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GUIDELINES FOR EVALUATION OF VISIBLE EMISSIONS

CERTIFICATION, FIELD PROCEDURES, LEGAL ASPECTS, AND BACKGROUND MATERIAL

by

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1. INTRODUCTION

1.1 GENERAL

Once a plume or effluent is identified as an air contaminant, it must be measured by some standard to determine whether or not a violation of the law has occurred, or it must be evaluated to determine the size or severity of a given air pollution problem.

Visual observation of plumes by field personnel can be an effective and economical method of determining compliance with air pollution regulations, provided the regulations are based on the visual aspect of plumes, or on other properties that can be shown to be directly related to the visual aspect.

The benefits of basing emissions statutes on opacity, or density, are quite evident, even though equipment and fuel regulations have increasingly assumed precedence in control legislation. When the visual standard is specific with reference to a cutoff point and time interval, it is simply and directly enforced. All enforcement officers need do is observe an emission of an opacity or density beyond that allowed by the regulations for a minimum time interval in order to cite a violator for excessive emissions.

Although the visual standard is limited to estimations of particulate pollution which obscures vision, its application simultaneously tends to reduce grain loading, since there is a relationship between grain loading and opacity, although this relationship is somewhat complex. The standard, therefore, is most versatile in accomplishing gross reductions of atmospheric pollutants in a community, and can be applied not only to smoke, but to fumes, dusts and mists arising from a variety of sources.

It should be cautioned, however, that while such benefits can be assumed, they cannot always be precisely predicted or evaluated. Determination of opacity and shade of any emission alone gives no specific measurements of the quantities of contaminants being emitted.

1.2 PURPOSE OF MANUAL

The purpose of this manual is to provide the certified visible emissions evaluator, often referred to as a "smoke reader", with certain guidelines to be followed when making visual observations of stationary source emissions. It is intended to supplement EPA policy and procedural guidelines for making opacity determinations.

Method 9 of Appendix A to Section 60 of the Federal Register Vol. 39, No. 219, November 12, 1974, is the basis for the visual observation procedures. Any subsequent revisions to Method 9 that may be published in the Federal Register should take precedence over the procedures given in this manual.

The manual is primarily intended to assist EPA personnel:

(a) in making field evaluations of the opacity of visible emissions in accordance with the approved procedures,

(b) in ensuring that all necessary observations are made, and all pertinent information is obtained and recorded in a standard, clear format, and

(c) by providing recommended procedures to be adopted in preparing and presenting a court case, should the results of the field investigation indicate that the visible emission regulation was violated.

2. TRAINING AND CERTIFICATION PROCEDURES

2.1 SUMMARY

To become a qualified visible emissions evaluator the student must successfully complete a training school, normally of three days duration, presented by a Federal, State or local air pollution agency, or educational establishment. The training school consists of a series of lectures, and slide and film presentations, in addition to the actual training of the student to evaluate the opacity of visible emissions.

2.2 CLASSROOM WORK

The purpose of the classroom work is to present to the student sufficient background material such that competent evaluations of the opacity of visible emissions can be made in the field during enforcement operations, and to enable these observations to be translated into testimony that will be admissable as evidence in any future court or hearing board proceedings. The classroom work should consist of a description of the Ringelmann chart, the definition of opacity, a description of aids that are available for evaluating visible emissions, procedures to be followed in the field, training procedures, a description of the smoke generator, sources of visible emissions, the problems associated with water vapor plumes, preparation of the evidence, courtroom and hearing board procedures, presentation of the evidence and some basic meteorology.

2.3 EVALUATION PROCEDURES

The aim of the training school is to produce a qualified observer whose judgment of plume density will be accurate and unaffected by variable field conditions. To ensure uniformity of observing conditions, as far as is possible, the following procedures should be adhered to:

a. The sun should be within a 140° sector behind the observer during daylight hours. This avoids the problems arising from the forward scattering of light by the particles in the plume.

b. Reading should be made at right angles to the plume direction, and from any distance necessary to obtain a clear view of the stack and background.

c. Readings should be taken at the densest part of the plume i.e., through the center of the plume immediately above the stack exit.

d. The student should, if possible, read the plume against a contrasting background, such as blue sky for black plumes or a dark background for white plumes.

e. The student should not stare at the plume, since staring at the plume tends to cause eye fatigue which produces erroneous readings.

f. An indication will be given by the examiner to the students to inform them when a reading should be taken. This will usually be the sounding of a horn. When the horn is sounded the student should look up at the plume and make the opacity determination as soon as possible.

   Usually the control settings on the smoke generator will not be changed for a few seconds after the horn has sounded but the opacity can vary slightly even though the control settings remain unchanged. For this reason it is good practice for the student to look at the plume and take the reading immediately when the horn is sounded, since the time taken to accomplish this is approximately the same as the time taken by the smoke to travel from the transmissometer location to the stack exit. The two readings are therefore taken through approximately the same cross-section of smoke.

g. Readings will be taken when the opacity, as determined by the transmissometer readout, has stabilized, which will be about every 15 seconds.

The operator of the generator decides when the opacity, as given by the transmissometer readout, is constant and will sound the horn to indicate that the reading should be taken. The control settings will remain constant for a few seconds after which another control setting will be selected for the next reading.

If the local agency permits it, the student may use small, hand-held Ringelmann Charts or other aids as guides in judging the black and gray shades. However, it is recommended that the student not use any of these aids, since within a very short period of time the student will gain sufficient confidence in his ability in making the observations that these aids will become of no significant benefit.

If the student wishes to be qualified as a certified smoke reader under nighttime conditions a separate test must be taken. For nighttime reading a light source is required and the student should be positioned such that the light is immediately behind the plume. However, at this time EPA does not have any approved procedures for evaluating plume opacity under nighttime conditions.

Table 2.1: THE BEAUFORT SCALE OF WIND-SPEED EQUIVALENTS

General Description	Specifications	Limits of Velocity 33 feet (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 wind.	32 to 38
	Breaks twigs off trees; generally impedes progress.	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

nearest 5 percent. The lowest possible reading is 0 - indicating a clear plume - and the highest is 100 - indicating a completely opaque plume.

After the 50 evaluations have been made the form is checked by a fellow student. The opacity as determined by the transmissometer is entered in the "Transmissometer Reading" columns, and the rest of the form is then completed.

2.5 CERTIFICATION PROCEDURE

The smoke opacity evaluation training requires that the student must observe and successfully evaluate the opacity for a run of 50 consecutive smoke emissions - 25 of black smoke, and 25 of white smoke - in accordance with the EPA certification procedures.

The current criteria are:

1. The deviation of any reading must not be greater than 15%.
2. The average deviation for both the black and white smoke runs must be less than 7.5%.

A Smoke School Qualification Form similar to the one shown above in Figure 2.1 is to be used to record the readings and deviations, and to compute the information required for qualification.

Initially there will be some emissions of both black and white smoke during which time the opacity will be announced while the smoke is being emitted, so that the student can become familiar with the procedures and learn to correlate his observations with the announced readings. After the familiarization period, there will be at least one practice run of 50 emissions.

Following the practice run, there will be certification runs of 50 emissions (25 black and 25 white). To qualify as a certified visible emissions evaluator the student must achieve the criteria given above, i.e., average deviation less than 7.5% and no deviation greater than 15%, for both the black and white smoke.

After the qualification criteria have been achieved the student should ensure that the form has been completely filled in. The student should also check the transmissometer readings on the form against the actual transmissometer readings recorded by the examiner, which will be on display expressly for this purpose. It is also recommended that the student check the arithmetic on the form. The reasons for these checks are to find any errors in transcription or arithmetic that might have occurred, which would preclude the student from qualifying, even though the student believes in good faith that the qualification criteria have been met.

After the student has checked and completed the form he submits it to the examiner, who will check all the data and the arithmetic on the qualification form. To those students who successfully meet the qualification criteria, the examiner will send written affirmation in the form of a letter, together with a copy of the student's qualification form. An example of this letter is shown in Figure 2.2.

The original of the completed qualification form is retained by the examiner in his office, so that it may be available for presentation in any future legal proceedings that may occur, as evidence that the inspector has been certified as a qualified visible emissions evaluator by a recognized air pollution agency.

The certification is valid for a period of six months.

2.6 APPRENTICESHIP PERIOD

Under the Method 9 procedures an inspector becomes a fully qualified visible emissions evaluator as soon as he has attended a "Smoke School" and met the certification criteria. However, it is suggested that before he is regarded as being fully-qualified the newly-certified inspector should demonstrate his ability to satisfactorily evaluate visible emissions in the field during an "apprenticeship period" under the guidance and supervision of an experienced inspector.

Since this apprenticeship period is not part of the current EPA procedures there are no specific guidelines that should be adopted, but it is suggested that during this period the trainee inspector should perform about ten field evaluations on plumes of various colors, and if possible, on at least one plume containing condensed water vapor.

The purposes of the apprenticeship period are to demonstrate to the

ENVIRONMENTAL PROTECTION AGENCY
RESEARCH TRIANGLE PARK, NORTH CAROLINA 27711

April 30, 1975

Mr. Kenneth B. Malmberg
U.S. EPA, Region V
1 North Wacker Driver
Chicago, Illinois 60606

Dear Mr. Malmberg:

Please be advised that you successfully completed our recent "Visible Emissions Evaluation" course. Having attended the lectures (April 8, 1975) and participated in the smoke evaluation sessions, you met the following certification criteria:

1. The average deviation for the sets of 25 black smoke and 25 white smoke emissions was less than 7.5%.

2. The deviation of each reading was 15%, or less.

This certification is valid until October 7, 1975.

Sincerely yours,

Dennis P. Holzschuh
Physical Science Technician
Engineering and Enforcement Section
Air Pollution Training Institute

Figure 2.2: CERTIFICATION LETTER

supervisor of the Inspection Department that the trainee inspector is not only capable of evaluating a wide variety of sources under various weather conditions, but is familiar with the field equipment and the data reduction procedures.

2.7 RECERTIFICATION PROCEDURE

To become recertified it is not necessary for the inspector to attend the lecture program again - achieving the certification criteria on the emissions evaluation test is sufficient. Otherwise, the procedures are identical to those described above in the preceding sections.

It is recommended that even after an inspector has successfully met the criteria, that he continue to make evaluations of the opacity of the emissions to gather additional experience and improve his accuracy. The results of these evaluations need not be given to the examiner.

After becoming recertified the inspector is qualified to determine the opacity of visible emissions for a period of six months from the date of the test.

2.8 SMOKE GENERATOR

2.8.1 DESCRIPTION

In order to train personnel to evaluate visible emissions, it is necessary to have a system which will produce both black and white plumes, and is equipped with an instrument for measuring and recording the amount of light transmitted by the smoke. Several companies are now manufacturing these devices, and at least one smoke generator is now available for training purposes in most states.

White smoke is usually generated by vaporizing fuel oil in the exhaust manifold of a gasoline engine, and black smoke is generated by burning benzene in a combustion chamber.

2.8.2 SPECIFICATIONS

The specifications for the smoke generator are given in the Method 9 procedures published in the Federal Register. The current Method 9 procedures are given in Section 12 of this manual.

2.9 BIBLIOGRAPHY

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3. PROCEDURES FOR EVALUATING VISIBLE EMISSIONS IN THE FIELD

3.1 INTRODUCTION

This chapter outlines the steps to be followed to satisfactorily evaluate visible emissions in the field. Recommended guidelines are included for the collection of all information that is necessary to document a violation of the opacity regulation and for use in any subsequent legal proceedings.

3.2 OFFICE PREPARATION

In most instances the inspector will have sufficient notice before making a field observation to adequately prepare for the visit. Preparation is a very important aspect of the inspector's work. The following items concerning the facility in question should be researched.

a) Plant location
b) Names and positions of responsible plant contacts (company officers or management personnel)
c) Type and number of processes
d) Type of process to be observed
e) Process operating conditions
f) Type and location of control equipment
g) Probable location of source emissions
h) Possible observation sites
i) Regulations applicable to the source
j) Status of source with respect to any variance or exemption from the agency's rules and regulations. Observation is not required if the source is on a variance, or exempt from the regulations.
k) Involvement of steam plume, if any. The procedure in the "Condensed Water Vapor Plume" section will indicate if a steam plume might be present, and could indicate a time of day when a steam plume might not be present.

Familiarity with the opacity regulations, and the regulation exemptions will help to prevent an inspector from documenting what he perceives to be a violation when in actuality it is not. For example, although Colorado regulations state that an opacity greater than 20% constitutes a violation, a source may emit visible emissions of 40% opacity for 3 minutes out of 60 minutes if it is undergoing process modification, start up, cleaning, etc.

The recommended procedure is to determine a violation regardless of plant operation (e.g. for Colorado, an emission greater than 20% for any time period greater than 3 minutes would constitute a violation). In this way the investigator knows that a documented and enforceable violation has occurred without having to fear a company reporting at a later date that the readings (in the case of Colorado, greater than 20%, but less than 40% opacity) cannot be utilized because the plant was undergoing a process change at the time of the visible emission evaluation.

3.3 FIELD EQUIPMENT

The following equipment should be available for use by the observer:

a) Hard hat
b) Stopwatch
c) Clipboard, note pad and at least two pens (Pencils must not be used for recording opacity readings).
d) Geologist's compass
e) Air velocity meter
f) Range finder
g) Psychrometer
h) Binoculars
i) Camera
j) Topographic maps
k) Necessary forms, including ample spare copies:
   1. Observation Form
   2. Summary Form
   3. Sketch Form and Data Sheet, if standard formats are used.
l) Safety goggles
m) Safety shoes
n) Respirator face mask
o) Pouch, to carry the equipment

NOTE: Items l, m and n are required only if site conditions warrant their use.

The equipment should be inspected in the office before going out on a field observation in order to ensure that it is in good working order.

3.4 OBSERVER'S LOCATION

3.4.1 GUIDELINES

The evaluator should select an observation point consistent with the following guidelines:

1) The line of sight from the source to the observer should be unobstructed.
2) The line of sight should be at right angles to the wind direction.
3) The sun should be oriented within a 140° sector to the observer's back.
4) The location should be safe.
5) If the pollutants are emitted at ground level, the observer should be as close to the source as possible.
6) If the pollutants are emitted from an elevated position, the inspector should be at a suitable distance from the source. (See Section 7.9).
7) With good visibility it is suggested that the observer should be within about a quarter of a mile from the source.
8) When visibility is restricted, the observer should be within a distance that is about one quarter of the visual range.
9) When evaluating emissions from rectangular outlets, the observer should be positioned at right angles to the longer axis of the outlet.

3.4.2 OBSERVATION SITE-OFF COMPANY PROPERTY

If a position can be selected that is not on company property, that meets all the above requirements, the evaluator may begin the field evaluation of the source in accordance with Section 3.5. The inspector should not notify company officials that an evaluation is to be conducted.

3.4.3 OBSERVATION SITE-ON COMPANY PROPERTY

If the evaluator decides that it is not possible to select a suitable point that is not on company property from which to make the evaluation, then the evaluation should be carried out from a location on company property.

If a site can be selected that is on company property, but is accessible to the public, the evaluator may begin the evaluation without notifying company officials.

