facility maps and previous inspection reports to determine if the viewing position is restricted because of buildings or natural barriers. If the viewing position requires observations to be taken at a particular time of day (morning or evening) because of sun angle, consider this when planning the inspection.
16. Determine the possibility of water vapor in the plume condensing (see Section 3.12.6). This determination may prevent a wasted trip to the facility on days when a persistent water droplet plume is anticipated because of adverse ambient conditions.

Note: If the observer is not familiar with the type of facility or operation, he/she should consult available reference material and inspection manuals on the source category.

3.2 Prior Notification

The usual procedure is to make the VE determination without prior notification unless the plant must be entered first to obtain a good view of the emission point of interest. However, this procedure is not always possible, especially in remote locations, when operations are intermittent, or when specific personnel must be present or contacted. Determining VE for compliance with State Implementation Plan (SIP) or NSPS opacity regulations requires on-site observations during conditions of typical or normal maximum operations. If the facility is notified of the time of this evaluation, some operating conditions may be altered. If this situation appears likely, it is EPA's policy not to give prior notification. EPA is obligated to notify State/local agencies of inspections and generally prefers to invite the applicable agency to participate. The observer should notify the affected facility and control agencies as soon as practical following any official opacity readings.

3.3 Establish Observation Protocol

Based on information collected under Section 3.1 and any prior experience with the source, an observation protocol should be established. First, the observer should determine whether one, two, or more observers will be required. For example, two observers may be required to simultaneously make the VE determination and gather other on-site data (e.g., take photographs, draw a new modified facility map if one is not available from the plant or gather other needed plant information). In certain situations where the VE observations must be correlated to process operation, the second person will closely monitor the process activity and record the exact time of the operating modes of interest. Only one observer will make the VE determination unless an observer audit is being conducted. In this case, the designated observer is the one being audited.

The applicability of Method 9 (and hence the method of observation) should be determined. If Method 9 is not applicable, see Section 3.12.4, Special Problems.

A written checklist regarding an expected walk-through of the plant including questions to ask plant officials may be helpful.

3.4 Perform Equipment Checks for On-Site Use

Be sure that the necessary equipment and supplies are available for making the VE determination and documenting the results. All equipment should be visually checked for damage and satisfactory operation before each VE determination field trip.

Table 3.1. Activity Matrix for Preobservation Operations

Activity	*Acceptance limits*	*Frequency and method of measurement*	*Action if requirements are not met*
Gather facility information	*Obtain necessary facility data, Subsec 3.1*	*Check for completeness of data*	*Obtain missing data before on-site visit, if possible*
Make prior notification	*Make VE determination without prior notification except as stated in Subsec 3.2*	*Check the protocol for notification before each on-site visit and revise the protocol as necessary*	*Make required notifications*
Establish protocol	*Prepare observation protocol, Subsec 3.3*	*Check before on-site visit*	*Complete or prepare protocol as required*
Perform equipment check	*All equipment/ supplies available and in satisfactory working order*	*Same as above*	*Replace or adjust equipment*

4.0 On-Site Field Observations

This section describes field observation procedures, including perimeter survey, plant entry, VE determination, and special observation problems. The latter subsection supplements the subsection on VE determination by providing some information on how to take VE readings when unfavorable field conditions prevent the use of the procedure described in Subsection 4.3 (e.g., when the emissions are intermittent or the observer position is restricted). The QA activities are summarized in Table 4.2 at the end of this section.

4.1 Perimeter Survey

Before and after the VE determination, it is strongly recommended that the observer make a perimeter survey of the area surrounding (1) the point of observation and (2) the emission point on which the determination is being made. Such a survey also may be made during the VE determination, if warranted.

A perimeter survey can be useful in determining the presence of other factors that could affect the opacity readings. For example, the representativeness of the VE readings for a given emission point could be questioned unless data is available to show that the observer excluded emissions related to material stockpiling, open burning, and ambient condensed water vapor in adjoining areas of the plant. It is vital that the observer be as aware as much as possible of extenuating conditions. The perimeter survey is made to document these conditions. Common sense should be used in determining the need and extent of the survey; in some cases (e.g., a single 350-foot stack) a perimeter survey is not vital.

Perimeter surveys can be made from either outside or inside the plant property, or both. This decision would depend on whether the VE observations are made from inside or outside of the plant, whether the observer actually gains entry to the plant premises, and whether the plant is sufficiently visible from outside the premises to make a reasonable survey. It is suggested that during the survey the observer should note such factors as:

1. Other stacks and emission points whose visible emissions might interfere with opacity readings.
2. Fugitive emissions that result from product or waste storage piles and material handling and may interfere with observations.
3. Fugitive emissions that result from unpaved road travel and may interfere with observations.
4. Water vapor emissions from sludge or cooling ponds.
5. Open burning.
6. Any unusual activities on or around plant premises that could result in nonrepresentative emissions or interfere with opacity readings.

If deemed useful by the observer, photographs may be taken to document extenuating conditions

4.2 Plant Entry

The following discussion presents the recommended plant entry procedures. The VE readings themselves should not be affected by a change in these procedures. However, the usefulness of the readings in showing a possible violation of the applicable standards may be compromised by not following agency procedures for entering plants. Depending on the location of emission points at the plant and the availability of observation points in the area surrounding a facility, the VE observer may not have to gain entry to the plant premises *prior* to making VE observations. It may be preferable to gain access after taking readings to check on plant process control equipment operating conditions or to complete a perimeter survey.

To maintain a good working relationship with plant officials and, most importantly, to comply with the Clean Air Act and avoid any legal conflict with trespass laws or the company's right to privacy and due process of law under the U.S. Constitution, the observer must follow certain procedures in gaining entry to the plant's private premises. In most cases, consent to enter (or the absence of express denial to enter) is granted by the owner or company official. Figure 4.1 lists the pertinent section of the Clean Air Act on facility entry as well as information on confidentiality of process information. It is recommended that the inspector have a copy of this information available in case questions are raised by source representatives.

4.2.1 Entry Point — It is recommended that the plant premises be entered through the main gate or through the entrance designated by the company officials in response to prior notification. The observer's arrival will usually occur during normal working hours unless conditions contributing to excess opacity levels are noted at certain times other than normal working hours. If only a guard is present at the entrance, it is desirable for the observer to present the appropriate credentials and to suggest that the guard's supervisor be contacted for the name of a responsible company official. The observer would then ask to speak with this official, who may be the owner, operator, or agent in charge (including the environmental engineer).

4.2.2 Credentials — After courteously introducing himself/herself to the company official, the observer should briefly describe the purpose of the visit and present the appropriate credentials confirming that he/she is a lawful representative of the agency. Such credentials will naturally differ depending upon the agency represented, but it is recommended that they include at least the observer's photograph, signature, physical description (age, height, weight, color of hair and eyes), and the authority for plant entry. Agencies issue credentials in several forms, including letters, badges, ID cards, or folding wallets.

4.2.3 Purpose of Visit — When first meeting with a company official, the observer needs to be prepared to state succinctly the purpose of the visit, including the reason for the VE determination.

The principal purpose for an observer's visit to a plant will probably fall into one of three categories: (1) a VE determination is being made pursuant to a neutral administrative scheme* to verify compliance with an applicable SIP or NSPS, (2) a VE determination is being made because some evidence of an opacity violation already exists, or (3) an unscheduled VE determination has just been made from an area off the plant property. The statement of purpose should state clearly what has prompted the visit.

At this time, the observer also should provide the company official with a copy of the opacity readings and ask that person to sign an acknowledgment of receipt of any VE readings made previous to entry. In lieu of the above, the agency should provide a copy within a reasonable time.

4.2.4 Visitor's Agreements, Release of Liability (Waivers) — The observer should not sign a visitor's agreement, release of liability (waiver), hold-harmless agreement, or any other agreement that purports to release the company from tort liability.

*Any routine of selecting sites for observation that is not directed toward any company.

4.2.5 (Reserved)

4.2.6 Entry Refusal — In the event that an observer is refused entry by a plant official or that consent is withdrawn before the agreed-upon activities have been completed, the following procedural steps should be followed:

1. *Tactfully* discuss the reason(s) for denial with the plant official; this is to insure that the denial has not been based on some sort of misunderstanding. Discussion might lead to resolution of the problem and the observer may be given consent to enter the premises. If resolution is beyond his/her authority, the observer should withdraw from the premises and contact his/her supervisor to decide on a subsequent course of action.
2. Note the facility name and exact address, the name and title of the plant officials approached, the authority of the person issuing the denial, the date and time of denial, the reason for denial, the appearance of the facility, and any reasonable suspicions as to why entry was refused.
3. The observer should be very careful to avoid any situations that might be construed as threatening or inflammatory. Under no circumstances should the potential penalties of entry denial be cited.

All evidence obtained prior to the withdrawal of consent is considered admissible in court.

When denied access only to certain parts of the plant, the observer should make note of the area(s) and the official's reason for denial. After completing normal activities to the extent possible and leaving the facility, the observer should contact his/her supervisor for further instructions.

4.2.7 (Reserved)

4.2.8 Determination of Safety Requirements — The violation of a safety rule does not invalidate VE readings; however, the observer should always anticipate safety requirements by arriving at the plant with a hardhat, steel-toed safety shoes, safety glasses with side shields, and ear protectors. Safety equipment also should include any other equipment that is specified in the agency files and noted on the entry checklist form.

Some companies require unusual safety equipment, such as specific respirators for a particular kind of toxic gas. In many cases, these companies will provide the observer with the necessary equipment. In any event, the observer must be aware of and adhere to *all* safety requirements before entering the plant. Information on plant alarms and availability of first aid and medical help may be needed.

4.2.9 Observer Behavior — Observers must perform their duties in a professional, businesslike, and responsible manner. They should always consider the public relations liaison part of their role by seeking to develop or improve a good working relationship with plant officials through use of diplomacy, tact, and if necessary, gentle persuasion in all dealings with plant personnel.

Specifically, observers should *be objective and impartial* in conducting observations and interviews with plant officials. All information acquired during a plant visit is intended for official use only and should never be used for private gain. Observers must be careful never to speak of any person, agency, or facility in any manner that could be construed as derogatory. Lastly, observers should use discretion when asked to give a professional opinion on specific products or projects and should *never* make judgments or draw conclusions concerning a company's compliance with applicable regulations. Upon giving the data to the plant the observer can tell the source these are the data that were obtained and no judgment as to compliance can be made until all the data and the regulations are closely reviewed.

4.3 Visible Emission Determination

This subsection describes the preferred approach to VE determination. Because practical considerations do not always permit the observer to follow this procedure, however, special observation problems are discussed in Subsection 4.4.

4.3.1 Opacity Readings — The observer must be certified in accordance with Section 3.12.1, Subsection 1.3, and should use the following procedure for visually determining the opacity of emissions.