If, however, a site meeting the criteria given in Section 3.4.1 is on company property, that is not publicly accessible, then the evaluator must obtain permission from a responsible company official to enter the plant. Before notifying the company of the proposed evaluation, however, it is recommended that the inspector take several opacity readings from the best available site off company property. These preliminary readings can then be used as a comparison between stack emissions before and after company notification. If a noticeable change is observed, the inspector should record this fact.

If it is necessary to enter the plant property in order to make the observations, every attempt should be made to ensure management cooperation. Entering a plant, especially for the first time, can present a delicate situation; tact and courtesy are most important considerations under these conditions. The evaluator should follow the steps below to correctly and courteously enter the plant for the purpose of conducting the evaluation.

a) When entering the plant be prepared to state your name, affiliation and position, and have identification available for presentation.

b) State the nature of your visit and request an interview with a company officer or responsible employee of the company.

c) Describe to the company representative the nature of work or duties you intend to perform on the premises and request their permission to do so.

d) Should you meet with refusal, and if attempts to discuss the situation are unsuccessful, contact your office for further instructions.

e) Should you be given permission to proceed to a specific area without escort, ask for directions and go there directly.

f) Spend as little time as possible with entrance procedures so as not to become liable to charges of "interfering with company work."

g) Do not sign any documents, such as liability waivers or others, that are conditions for your presence on the company premises. Discussion between your responsible officer and the plant official are the best means of resolving any problems that might arise in this matter.

h) Maintain a business-like and cordial relationship with company officials and employees at all times.

i) The evaluator should take note of the length of time he is kept waiting, cooperation and attitude of plant personnel, and any changes in operating conditions which may result from his presence. The latter may affect the credibility of the evaluator's findings should he later be asked about these conditions during the presentation of testimony.

j) Record the name, title and telephone number of the company official and note the time that the official was informed that an evaluation was to be conducted.

The inspector's ultimate objective is the improvement of the ambient air quality by ensuring that sources emit pollutants in compliance with the regulations. This objective can be achieved much more readily with the willing cooperation of the company. The visible emissions evaluation affords the inspector an opportunity to engage in some "public relations" work. The inspector should therefore endeavor to maintain a polite, yet professional, attitude while he is on company premises.

3.5 EVALUATION PROCEDURES

3.5.1 OBSERVATION FORMS

Once a suitable observation site has been selected the inspector should begin the evaluation of the source, recording all the pertinent information on an approved set of forms.

Two sets of forms are included in the manual:

1) Those forms that appeared in the Federal Register, Volume 39, No. 219, dated Tuesday, November 12, 1974, and included as Figures 3.1 and 3.2.
2) Suggested alternative forms, included as Figures 3.3 and 3.4.

The forms in the Federal Register represent the approved forms to be used when making a visual determination of opacity at the time this manual was written. Although Method 9, the reference method for visual determination of the opacity of emissions, has been finalized, EPA is still considering additional changes to the observation time, and the method of evaluating exception periods and non-consecutive violations. The forms included as Figures 3.3 and 3.4 have been proposed as possible improvements to the Federal Register forms.

The forms that appear in any subsequent issues of the Federal Register should be used for recording the field data.

3.5.2 TYPES OF OPACITY REGULATIONS

At the present time there are two types of opacity regulations in use. These are based on the following concepts:

FIGURE 3.1 OBSERVATION RECORD PAGE ___ OF ___

COMPANY ____________
LOCATION ____________
TEST NUMBER ____________
DATE ____________

OBSERVER ____________
TYPE FACILITY ____________
POINT OF EMISSIONS ____________

		Seconds				STEAM PLUME (check if applicable)		
Hr.	Min.	0	15	30	45	Attached	Detached	COMMENTS
	0							
	1							
	2							
	3							
	4							
	5							
	6							
	7							
	8							
	9							
	10							
	11							
	12							
	13							
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	15							
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	25							
	26							
	27							
	28							
	29							

OBSERVATION RECORD PAGE ___ OF ___
(Continued)

COMPANY ____________
LOCATION ____________
TEST NUMBER ____________
DATE ____________

OBSERVER ____________
TYPE FACILITY ____________
POINT OF EMISSIONS ____________

		Seconds				STEAM PLUME (check if applicable)		
Hr.	Min.	0	15	30	45	Attached	Detached	COMMENTS
	30							
	31							
	32							
	33							
	34							
	35							
	36							
	37							
	38							
	39							
	40							
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	57							
	58							
	59							

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FIGURE 3.2
RECORD OF VISUAL DETERMINATION OF OPACITY

PAGE___ of___

COMPANY____________________
LOCATION____________________
TEST NUMBER____________________
DATE____________________
TYPE FACILITY____________________
CONTROL DEVICE____________________

HOURS OF OBSERVATION____________________
OBSERVER____________________
OBSERVER CERTIFICATION DATE____________________
OBSERVER AFFILIATION____________________
POINT OF EMISSIONS____________________
HEIGHT OF DISCHARGE POINT____________________

	Initial			Final
CLOCK TIME				
OBSERVER LOCATION Distance to Discharge				
Direction from Discharge				
Height of Observation Point				
BACKGROUND DESCRIPTION				
WEATHER CONDITIONS Wind Direction				
Wind Speed				
Ambient Temperature				
SKY CONDITIONS (clear, overcast, % clouds, etc.)				
PLUME DESCRIPTION Color				
Distance Visible				
OTHER INFORMATION				

SUMMARY OF AVERAGE OPACITY

Set Number	Time	Opacity	
	Start--End	Sum	Average

Readings ranged from ____ to ____ % opacity

The source was/was not in compliance with ____ at the time evaluation was made.

Figure 3.3: VISIBLE EMISSION OBSERVATION FORM

Source Name ______________________ Observer ______________________

Address ______________________ Date ______________________

Observation Point: ______________________

Stack: Distance From ____ Height ______

Wind: Speed ________ Direction ______

Sky Condition: ______________________

Color of Emission: ______________________

Ambient Temp: Dry Bulb ______ °F
Wet Bulb ______ °F

Relative Humidity: ________

Observation began ______ Ended ______

Observer's Signature:

Certification Date: ______________________

Comments:

	0	15	30	45		0	15	30	45
0					30				
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				
16					46				
17					47				
18					48				
19					49				
20					50				
21					51				
22					52				
23					53				
24					54				
25					55				
26					56				
27					57				
28					58				
29					59				

Figure 3.4: RECORD OF VISUAL DETERMINATION OF OPACITY Page ____ of ____

COMPANY ______________________	HOURS OF OBSERVATION ______________________
LOCATION ______________________	OBSERVER ______________________
TEST NUMBER ______________________	OBSERVER CERTIFICATION DATE ______________________
DATE ______________________	OBSERVER AFFILIATION ______________________
TYPE FACILITY ______________________	POINT OF EMISSIONS ______________________
CONTROL DEVICE ______________________	HEIGHT OF DISCHARGE POINT ______________________

NOTE: Record the following information prior to, and upon completion of, observations at each source. If observations are made over an extended period of time, additional recordings should be made, as applicable

	Initial			Final
Clock Time				
OBSERVER LOCATION: Distance to Discharge (ft.)				
Direction from Discharge				
Height of Observation Point (ft.)				
METEOROLOGICAL CONDITIONS: Ambient Temp (^{o}F) Dry Bulb/Wet Bulb	/	/	/	/
Relative Humidity %				
Wind Direction				
Wind Speed (mph)				
SKY CONDITIONS: % Cloud Cover				
PLUME DESCRIPTION: Color				
Distance Visible (ft.)				
Other data				

SUMMARY OF READINGS

Opacity	0-20	21-30	31-40	41-60	61-80	81-100	Total
No. of Readings							
Frequency %							

Readings over ____%. Average Opacity = ______%

Readings ranged from _____ to ______% opacity.

Opacity exceeded ____% for ____mins____secs.

Regulation:

a) Opacity is to be averaged over a specified time period--six minutes in the current Method 9 procedures--and this average opacity is compared to the regulation limit.

b) There is no need to average the observed opacities--any observed opacity that is greater than the regulation limit constitutes a violation.

Usually the opacity regulation will permit the source to emit visible emissions greater than the regulation limit for a specified time interval--often this exemption period is three minutes in a one hour period.

Figures 3.1 and 3.2 are used if the "average opacity" concept is employed.

Figures 3.3 and 3.4 are used if the "time" concept is employed.

3.5.3 OBSERVATIONAL DATA

The inspector should begin the evaluation by recording the source identification parameters, site location and ambient weather conditions on the observation forms, Figures 3.1 and 3.2, or Figures 3.3 and 3.4.

A photograph of the source should be taken at this point.

3.5.4 PROCEDURES FOR READING STEAM PLUMES

This section describes procedures for reading steam plumes. The nature of steam plumes is treated in detail in Volume II. Chapter 5 treats the sources of steam plumes, how they can be eliminated and how to use a psychrometric chart.

3.5.4.1 ATTACHED STEAM PLUMES

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

3.5.4.2 DETACHED STEAM PLUMES

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

3.5.4.3 RECORDING PRESENCE OF STEAM PLUMES

If the forms in the November 12, 1974 Federal Register, Figures 3.1 and 3.2, are used, a check mark should be placed in the appropriate box to denote the presence of a steam plume.

If the suggested alternative forms, Figures 3.3 and 3.4 are used, a note indicating the presence of an attached or detached steam plume should be made in the "Comments" section.

3.5.5 RECORDING OBSERVATIONS

Observations should be made at the point of greatest opacity in that portion of the plume where condensed water vapor is not present. The observer should not look continuously at the plume, since this can lead to eye fatigue, but instead should observe and evaluate the plume momentarily at 15-second intervals.

3.5.6 NUMBER OF READINGS

In order to meet the requirements of EPA method 9, the required number of readings is as follows:

1) In all cases, a minimum of 24 readings must be taken corresponding to six minutes of observation.
2) In cases where the regulation permits an exemption period for excess emissions, a minimum of 24 observations must be recorded over and above the number of readings equal to the permissible exemption period. For example, if the regulation permits 3 minutes of excess emissions in any hour, a minimum of 12 readings (3 minutes) plus 24 readings (6 minutes) must be recorded. That is, a total of 36 readings (9 minutes) must be recorded in order to establish a single six-minute average for that hour.

While it is a simple matter to establish the minimum number of readings necessary to meet the requirements of Method 9, it is not a simple matter to establish the number of readings necessary to document an enforceable violation of the opacity regulations. Whether there is sufficient proof that a violation did occur will depend upon the amount of evidence collected in the field. The more readings above the regulation limit that are observed, the stronger will be the ensuing case if the results of the evaluation are used as evidence at any subsequent legal proceedings.

Some guidelines to aid in this matter are given below:

3.5.6.1 GUIDELINE 1:

In most cases, the amount of evidence that should be regarded as the minimum necessary to document an enforceable violation should consist of at least one set of 24 readings with an average opacity of at least 10% above the regulation limit.

3.5.6.2 GUIDELINE 2:

Concerning regulations based on actual opacity instead of average opacity, it is recommended that before legal proceedings are initiated, the observed opacity should exceed the regulation limit by at least 10% for at least three minutes in any hour; this is in addition to any exemption time period that may be permitted for excess emissions.

3.5.6.3 GUIDELINE 3:

Weather conditions during the observation period should be taken into account when considering the number of observations and the degrees of excess emissions necessary to document a violation. Tests conducted by EPA (See Section 7.5), indicate that the possibility of a positive bias is greatest when a contrasting background is used (i.e. - white plume, blue sky). In a similar manner when a noncontrasting background is used (i.e. - white plume, overcast sky) the possibility of a negative bias is greatest. In fact, the test results indicate that the chance for positive error in determining the opacity of white plumes is essentially non-existent when a noncontrasting background is present. This should be taken into consideration when the inspector is determining the amount of data needed to verify a violation.

3.5.6.4 GUIDELINE 4:

The actual opacity of emissions from the source can be used as a further guideline in determining the number of readings that are necessary, e.g. if the opacity of the emissions is 100% an observation time of six minutes in excess of the exemption period should be sufficient evidence to ensure that the violation could be enforced. If, however, the opacity of the emissions averages about 30%, in those areas where the regulation limit is 20%, considerably more readings would be necessary.

3.5.7 SKETCH

A reasonably detailed sketch should be drawn. It should include sufficient detail to allow a person who has not visited the site to determine the source that was evaluated and the location of the observation point. The sketch should depict:

Source Location
Observer Location
Distance from observer to source
North direction
Wind direction - from which wind is blowing
Sun position
Landmarks and nearby streets
Plume type
Distance plume visible

An example of a sketch is shown in Figure 3.5.

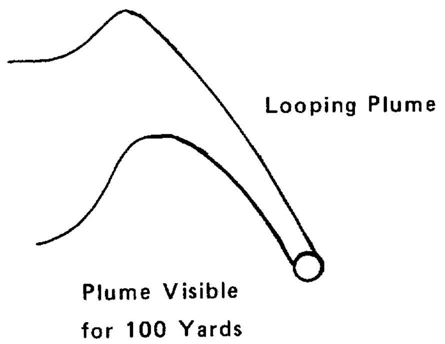
3.5.8 PHOTOGRAPHS

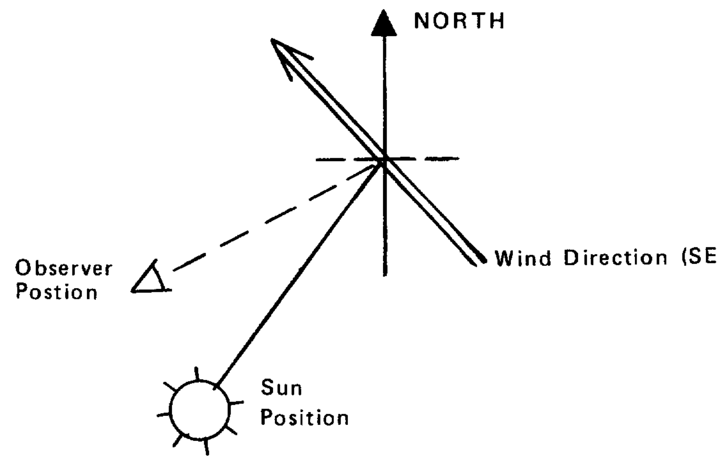
Photographs should not be taken during the observation period. They should be taken before and after the observation is made. Even though photographs cannot be used as evidence in court, they do put on permanent record conditions as they existed at the time of the observation. The use of a 35 mm - type camera is recommended, so that good photographs are ensured.

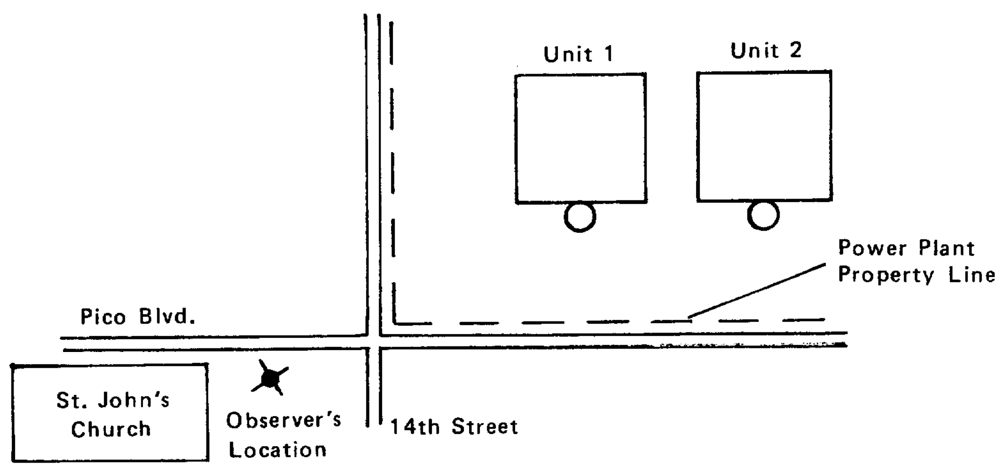
Each photograph should be identified - including such information as date and time the photograph was taken, the source and the position from which the photograph was taken.