Observer Position

1. The observer must stand at a distance that provides a clear view of the emissions with the sun oriented in the 140° sector to his/her back. If the observer faces the emission/viewing point and places the point of a pencil on the sun location line such that the shadow crosses the observers position, the sun location (pencil) must be within the 140° sector of the line. During overcast weather conditions, the position of the sun is less important.
2. Consistent with number 1 above, when possible, the observer should, make observations from a position in which the line of vision is approximately perpendicular to the plume direction; when observing opacity of emissions from rectangular outlets (e.g., roof monitors, open baghouses, and noncircular stacks), the observer's position should be approximately perpendicular to the longer axis of the outlet.
3. When multiple stacks are involved, the observer's line of sight should not include more than one plume at a time, and in any case, during observations, the observer's line of sight should be perpendicular to the longer axis of a set of multiple stacks (e.g., stub stacks on baghouses).
4. The observer must stand at a distance that provides total perspective and a good view.
5. In order to comply with the sun angle requirements (see item 1) it is recommended that the observer should try to avoid the noon hours (11:00 a.m. to 1:00 p.m.) in the summertime (when the sun is almost overhead). This is more critical in the southern continental United States. The preferred reading distance is between 3 stack heights and 1/4 mile from the base of the stack.
6. The reading location should be safe for the observer.

Opacity Observations

1. Opacity observations must be made at the point of greatest opacity in that portion of the plume where condensed water vapor is not present.
2. The observer must not look continuously at the plume (this causes eye fatigue), but should observe the plume momentarily at 15-s intervals. A 15-s beeper is recommended to aid in performing the VE readings.
3. When steam plumes are attached, i.e., when condensed water vapor is present within the plume as it emerges from the emission outlet, the opacity must be evaluated beyond the point in the plume at which condensed water vapor is no longer visible. The observer must record the approximate distance from the emission outlet to the point in the plume at which the observations are made.
4. When steam plumes are detached, i.e., 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 near the outlet, prior to the condensation of water vapor and the formation of the steam plume, unless the opacity is higher after dissipation.
5. Readings must be made to the nearest 5 percent opacity. A minimum of 24 observations must be recorded. It is advisable to read the plume for a reasonable period in excess of the time stipulated in the regulations (i.e., at least 10 readings more than the minimum required).
6. A clearly visible background of contrasting color is best for greatest reading accuracy. However, the probability of positive error (higher values) is greater under these conditions. Generally, the apparent plume opacity diminishes and tends to assume a negative bias as the background becomes less contrasting.
7. It is recommended the observer wear the same corrective lenses that were worn for certification. If sunglasses were not worn during certification, the observer should remove them and allow time for the eyes to adjust to the daylight before making VE determinations. It is recommended that the observer not wear photo compensating sunglasses.
8. The best viewing spot is usually within one stack diameter above the stack exit, where the plume is densest and the plume width is approximately equal to the stack's diameter.

4.3.2 Field Data: The "Visible Emission Observation Form" — The 1977 revision of EPA Method 9 specifies the recording of certain information in the field documentation of a visible emission observation. The required information includes the name of the plant, the emission location, the type of facility, the observer's name and affiliation, the date, the time, the estimated distance to the emission location, the approximate wind direction, the estimated windspeed, a description of the sky conditions (presence and color of clouds), and the plume background.

Experience gained from past enforcement litigation involving opacity readings as primary evidence of emission standards violations has demonstrated a need for additional documentation when making visual determinations of plume opacity. The Visible Emission Observation Form presented in Figure 4.2 is recommended. This form was developed after reviewing the opacity forms used in EPA Regional Offices and State and local air quality control agencies. The form includes not only the data required by Method 9, but also the information necessary for maximum legal acceptability. Valid data can be collected on any form; however, the recommended form may enhance observer efficiency and data documentation. A detailed description of the use of the recommended form is given in the following paragraphs.

The Visible Emission Observation Form can be functionally divided into 11 major sections, as shown in Figure 4.3. Each section documents one or two aspects of the opacity determination. The form endeavors to cover all the required and recommended areas of documentation in a typical opacity observation. A "comments" section is included for notation of any relevant information that is not listed on the form.

FIGURE 4.2

IDAHO AIR QUALITY BUREAU
IDHW/DIVISION OF ENVIRONMENT

Visible Emission Observation Form

SOURCE NAME

ADDRESS

CITY | STATE | ZIP

PHONE | SOURCE ID NUMBER

PROCESS EQUIPMENT | OPERATING MODE

CONTROL EQUIPMENT | OPERATING MODE

DESCRIBE EMISSION POINT
START STOP

HEIGHT ABOVE GROUND LEVEL
START STOP

HEIGHT RELATIVE TO OBSERVER
START STOP

DISTANCE FROM OBSERVER
START STOP

DIRECTION FROM OBSERVER
START STOP

DESCRIBE EMISSIONS
START STOP

EMISSION COLOR
START STOP

PLUME TYPE CONTINUOUS ☐
FUGITIVE ☐ INTERMITTENT ☐

WATER DROPLETS PRESENT
NO ☐ YES ☐

IF WATER DROPLET PLUME
ATTACHED ☐ DETACHED ☐

POINT IN THE PLUME AT WHICH OPACITY WAS DETERMINED
START STOP

DESCRIBE BACKGROUND
START STOP

BACKGROUND COLOR
START STOP

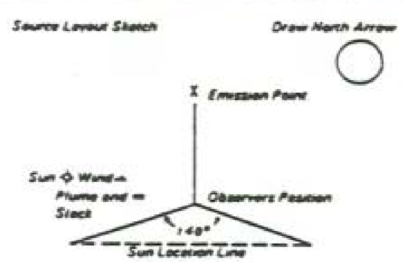
SKY CONDITIONS
START STOP

WIND SPEED
START STOP

WIND DIRECTION
START STOP

AMBIENT TEMP
START STOP

WET BULB TEMP | RH, percent



COMMENTS

I HAVE RECEIVED A COPY OF THESE OPACITY OBSERVATIONS
SIGNATURE

TITLE | DATE

OBSERVATION DATE | START TIME | STOP TIME

MIN \ SEC	0	15	30	45	MIN \ SEC	0	15	30	45
1					31				
2					32				
3					33				
4					34				
5					35				
6					36				
7					37				
8					38				
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26					56				
27					57				
28					58				
29					59				
30					60				

NUMBER OF READINGS ABOVE % was | NUMBER OF MINUTES ABOVE % was

AVERAGE OF READINGS ABOVE % was | RANGE OF READINGS ABOVE % was to

OBSERVER'S NAME

OBSERVER'S SIGNATURE | DATE

CERTIFIED BY | DATE

VERIFIED BY | DATE

HWE 0072

EXPLANATION OF
ELEMENTS OF OBSERVATION FORM
(FIGURE 4.2)

*Source Name - company name and division, if necessary

*Address - street (not mailing) address or physical location of facility

Source ID Number - number from CDS, if necessary

*Process Equipment, Operating Mode - brief description of process equipment, operating rate, % utilization or other relevant information

*Control Equipment, Operating Mode - types of control equipment

*Describe Emission Point - stack or emission point location, diameter, color, for identification purposes

*Height Above Ground Level - stack or emission point height

*Height Relative to Observer -vertical position of observation point to stack top

*Distance from Observer - distance to stack

*Direction from Observer - accurate to eight points of the compass

*Describe Emissions - include plume behavior and other physical characteristics (e.g., looping, condensing, secondary particle formation, etc.)

*Emission Color - gray, black, white, tan, etc.

Plume Type -
Continuous - opacity cycle greater than 6 minutes
Fugitive - no stack outlet
Intermittent - opacity cycle less than 6 minutes

**Water Droplets Present - is it a "wet" plume

**If water droplet plume:
Attached - water plume forms prior to exiting stack
Detached - water plume forms after exiting stack

**Point in the Plume at which Opacity was Determined - describe physical location in plume where readings were made (e.g. 4 inches above stack exit or 10 feet after dissipation of water plume

*Describe Background - object plume is read against (sky, bare trees, hillside, etc.)

*Background Color - blue, green leaves, etc.

*Sky Conditions - clear, overcast, broken, etc.

*Windspeed - use Beufort wind scale or annemometer

*Wind Direction - direction wind is <u>from</u>, accurate to eight points of compass.

*Ambient Temperature - in ^{o}F or ^{o}C

**Wet Bulb Temperature - from sling psychrometer

**Relative Humidity - from charts

*Source Layout Sketch - include wind direction, associated stacks, roads, or other landmarks to identify section of source and observer

Draw North Arrow - point line-of-sight in direction of emission, place compass beside circle, and draw in arrow parallel to compass needle

Sun Location Line - point line-of-sight in direction of emission, place pen upright on sun location line, and mark location of sun when pen's shadow crosses the observer's position

**Comments - factual observations, deviations, altercations, and/or problems not addressed elsewhere

Acknowledgement - signature, title, and date of company official receiving copy, if official declines to sign, write in "refused signature - copy left with (name) "

*Observation Date - date observation conducted

*Start time, stop time - beginning and end times of observation period (e.g., 1635 or 4:35 pm)

*Data Set - percent opacity to nearest 5%, enter from left to right starting in left column

Number of Readings Above ___% was ___ - enter the applicable percent opacity limit and the number of readings exceeding that limit.

*Number of Minutes Above ___% was ___ - enter the applicable percent opacity limit and the number of minutes (number of readings above percent opacity limit divided by four) exceeding the opacity value

*Average of Readings Above ___% was ___ - compute and enter the arithmetic mean of all readings in excess of the applicable percent opacity value

Range of Readings Above ___% was ___ to ___ - enter the applicable percent opacity limitation value and the lowest and highest readings exceeding that value

*Observers Name - print first and last name

*Observers Signature - observer signs and date form

*Certified By - name of person conducting certification and date of certification

*Verified By - Name of person checking observation for technical validity (done as part of case review, not in field)

*Required for Method
**Required only when particular factor could affect reading

FIGURE 4.3

IDAHO AIR QUALITY BUREAU
IDHW/DIVISION OF ENVIRONMENT

Visible Emission Observation Form

SOURCE NAME

ADDRESS

CITY — STATE — ZIP

PHONE — SOURCE ID NUMBER

A

PROCESS EQUIPMENT — OPERATING MODE

CONTROL EQUIPMENT — OPERATING MODE

B

DESCRIBE EMISSION POINT
START — STOP

HEIGHT ABOVE GROUND LEVEL — HEIGHT RELATIVE TO OBSERVER
START STOP — START STOP

DISTANCE FROM OBSERVER — DIRECTION FROM OBSERVER
START STOP — START STOP

C

DESCRIBE EMISSIONS
START — STOP

EMISSION COLOR — PLUME TYPE CONTINUOUS ☐
START STOP — FUGITIVE ☐ INTERMITTENT ☐

WATER DROPLETS PRESENT — IF WATER DROPLET PLUME
NO ☐ YES ☐ — ATTACHED ☐ DETACHED ☐

D

POINT IN THE PLUME AT WHICH OPACITY WAS DETERMINED
START — STOP

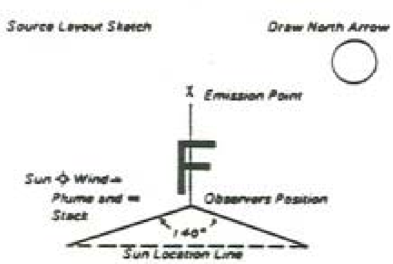
DESCRIBE BACKGROUND
START — STOP

BACKGROUND COLOR — SKY CONDITIONS
START STOP — START STOP

WIND SPEED — WIND DIRECTION
START STOP — START STOP

AMBIENT TEMP — WET BULB TEMP — RH, percent
START STOP

E



COMMENTS

G

I HAVE RECEIVED A COPY OF THESE OPACITY OBSERVATIONS
SIGNATURE
TITLE — DATE

H

OBSERVATION DATE — START TIME — STOP TIME

SEC / MIN	0	15	30	45	SEC / MIN	0	15	30	45
1					31				
2					32				
3					33				
4					34				
5					35				
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28					58				
29					59				
30					60				

I

NUMBER OF READINGS ABOVE — % was
NUMBER OF MINUTES ABOVE — % was

AVERAGE OF READINGS ABOVE — % was
RANGE OF READINGS ABOVE — % was — to

J

OBSERVER'S NAME

OBSERVER'S SIGNATURE — DATE

K

CERTIFIED BY — DATE

VERIFIED BY — DATE

HWE 0072

Each major section of the form is discussed in the following text. A short explanation of each section's purpose, a background explanation of each data element, a description of the type of information being sought, and in some cases, appropriate entries are included. These discussions are keyed to Figure 4.3 by corresponding capital letters, and it is clearly indicated whether information is required or recommended.

A. SOURCE IDENTIFICATION. Provides information that uniquely identifies the source and permits the observer to locate or make contact with the source.

Source name		
Address		
City	*State*	*Zip*
Phone	*Source ID number*	

Source Name (Required) - include the source's complete name. If necessary for complete identification of the facility, the parent company name, division, or subsidiary name should be included.

Address (Required) - Indicate the street address of the source (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 may be listed elsewhere.

City, State, Zip, Phone (Recommended) - Self-explanatory.

Source ID Number (Recommended) This space is provided for the use of agency personnel and should be used to enter the number the agency uses to identify that particular source, such as the State file number, Compliance Data System number, or National Emission Data System number.

B. PROCESS AND CONTROL DEVICE TYPE. Includes a several word descriptor of the process and control device, indication of current process operating capacity or mode, and operational status of control equipment.

Process equipment	*Operating mode*
Control equipment	*Operating mode*

Process Equipment (Required) - Enter a description of the process equipment that emits the plume or emissions to be read. The description should be brief but should include as much information as possible, as indicated in the following examples:

Coal-Fired Boiler
#2 Oil-Fired Boiler
Wood Waste Conical Incinerator
Paint Spray Booth
Primary Crusher
Fiberglass Curing Oven
Reverberatory Smelting Furnace
Basic Oxygen Furnace

Operating Mode (Recommended) - Depending on the type of process equipment, this information may vary from a quantification of the current operating rate to a description of the portion of a batch-type process for which the emission opacity is being read. For example, entries could include "90 percent capacity" for a boiler or "85 percent production rate" for the shakeout area of a grey iron foundry. For a steel making furnace, entries would include the exact part of the process for which readings are being made, such as "charging" or "tapping." In some cases, the observer may have to obtain this information from a plant official.

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

Operating Mode (Recommended) - Indicate the degree to which the control equipment is being utilized at the time of the opacity observations (e.g., 75% capacity, full capacity, shut down, off line) and the operating mode (e.g., automatic). The observer will probably have to obtain this information from a plant official.

C. EMISSION POINT IDENTIFICATION. Contains information uniquely identifying the emission point and its spatial relationship with the observer's position.

Describe emission point *Start* *Stop*	
Height above ground level *Start* *Stop*	*Height relative to observer* *Start* *Stop*
Distance from observer *Start* *Stop*	*Direction from observer* *Start* *Stop*

Describe Emission Point (Required) - Include the identifying physical characteristics of the point of release of emissions from the source. The description must be specific enough so that the emission outlet can be distinguished from all others at the source. In subsequent enforcement proceedings, the observer must be certain of the origin of the emissions that were being read.

Typical descriptions of the emission outlet include the color, geometry of the stack or other outlet, and the location in relation to other recognizable facility landmarks. Any special identification codes the agency or source uses to identify a particular stack or outlet should be noted along with the source code used by the observer. The source of this information should be recorded (e.g., plant layout map or engineering drawing).

Height Above Ground Level (Required) - Indicate the height of the stack or other emission outlet from its foundation base. This information is usually available from agency files, engineering drawings, or computer printouts (such as NEDS printouts). The information also may be obtained by using a combination of a rangefinder and an Abney level or clineometer. The height may also be estimated.

Height Relative to Observer (Required) - Indicate an estimate of the height of the stack outlet (or of any other type of emission outlet) above the position of the observer. This measurement indicates the observer's position in relation to the stack base (i.e., higher or lower than the base) and may later be used in slant angle calculations (see Section 3.12.6 and Subsection 4.4.6) if such calculations become necessary.

Distance From Observer (Required) - Record the distance from the point of observation to the emission outlet. This measurement may be made by using a rangefinder. If necessary, a map also may be used to estimate the distance.

It is important that this measurement be reasonably accurate if the observer is close to the stack (within 3 stack heights) because it is coupled with the outlet height relative to the observer to determine the slant angle at which the observations were made (see Figure 4.4). A precise determination of the slant angle may become important in calculating any positive bias inherent in the opacity readings.

Direction From Observer (Required) - Specify the direction of the emission point from the observer to the closest of the eight points of the compass (e.g., S, SE, NW, NE) or 45°. Use of a compass to make this determination in the following manner is suggested: hold the compass while facing the emission *point*; rotate the compass until the North compass *point* lies directly beneath the needle (which will be pointing towards magnetic North); then the point of the compass closest to the emission outlet will indicate the direction (Figure 4.5). A map (plant layout) also may be used to make this determination.

Describe Emissions (Required) - Include both the physical characteristics of the emissions not recorded elsewhere on the form and the behavior of the resultant plume. The description of the physical characteristics might include terms such as lacy, fluffy, and detached nonwater vapor condensibles.

The terminology illustrated in Figure 4.6 can be used to describe plume behavior. The behavior can be used to determine the atmospheric stability on the day of the opacity observations.

Emission Color (Required) - Note the color of the emissions. The plume color can sometimes be useful in determining the composition of the emissions and will also serve to document the total contrast between the plume and its background as seen by the opacity observer during the observation period.

Plume Type (Recommended) - Check "continuous" if the duration of the emissions being observed is greater than 6 minutes. Check "intermittent" if the opacity cycle is less than 6 minutes. Check "fugitive" if the emissions have no specifically designated outlet.

Water Droplets Present (May be required) - Check "yes" or "no" as appropriate. In some cases, the presence of condensed water vapor in the plume can be easily observed.

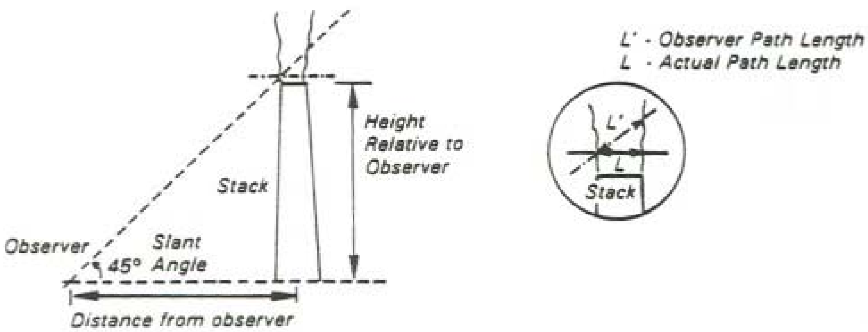


Figure 4.4. *Slant angle relationships.*

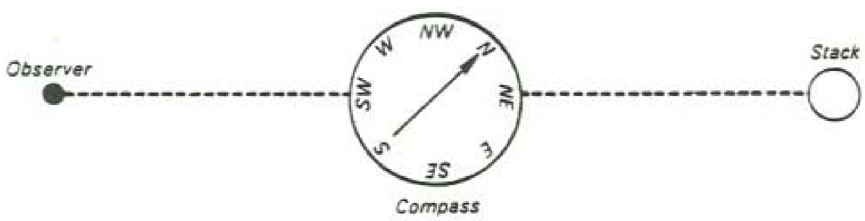


Figure 4.5. *Direction from observer is NE.*

D. EMISSIONS DESCRIPTION. Includes information that definitely establishes what was observed while making the visible emissions determination.

Describe emissions *Start* *Stop*	
Emission color *Start* *Stop*	*Plume type: Continuous* ☐ *Fugitive* ☐ *Intermittent* ☐
Water droplets present *No* ☐ *Yes*☐	*If water droplet plume* *Attached* ☐ *Detached* ☐
Point in the plume at which opacity was determined *Start* *Stop*	

Plumes containing condensed water vapor (or "steam plumes") are usually very white, billowy, and wispy at the point of dissipation, where the opacity decreases rapidly from a high value (usually 100%) to 0 percent if there is no residual opacity plume contributed by contaminate in the effluent.

To document the presence or absence of condensed water vapor in the plume, the observer must address two points. First, is sufficient moisture present (condensed or uncondensed) in the plume initially? Second, if enough moisture is present, are the in-stack and ambient conditions such that it will condense either before exiting the stack or after exiting (when it meets with the ambient air)? 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:

- Water produced by combustion of fuels,
- Water from dryers,
- Water introduced by wet scrubbers,
- Water introduced for gas cooling prior to an electrostatic precipitator, or other control device, and
- Water used to control the temperature of chemical reactions.

If water is present in the plume, data from a sling psychrometer, which measures relative humidity, in combination with the moisture content and temperature of the effluent gas can be used to predict whether the formation of a steam plume is a possibility (see Section 3.12.6).

If Water Droplet Plume: (May be required) - Check "attached" if condensation of the moisture contained in the plume occurs within the stack and the steam plume is visible at the stack exit. Check "detached" if condensation occurs some distance downwind from the stack exit and the steam plume and the stack appear to be unconnected.