FIELD SKETCH

Date:	November 1, 1974
Time:	1400–1500
Observer:	Robert Missen
Source:	CGE Power Plant
	Unit 1, Santa Monica, Calif.







Comments: No steam plume visible

Observation made from St. John's Church parking lot.

Figure 3.5: FIELD SKETCH

3.5.9 NUMBER OF OBSERVERS

Only one inspector should evaluate a given source during any given period of time. In cases where the source is continually evaluated and reevaluated over extended periods of time (days and months), it is acceptable, indeed preferable, to have different inspectors perform the evaluations.

3.5.10 DATA REDUCTION

3.5.10.1 DATA REDUCTION - "AVERAGE OPACITY" CONCEPT

Opacity is determined as an average of all the readings taken over a time period corresponding to the applicable standard. For example, for a six minute standard, the opacity is defined as the average of a "set" of any 24 consecutive readings taken over a six minute period at 15 second intervals. The observations recorded on the observation record sheet, Figure 3.1 are divided up into sets of 24 consecutive readings and the average opacity for that set is determined by dividing the sum of the readings by 24.

The sum and average opacity for each set is entered in the "Summary of Average Opacity" table in Figure 3.2. The sets need not be consecutive in time, but in no case should two sets overlap.

3.5.10.2 DATA REDUCTION - "TIME" CONCEPT

The opacity readings recorded on Figure 3.3 should be summarized by completing the items on the right hand side of Figure 3.4.

3.6 SOURCE INSPECTION

After the visual observation has been made, whether from a location inside or outside the plant property, an inspection of the source that was evaluated, should be made. To do this, the highest ranking official of the company, who is readily available, should be contacted.

At all times during the inspection the inspector should maintain a business-like relationship with company personnel. If requested by the company representative, the inspector may give a brief discussion of the purposes of the opacity evaluation.

The inspector should not under any circumstances indicate whether a violation of the regulations was observed, and indeed at the time of the inspection a determination of whether a violation was observed will not have been made, since the information on Figures 3.3 or 3.4 has to be completed before such a determination can be made.

During the inspection, information concerning the source should be obtained from the company official. This information can be obtained by asking such questions as:

1) Were the plant and the source of interest operating normally at the time the evaluation was conducted?
2) Are there any control devices associated with the source? Were they operating properly?
3) When were the source and its control devide installed or modified?

Since an inspection report has to be written after the evaluation has been made, the relevant information about the source should be collected and recorded in a standard format. A data sheet similar to Figure 3.6 should be used to record this information.

3.7 BIBLIOGRAPHY

1. Lucas.M, The Objective Calibration and Air Pollution Significance of Ringelmann Numbers, Atmos. Env., pp. 775-780. 1972.
2. Marks, L.S. Inadequacy of the Ringelmann Chart, Mech. Eng., p. 681. 1973.
3. Stein, A. Guide to Engineering Permit Processing, APTD-1164, EPA Office of Air Programs. 1972.
4. Weisburd, M.I. Field Operations and Enforcement Manual for Air Pollution Control. Volume I: Organization and Basic Procedures, APTD-1100, EPA Office of Air Programs. 1972.
5. Weisburd, M.I. Field Operations and Enforcement Manual for Air Pollution Control. Volume II: Control Technology and General Source Inspection, APTD-1101, EPA Office of Air Programs. 1972.
6. Weisburd, M.I. Field Operations and Enforcement Manual for Air Pollution Control. Volume III: Inspection Procedures for Specific Industries, APTD-1102, EPA Office of Air Programs. 1972.
7. Yocum, J.E. Problems in Judging Plume Opacity, J. Air Poll. Control Assoc. 13, 36-39. January 1963.

VISIBLE EMISSIONS EVALUATION DATA SHEET

OBSERVER: ____________________

DATE: ____________________

COMPANY DATA

COMPANY NAME: ____________________

COMPANY ADDRESS: ____________________

COMPANY CONTACT: ____________________ TELEPHONE: ____________________

SOURCE DATA

SOURCE IDENTIFICATION: ____________________

APPLICABLE REGULATION: ____________________

OPERATING RATE: ____________________

NORMAL OPERATING RATE: ____________________

CONSTRUCTION/MODIFICATION DATE: ____________________

CONTROL SYSTEM DATA

TYPE: ____________________

DESIGN EFFICIENCY: ____________________

INSTALLATION DATE: ____________________

COMMENTS: ____________________

____

____

____

Figure 3.6: INSPECTION DATA SHEET

4. SOURCES OF VISIBLE EMISSIONS

4.1 INTRODUCTION

This chapter is divided into two main sections. The first section covers emissions from non-stack sources, for example, coke ovens and equipment used for handling various kinds of materials. The second section briefly outlines many of the sources that emit visible emissions from stacks.

The chapter presents a review of most of the major sources of visible emissions commonly encountered on field inspections. Because an industry or a specific source has not been reviewed,this should not be taken as an indication that the industry or source does not present a problem as far as visible emissions are concerned.

4.2 PROCEDURES FOR NON-STACK EMISSION SOURCES

Many sources of emissions are common to several industries. These include, for example, roof monitors on buildings, crushers, conveyors, screening operations, storage piles, etc. Other sources are specific to any given industry such as coke ovens in the steel industry.

4.2.1 ROOF MONITORS

Many sources of visible emissions simply vent into the building, particularly if there are a large number of small point sources, and the emissions are allowed to escape into the atmosphere through an opening in the roof.

Figure 4.1 is a sketch of a roof monitor showing the emission points.

Evaluations should be made at the point of densest emissions, from a position at ground level that is approximately perpendicular to the longer axis.

In connection with the current trend for tightening the existing air pollution regulations, some agencies are not only observing the emissions from the roof monitor, but are also making observations of individual point sources from positions within the building. This procedure, however, depends on strict interpretation of local definitions of "atmosphere". This practice is not currently followed by EPA.

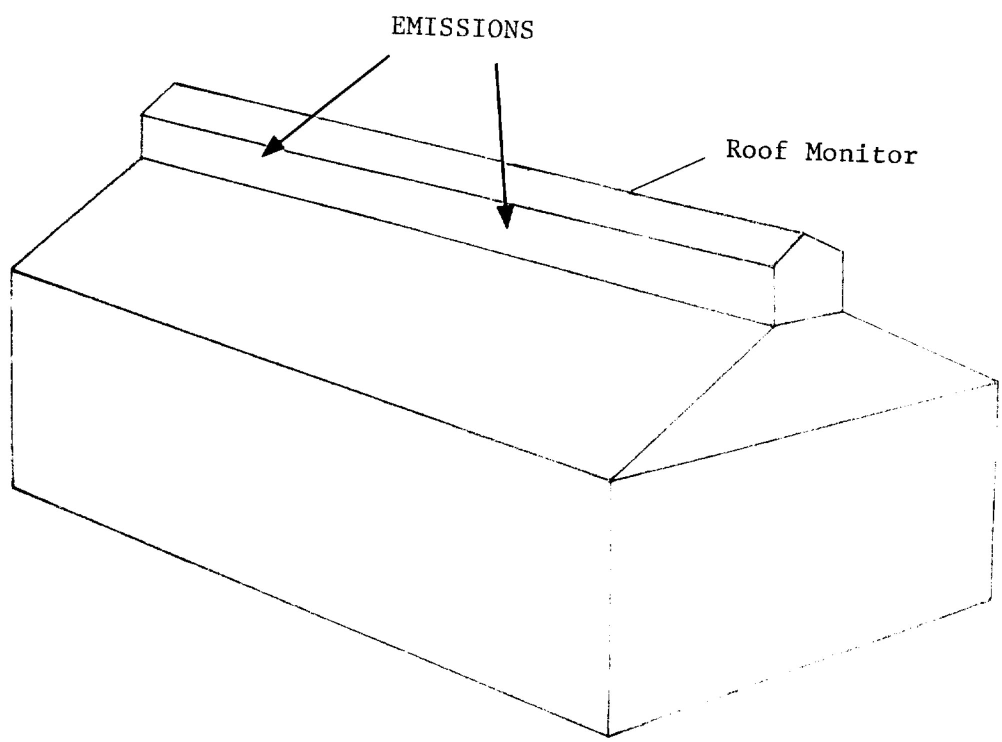


Figure 4.1: ROOF MONITOR EMISSIONS

4.2.2 MATERIAL HANDLING OPERATIONS

Although the material may vary, the processes involved in the handling of many diverse substances remain essentially similar. These processes include drilling, crushing, conveying, screening and stockpiling operations from the following industries:

- rock, sand and gravel handling
- dry concrete batching plants
- deep hopper grain unloading
- grain drying
- woodworking plants
- abrasive cleaning operations
- coal preparation plants
- fertilizer plants
- lime plants
- mining operations

4.2.2.1 DRILLING

Emissions from drilling operations are evaluated as they are released from the drilling device or the drill hole at a safe distance (30-40 feet) from the drilling machine. See Figure 4.2a.

4.2.2.2 CRUSHING

Emissions are released as material is discharged from the primary and secondary crushing machines. Observations should be performed at a safe distance (e.g. 10-15 feet) from the discharge point, and at the same elevation as the discharge, if possible. See Figure 4.2b.

4.2.2.3 CONVEYING

Visible emissions should be evaluated as material is discharged at conveyor belt loading and transfer points. Evaluation should be made at the same elevation as the discharge, if possible. See Figure 4.3a.

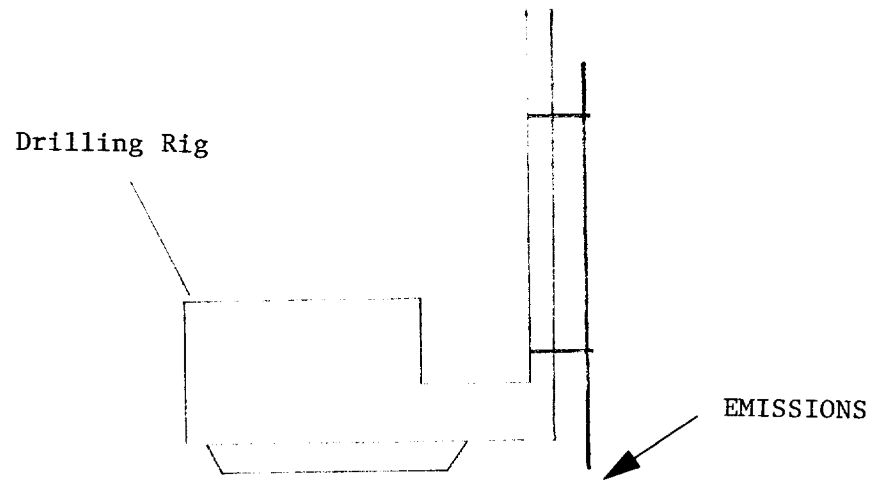


Figure 4.2a: ROCK DRILLING EMISSIONS

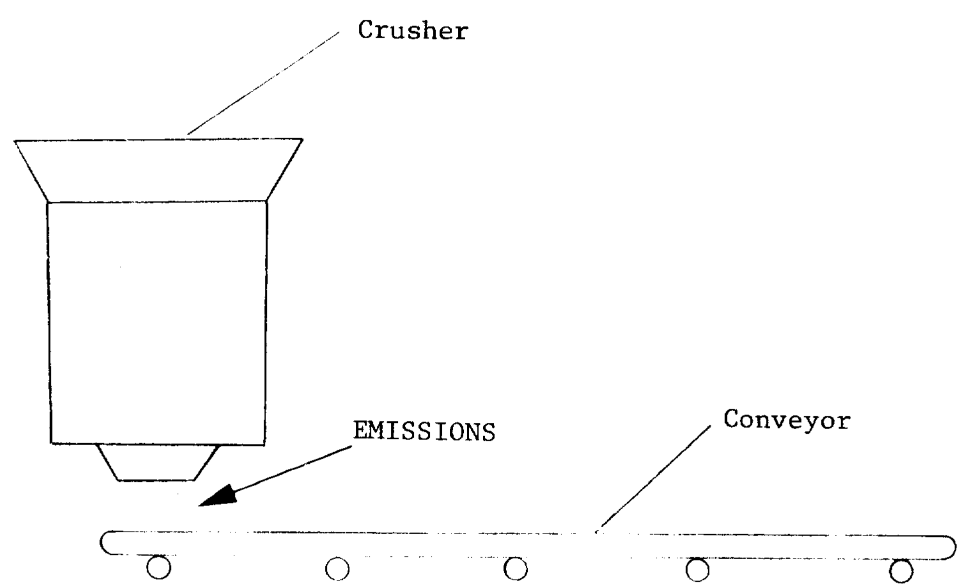


Figure 4.2b: CRUSHING EMISSIONS

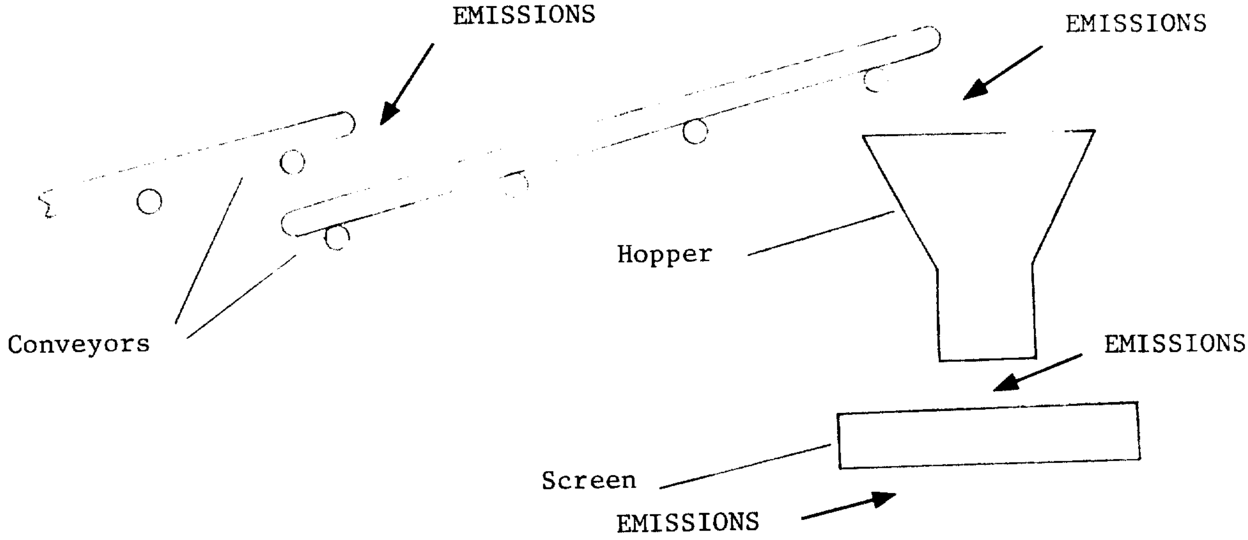


Figure 4.3a: CONVEYING-SCREENING EMISSIONS

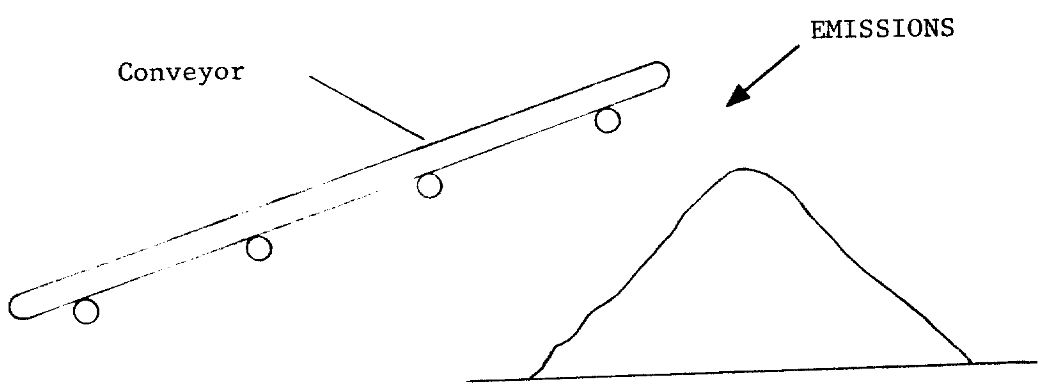


Figure 4.3b: STORAGE EMISSIONS

4.2.2.4 SCREENING

Visible emissions should be evaluated as material is discharged from the screen into the chute. The observer should maintain an observation point as close to the elevation of the screens as possible. See Figure 4.3a.

4.2.2.5 STOCKPILING

Emissions occur as material is dumped from the conveyor onto the storage pile. Observations should be made from ground level. See Figure 4.3b.

Usually visible emissions from stockpiles are not performed and this source may be governed by the fugitive emission regulation rather than the opacity regulation. Emissions from stockpiles are a possible source to be evaluated, however.

4.2.3 COKING OPERATIONS

These operations are found mostly in conjunction with the iron and steel industry. Emissions of smoke and particulate matter occur during charging and pushing operations, from leaks in the system and from storage piles. Charging and pushing are generally the most serious problems.

4.2.3.1 CHARGING OPERATIONS

During charging, emissions emanate from:

a) charging holes
b) larry car hoppers
c) larry car control systems
d) standpipes

Figure 4.4 is a sketch of the top of a typical coke oven showing these features. Emissions from these sources should be evaluated from a position on top of the battery, in which case a respirator is essential.

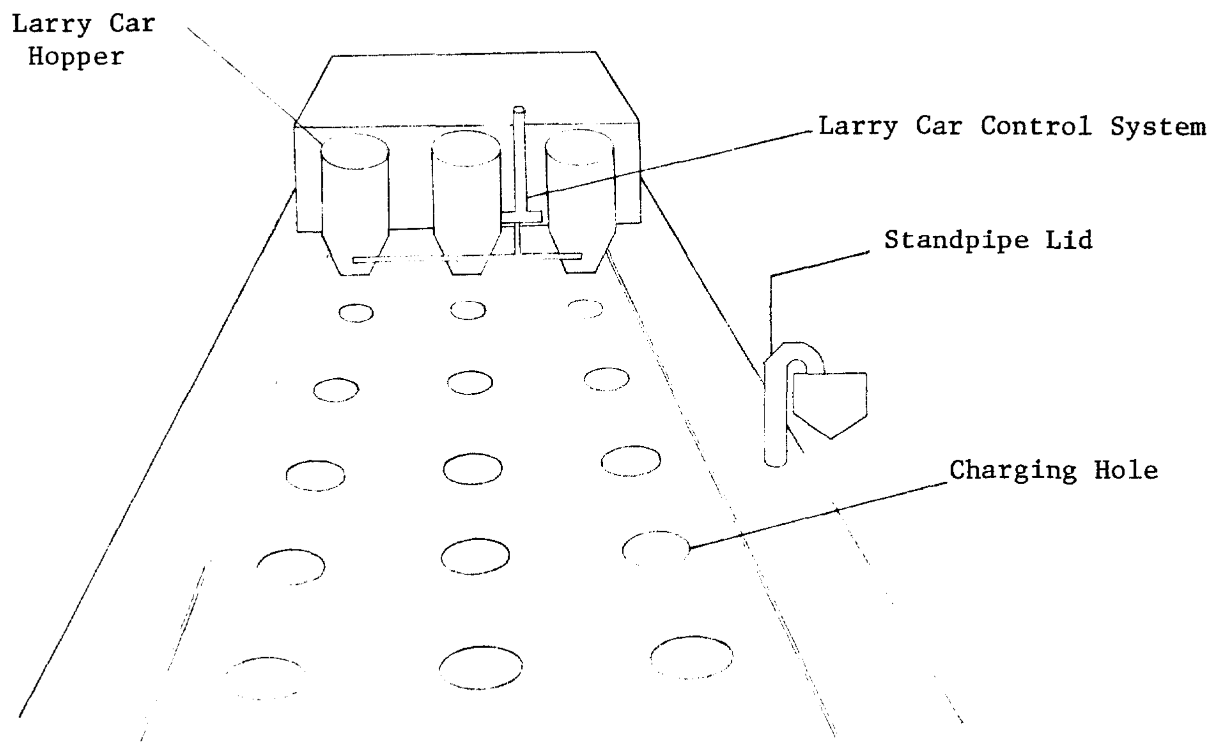


Figure 4.4: TOPSIDE VIEW OF COKE BATTERY

4.2.3.2 PUSHING OPERATIONS

During pushing, the emissions are to be read while the door is in the open position. Observations should be made from a ground level position on the coke side of the battery, using the sky as the background. Figure 4.5 shows a sketch of the ovens during the pushing operation.

4.2.33 DOOR LEAKAGE

Leakage can occur from both the leveler door and the coke oven door. Emissions should be evaluated after the doors are closed and until emissions diminish, from a ground level position, using the battery structure as the background. Figure 4.6 is a sketch of the ovens with the doors closed.

4.2.3.4 STORAGE

When finished coke is stored in piles large quantities of windblown dust can cause emission, as well as nuisance, problems.

REFERENCES:

1. Weisburd, M.I. Field Operations and Enforcement Manual for Air Pollution Control. Volume II: Control Technology and General Source Inspection. APTD-1101, Section 7.5. EPA Office of Air Programs. 1972.

2. EPA. Compilation of Air Pollutant Emission Factors. AP-42, Section 7.2. EPA, Office of Air and Water Programs. 1973.

4.3 PROCEDURES FOR SPECIFIC STACK EMISSION SOURCES

4.3.1 POWER PLANTS, REFINERY HEATERS, BOILERS AND MISCELLANEOUS FUEL BURNING EQUIPMENT

This type of equipment generally only represents an opacity problem while burning liquid or solid fuels without an adequate control system. Fuel oils of greater than 0.5% sulfur content, coal and hogged fuel or sawdust will usually creater opacities of greater than 20% and mostly in the 30-50% range. As ash is formed, it clings to the tubes and is a deterrent to efficient heat transfer. Hence, an operation called "soot-

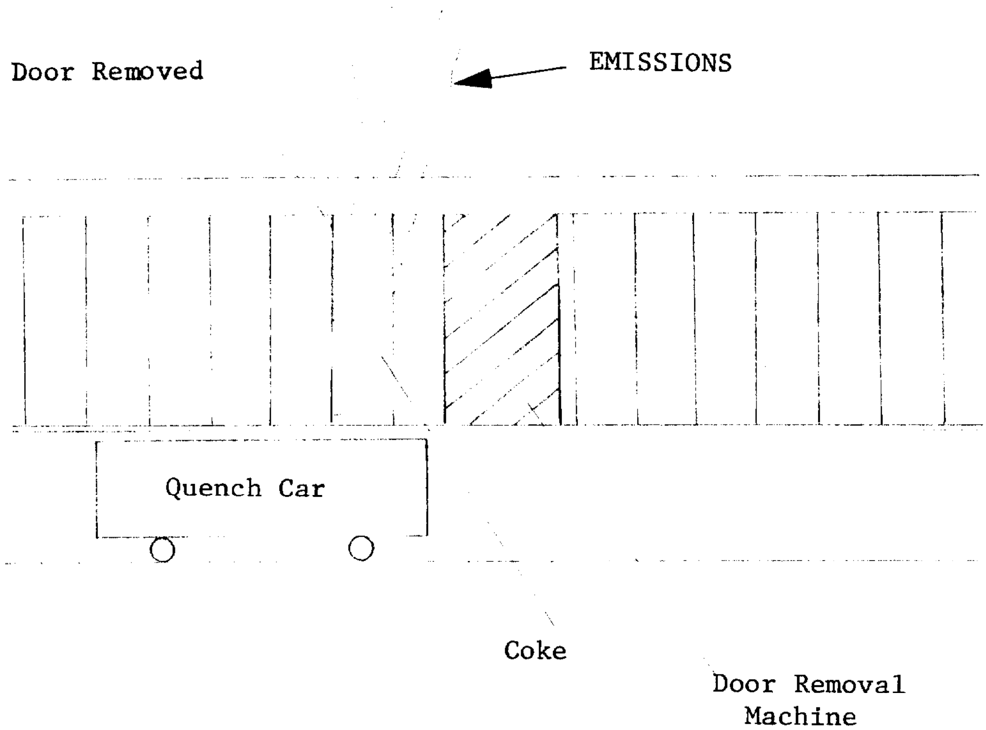


Figure 4.5: VIEW OF OVENS FROM COKE SIDE DURING PUSHING OPERATIONS

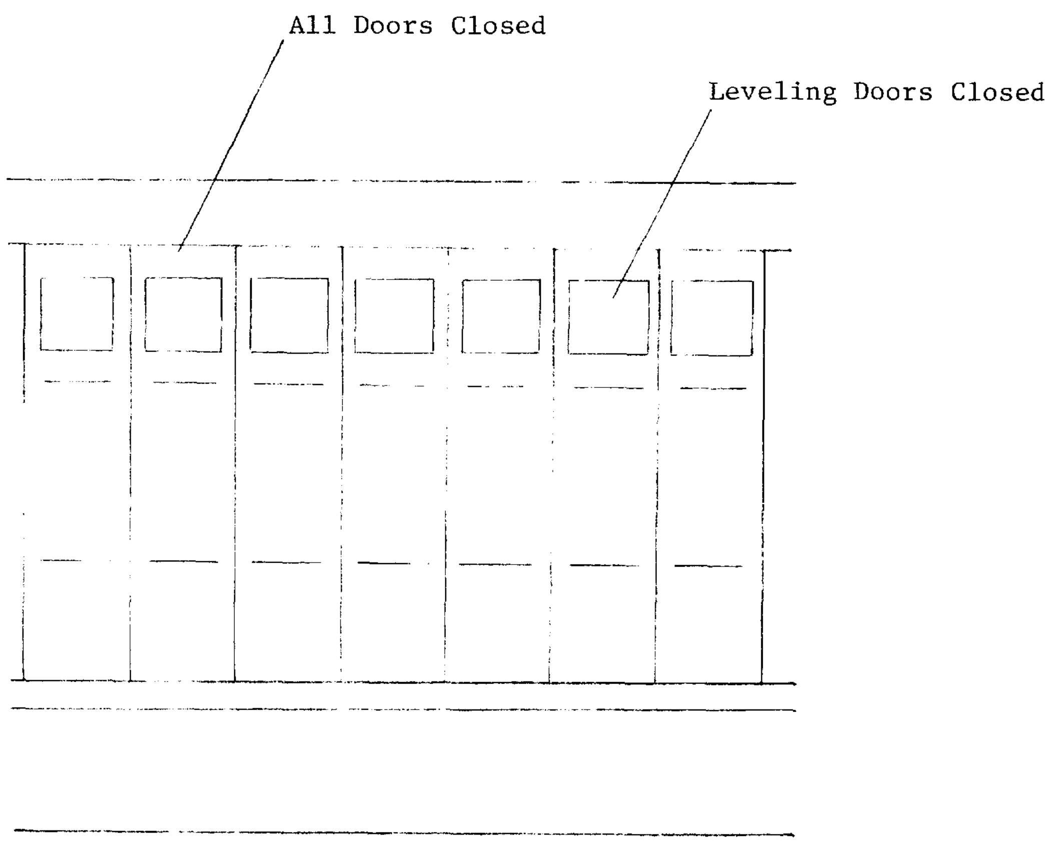


Figure 4.6: VIEW OF OVENS FROM PUSH SIDE

blowing" must be performed periodically to remove the ash deposit. This is done with air or steam jets from retractable lances and the operation tends to increase the opacity of the plume. If a detached plume exists, this indicates that SO_3 is reaching its dew-point at some small distance downstream from the lip of the stack, and the plume must be evaluated at the point that the acid mist plume becomes visible.

Orchard heaters for agricultural purposes are generally under a separate category of regulation and are limited to an approved type of equipment which can operate fairly cleanly. The old "smudge-pots" and rubber tires for this purpose are no longer used.

Observations are to be made from ground level according to the usual procedures for evaluating stack emissions.

REFERENCE:

Weisburd, M.I. Field Operations and Enforcement Manual for Air Pollution Control. Volume II: Control Technology and General Source Inspection. APTD-1101, Section 6.2. EPA, Office of Air Programs. 1972.

4.3.2 REFINERIES

In addition to the numerous boilers and heaters in refineries, the main sources of visible contaminants are: coking and coke-handling operations; catalyst regenerators and catalyst-handling equipment; incinerators or flares as they are commonly called; brightening operations; hot asphalt loading operations; asphalt air-blowing and grease-compounding.

Coking is usually done batch-wise in large vessels. During the heating cycle the gases vent off into a closed system. At the end of the cycle, the quench is made by filling the vessel with water. The vessel is then opened to remove the coke, usually into a pit. If the quench was not properly made or the level sensors malfunctioned, then heavy visible emissions can be noted when the towers are opened. These emissions will contain condensed water and must be evaluated with this in mind.

The coke is then crushed and conveyed to storage. If allowed to become too dry, visible dust emissions may be a potential problem at every operation and transfer point. The coke is then maintained in either covered storage or in open piles. In the latter case, it is again a potential problem in excessive winds.

To carry the situation further, the coke is then loaded into trucks or rail transportation for transfer to a port and a shiploading operation. Almost all of these handling operations present an emissions problem.

Catalyst regeneration for all the catalytic cracking and reforming processes is performed to restore the catalyst activity by burning off carbon and other contaminants deposited on the surface. Controlled temperature and air rates provide the means. When the air is discharged it contains a considerable amount of catalyst "fines" and even though the kilns are generally constructed to allow the discharge of the flue gases through dry type inertial dust collectors, a sufficient number of small particles carry through to provide a severe opacity problem. Control equipment such as an electrical precipitator is often added and many times the discharge from these devices still represents a problem.

The catalyst handling facilities such as conveyor systems, etc., present the usual dust and opacity problems at all open transfer or discharge points. Systems are varied in construction and operation and must be evaluated during their operational cycle.