Point in the Plume at Which Opacity was Determined (May be required) - Describe as succinctly as possible the physical location in the plume where the observations were made. This description is especially important in the case where condensed water vapor and/or secondary plume is present. For example, were the readings made prior to formation of the steam plume? If the readings were made subsequent to dissipation (e.g., in the case of an attached steam

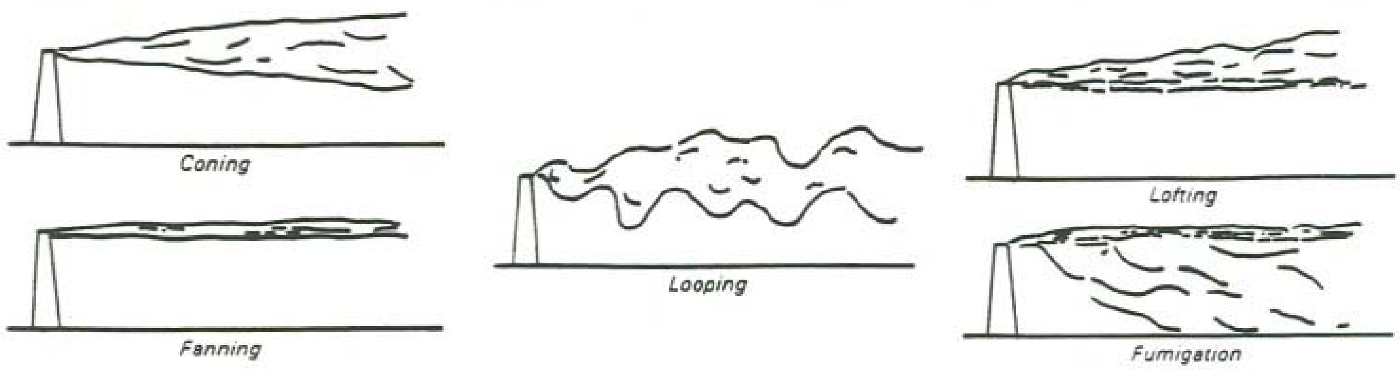


Figure 4.6. *Plume behavior descriptors.*

plume), then specify how far downwind of the dissipation point and how far downwind of the stack exit the reading was made. This information can be used to estimate the amount of dilution that occurred prior to the point of opacity readings. Descriptions such as 4 feet above outlet and 80 feet downstream from outlet, 10 feet after steam dissipation are appropriate.

Figure 4.7 shows some examples of the correct location for making opacity readings in various steam plume and secondary plume situations.

Describe Background (Required) - Describe the background that the plume is obscuring and against which the opacity is being read. While describing the background, note any imperfections or conditions, such as texture, that might affect the ease of making readings. Examples of background descriptions are roof of roof monitor, stand of pine trees, edge of jagged stony hillside, clear blue sky, stack scaffolding, and building obscured by haze.

Background Color (Required) - Accurately note the background color (e.g., new leaf green, conifer green, brick red, sky blue, and gray stone).

E. OBSERVATION CONDITIONS. Covers the background and ambient weather conditions that occur during the observation period and could affect observed opacity.

Describe background			
Start		*Stop*	
Background color		*Sky conditions*	
Start	*Stop*	*Start*	*Stop*
Windspeed		*Wind direction*	
Start	*Stop*	*Start*	*Stop*
Ambient temp.	*Wet bulb temp.*	*Relative humidity*	
Start Stop			

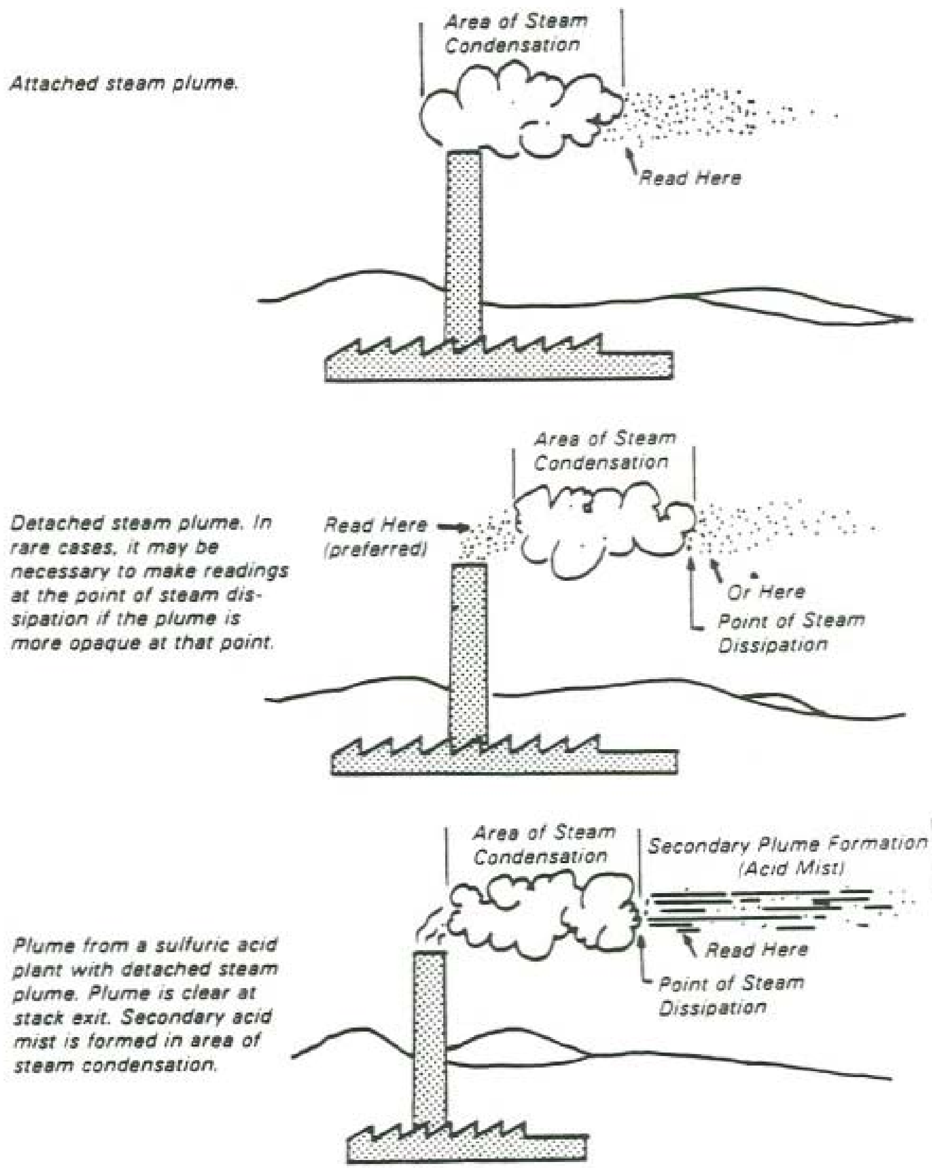


Figure 4.7. *Location for reading opacity under various conditions.*

Sky Conditions (Required) - Indicate the percent cloud cover of the sky. This information can be indicated by using straight percentages (e.g., 10% overcast, 100% overcast) or by description, as shown below.

Term	*Amount of cloud cover*
Clear	*<10%*
Scattered	*10% to 50%*
Broken	*50% to 90%*
Overcast	*>90%*

Windspeed (Required) - Give the windspeed accurately to ±5 miles per hour. The windspeed can be determined using a hand-held anemometer (if available), or it can be estimated by using the Beaufort Scale of Windspeed Equivalents in Table 4.1.

Wind Direction (Required) - Indicate the direction *from which* the wind is blowing. The direction should be estimated to eight points of the compass by observing which way the plume is blowing. If this type of estimation is not possible, the direction may be determined by observing a blowing flag or by noting the direction a few blades of grass or handfull of dust are blown when tossed into the air. Keep in mind that the wind direction at the observation point may be different from that at the emission point; the wind direction at the emission point is the one of interest.

Ambient Temperature (Required) - The outdoor temperature at the plant site is measured by a thermometer (in degrees Fahrenheit or centigrade) obtained from a local weather bureau or estimated. Be certain to note which temperature scale is used. This is done in conjunction with the wet bulb temperature and is only needed when there are indications of a condensing water droplet plume.

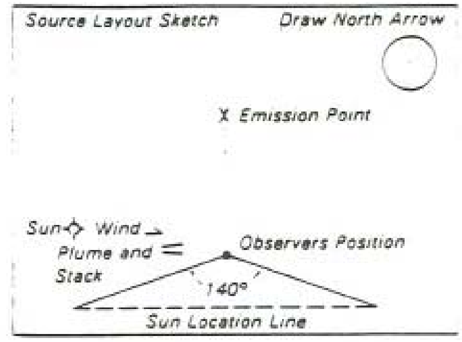
Wet Bulb Temperature (May be required) - Record the wet bulb temperature from the sling psychrometer. This is to be done only when there are indications of a condensing water droplet plume.

Relative Humidity (May be required) - Enter the relative humidity measured by using a sling psychrometer in conjunction with a psychrometric chart. This information can be used to determine if water vapor in the plume will condense to form a steam plume (see Section 3.12.6). If a sling psychrometer is not available, data from a *nearby* U.S. Weather Bureau can be substituted.

Table 4.1. *The Beaufort Scale of Windspeed Equivalents*

General description	*Specifications*	*Limits of velocity 33 ft (10 m) above level ground, mph*
Calm	*Smoke rises vertically*	*Under 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; small branches are moved*	*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 generally impeded	*39 to 46*
Gale	*Slight structural damage occurs (chimney pots and slate 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		*Above 75*

F. OBSERVER POSITION AND SOURCE LAYOUT. Clearly identifies the observer's position in relation to the emission point, plant landmarks, topographic features, sun position, and wind direction.



Source Layout Sketch (Required) - This sketch should include as many landmarks as possible. At the very least, the sketch should locate the relative position of the observed outlet in such a way that it will not be confused with others at a later date, and clearly locate the position of the observer while making the VE readings. The exact landmarks will depend on the specific source, but they might include:

- Other stacks
- Hills
- Roads
- Fences
- Buildings
- Stockpiles
- Rail heads
- Tree lines
- Background for readings

To assist in subsequent analysis of the reading conditions, sketch in the plume (indicate the direction of wind travel). The wind direction also must be indicated in the previous section.

Draw North Arrow (Recommended) - 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. A map (plant layout) may also be used to determine direction north.

Sun's Location (Recommended) - It is important to verify this parameter 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, point the line of sight in the source layout sketch in the direction of the actual emission point, place a pen upright along the "sun location line" until the shadow of the pen falls across the observer's position. Then draw the sun at the point where the pen touches the "sun location line."

G. COMMENTS. Includes all implications, deviations, disagreement with plant personnel and/or problems of a factual nature that have bearing on the opacity observations and that cannot be or have not been addressed elsewhere on the form.

Comments

Comments (May be required) - Note all implications, deviations, disagreements with plant personnel, or problems of a factual nature that cannot be or have not been addressed elsewhere on the form. Examples of points to be included in this section are:

- Changes in ambient conditions from the time of the start of readings.
- Changes in plume color, behavior, or other characteristics.
- Changes in observer position and reasons for the change; a new form should also be initiated in this case so that a new source layout sketch may be drawn.
- Difficulties encountered in plant entry.
- Conditions that might interfere with readings or cause them to be biased.
- Drawing of unusual stack configuration (to show multiple stacks or stack in relation to roof line).
- Suspected changes to the emissions or process during observation.
- Unusual process conditions.
- Additional source identification information.
- Type of plant (if not specified elsewhere).
- Reasons for missed readings.
- Other observers present.