The three general types of flares for refinery waste gas disposal are: Elevated flares, ground-level flares and burning pits. The opacity problems occur when smoke is created by virtue of the combustion process being incomplete. When there are inadequate heat values necessary to obtain minimum theoretical combustion temperatures or an inadequate supply of combustion air or an inadequate mixing of the air and fuel, there will be hydrocarbon side reactions with the resultant production of smoke. Steam jets are normally used to inspirate sufficient air and produce the turbulence required for good mixing and a smokeless flame.

Brightening operations is the broad term given to blowing a stream of air through oil containing a slight amount of water dispersed through it. The oil has a cloudy look and it loses sales appeal unless it is "brightened". Thus any air stream discharging from equipment used for this purpose generally contains in addition to the water vapor removed, a certain amount of entrained, finely divided oil droplets. This results in an emissions problem unless some sort of filter or demister is used.

When hot asphalt (normally at a temperature of about 400°F) is loaded into tank cars or trucks an emissions problem arises, if the loading operation is not controlled. The surface of the asphalt is disturbed and exposed to the air as it discharges from the loading spout. The light ends escape as a visible vapor. Opacity readings can usually be made at the loading opening of either the trucks or rail tank cars.

Grease compounding is a rather minor problem but emissions of sufficient opacity to violate certain rules and regulations can be generated. As the temperature is increased, no appreciable emissions occur for the first half of the cycle. At that time some emissions occur and when a final quench is made by adding water at a temperature in the vicinity of 400°F some oil mist droplets as well as condensed water vapor constitute the elements of a fairly dense plume. The condensed water vapor disappears and leaves a residual plume of oil vapor a short distance downwind under normal conditions.

Observations can be made from gound level according to the usual procedures for evaluating stack emissions.

REFERENCES:

1. Los Angeles County APCD. Air Pollution Engineering Manual. AP-40, p. 579-698. EPA, Office of Air and Water Programs. 1973.

2. Weisburd, M.I. Field Operations and Enforcement Manual for Air Pollution Control. Volume III: Inspection Procedures for Specific Industries. APTD-1102, Section 7.6. EPA Office of Air Programs. 1972.

4.3.3 RESIN KETTLES AND VARNISH COOKING KETTLES

Briefly described, this equipment most often is merely a large open-topped kettle in which the ingredients for a polymerized resin or varnish are heated and at certain points in the process, dry dusty ingredients may be added. The chemical reactions taking place at elevated temperatures can cause heavy visible emissions at times. Dumping of the dry ingredients often is an opacity problem also.

Any convenient place from which the emissions can be observed is suitable.

REFERENCE:

Los Angeles County APCD. Air Pollution Engineering Manual. AP-40, p. 701-716. EPA, Office of Air and Water Programs. 1973.

4.3.4 SULFURIC ACID MANUFACTURING

The only major opacity problem from this operation is the SO_3 mist that is emitted in the tail gas from the absorber. SO_3 readily absorbs the moisture that is present in the plume, forming droplets of sulfuric acid. These droplets are in the submicronic size range and thus high values for the opacity can occur.

Often the plume does not become visible until a few stack diameters downwind, and this should not be confused with a detached steam plume.

Observations should be taken through the densest part of the plume, which will not necessarily be at the plume exit.

The evaluation should be made from ground level.

REFERENCES:

1. Public Health Service. Atmospheric Emissions from Sulfuric Acid Manufacturing Processes, U.S. Department of Health, Education and Welfare. AP-13, 1965.
2. Los Angeles County APCD. Air Pollution Engineering Manual. AP-40, p. 716. EPA, Office of Air and Water Programs. 1973.
3. Weisburd, M.I. Field Operations and Enforcement Manual for Air Pollution Control. Volume III: Inspection Procedures for Specific Industries. APTD-1102, Section 7.7. EPA, Office of Air Programs. 1972.
4. EPA. Compilation of Air Pollutant Emission Factors. AP-42, Section 5.17. EPA, Office of Air and Water Programs, 1973.

4.3.5 PHOSPHORIC ACID MANUFACTURING

The use of phosphoric acid, its salts and derivatives has enjoyed a great increase in recent years. With the exception of fertilizers, most phosphorous compounds are derived from orthophosphoric acid. Phosphorous is burned to form the pentoxide which is reacted with water to form the acid. Excess air is used to prevent formation of the trioxide. The final stage of manufacture is the hydrator in which the pentoxide reacts with water vapor to form the acid mist. The tail gas out of this vessel is saturated with water and can produce a very dense plume. The concentration of acid in the plume can be kept low with a well-designed plant. However, even this small amount is effectively removed by an electrical precipitator, a venturi scrubber or a Brink fiber mist eliminator.

Observations should be made from gound level in the usual manner, bearing in mind that there is a strong possibility of a condensed water vapor plume being present.

REFERENCES:

1. Public Health Service. Atmospheric Emissions from Wet-Process Phosphoric Acid Manufacture. AP-57, U.S. Department of Health, Education and Welfare, 1970.
2. Los Angeles County APCD. Air Pollution Engineering Manual. AP-40, p. 734-737. EPA, Office of Air and Water Programs. 1973.
3. EPA. Compilation of Air Pollutant Emission Factors. AP-42, Section 5.11. EPA, Office of Air and Water Programs, 1973.

4.3.6 SOAP AND DETERGENT MANUFACTURE

In soap finishing operations dust can be emitted from equipment performing the following operations: Addition of powdered and fine crystalline materials to crutchers (mixers), mechanical sawing and cutting of cold frame soap, milling and plodding soap, air-drying of soap in steam heated dryers, forming and packaging. Emissions from these operations are generally not extremely dense and may be marginal or very low key. However, the grinding of soap chips, pneumatic conveying of powders, and spray drying operations will generally cause emissions of excessive opacities.

The oleum or fuming sulfuric acid used in detergent manufacture produces a dense mist when displaced vapors are allowed to escape into the atmosphere. Thus, dense white 100% opacity emissions can be seen from the vents of storage tanks and process vessels during filling operations with oleum.

The receiving, storage and batching of the various dry ingredients as well as pneumatic conveying, create dust and opacity problems. Dust emissions occur during mixing and batching at the scale hoppers, mixers and the crutcher.

Observations can be made in the usual manner.

REFERENCES:

1. Los Angeles County APCD. Air Pollution Engineering Manual. AP-40, p. 737-749. EPA, Office of Air and Water Programs. 1973.

2. EPA. Compilation of Air Pollutant Emission Factors. AP-42, Section 5.15. EPA, Office of Air and Water Programs, 1973.

4.3.7 GLASS MANUFACTURING

Soda-lime glass constitutes about 90 percent of the total production of commercial glass. It is produced on a massive scale in large, direct-fired, continuous melting furnaces. Most other types are produced in small batch furnaces and are a minor problem compared to soda-lime glass production.

Silica sand, dry powders, granular oxides, carbonates, cullet (broken recycled glass), and other raw materials are transferred from railroad hopper cars to storage bins. These materials are then batch-weighed and blended in a mixer. The mixed batch is then conveyed to the feeders attached to the sides of the furnace. A potential opacity problem exists wherever the dust from these operations can be seen.

As the feeders supply the dry materials previously blended, they float upon the molten glass in the furnace until they melt. Carbonates decompose, releasing CO_2 in the form of bubbles. Volatilized particulates, composed mostly of alkali oxides and sulfates, are captured by the flame and hot gases passing across the molten surface. The particulates that do not settle out in the checkers are discharged out the stack and a visible white plume is formed.

The molten glass goes to the forming machines where the greases and parting compounds create a visible emission which can be a very significant source.

Observations are made in the usual manner.

REFERENCES:

1. Los Angeles County APCD. Air Pollution Engineering Manual. AP-40, p. 765-782. EPA, Office of Air and Water Programs. 1973.

2. EPA. Compilation of Air Pollutant Emission Factors. AP-42, Section 8.13. EPA, Office of Air and Water Programs, 1973.

4.3.8 FRIT SMELTERS

Ceramic coatings are water suspensions of ground frit and clay and are used on glass, pottery or metal.

The frit is prepared by fusing various minerals in a smelter and then quenching the molten material with air or water. The thermal shock shatters the solidified material into small glass particles called "frit". The frit is dried and put into a ball mill and ground with some other materials. Ceramic slip is then prepared by suspending the ground frit in a mixture of water and clay. The slip is applied to the metal or glass or pottery surface and fired in a kiln.

Significant visible dust and fume emissions may or may not be present depending on the batch composition. There most generally are some visible emissions when charging. Other emissions come from condensed metallic oxide fumes that have volatilized from the molten batch. They often contain a mineral dust carryover in addition. Some glass fibers are released and contribute to the opacity of the emissions.

Observations can be made in the usual manner.

REFERENCES:

1. Los Angeles County APCD. Air Pollution Engineering Manual. AP-40, p. 788-804. EPA, Office of Air and Water Programs. 1973.

2. EPA. Compilation of Air Pollutant Emission Factors. AP-42, Section 8.12. EPA, Office of Air and Water Programs, 1973.

4.3.9 FOOD PROCESSING

Food processing includes such operations as slaughtering, smoking, drying, cooking, baking, frying, boiling, dehydrating, hydrogenating, fermenting, distilling, curing, ripening, roasting, broiling, barbecuing, canning, freezing, enriching and packaging. Obviously some produce large volumes of visible contaminants and others only insignificant amounts. Two of the more troublesome operations will be discussed.

4.3.9.1 MEAT SMOKING

Smoke is normally generated from hardwood to provide a smoky atmosphere for the purpose of partially cooking, curing and adding flavor to ham, bacon, wieners, etc. A certain amount of the smoke is exhausted continuously from both atmospheric and recirculating type smoke houses. Unfortunately the particulates are in a submicron size range where light scattering is maximum. These exhaust plumes can periodically be expected to exceed 40% opacity.

4.3.9.2 FISH MEAL DRIERS

Excessive visible air contaminants can be created in fish meal driers by the overheating of meal and volatilization of low-boiling oils and other organic compounds. Smoke is more likely to be emitted from direct-fired driers than from steam-tube units. Driers operated in the 200-300°F range of the gas discharge temperature can be expected to produce a visible plume. Addition of certain low boiling materials to drier feedstocks can also create visible emissions when there is essentially no overheating of meal in the drier.

Observations for these sources may be made in the usual manner.

REFERENCES:

1. Public Health Service. Air Pollution in the Coffee Roasting Industry. AP-9,U.S. Department of Health, Education and Welfare, 1964.

2. Los Angeles County APCD. Air Pollution Engineering Manual. AP-40, p. 788-812. EPA, Office of Air and Water Programs. 1973.

3. EPA. Compilation of Air Pollutant Emission Factors. AP-42, Section 6.6, 6.7. EPA, Office of Air and Water Programs, 1973.

4.3.10 PAINT BAKING

Many systems for the application of protective or decorative coatings on surfaces consist of a method for applying the coating. The coating is then cured, or baked, into a hard finish in an oven. The ovens may be batch or continuous; direct- or indirect-fired; resistance or infra-red heating; etc. As the initial solvent or vehicle flashes off and the temperature increases, there is often a great deal of smoke produced. Vent stacks in the roof and oven doors, or openings in the ovens of the continuous type, are sources of visible emissions.

Observations may be made in the usual manner.

REFERENCE:

1. Los Angeles County APCD. Air Pollution Engineering Manual. AP-40, p. 865-871. EPA, Office of air and Water Programs. 1973.

4.3.11 INCINERATORS

There are numerous types of incinerators used to dispose of waste material of one sort or another. Almost all present an opacity problem unless they are properly designed with an additional combustion chamber to incinerate the smoke. Both smoke and fly ash contribute to the opacity of the visible emissions emanating from the incinerator stack.

Some of the more common names of incinerators used for various purposes are as follows:

a. General-refuse
b. Mobile
c. Wood-waste
d. Flue-fed apartment
e. Pathological-waste
f. Brake-shoe debonder
g. Electrical winding reclaiming
h. Drum reclaiming
i. Wire burners

Observations may be made in the usual manner.

REFERENCES:

1. Los Angeles County APCD. Air Pollution Engineering Manual. AP-40, p. 435-531. EPA, Office of Air and Water Programs. 1973.

2. EPA. Compilation of Air Pollutant Emission Factors. AP-42, Section 2.1, 2.2, 2.3. EPA, Office of Air and Water Programs, 1973.

3. Weisburd, M.I. Field Operations and Enforcement Manual for Air Pollution Control. Volume II: Inspection Procedures for Specific Industries. APTD-1101, Section 6.3 EPA, Office of Air and Water Programs, 1972.

4.3.12 HOT-MIX ASPHALT PAVING BATCH PLANTS

A typical hot-mix asphalt paving plant has the following components: an oil- or gas-fired rotary drier, a screening and classifying system, weigh boxes for asphalt and aggregate, a mixer, and necessary conveying and storage equipment.

Aggregate is conveyed to the drier which heats it to 250-350°F. This is then screened and classified and dumped into elevated storage bins. Selected amounts of given sizes along with asphalt are weighed into the mixer. The batch is then dumped into trucks.

Opacity problems arise from dust from the drier, conveying equipment, screens and weigh hopper. Smoke comes from the mixing section. Trucks are generally sprayed with a diesel oil to prevent sticking and as the hot asphalt hits the diesel oil, it is vaporized into a bluish-white cloud of considerable opacity.

Observations may be made in the usual manner.

REFERENCES:

1. Los Angeles County APCD. Air Pollution Engineering Manual. AP-40, p. 325-333. EPA, Office of Air and Water Programs. 1973.
2. EPA. Compilation of Air Pollutant Emission Factors. AP-42, Section 8.1. EPA, Office of Air and Water Programs, 1973.

4.3.13 CONCRETE-BATCHING PLANTS

The aggregate generally arrives from the rock and gravel plant along with sand in a sufficiently moist condition as not to be a problem. The cement dust represents the main problem which can be emitted from the receiving hopper, elevating equipment, and silo in the receiving and storage system. Other points of emission are the weigh hopper, the gathering hopper and the mixer. All cement-handling operatings may be considered in this category.

Observations may be made in the usual manner.

REFERENCES:

1. Los Angeles County APCD. Air Pollution Engineering Manual. AP-40, p. 334-339. EPA, Office of Air and Water Programs. 1973.

2. EPA. Compilation of Air Pollutant Emission Factors. AP-42, Section 8.10. EPA, Office of Air and Water Programs, 1973.

4.3.14 STONE QUARRYING, ROCK AND GRAVEL PLANTS

Rock and crushed stone products are loosened by drilling and blasting and removed by heavy earth-moving equipment to the crushers.

Gravel from old dry beds is screened to obtain useable sizes, with the oversize rock being crushed into various size ranges. A conveyor system from the quarry carries the material into the plant proper. The material passes through the first jaw crusher which is set to act on rocks larger than 6 inches and to pass smaller sizes. The material is then screened to get sizes smaller and larger than 1½ to 2 inches. The undersize goes to a screening plant and the oversize to another crushing plant. This plant usually has several primary cone-crushers in parallel and several more secondary cone-crushers also in parallel. The material is again screened and goes to storage of the proper size.

As the material leaves the pit or quarry it is usually moist either naturally or having been wetted down. Once crushing operations have started, dry surfaces are exposed and dust emissions creating opacity problems begin. Then as the material moves to more screens and crushers, the rock becomes more finely ground and the dust problem becomes greater.

All conveyor transfer points, screens, and crushers after the first jaw crusher are potential sources of dust clouds with excessive opacity.

Observations should be made in accordance with the procedures outlined in Section 4.2, above.

REFERENCES:

1. Stern, A., Air Pollution, Volume III. Academic Press, New York. p. 123-127. 1968.

2. Los Angeles County APCD. Air Pollution Engineering Manual. AP-40, p. 340-342. EPA, Office of Air and Water Programs. 1973.

3. EPA. Compilation of Air Pollutant Emission Factors. AP-42, Sections 8.19, 8.20. EPA, Office of Air and Water Programs, 1973.

4.3.15 MINERAL WOOL FURNACES

Mineral wool, known also as slagwool, rock wool, and glass wool, is merely silicate fibers made in a cupola by using blast furnace slag, silica, and coke (to serve as fuel). Its use is mainly for thermal and acoustical insulation.

The major source of pollutants is the cupola or furnace stack. The visible portion is mainly condensed fumes that have volatilized from the molten charge. Heavy emissions can also be noted from the blowchamber which consist of condensed fumes, oil vapors, binding agent aerosols, and wool fibers. The curing oven may also have up to 70% opacity and the asphalt applicator can smoke if the temperature of the holding pot exceeds 400°F.

Observations may be made in the usual manner.

REFERENCES:

1. Los Angeles County APCD. Air Pollution Engineering Manual. AP-40, p. 342-350. EPA, Office of Air and Water Programs. 1973.
2. EPA. Compilation of Air Pollutant Emission Factors. AP-42, Section 8.16. EPA, Office of Air and Water Programs, 1973.

4.3.16 PERLITE-EXPANDING FURNACES

Perlite ore is surface-mined, or quarried, and is normally dried, crushed, and screened at the mine.

A perlite plant for expansion of perlite, often referred to as "bloated clay", consists of ore-unloading and storage facilities, a furnace-feeding device, expanding furnace (rotary kiln), gas and product cooling equipment, product classifying equipment and product collecting equipment. Most of the opacity problems arise from leakage in the product handling system and the outlet of the last product collector. Even when this is a well-designed baghouse, the nature of the particles (sub-micron and needle-like in shape) is such that they can penetrate the cloth filter and evolve as an opacity problem.

Observations may be made in the usual manner.

REFERENCES:

1. Los Angeles County APCD. Air Pollution Engineering Manual. AP-40, p. 350-352. EPA, Office of Air and Water Programs, 1973.
2. EPA. Compilation of Air Pollutant Emission Factors. AP-42, Section 8.17. EPA, Office of Air and Water Programs, 1973.

4.3.17 FEED AND GRAIN MILLS

This is strictly a mechanical problem of receiving, handling, storing, size reduction, cleaning, and possibly bulk-loading from spouts. The problems which occur are created mostly by dust. This is often controlled for other reasons, mainly to reduce the possibility of explosions.

Observations may be made in the usual manner.

REFERENCES:

1. Los Angeles County APCD. Air Pollution Engineering Manual. AP-40, p. 352-361. EPA, Office of Air and Water Programs. 1973.
2. EPA. Compilation of Air Pollutant Emission Factors. AP-42, Section 6.4. EPA, Office of Air and Water Programs, 1973.

4.3.18 PNEUMATIC CONVEYING AND DRYING

Almost all material handling by pneumatic conveying is accomplished by new sophisticated, efficient equipment. However, occasionally something happens to the air unlocking device (cyclone, etc.) and emissions occur in the discharging air stream.

Driers can also be operated in myriads of processes without any visible emissions other than water vapor. However, if the product being dried is of an organic nature or otherwise capable of being decomposed, scorched, burned, etc., there is always a possibility of an opacity problem. All driers and their gases, either from the exit or entrance openings or vent(s), should be scrutinized and analyzed for a possible emission of visible contaminants.

Observations may be made in the usual manner.

REFERENCE:

Los Angeles County APCD. Air Pollution Engineering Manual. AP-40, p. 362-365. EPA, Office of Air and Water Programs. 1973.

4.3.19 WOODWORKING EQUIPMENT

Woodworking machines produce large quantities of waste sawdust, chips, and shavings that must be removed from the work site. An exhaust system is almost always used for this purpose and it almost always has an unlocking or control device to remove the material from the plume. However, at times this equipment can be somewhat inefficient on the smaller particle sizes and a resultant visible plume occurs. Although the amount of particulate may not be great, it should be remembered that there is no simple correlation between weight of material emitted and the opacity of the plume in which it is distributed.

Observations may be made in the usual manner.

REFERENCE:

Los Angeles County APCD. Air Pollution Engineering Manual. AP-40, p. 372-375. EPA, Office of Air and Water Programs. 1973.

4.3.20 ASPHALT ROOFING FELT SATURATORS

Asphalt saturators are machines used to impregnate a moving web of paper felt with hot asphalt by spraying and by dipping. The saturated felt is converted into shingles by applying mineral granules while the asphalt is in a soft condition, allowing the felt to cool and then cutting to shape.

A very visible plume containing some moisture is generally exhausted from the spraying and dipping area. The opacity is created by the condensed oil vapor from the hot asphalt. Some dust from the mineral handling and loose fibers from the felt also contribute to the opacity.

Observations may be made in the usual manner.

REFERENCES:

1. Los Angeles County APCD. Air Pollution Engineering Manual. AP-40, p. 378-390. EPA, Office of Air and Water Programs. 1973

2. EPA. Compilation of Air Pollutant Emission Factors. AP-42, Section 8.2. EPA, Office of Air and Water Programs, 1973.

4.3.21 ABRASIVE BLAST CLEANING

The applications of this type of cleaning are many and varied. The type of abrasive can vary from sand, nutshells, and other light materials that break into dust easily, to all types of metals such as small sharp pieces of steel wire or lead shot. The method of propelling these onto a surface can be high pressure air or merely a centrifugal throwing wheel or even an air and water jet. The nature of the surface also influences the amount of dust created. Surfaces covered with rust and scale for example can have a great deal of finely divided material removed. Blasting is often done in the open, but in populous areas an enclosure housing the blasting operation is used. Unless controlled, the vents from most enclosures will represent an opacity problem from time to time.

Observations may be made in the usual manner.

REFERENCE:

1. Los Angeles County APCD. Air Pollution Engineering Manual. AP-40, p. 397-401. EPA, Office of Air and Water Programs. 1973.

4.3.22 ZINC GALVANIZING EQUIPMENT

Zinc galvanizing is defined as the art of coating clean oxide-free iron or steel with a thin layer of zinc by immersion into molten zinc held at temperatures from 840°-860°F.

Opacity problems arise from this operation from a number of mechanisms. If the metal has not been properly cleaned and degreased, an oil mist is discharged when the article is dipped into the molten zinc. If the articles are not properly pickled and rinsed, more flux must be used to get the desired coating. This creates more fumes. Whenever the flux cover is disturbed or more flux added the fumes increase. Some zinc and zinc chloride are to be found in the fumes even though they are normally of very low vapor pressure. It is thought that a wet article immersed in the molten zinc will form steam that atomizes some zinc and flux into the air. A dusting with finely ground sal ammoniac on the article immediately after removal from the molten zinc is sometimes used to produce brighter, smoother finishes. Although only small amounts of dusting fluxes are used, dense fumes are always created.

REFERENCE:

1. Los Angeles County APCD. Air Pollution Engineering Manual. AP-40, p. 402-410. EPA, Office of Air and Water Programs, 1973.

4.3.23 CERAMIC SPRAYING AND METAL DEPOSITION EQUIPMENT

Ceramic sprays are slurries made up by suspending mixtures of feldspar, quartz, clays, finely ground frit, pigments, etc. in water. When they are sprayed onto metallic or pottery surfaces, the overspray can be emitted through the vent in the spray booth. Although easily captured by a water-wash control section they can be an opacity problem if not properly controlled.

Metal deposition is accomplished by spraying molten metal onto a surface to form a coating. Metallizing, thermal spraying or plasma arc spraying all produce a discharge of clouds of molten metal fumes along with finely divided oxide particles which are quite visible as emissions from the spray booth vents. Attempts to control the emissions with a dry type baffle or paint arrestor will result in remaining opacities in the effluent which will be excessive.

Observations may be made in the usual manner.

REFERENCE:

1. Los Angeles County APCD. Air Pollution Engineering Manual. AP-40, p. 421-433. EPA, Office of Air and Water Programs. 1973.

4.3.24 STEEL MANUFACTURING PROCESSES

The two common steel-refining processes are: (1) The basic process, wherein oxidation takes place in combination with a strong base such as lime; and (2) the acid process, wherein oxidation takes place without the base addition. These processes are usually carried out in the open hearth furnace, the electric furnace, or the Bessemer converter. Electric furnaces are of three types: direct-arc, indirect-arc and induction.

Visible emissions are produced in the open hearth furnace throughout the heat which lasts from 8-10 hours. A portion of the emissions is due to the combustion of grease, oil and other contaminants in the scrap along with the fuel, but most comes from the fumes or oxides of the various metal constituents from which the alloy is being made. Much of the emissions are submicronic in size which lends to their very good light-scattering ability, producing plumes of high opacity.

The quantity and type of fumes emitted from an electric arc furnace depend on several factors: Furnace size, type of scrap, composition and cleanliness of the scrap, type of furnace process, order of charging materials, melting rate, refining procedure, and tapping temperature. Most of the emissions which are generated during the first half of the heat, are either retained in the slag or discharged from the furnace vent.

Induction furnaces produce fumes with the same characteristics as the electric-arc furnaces. They are generally smaller in size but the opacity problem is just as great.

The Bessemer converters are not very common at present having been supplanted by the open hearth and electric-arc furnaces.

It should be kept in mind that in addition to the furnaces, other associated sources of emissions are the launder, ladles and molds during tapping and pouring operations.

Observations should be made from a safe position using the usual manner.

REFERENCES:

1. Los Angeles County APCD. Air Pollution Engineering Manual. AP-40, p. 239-255. EPA, Office of Air and Water Programs. 1973.

2. EPA. Compilation of Air Pollutant Emission Factors. AP-42, Section 7.5. EPA, Office of Air and Water Programs, 1973.

3. Weisburd, M.I. Field Operations and Enforcement Manual for Air Pollution Control. Volume III: Inspection Procedures for Specific Industries. APTD-1102, Section 7.4. EPA, Office of Air Programs. 1972.

4. Public Health Service. Air Pollution Aspects of the Iron and Steel Industry. AP-1. U.S. Department of Health, Education and Welfare. 1963.

4.3.25 IRON CASTING

The cupola, electric arc, and reverberatory furnaces are the types mostly widely encountered. Dust and fumes, smoke, and oil vapor contribute to the opacity problem. About 15% of the effluent is in the 1-3 micron range. The dust in the discharge gases of the cupola comes from dirty scrap and fines in the coke and limestone charge. Smoke and oil vapors stem from partial combustion and distillation of oils from a greasy or oily scrap charge. The other types are somewhat cleaner but may still have an opacity problem from condensed metal fumes and dirty or oil scrap.

Observations may be made in the usual manner.

REFERENCES:

1. Public Health Service. Air Pollution Aspects of the Iron and Steel Industry. AP-1. U.S. Department of Health, Education and Welfare. 1963.

2. Los Angeles County APCD. Air Pollution Engineering Manual. AP-40, p. 256-269. EPA, Office of Air and Water Programs. 1973.

3. EPA. Compilation of Air Pollutant Emission Factors. AP-42, Section 7.10. EPA, Office of Air and Water Programs, 1973.

4.3.26 SECONDARY BRASS- AND BRONZE-MELTING PROCESSES

Brass, an alloy of zinc and copper, and bronze, an alloy of copper and tin are generally melted in reverberatory, electric-arc, induction, or crucible-type furnaces. The visible emissions are comprised mostly of dust and metallic fumes. The particle sizes of zinc oxide fumes vary from 0.03 to 0.3 microns. Lead oxide fumes, emitted from many brass alloys are in this same size range. Consequently very opaque effluents may be expected since the particles are in the 0.2-0.6 micron range producing a maximum scattering of light.

Some of the factors causing large zinc fume concentrations are: alloy composition, pouring temperature, type of furnace and poor foundry practice.

Observations may be made in the usual manner.

REFERENCES:

1. Public Health Service. Air Pollution Aspects of Brass and Bronze Smelting and Refining Industry. AP-58. U.S. Department of Health, Education and Welfare. 1969.
2. Los Angeles County APCD. Air Pollution Engineering Manual. AP-40, p. 269-283. EPA, Office of Air and Water Programs. 1973.
3. EPA. Compilation of Air Pollutant Emission Factors. AP-42, Section 7.9. EPA, Office of Air and Water Programs, 1973.

4.3.27 SECONDARY ALUMINUM MELTING AND SMELTING

These operations are essentially the remelting or re-refining of aluminum. Accompanying these operations are: fluxing, alloying, degassing and "demagging". The metal in the form of pigs, foundry returns or scrap is melted in crucibles,induction furnaces or reverberatory furnaces. Much of the scrap charged to a reverberatory furnace is covered with paint, dirt, oil, grease and other contaminants which create dense fumes and smoke. Chemicals added during the accompanying operations noted above create opacity problems also. The mean particle size given off during fluxing, for example, is about 0.7 microns.

Observations may be made in the usual manner.

REFERENCE:

1. Los Angeles County APCD. Air Pollution Engineering Manual. AP-40, p. 283-292. EPA, Office of Air and Water Programs. 1973.

4.3.28 SECONDARY ZINC-MELTING PROCESSES

Zinc is melted in crucible, pot, kettle, reverberatory or electric-induction furnaces as well as in retort and muffle furnaces. Muffle furnaces can also be used to manufacture zinc oxide by vaporizing and burning the zinc in air.

The visible emissions from melting furnaces are generally caused by excessive temperatures and melting of metal contaminated with organic material. Fluxing can also create excessive emissions.

Zinc vapors escape from retort-type equipment when the residue is removed and a new charge is put in. As the zinc vapors mix with air, dense white zinc oxide fumes are formed. This operation can take up to one hour.

The condenser portion is vented through a "speiss" hole and although the emission rate is low, the opacity is high and goes on for 20 hours per day.

Observations may be made in the usual manner.

REFERENCES:

1. Los Angeles County APCD. Air Pollution Engineering Mannual. AP-40, p. 293-299. EPA, Office of Air and Water Programs. 1973.

2. EPA. Compilation of Air Pollutant Emission Factors. AP-42, Section 7.14. EPA, Office of Air and Water Programs, 1973.

3. Weisburd, M.I. Field Operations and Enforcement Manual for Air Pollution Control. Volume III. Inspection Procedures for Specific Industries. APTD-1102, Section 7.8. EPA, Office of Air Programs. 1972.

4.3.29 LEAD REFINING

For this operation the three principal types of furnaces used are: The reverberatory, blast, and pot. Lead oxide is also produced by some lead refiners by the Barton process. The pot furnaces create less problems than either the reverberatory or the blast furnaces. All have the usual problems of oxide formation, dirt and vaporized metal. The unagglomerated particulate matter from secondary lead-smelting operations has been found to be in a range of 0.07 to 0.4 microns with a mean of 0.3 microns.