H. COMPANY ACKNOWLEDGEMENT. Company acknowledgement of, but not necessarily agreement with, the opacity observations stated on the form.

I have received a copy of these opacity observations	
Signature	
Title	*Date*

Signature (Recommended) - This space is provided for the signature of a plant official who acknowledges that he/she has received a copy of the observer's opacity readings. His/her signature does not in any way indicate that he/she or the company concurs with those readings.

Title (Recommended) - Include the acknowledging official's company title.

Date (Recommended) - The company official should enter the date of acknowledgment.

I. DATA SET. Opacity readings for the observation period, organized by minute and second. This section also includes the actual date and start and stop times for the observation period.

Observation date					*Start time*		*Stop time*			
M \ s	*0*	*15*	*30*	*45*	*M \ s*	*0*	*15*	*30*	*45*	
1					*31*					
2					*32*					
29					*59*					
30					*60*					

Observation Date (Required) - Enter the date on which the opacity observations were made.

Start Time, Stop Time (Required) - Indicate the times at the beginning and the end of the actual observation period. The times may be expressed in 12-hour or 24-hour time (i.e., 8:35 a.m. or 0835); however, 24-hour time tends to be less confusing.

Data Set (Required) - Spaces are provided for entering an opacity reading every 15 s for up to a 1-hour observation period. The readings should be in percent opacity and made to the nearest 5 percent. The readings are entered from left to right for each numbered minute, beginning at the upper left corner of the left-hand column, labeled row "M 1" (minute 1) and column "s 0" (0 seconds). The next readings are entered consecutively in the spaces labeled M 1, s 15; M 1, s 30; M 1, s 45; M 2, s 0, M 2, s 15, etc.

If, for any reason, a reading is not made for a particular 15-second period, that space should be skipped and an explanation should be provided in the comments section. Also a dash (-) should be placed in the space which denotes that the space is not just an oversight.

J. DATA REDUCTION. (See Subsection 6)

K. OBSERVER DATA. Information required to validate the opacity data.

Observer's name (print)	
Observer's signature	*Date*
Organization	
Certified by	*Date*
Verified by	*Date*

Observer's Name (Required) - Print observer's entire name.
Observer's Signature/Date (Recommended) - Self-explanatory.
Organization (Required) - Provide the name of the agency or company that employs the observer.

Certified By (Recommended) - Identify the agency, company, or other organization that conducted the "smoke school" or VE training and certification course where the observer obtained his/her most current certification.
Date (Required) - Provide the date of the most current certification.
Verified By (Recommended) - The actual signature of someone who has verified the opacity readings and calculations, usually the observer's supervisor, or the individual who is responsible for his/her work.
Date (Recommended) - Provide the date of verification.

4.3.3 Facility Operating Data - It is strongly recommended that a VE inspection/observation conclude with a source inspection if opacity values are in excess of the standard. The observer would first follow the plant entry procedure in Subsection 4.1 and then follow the indicated procedure to obtain facility operating data.

After the VE determination, it is recommended that the following source information be determined:

1. Were the plant and the source of interest operating normally at the time of the VE evaluation?
2. Are there any control devices associated with the source?
3. Were the control devices operating properly?
4. Have there been any recent changes in the operation of the process or control devices?
5. Have any malfunctions or frequent upsets in the process or control devices been noted and reported (if required by the agency)?
6. Is the plant operator aware of excessive visible emissions and have any corrective steps been taken to alleviate the problems?
7. Are there any other sources of visible emissions in close proximity to the source in question that may interfere with reading the plume opacity or contribute to the appearance of the plume?

4.3.4 Photographs - It is suggested that photographs be taken before and after the observation is made, not during the observation period. Conditions should be recorded as they existed at the time of the observation. The use of a 35-mm camera is recommended to ensure good photographs.

Each photograph should be identified with the date and time, the source, and the position from which the photograph was taken.

4.4 *Special Observation Problems*

The VE observer constantly should be aware that his/her observations may be used as the basis of a violation action and subject to questioning as to the reliability of the observations. Therefore, he/she must also be aware that under some conditions or situations it may be difficult or impossible to conduct a technically defensible visible emissions observation.

This section discusses some of the most prevalent difficult conditions or special problems associated with the visible emission observation. Each discussion is directed toward defining the problem, indicating how it might invalidate readings taken, and addressing possible solutions and/or ways to minimize the invalidating effects.

Not all of these discussions offer a complete solution for a particular problem; thus, it is important for the individual observer to keep in mind the purpose of the visible emission observation when considering exactly what action to take when faced with a special problem.

4.4.1 Positional Requirements - Valid VE evaluations can be conducted only when the sun is properly positioned at the observer's back. Failure to adhere to this positioning can result in significant positive bias caused by forward light scatter in opacity readings. Because of this overriding constraint, some times and locations make it difficult for the observer to meet other opacity reading criteria, e.g., reading the narrow axis of a rectangular stack, reading a series of stacks across a short axis to prevent multiple plume effects, and obtaining a contrasting background. Plant topography also may generate constraints that restrict viewing positions to one or more locations. The observer will be aided in determining the best observation location by following the criteria listed below.

1. Make sure that the emission point is north of the observation point.
2. Obtain a clear view of the emission point with no interfering plumes.
3. Be sure that rectangular stacks are read across the narrow axis and multiple stacks are read perpendicular to the line of stacks.
4. Minimize the slant angle by moving a sufficient distance from the stack or to an elevated position (see Subsection 4.4.4).
5. Find a contrasting background or a clear sky background.
6. Finally, determine the best time of day for observations based on the daily sun tracks at that location.

Collaborative studies of the performances of trained observers have indicated that, with the exception of the positive bias caused by having the improper sun angle, visible emission observation biases tend to be negative. Thus, if viewing conditions are not ideal and a negative bias (lower value) results, opacity readings may not provide the true measure of plume opacity required to correlate to mass emissions or control equipment efficiency. However, readings that indicate a violation can be regarded as the minimum opacity; therefore, documentation of the violation is valid.

In situations where the observer must make plume opacity readings when all the criteria for correct viewing cannot be met, all extenuating circumstances must be documented on the VE evaluation form.

4.4.2 Multiple Sources/Multiple Stacks - An observer is sometimes compelled to evaluate a stack that discharges emissions from more than one source or to evaluate a single source that has more than one emission point.

In the case where one stack serves more than one emission source, the observer may be able to isolate the emissions from one source as a result of intervals of operation, or by requesting the facility's cooperation in temporarily shutting down the other source(s). Otherwise, the observer should proceed with the VE observation and document the situation completely on the VE evaluation form.

In the case of multiple emission points for a single source (e.g., in positive-pressure baghouses and multiple vents in roof monitors), Section 2.1 of Method 9 directs the observer to read multiple stacks independently if it is possible to do so while meeting sun position requirements. If it is necessary to get an overall reading for the group of stacks, the following set of formulas can be used to calculate this reading from the individual opacity values.

$$1 - \frac{O_1}{100} = T_1$$

$$1 - \frac{O_2}{100} = T_2$$

$$1 - \frac{O_N}{100} = T_N$$

$$T_1 \times T_2 \times .... T_N = T_T$$

$$100 \times (1 - T_T) = O_T$$

where

O_1 = % opacity of 1st plume
O_2 = % opacity of 2nd plume
O_N = % opacity of nth plume
T_1 = Transmittance of 1st plume
T_2 = Transmittance of 2nd plume
T_N = Transmittance of nth plume
T_T = Total transmittance
O_T = % total opacity

4.4.3 High Winds - Occasionally the crosswind conditions are unfavorable during field observations of plume opacity. When the winds are strong enough to shear the emissions at the stack outlet, it is difficult for the observer to make an accurate and fair VE observation. Strong crosswinds can have several effects on the plume:

1. The plume becomes essentially flattened and is no longer conical in shape thus the path length and apparent opacity increases.
2. The plume is torn into fragments and becomes difficult to obtain a representative reading.
3. The plume becomes diluted, and the apparent opacity is lowered.

The observer can compensate somewhat for the effect of flattening by reading the plume downwind of the stack, after it has reformed into a cone. The dilution effect of high winds, which lowers the apparent opacity, presents more of a problem. Because of the negative bias introduced, the effectiveness of Method 9 as a control tool under these conditions is diminished. If a violation is still observed under these conditions, it should be considered valid. It is recommended that whenever feasible, VE observations be suspended until the wind-caused interferences have abated.

4.4.4 Poor Lighting - Poor lighting conditions for VE observations usually involve one or more of the following: (1) a totally overcast sky, (2) early morning or late afternoon hours, or (3) nighttime. Each of these three lighting conditions has the same net effect on the plume; they differ slightly only in the cause of the poor illumination. When the amount of available sunlight is below a certain level, the contrast between a white plume and the background decreases. Therefore, readings are not recommended in either the early morning hours (at or approaching dawn) or late afternoon hours (at or approaching dusk).

Nighttime viewing obviously represents the most severe of poor lighting conditions. Some agencies have attempted, with mixed results, to use night vision devices (light intensification scopes) for plume viewing and testing in the dark. Others have achieved better results by placing a light behind the emissions, which provides a very high contrast background. For this method, it is important to select a source of light of moderate strength that does not cause the iris of the eye to close.

4.4.5 Poor Background - The color contrast between the plume and the background against which it is viewed can affect the appearance of the plume as viewed by an observer. Field studies have corroborated predictions of the plume opacity theory by demonstrating that a plume is most visible and has the greatest apparent opacity when viewed against a contrasting background.

Consistent with these findings is the fact that with a high contrast background, the potential for positive observer bias is the greatest. However, field trials consisting of 769 sets of 25 opacity readings each have shown that for more than 99 percent of the sets, the positive observer error was no greater than 7.5 percent opacity.[2]

Also consistent with these findings is the fact that as the contrast between the plume and its background *decreases*, the apparent opacity decreases; this greatly increases the chance for a negative observer bias. Under these conditions, the likelihood lessens of a facility being cited for a violation of an opacity standard because of observer error.

When faced with a situation where there is a choice of backgrounds, the observer should always choose the one providing the highest contrast with the plume because it will permit the most accurate opacity reading. However, if a situation arises where other constraints make it impossible to locate an observation point that provides a high contrast background, the observer may read against a less contrasting one with confidence that a documented violation should be legally defensible.

4.4.6 Reduced Visibility - Environmental factors at the time of observation also are of concern to the visible emissions observer. Environmental considerations include rain, snow, or other forms of precipitation, and photochemical smog buildup, fog, sea spray, high humidity levels, or any other cause of haze. These environmental factors create a visual obscuration that can increase the apparent opacity of the plume, but more commonly reduce the background contrast and thus decrease the apparent opacity.

In recognition of the problems that could result from reduced visibility caused by environmental factors, the amended Method 9 (November 12, 1974) states, in paragraph 2.1 of the Procedures Section: "The qualified observer shall stand at a distance sufficient to provide a clear view of the emissions ..." A "clear view" must be interpreted as a view free from obstacles or interferences. Most problems caused by reduced visibility can be alleviated simply by making the observations on another day.

4.4.7 Tall Stacks/Slant Angle - When an observer's distance from the stack approaches 1/4 mile (approximately 1300 feet, or a little over four football fields), the ambient light scattering may begin to have an adverse effect on the contrast between the plume and the background. Also, if the sky is overcast or hazy on the day of observation, the farther the observer is from the emission point, the more the haze interferes with the view of the plume and hence, the less reliable the readings.

On the other hand, the recommendation that the observer stand at least three stack heights from the stack being observed is intended to ensure that the width of the plume as it is viewed is approximately the same as it is at the stack outlet. As the observer gets closer to the stack and the viewing (slant) angle increases, the observed path length also increases; this causes the observed opacity to increase because the observer is reading through more emissions. These relationships are shown in Figure 4.8. At an observer distance of three stack heights, which corresponds to a slant angle of 18°, the deviation of observed opacity from actual opacity decreases to 1 percent opacity, which is considered acceptable (see Section 3.12.6).

The three-stack-heights relationship only occurs if the observer and the base of the stack are in the same horizontal plane. If the observer is on a higher plane than the base of the stack, then the minimum distance for proper viewing can be reduced to *less* than three stack heights; conversely, if the observer's plane is lower than that of the stack base, then the minimum suggested distance will be *greater* than three stack heights (see Figure 4.8). The real determining factor is the slant angle. To assure no more than a 1 percent opacity deviation of observed opacity from actual opacity, the observer must have a visual slant angle of 18° or less.

4.4.8 Steam Plumes - Under certain conditions, water vapor present in an effluent gas stream will condense to form a visible water droplet or "steam" plume. Because the NSPS (specifically Method 9) and almost all SIP's exclude condensed, uncombined water vapor from opacity regulations, the VE observer must be careful that he/she does not knowingly read a plume at a point where condensed water vapor is present and record the value as representative of stack emissions.

Knowledge of the kind of process that generates the emissions being read and simple observation of the resultant plume almost always allows the observer to determine if a steam plume is present. Steam plumes are commonly associated with processes or control equipment that introduce water vapor into the gas stream. These sources include:

- Fuel combustion,
- Drying operations,
- Wet scrubbers,
- Water-induced gas cooling prior to an emissions control device, and
- Water-induced chemical reaction cooling.

Also, observation of steam plumes will reveal that they are usually very white, billowy, and have an abrupt point of dissipation. At the point of dissipation, the opacity generally decreases *rapidly* from a high value (usually 100%) to a low value. Depending on the moisture and temperature conditions in the stack and in the ambient air, steam plumes may be either "attached" or "detached." An attached steam plume forms within the stack and is visible at the exit; a detached steam plume forms downwind of the stack exit and does not appear to be connected to the stack. In cases when it is not clear whether a steam plume is present or when an observer would like to predict the formation of a steam plume, the stack gas conditions may be used in conjunction with the ambient relative humidity to make the prediction (see Section 3.12.6).

When a steam plume *is* present, the particulate plume is read at a point where 1) no condensed water vapor exists, and 2) the opacity is the greatest. In the case of a detached steam plume, this point is usually at the stack exit, prior to the water vapor condensation; in the case of an attached steam plume, it is usually slightly downwind of the point of steam plume dissipation (for examples, see Figure 4.7). The observer should always carefully document the point chosen.

4.4.9 Secondary Plume Formation - Some effluent gas streams contain species that form visible mists or plumes by a physical and/or chemical reaction that occurs either at some point in the stack or after the emissions come in contact with the atmosphere. This situation is known as secondary plume formation. Examples of such secondary plume formation include:

- A change in the physical state of a compound condensing from a gas into a liquid, such as vaporized hydrocarbon condensing into an aerosol or a solid.
- A physiocochemical reaction between two or more gaseous (or in some cases, liquid) species in a plume, such as the condensation of ammonia, sulfur dioxide, and water vapor to form

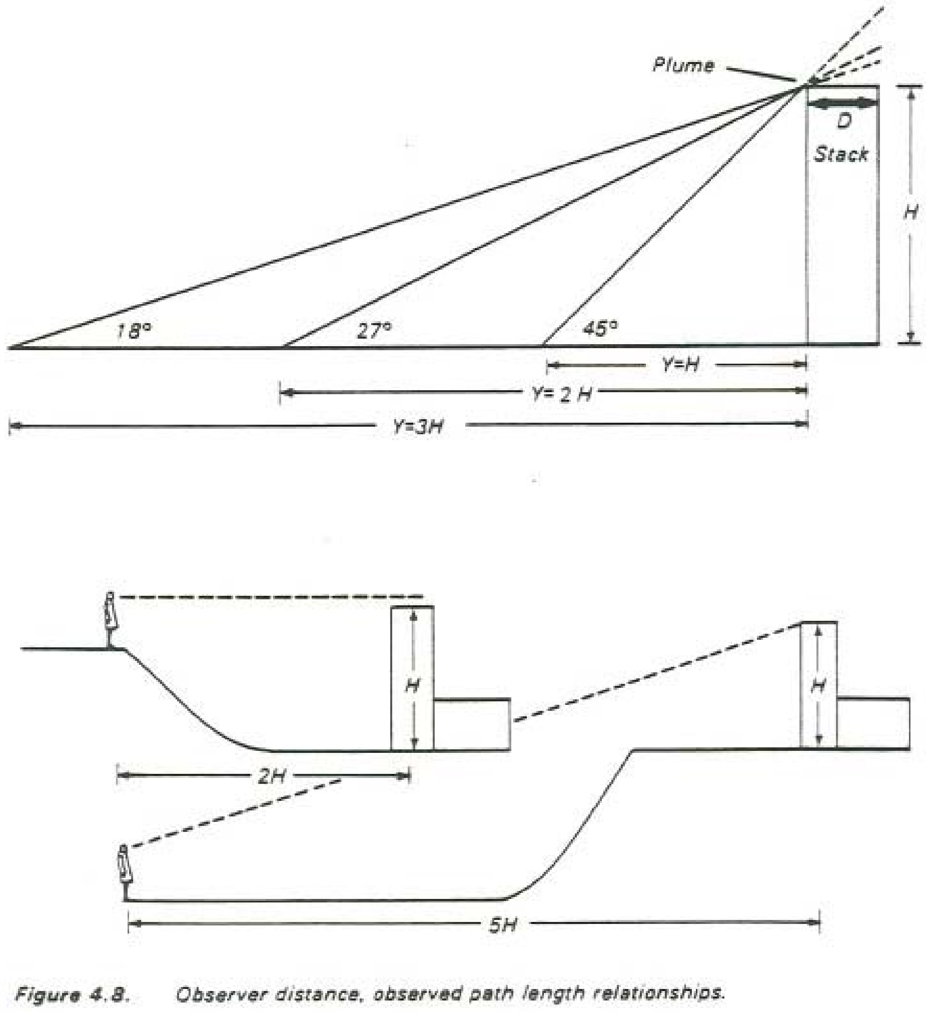


Figure 4.8. Observer distance, observed path length relationships.

particulate ammonium sulfite or the condensation of sulfur trioxide and water vapor to form sulfuric acid mist.

- A physiocochemical reaction between species in a plume and species in the atmosphere, such as the formation of N_2O_3.

Secondary plumes are sometimes found in the following processes (with these suspected secondary reactions):

- Coal- and oil-fired cement kilns ($SO_3 + H_2O - H_2SO_4$ mist) or [$NH_3 + SO_2 + H_2O - (NH_4)_2 SO_3$]
- Fossil-fuel-fired steam generators ($SO_2 + H_2O - H_2SO_4$ mist)
- Sulfuric acid manufacturing ($SO_3 + H_2O - H_2SO_4$ mist)
- Plywood and particleboard wood heating (organic vapor — organic mist)
- Glass manufacturing (inorganic vapor — organic aerosol).

As in the case of steam plumes, secondary plumes can be attached or detached, depending on the specific condensation reaction and the ambient conditions. For example, a secondary plume will be attached if a reaction between plume species occurs in the stack and the stack temperature is sufficiently low to cause condensation of the reaction products to a visible liquid or solid phase. A detached secondary plume will be evident when the reaction does not occur until the gas stream comes in contact with the atmosphere. The degree of detachment depends on the ambient conditions, the degree of mixing between the effluent and the atmosphere, and the specific reaction(s) involved.

Secondary plumes may occur with or without an accompanying steam plume, and it is important that the observer be able to distinguish between the two. Unlike steam plumes, secondary plumes are often persistent (they do not dissipate rapidly), are usually bluish white (due to the fine particles present), and are grainy rather than billowy.

To read a secondary plume, the observer must locate the densest point of the plume where water vapor is not evident and make the readings at that point. This point may occur in several different areas, depending on the type of secondary plume. An attached secondary plume will usually be read at the stack exit if an attached *steam* plume is not present; if an attached steam plume *is* present, the secondary plume must be read at the point of steam dissipation. A detached secondary plume will usually be read slightly downwind of the area of formation, assuming there is no interfering condensed water vapor. Under some conditions, a secondary plume may not fully condense until some distance downstream of the point of formation; in this case, the observer simply looks for the densest area of the plume and makes the reading at that point. It is especially important in reading a secondary formation plume to describe fully the point at which the reading was taken and the exact appearance of the plume. (Refer to Figure 4.7 for one example of where to read a secondary plume.)

4.4.10 Fugitive Emissions - Fugitive emissions are those emissions that do not emanate from a conventional smoke stack or vent. Examples of these nonconventional emissions include:

- Dusty or unpaved roads
- Stock or raw material piles under windy conditions or when moved by machinery
- Conveyor belts, pneumatic lifts, clamshells, and draglines
- Cutting, crushing, grinding, and sizing of minerals or other materials
- Plowing, tilling, and bulldozing
- Open incineration
- Demolition activities
- Roof monitors or building vents, especially in foundries, iron and steel facilities, and related industries.

Because of the irregular shape of their emission point or area, conducting a conventional Method 9 test on fugitive emissions may appear difficult; however, it usually involves only relatively minor adjustments. Commonly used procedures for observation of fugitive emissions are listed below:

1. If possible, isolate the particular emission from other emissions by choosing an appropriate position for observation.
2. Adhere to the lighting requirements of Method 9 by keeping the sun in the 140° sector to the observer's back.
3. Also adhere to Method 9 in selecting a position with regard to wind direction and a contrasting background.
4. Whenever possible, select the shortest path length through the plume.
5. Before taking readings, view the emission for several minutes to determine its characteristics. Changes that may occur in the airborne particulate pattern over time are important to note and to consider in selecting a viewing point.
6. Select the line of sight and the viewing point in the emissions so that, on the average, the densest part of the emissions will be observed. It is recommended that all subsequent readings in a data set be taken at the same relative position to the emission source.
7. The configuration of the emission point or area may necessitate taking readings at a point downwind where the emissions have assumed a more conventional plume shape.
8. If the plume cannot be viewed through a nearly perpendicular angle, corrections may be necessary.