The Barton process requires a baghouse for product collection of the oxide, hence it normally does not represent a problem except for malfunction and leakages.

Observations may be made in the usual manner.

REFERENCES:

1. Los Angeles County APCD. Air Pollution Engineering Manual. AP-40, p. 299-304. EPA, Office of Air and Water Programs. 1973.

2. EPA. Compilation of Air Pollutant Emission Factors. AP-42, Section 7.6. EPA, Office of Air and Water Programs, 1973.

3. Weisburd, M.I. Field Operations and Enforcement Manual for Air Pollution Control. Volume III: Inspection Procedures for Specific Industries. APTD-1102, Section 7.8. EPA, Office of Air Programs. 1972.

sulfate, sodium carbonate, and carbon of 1 micron in diameter or less. Other points that are potential sources of visible emissions include the smelt tank, lime kiln, and hog fuel burning equipment which is used to produce power.

Observations may be made in the usual manner.

REFERENCES:

1. Weisburd, M.I. Field Operations and Enforcement Manual for Air Pollution Control. Volume II: Inspection Procedures for Specific Industries. APTD-1101 Section 7.2. EPA, Office of Air Programs. 1972.

2. EPA. Compilation of Air Pollutant Emission Factors. AP-42, Section 10.1. EPA, Office of Air and Water Programs, 1973.

4.3.33 CEMENT PLANTS

Virtually all of the processes involved in producing cement are potential sources of visible emissions. These include: quarrying, crushing, grinding, bagging, and material storage, although usually the major source of emissions is the kiln. Normally there is some form of control device on the kiln, but even so it is still a potential problem as far as compliance with the opacity regulation is concerned.

Observations may be made in the usual manner.

REFERENCES:

1. Los Angeles County APCD. Air Pollution Engineering Manual. AP-40. p. 335-340. EPA, Office of Air and Water Programs. 1973.

2. Weisburd, M.I. Field Operations and Enforcement Manual for Air Pollution Control. Volume III: Inspection Procedures for Specific Industries. APTD-1102, Section 7.10. EPA, Office of Air Programs. 1972.

3. EPA. Compilation of Air Pollutant Emission Factors. AP-42, Section 8.6. EPA, Office of Air and Water Programs, 1973.

4.3.30 METAL SEPARATION PROCESSES

This operation is also commonly known as "sweating" and can be accomplished in rotary, reverberatory or muffle-type furnaces. The material consisting of scrap or junk is charged to the furnace, and by virtue of different melting points of the metals, the desired metal can be made molten while the others remain solid by carefully controlling the temperature.

This operation, as most metal-melting processes, is plagued by the smoke from organic constituents as well as metal and metal oxide fumes.

Observations may be made in the usual manner.

REFERENCE:

1. Los Angeles County APCD. Air Pollution Engineering Manual. AP-40, p. 304-308. EPA, Office of Air and Water Programs. 1973.

4.3.31 FOUNDRY SAND-HANDLING EQUIPMENT

After the metal has cooled in the mold, the sand from the core is generally recovered and mixed with fresh sand. The minimum equipment required for reconditioning the old sand is a shake-out screen to remove oversize particles, and a mixer-muller where clay and water are combined with the sand to render it suitable for remolding. In addition, there may be equipment for cooling, oversize crushing, fines removal, coating removal and conveying. Emissions occur at any point where the dust from sand breakdown can escape to the atmosphere.

Observations may be made in the usual manner.

REFERENCE:

1. Los Angeles County APCD. Air Pollution Engineering Manual. AP-40, p. 315-319. EPA, Office of Air and Water Programs, 1973.

4.3.32 KRAFT PULP MILLS

This is the process most frequently employed in reducing wood to cellulose fibers for paper manufacture. The largest source of visible emissions is the recovery furnace, where the emissions include sodium

4.3.34 ALUMINUM REDUCTION PLANTS

This activity is confined to the southeast portion of the United States where the bauxite ore is mined. Imported ore is also processed in areas where cheap power is available. The obvious visible emissions come predominantly from the stacks of the anode plant and the potroom air vents and roof monitors. Floor operations such as crushing and other feed preparation operations may cause other emissions.

Observations may be made in the usual manner:

REFERENCES:

1. Weisburd, M.I. Field Operations and Enforcement Manual for Air Pollution Control. Volume III: Inspection Procedures for Specific Industries. APTD-1102, Section 7.11. EPA, Office of Air Programs. 1972.

2. EPA. Compilation of Air Pollutant Emission Factors. AP-42, Section 7.1. EPA, Office of Air and Water Programs, 1973.

4.3.35 MINING

Open-pit mines and strip-mining produce large amounts of visible emissions. Dusts, smoke and organic emissions are produced from surface operations such as amassing spoil piles, loading and dumping, blasting and transportation activities. Some mines will have greater emission potentials than others, due to the type of mine and nature of the deposits.

Observations should be made from safe vantage points as close to the individual emission sources as is feasible.

REFERENCE:

1. Weisburd, M.I. Field Operations and Enforcement Manual for Air Pollution Control. Volume III: Inspection Procedures for Specific Industries. APTD-1102, Section 7.12. EPA, Office of Air Programs. 1972.

5. PROBLEMS ASSOCIATED WITH CONDENSED WATER PLUMES

5.1 GENERAL

Plumes containing large amounts of water in the liquid form have been variously described as "moist", "wet", "steam", "condensed water", or "condensed water vapor" plumes. Usually they are referred to as "steam plumes", which technically is not a correct term since steam is defined as water in the gaseous phase. This term, however, has become the generally accepted description of a plume containing droplets of condensed water. As long as the temperature of the plume remains above the dew point,--defined as the temperature at which water vapor just begins to condense--the water remains in the gaseous phase and has no effect on the opacity. In this context the plume is sometimes referred to as being "dry".

Many sources of air pollution also emit large quantities of water vapor. While water vapor itself is not normally classified as an air pollutant, it can have adverse effects on the environment and can cause problems to an inspector who wishes to make an opacity determination of a source. In making the opacity determination of a source, the problem occurs when the water vapor in the plume condenses, in which case the effect of the water vapor cloud that is formed far exceeds the effect of the particulate present in the plume.

Water vapor itself is invisible and thus has no effect on opacity, but as soon as condensation occurs, the condensed water droplets scatter light and affect the opacity. The droplets formed are in the submicronic size range so that a relatively small mass concentration can have a large effect on the plume opacity. Usually the effect is so great the the plume is completely opaque and the opacity reading would be 100%. This is not a valid reading however, since it reflects the opacity of the condensed water vapor plume rather than the opacity of the pollutant plume.

Condensation of the moisture contained in the plume can occur within the stack itself--when the steam plume is said to be "attached" to the stack--or it can occur some distance downwind of the stack--in which case the steam plume is said to be "detached". In both cases the steam plume will eventually revaporize as the plume is transported downwind. Whether the plume will be attached or detached, and the distance taken for re-vaporization to occur, depends upon the specifics of the case of interest: plume temperature and moisture content, atmospheric pressure, temperature and relatively humidity, and the degree of mixing between the hot effluent gases and the ambient air.

5.2 SOURCES OF WATER VAPOR PLUMES

The largest water vapor plumes are produced from cooling ponds or cooling towers which are not of direct concern to air pollution enforcement officers, except from an esthetic point of view. These plumes can cause fogging or icing problems over a considerable area, obstructing visibility and creating a safety hazard to automotive traffic, aircraft operations or shipping.

With the increasing public awareness and concern over the environment that has been occurring in recent years, air pollution agencies appear to be receiving increasing numbers of complaints about air pollution emissions from the public. Many of these complaints, concern condensed water vapor plumes which are not covered by air pollution regulations. The inspector must be able to tell at a glance whether the plume contains condensed water vapor or not. This can be determined fairly easily since a steam plume has a very wispy appearance and the opacity decreases rapidly from 100% to 0%. For a dry plume containing no condensed moisture the opacity is seldom as high as 100%, except under upset conditions, and the rate of change of opacity with distance is not so rapid.

The main effect of steam plumes is the possibility of masking the presence of other pollutants in the plume.

Moisture in the plume may come from several sources, such as:

1) water produced by the combustion of fuels
2) from dryers
3) water introduced by scrubbers
4) water introduced to control the heat released by chemical reactions
5) water introduced to cool the flow before it enters an electrostatic precipitator.

5.3 READING WATER VAPOR PLUMES

If the condensed water vapor plume is detached, opacity determinations can be made immediately at the stack exit, i.e. before the water vapor begins to condense.

If the water vapor plume is attached to the stack, readings should be made at the point where the water droplets have revaporized completely. This point may be some distance downwind thus allowing the pollutants to become diluted by mixing with the ambient air. The further downwind this point is, the more dilute will be the pollutants and the lower the opacity readings will become, which of course, tends to act in the favor of the source.

If the inspector has any question about the quantity of pollutants being emitted by a source and is unable to take a reading close to the stack because of the condensed water vapor plume a source test should be ordered.

The best way of handling the problem is to make the visit to the plant when there is a good possibility that the condensed water vapor plume will not be present. Using a psychrometric chart according to the procedures of Section 5.5 in conjunction with estimates of meteorological and effluent conditions, and a few minutes of computation, will allow the inspector to determine whether or not there is a good possibility that the water vapor in the plume will condense. This procedure could save the inspector a wasted trip to the plant in question. An example of the use of the psychrometric chart is given below.

5.4 DESCRIPTION OF THE PSYCHROMETRIC CHART

A psychrometric chart is a graphical solution of various temperature and humidity states of air and water vapor mixtures. Each point on the chart represents one unique combination of the following atmospheric properties:

1) Dry bulb temperature, which is the actual temperature of the gas.

2) Wet bulb temperature, which is the temperature indicated by a thermometer that has its bulb covered with water and placed in a stream of moving air.

3) Relative humidity, which is the ratio of the partial pressure to the saturation vapor pressure of water, at the same temperature.

4) Humidity ratio, which is the ratio of the mass of water vapor present per unit mass of dry air.

5) Specific volume of dry air, which is the volume occupied by unit mass of dry air.

If any two of these parameters are known, then the state point on the psychrometric chart is defined.

The psychrometric chart for normal atmospheric pressure conditions is shown in Figure 5.1 which is sufficiently accurate for the estimates involved in this procedure for most parts of the country.

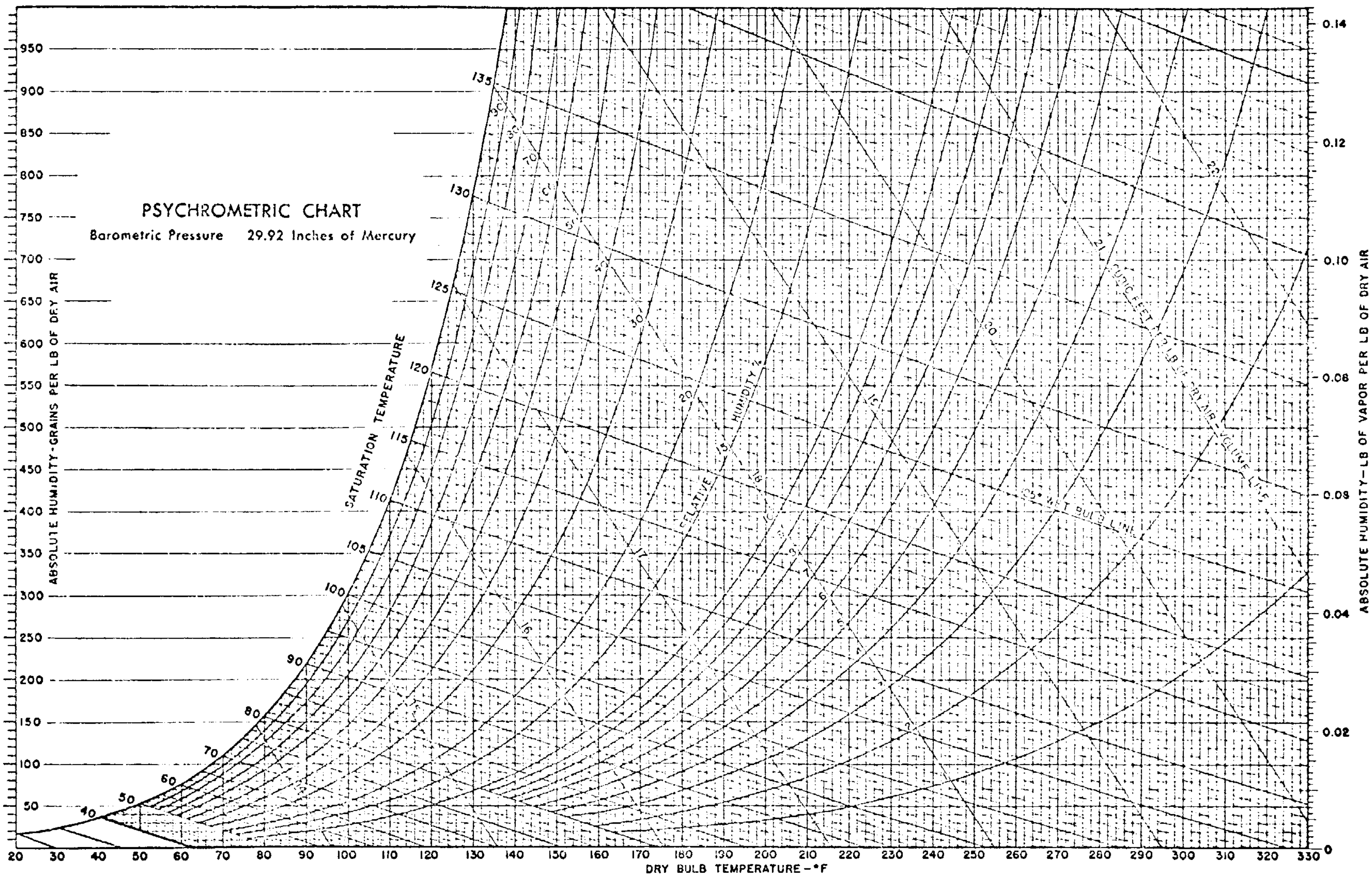
The curved line along the left side of the chart represents the 100 percent relative humidity line, or the saturation line. Any state point to the left of this line, or the path of any process crossing this line, will normally be accompanied by condensation of the water vapor resulting in the formation of a steam plume. As can be seen from the psychrometric chart: 1) Toward the lower end of the ambient temperature range it takes very little moisture to fully saturate the air, and thus the possibility of the moisture in the plume condensing is very high, no matter what the stack exit conditions may be; 2) The possibility of a steam plume being formed is smallest on hot, dry days.

5.5 EXAMPLE OF THE USE OF THE PSYCHROMETRIC CHART

The psychrometric chart shown in Figure 5.1 may be used to determine if a condensed water vapor plume is to be formed from a specific source if the ambient weather conditions are known.

Usually the information given (or estimated) is the ambient temperature and relative humidity, and the effluent gas temperature and moisture content, the latter being defined as the volume percentage of water vapor in the effluent gases.

Knowing the moisture content (M.C.), a value for the humidity ratio may be obtained from the following expression:



Buffalo Forge Company

Figure 5.1: PSYCHROMETRIC CHART (Sea Level Conditions)

$$\text{Humidity Ratio} = \frac{4354\ (\text{M.C.})}{1-\text{M.C.}}\ \frac{\text{Grains}}{\text{Lb of Dry Air}}$$

which follows from the Ideal Gas Law and the definitions of humidity ratio and moisture content.