Table 4.2. Activity Matrix for Visible Emission Determination

Activity	Acceptance limits	Frequency and method of measurement	Action if requirements are not met
Perimeter survey	Completed perimeter survey	Prior to, following, and during (if warranted) the VE determination	N/A
Plant entry	Observer should follow protocol as suggested in Subsec 4.2 and adhere to confidentiality of data	Entry prior to taking VE readings only if necessary; entry after VE readings to provide plant representative with data and/or to obtain necessary plant process data	N/A
VE Determination			
1. Position	In accordance with Subsec 4.3.1	Take a position for observation as described in Subsec 4.3.1 and document on data form	Follow instructions under special problems (Subsec 4.4) when a proper position cannot be assumed
2. Observations	Taken in accordance with Subsec 4.3.1	Make VE determination as described in Subsec 4.3.1	As above
3. Field data: VE observation form	Completed data form	Complete data form as per instructions and examples in Subsec 4.3.2	Complete missing data (if possible) or give rationale for incomplete data
4. Facility operating data	Pertinent process data obtained	After VE observations, obtain facility data per Subsec 4.3.3	Data must be obtained as soon as possible after VE observation
Special observation problems	N/A	Refer to Subsec 4.4 when conditions do not permit VE observation under proper position, etc.	N/A

N/A = not applicable.

5.0 POST OBSERVATION OPERATIONS

The subsection deals with the procedures to be followed immediately following the making of a visible opacity observation.

5.1 Distribution of Copies

The VEO form should be thoroughly checked to see that all appropriate information has been recorded. The observer should then sign and date the form and request that a company representative sign in receipt. If the representative refuses to sign write "(name of representative) refused to sign in receipt copy left with _____" or similar notation. In any case, leave the pink copy with the company representative, retain the yellow for your files, and forward the white copy to the Boise Central Office with the accompanying report.

5.2 Validation

Once the VEO form is received in the Boise Central Office, a reviewer will check the data fields for completeness and accuracy, recalculate the average opacity, and verify the VEO by signing the appropriate box.

6.0 CALCULATIONS

Three types of calculations are described by this section: (1) the calculation of the average (arithmetic mean) opacity, and the (2) the calculation of path length through the plume, which is seldom needed, and (3) the prediction of the presence of a steam plume, also rarely needed.

6.1 Calculation of Average Opacity

Figure 6.1 shows an example VEO. In this case the source was subject to IDAPA 16.01.1201 and was not exempted by Subsections .01, .02, or .03. The opacity calculations are accomplished as follows:

1. The number of readings above the applicable opacity limitation (in this case 20%) is entered into box "a" in figure G-1.

2. The number of readings tabulated above is then divided by 4 (each reading is deemed to represent 1/4 of a minute) and the quotient entered into box "b" is shown in figure G-4.

3. The average (arithmetic mean) of the values exceeding 20% is computed and entered into box "c".

4. The highest and lowest values exceeding the opacity limitation are entered into box "d".

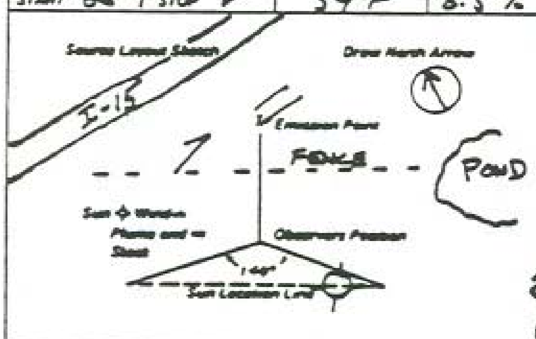
If the number of minutes above the specified opacity (box b) exceeds 3 minutes, a violation of APA 16.01.1201 or 1203 exists. Boxes c and d provide information as to the severity of the violation. If a reading is skipped due to wind changes, background changes or some other variable, that specific reading will not be used in any computations (i.e. omitted readings are not counted as "0" nor are they filled with computed values).

Sources subject to NSPS (40 CFR 60) must have calculated opacity as detailed in Method 9, 40 CFR 60 Appendix A.

FIGURE 6.1

IDAHO AIR QUALITY BUREAU
IDHW/DIVISION OF ENVIRONMENT
Visible Emission Observation Form

SOURCE NAME: STANLEY ASPHALT CO
ADDRESS: 2030 WESTGATE DR
CITY: Boise STATE: ID ZIP: 83704
PHONE: 378-0786 SOURCE ID NUMBER:
PROCESS EQUIPMENT: ASPHALT DRYER OPERATING MODE: 100 T/H
CONTROL EQUIPMENT: BAGHOUSE OPERATING MODE: Normal
DESCRIBE EMISSION POINT: METAL STACK
START ✓ STOP ✓
HEIGHT ABOVE GROUND LEVEL: START 40' STOP ✓ | HEIGHT RELATIVE TO OBSERVER: START 40' STOP ✓
DISTANCE FROM OBSERVER: START 150 STOP ✓ | DIRECTION FROM OBSERVER: START NNE STOP ✓
DESCRIBE EMISSIONS: LOFTING PLUME
START ✓ STOP ✓
EMISSION COLOR: BLK/GRAY | PLUME TYPE: CONTINUOUS ☒ FUGITIVE ☐ INTERMITTENT ☐
START ✓ STOP ✓
WATER DROPLETS PRESENT: NO ☒ YES ☐ | IF WATER DROPLET PLUME: ATTACHED ☐ DETACHED ☐
POINT IN THE PLUME AT WHICH OPACITY WAS DETERMINED: START LIP of STACK STOP ✓
DESCRIBE BACKGROUND: BLUE SKY
START ✓ STOP ✓
BACKGROUND COLOR: START Blue STOP ✓ | SKY CONDITIONS: CLEAR START ✓ STOP ✓
WIND SPEED: ~ 10 MPH START ✓ STOP ✓ | WIND DIRECTION: FROM W START ✓ STOP ✓
AMBIENT TEMP: START 85°F STOP ✓ | WET BULB TEMP: 54°F | RH, percent: 8.5%



OBSERVATION DATE: 15 July 1986 | START TIME: 1320 | STOP TIME: 1349

MIN \ SEC	0	15	30	45	MIN \ SEC	0	15	30	45
1	80	70	75	60	31				
2	60	55	75	70	32				
3	70	70	75	40	33				
4	45	45	60	60	34				
5	60	60	75	75	35				
6	80	70	90	75	36				
7	60	50	55	60	37				
8	65	80	80	80	38				
9	65	50	65	70	39				
10	65	85	60	50	40				
11	45	40	40	40	41				
12	45	50	45	45	42				
13	50	55	60	65	43				
14	70	75	80	85	44				
15	60	40	50	55	45				
16	60	70	80	85	46				
17	40	50	30	20	47				
18	15	20	25	30	48				
19	35	55	60	50	49				
20					50				
21					51				
22					52				
23					53				
24					54				
25					55				
26					56				
27					57				
28					58				
29					59				
30					60				

a NUMBER OF READINGS ABOVE 20 % WAS 73 | b NUMBER OF MINUTES ABOVE 20 % WAS 18.25
c AVERAGE OF READINGS ABOVE 20 % WAS 60.8 | d RANGE OF READINGS ABOVE 20% WAS 25 TO 90

COMMENTS: No Bags in Baghouse
OBSERVER'S NAME: Tom Smith
OBSERVER'S SIGNATURE: Tom Smith DATE: 15 July 1986
I HAVE RECEIVED A COPY OF THESE OPACITY OBSERVATIONS
SIGNATURE: William Vance
CERTIFIED BY: John Jones DATE: 10 APRIL 1986
TITLE: President DATE: 7/15/86
VERIFIED BY: Bob Philips DATE: 30 July 1986

HWE 0072

6.2 Calculation of Path Length Through the Plume

The observer should be located so that only one plume diameter is being sighted through. In rare cases, the observer has no choice but to be relatively close to the stack so that the view is up through the plume rather than across it. In these cases, this extra width of plume should be acknowledged and the individual data values may be adjusted mathematically in the final data report to show the increase in opacity reading due to the added path length. These adjusted opacity readings should be used in determining averages in excess of the standard.

The calculation of observed path length is shown in Appendix A of Reference 1 and is included here for the observer's convenience. Figure 6.5 shows how the slant angle varies with distance from an elevated source. As an observer moves closer to the base of the stack, the angle of sight and the path length through the plume both increase; this causes the observed opacity to increase even though the cross-plume opacity remains constant. This situation only applies when the opacity is read through a vertically rising plume and the observer is on the same plane as the base of the stack.

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

Method 1 (when slant angle θ is known)

$$1 - \left(\frac{O_o}{100}\right) = T_o \quad \text{Equation 6-1}$$

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

where

O_o = observed opacity in %

T_o = observed transmittance

F = cosine of θ

O_c = corrected opacity in %.

Method 2 (where distances are known)

$$F = \frac{Y}{\sqrt{H^2 + Y^2}} \quad \text{Equation 6-2}$$

$$1 - \left(\frac{O_o}{100}\right) = T_o$$

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

where

O_o = observed opacity in %

T_o = observed transmittance

F = cosine of θ

O_c = corrected opacity in %

H = height of stack

Y = distance of observer from stack.

Note: Since the correction is a power function, the correction must be made on each opacity reading and the corrected values used for calculations, in lieu of the correction being conducted on the reduced (averaged) data.

Table 6.1 presents the opacity corrected for slant angle or viewing angle θ versus the full range of opacity readings. For angles less than approximately 18° the adjustment is relatively insignificant.

6.3 Predicting Steam Plume Formation

The psychrometric chart can be used in conjunction with a simple

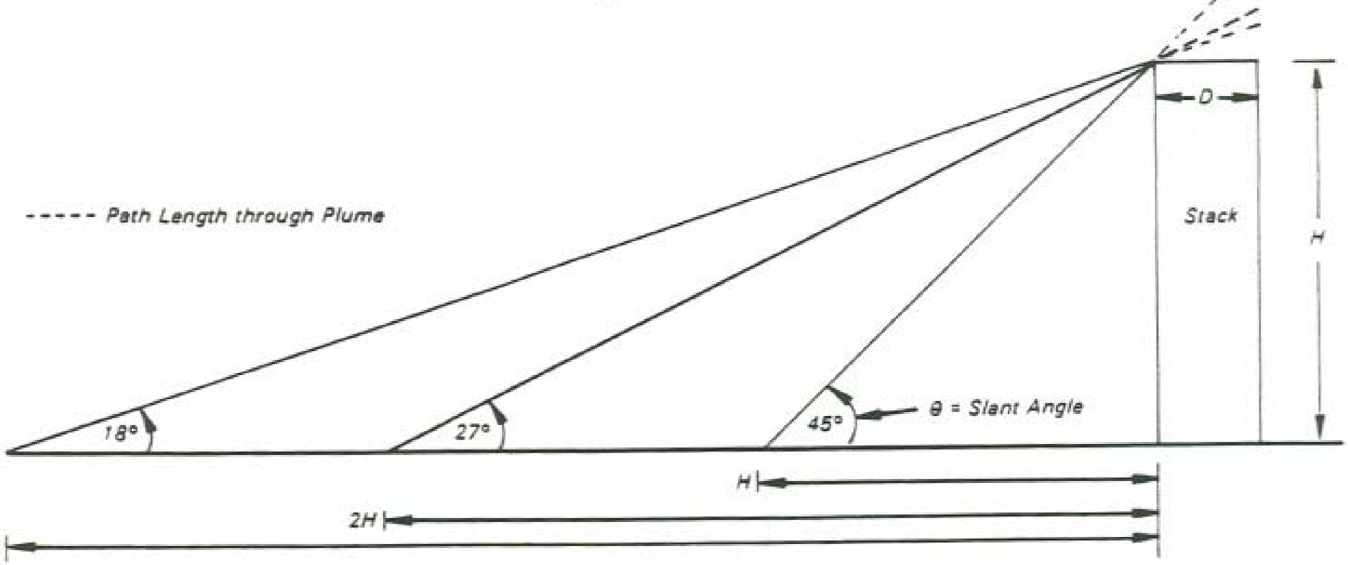


Figure 6.5. *Variation of observation angle and pathlength with distance from an elevated source.*

Table 6.1. Opacity Correction for Slant Angle

Measured opacity, %	Slant angle θ, 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

equation to predict the formation of a visible water vapor (steam) plume. The psychrometric chart is a graphical representation of the solutions of various equations of the state of air and water vapor mixtures (see Figure 6.6). Both the ambient and stack emission data points on the chart are referred to as their "state point" and represent one unique combination of the following five atmospheric properties.

Dry bulb temperature - The actual ambient temperature; represented by the horizontal axis.

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

Relative humidity - The ratio of the partial pressure of the water vapor to the vapor pressure of water at the same temperature; values are represented by the set of curved lines originating in the lower left portion of the chart.

Absolute humidity (humidity ratio) - The mass of water vapor per unit mass of air; expressed as grains per pound or pound per pound; represented by the vertical axes.

Specific volume - The volume occupied by a unit mass of air, expressed as cubic feet per pound; represented by the diagonal lines running from lower right to upper left. The relationships shown in the 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 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 the equation and not the chart.

Plotting the values for any two of the five atmospheric properties determines the values for the remaining three properties. For example, by using a sling psychrometer to measure the wet and dry bulb temperatures, one can determine the relative humidity, the absolute humidity, and the specific volume of the air.

To predict the occurrence of a visible steam plume, both the ambient air conditions and the stack gas conditions must be known or calculated and located on the psychrometric chart. If any portion of the line connecting the two points lies to the left of the 100 percent relative humidity line, it is an indication that the change of the exhaust gas from the stack state conditions to the ambient air state will be accompanied by the condensation of the water vapor present in the exhaust stream and a resultant visible steam plume.

Obtaining the state point for the ambient air conditions is relatively simple; as previously indicated, the wet and dry bulb temperatures, which will determine a unique state point, can be measured by using a sling psychrometer. Often the only data available for determining the state point of the stack gas are the dry bulb temperature of the exhaust gas stream and its moisture content.* However, a relationship exists between the moisture content and the humidity ratio (or absolute humidity), as shown in the following equation:

$$HR = \frac{0.62\,(MC)}{1 - MC} \quad \text{Equation 6-3}$$

where

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

MC = $\frac{\%}{100}$ moisture content, expressed as a decimal.

The following sample problem demonstrates the use of this equation.

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

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

Find:

Ambient relative humidity

Exhaust gas humidity ratio

Determine whether or not condensed water (steam plume) will form

*These are usually obtained from plant records or are estimated from recent source test data.

Table 6.2. Vapor Pressures of Water at Saturation

Temp., °F	Water vapor pressure, in. Hg									
	0	1	2	3	4	5	6	7	8	9
30	0.1647	0.1716	0.1803	0.1878	0.1955	0.2035	0.2118	0.2203	0.2292	0.2383
40	0.2478	0.2576	0.2677	0.2783	0.2891	0.3004	0.3120	0.3240	0.3364	0.3493
50	0.3626	0.3764	0.3906	0.4052	0.4203	0.4359	0.4520	0.4586	0.4858	0.5035
60	0.5218	0.5407	0.5601	0.5802	0.6009	0.6222	0.6442	0.6669	0.6903	0.7144
70	0.7392	0.7648	0.7912	0.8183	0.8462	0.8750	0.9046	0.9352	0.9666	0.9989
80	1.032	1.066	1.102	1.138	1.175	1.213	1.253	1.293	1.335	1.378
90	1.422	1.467	1.513	1.561	1.610	1.660	1.712	1.765	1.819	1.875
100	1.932	1.992	2.052	2.114	2.178	2.243	2.310	2.379	2.449	2.521
110	2.596	2.672	2.749	2.829	2.911	2.995	3.081	3.169	3.259	3.351
120	3.446	3.543	3.642	3.744	3.848	3.954	4.063	4.174	4.289	4.406
130	4.525	4.647	4.772	4.900	5.031	5.165	5.302	5.442	5.585	5.732

Solution:

Plot ambient wet bulb and dry bulb temperatures (see Figure 6.5).

Ambient relative humidity = 55%.

Exhaust gas humidity ratio = HR

$$HR = \frac{0.62\ (MC)}{1 - MC} = \frac{0.62\ (0.168)}{1 - 0.168} = 0.125 \text{ lb/lb dry air}$$

Plot humidity ratio and stack dry bulb temperature (see Figure 6.6). Connect the ambient state point and stack gas state point with a straight line (see Figure 6.5). The line crosses the 100 percent relative humidity line; thus, formation of a visible water vapor plume is probable.

When the wet bulb/dry bulb technique is used and the barometric pressure is less than 29.5 in. Hg, it is suggested that Equation 6-5 be used to calculate the moisture content (MC).

$$MC = \frac{VP}{P_{abs}} \qquad \text{Equation 6-5}$$

where

VP = Vapor pressure of H_2O using Equation 6-6

P_{abs} = Barometric pressure

$$VP = SVP - (3.57 \times 10^{-4})\,(P_{abs})\,(T_d - T_w)\left(1 + \frac{T_w - 32}{1571}\right) \qquad \text{Equation 6-6}$$

where

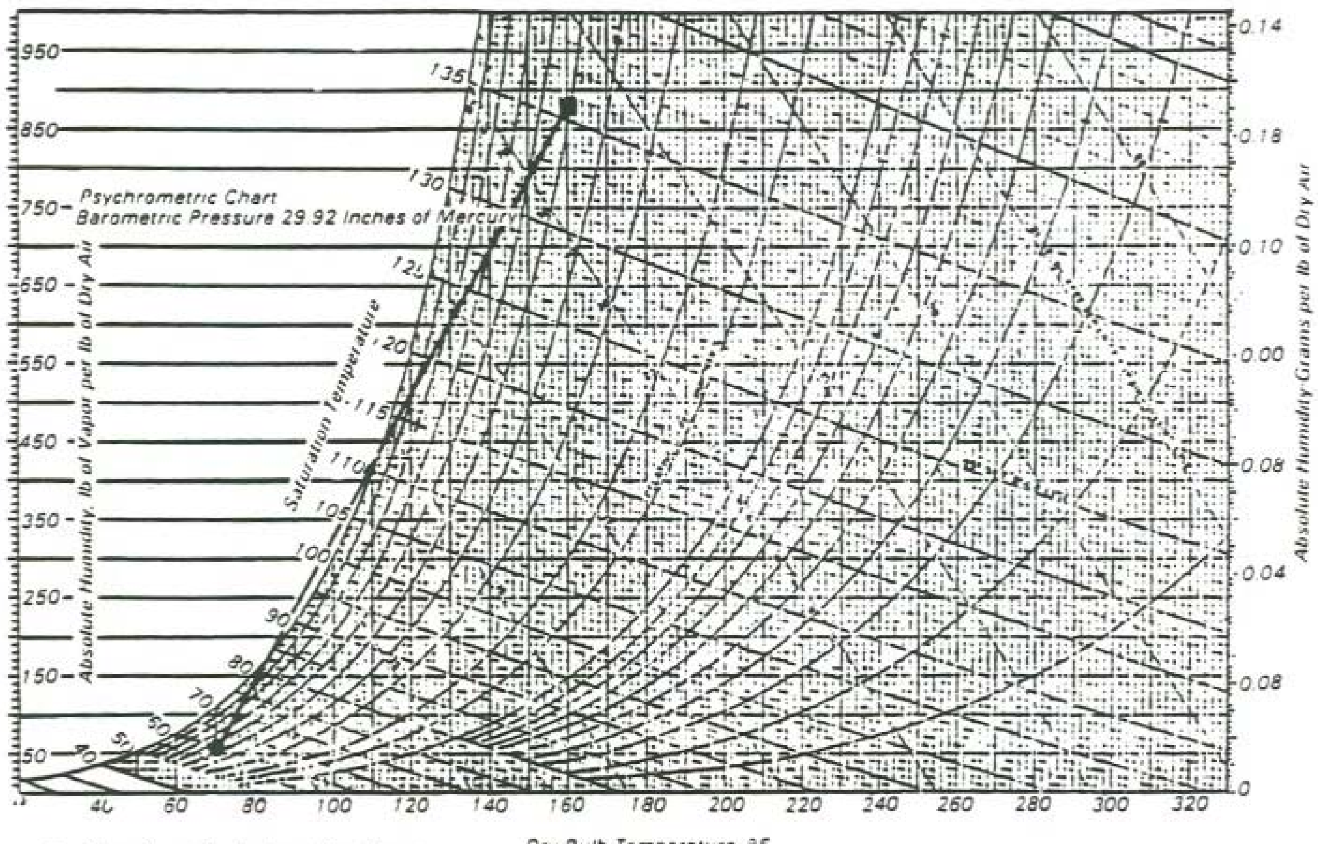
SVP = Saturated vapor pressure in in. Hg at wet bulb temperature (taken from Table 6.2)

T_d = Temperature of dry bulb thermometer, °F

T_w = Temperature of wet bulb thermometer, °F.

Table 6.3 *Activity Matrix for Calculations*

Calculation	*Acceptance limits*	*Frequency and method of measurement*	*Action if requirements are not met*
Average opacity	*Data in Fig 6.1 completed and checked to within roundoff error*	*For each compliance test, perform independent check of data form and calculations*	*Complete the data and initial any changes in calculations*
Running average opacity	*Data in Fig 6.2 completed and checked*	*As above*	*As above*
Path length through the plume	*No limits have been set*	*For each compliance test with the slant angle >18°, calculate using Eq. 6-1*	*Perform calculations*
Predicting steam plume	*No limits have been set*	*Use psychrometric chart and Equation 6-3*	*Perform calculations*



● - *State Point for Ambient Conditions.*

■ - *State Point for Stack Gas Conditions.*

Figure 6.6. *Psychrometric chart for problem solution.*

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