The initial state point is given by the effluent gas temperature and the humidity ratio, and the final state point is given by the ambient wet and dry bulb temperatures.

Ambient

Air Temperature (dry bulb) = 70°F

Wet Bulb Temperature = 60°F

Barometric Pressure = 29.92 inches Hg

Effluent Gas

Exhaust Temperature (Dry Bulb) = 160°F

Moisture Content = 16.8%

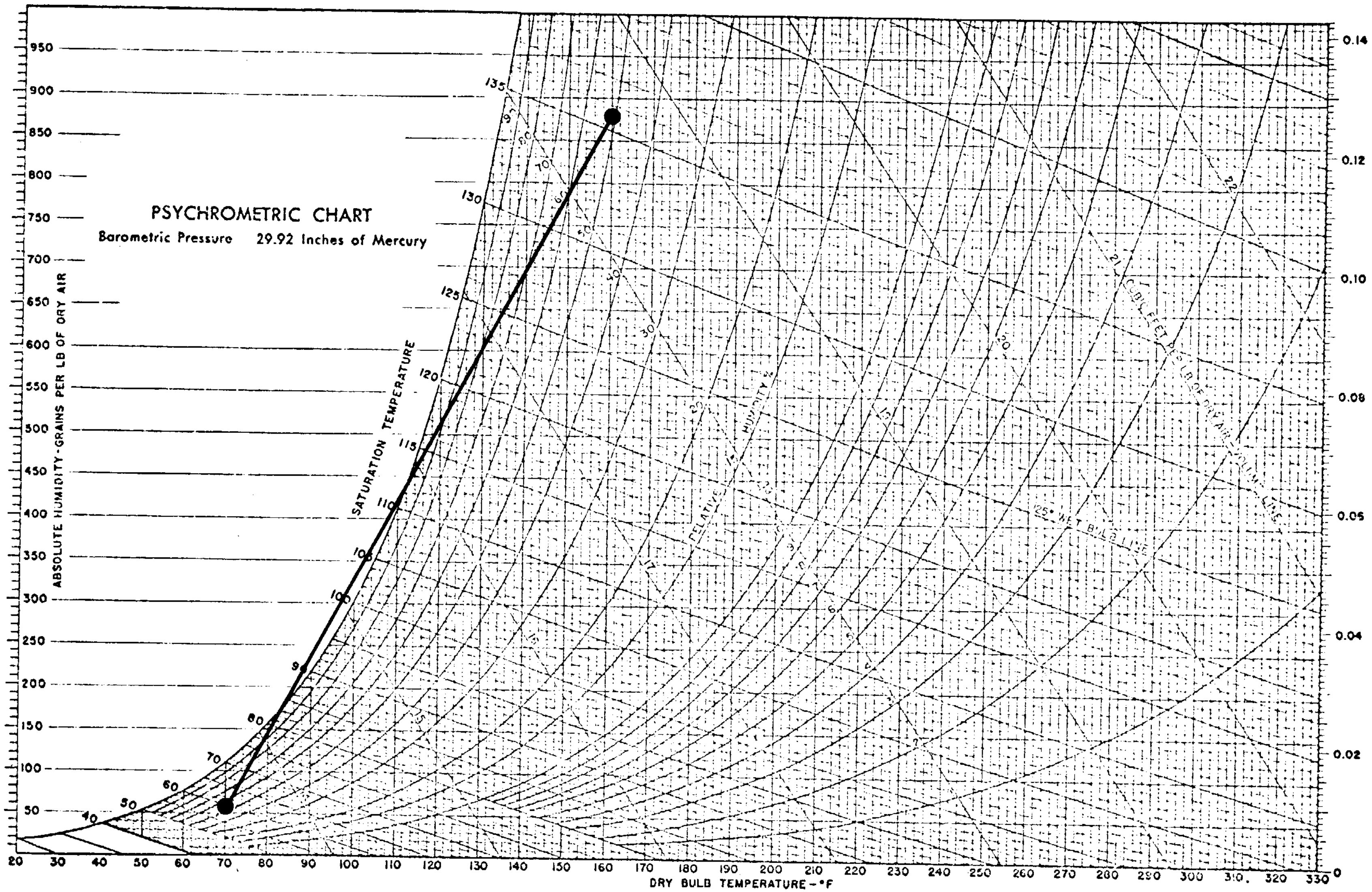
Substituting these values into the expression for the humidity ratio gives:

$$\text{Humidity Ratio} = \frac{4354\ (0.168)}{1-0.168}$$

$$= 880\ \frac{\text{Grains}}{\text{Lb. of dry air}}$$

The state point of the ambient air is at the intersection of the 70°F dry bulb temperature line and the 60°F wet bulb temperature line. The effluent gas state point is at the intersection of the 880 grains per pound of dry air line and the 160°F dry bulb temperature line.

Figure 5.2 shows the two state points plotted on the psychrometric chart. A line connecting these two state points crosses the saturation curve at about 112°F and 84°F indicating that a condensed water vapor plume is a distinct possibility. As the plume mixes with the ambient air the water vapor in the plume will begin to condense when the effluent temperature reaches 112°F and will begin to revaporize when its temperature is further cooled to 84°F.



Buffalo Forge Company

Figure 5.2: PSYCHROMETRIC CHART (Sea Level Conditions)

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6. LEGAL ASPECTS OF OPACITY OBSERVATIONS

6.1 SUMMARY

Most people are under the impression that "air pollution" and more particularly, the laws that have been passed to control it, are of rather recent origin. As a matter of fact, in the year 1273 during the reign of Edward I, the first smoke abatement statute was enacted. This law prohibited the use of coal as detrimental to health, and in 1307 one offender was condemned and executed.

Although present-day punishment for violators is not nearly so drastic, the original concept of the nuisance category has been accepted, enlarged upon, and developed into the modern laws. These laws have been tested in most State Supreme Courts, as well as the United States Supreme Court, and have been upheld as legal, proper, and constitutional in the control of excessive visible emissions.

Most of the current laws have been developed since the turn of the century. However, Kennedy, (1957), in a 50-year review paper, has summarized the accomplishments of the pre-1907 period. He states that "the following aspects of air pollution control law represent the majority, if not all, of the basic principles which became settled and accepted:

(1) Although at common law, smoke and other air contaminants were not considered to be a nuisance "per se" the legislature can declare air contaminants to be a public nuisance and the courts will not invalidate such legislative acts, provided that the legislative declaration is reasonably clear and certain.

(2) A statute or ordinance will be valid as far as due process is concerned, if it is reasonably necessary for the benefit of the public welfare, and if it is not arbitrary or oppressive.

(3) The state has the power to confer upon municipalities the power to enact ordinances for the purpose of regulating air pollution as constituting a proper exercise of the police power of the municipality.

(4) The courts take judicial notice that dense smoke is a nuisance or at least harmful enough to be declared a nuisance."

Kennedy states further: "Generally speaking, the law of air pollution has seen these major developments since 1907.

(1) The doctrine of nuisance has followed in the course of urban and industrial development.

(2) The control of air contamination by the use of strict statutory and administrative regulations has become quite popular.

(3) The courts have adhered fairly rigidly to the letter of the new police regulations. The way of the transgressor has become increasingly difficult."

6.2 LEGAL STANDING OF OPACITY OBSERVATIONS

Various courts in the country have found that:

(1) The opacity of emissions may be ascertained according to a definite scientific scale, such as the Ringelmann chart.

(2) Inspectors can be trained to read the opacity of emissions of any color. It is not necessary for them to have a Ringelmann chart, or any other aid, with them in the field at the time observations are made.

(3) The Ringelmann chart has been accepted into court as evidence.

(4) It is not unconstitutional to force a source to curtail its emissions in order to conform to the air pollution regulations, no matter what the cost may be to the source. The source may even be forced to close down if the regulations cannot be complied with.

(5) Officers of a corporation may be held responsible for actions performed by the corporation. An officer is not responsible for these actions, however, if he had no control over the actions.

(6) Certain operations may be exempt from the regulations.

(7) Regulations may be allowed to vary with locations depending upon the local problems and conditions.

(8) Evaluation of the opacity of the emissions may be made from either inside or outside the plant property. Advance notices or search warrants are not necessary.

6.3 SUMMARY OF COURT CASES

The following are summaries of some specific court cases that have given legal standing to the items listed above.

CASE 1. AIR POLLUTION VARIANCE BOARD OF COLORADO VS. WESTERN ALFALFA CORPORATION, U.S. SUPREME COURT, No. 73-690. (MAY 20, 1974)

The Air Pollution Variance Board of the State of Colorado challenged the Colorado Court of Appeals decision (No. 71-494, 1973, 510 P. 2d 907) that an evaluation of the opacity of visible emissions from an observation site on company property, and which was made without notifying the company, constituted an unreasonable search and lacked the fundamental elements of due process of law.

The Board then appealed this decision to the U.S. Supreme Court which ruled unanimously that State authorities are free to make unannounced inspections on the property of suspected air polluters and neither a search warrant nor advance notice is required for inspections. Justice Douglas, in his opinion, also stated that no search warrant is needed for "sights seen in open fields." The court determined that, depending on the layout of each plant, the inspection can be made from locations inside or outside company premises, in order to be able to make an evaluation from a suitable observation point.

CASE 2: NORTHWESTERN LAUNDRY VS. DES MOINES, 239 U.S. 486, 365, ct. 206, 60 L.ed. 396, Des Moines, Iowa (1916)

This is a very important early case in the history of air pollution laws. The court decided that:

1. The Des Moines ordinance declaring the emission of dense smoke to be a public nuisance was constitutional.
2. The Ringelmann Smoke Chart represented a valid method of measuring the opacity of emissions.
3. There are no constitutional objections to the regulations, even though the company may be forced to spend a considerable amount of money in order to comply with the regulations, or close down if compliance could not be achieved.

CASE 3: BOARD OF HEALTH OF WEEHAWKEN TOWNSHIP, HUDSON COUNTY VS. NEW YORK CENTRAL RAILROAD 4 N.J. 293, 72 A 2d (1950)

The court said: "...There are no constitutional restraints upon state actions against the emissions of dense smoke injurious to the common welfare; the only requirement is that the regulation be free from arbitrariness. Northwestern Laundry Co. vs. Des Moines supra."

CASE 4: CINCINNATI VS. BURKHARDT, 30 OHIO CIR. CT. REP. 350, ANN. CAS., 1918 B, 174. Cincinnati, Ohio. (1908)

An ordinance which provided for the measurement of the density of smoke by use of a color scale was upheld.

CASE 5: CITY OF ROCHESTER VS. MACAULAY-FIEN MILL COMPANY, 199 N.Y. 207, 92 N.E. 641, 32 L.R.A. (N.S.). 554, Rochester, N.Y. (1910)

The court held reasonable an ordinance of the City of Rochester which provided for the adoption of the standard of the Ringelmann Scale, prohibited dense smoke during the day, except from between 5 a.m. and 7:30 a.m., and which permitted the emission of dense smoke for 5 minutes in every 4 consecutive hours.

CASE 6: PEOPLE VS. INTERNATIONAL STEEL CORPORATION 102 CAL. APP. 2ND SUPP. 935, 226 p. 2d 587, Los Angeles, California. (1951)

The Appellate Department of the Los Angeles County Superior Court approved the use of the Ringelmann Chart for measuring the opacity of visible emissions, and asserted that inspectors trained in the use of the chart may be classified as experts and may testify as such to the Ringelmann number of a particular smoke emission, without using an actual chart during the evaluation.

CASE 7: PEOPLE VS. INTERNATIONAL STEEL CORPORATION ET AL., CR A 2654 Los Angeles, California. (1951)

The defendants claimed that the California opacity regulation was unconstitutional in that a distinction between permission and prohibition, as far as opacity is concerned cannot be drawn; or if such a distinction can be drawn, it is drawn in the wrong place. They further claimed that the opacity regulation does not apply to certain agricultural operations or orchard heaters which they claimed prevents the law from having a uniform operation, making the law arbitrary in its application. The court disallowed all the above claims.

Three witnesses testified regarding the opacity of the smoke being discharged from the defendants' place of business. The defendants claimed that the witnesses showed no qualifications sufficient to enable them to give expert testimony on the subject, and that their observations were not sufficient because they had no Ringelmann chart with them at the time the observations were made. The court ruled that the witnesses were qualified to testify as expert witnesses and that a Ringelmann chart was not necessary since they had all been certified as "smoke readers" without the use of the Ringelmann chart at a school given by the Los Angeles County Air Pollution Control District.

The court upheld the conviction against one of the officers of the corporation since the court decided that he was in charge of the operation. The court dismissed the charges against the other officer of the corporation, since it decided that although he knew of the operations he did not have any control over them.

CASE 8: PEOPLE VS. SOUTHERN PACIFIC COMPANY, ETC., CR A 3585 TRIAL COURT NO. 57288, Los Angeles, California. (1957).

This case concerned a fire that burned for several hours and the opacity of the smoke from this fire exceeded the regulation limit. It was not clear how the fire was started, but an employee of the company was aware of the fire and made no effort to extinguish it. The court held that the company was responsible for the fire and therefore was liable in the same manner as the one who started the fire.

CASE 9: PEOPLE VS. FRANK BABCOCK, CR A 3676, Los Angeles, California. (1957)

The defendant was the owner and operator of several apartment and hotel buildings in the Los Angeles area and was charged with two counts of emitting smoke from boilers in these buildings. It was his contention, on appeal of being gound guilty, that the statute was unconstitutional in that in San Francisco where there is also an Air Pollution Control District the violation would not have been a criminal offense, whereas in Los Angeles the same act would have been. He contended that there was unequal classification, therefore the statute was unconstitutional. The People's contention, on appeal, was that there was a reasonable classification in that in different localities there were different smog conditions, different problems, and therefore, different regulations. The court dismissed the defendant's claims.

CASE 10: PEOPLE VS. METROPOLITAN STEVEDORE COMPANY, CR A 3562, Long Beach, California (1957)

The defendants operated a bulk loader in such a manner that cargo being loaded into the hold of a ship emitted dust of an opacity darker than the regulation limit. They contended that: (1) Application of the opacity regulation to the bulk loader constituted an unlawful burden on foreign commerce, (2) the opacity regulation was not applicable to operations made pursuant to its contract, and (3) the evidence was insufficient to support the judgment. The court dismissed all of the defendants' claims.

CASE 11: ESSEX CHEMICAL CORPORATION, ET AL, VS. RUCKELSHAUS,U.S. APP. D.C. 486 F2d 427. (SEPTEMBER 10, 1973)

The 10% opacity standard for sulfuric acid plants, and the 20% opacity standard for coal-fired steam generators, were challenged on grounds identical to the Portland Cement Association case discussed below i.e. the standard is arbitrary and opacity determinations cannot be made with sufficient accuracy at these low opacity values.

This case was also remanded, and at the time of publication of this manual the case has not yet been reheard.

CASE 12: STATE VS. FRY ROOFING COMPANY, OREGON COURT OF APPEALS, 495 P. 2d 751. (1973)

The circuit court had found Fry Roofing Company guilty of violating the Oregon opacity regulation. The Oregon Court of Appeals found that the regulation limiting emissions that are greater than 40% opacity to three minutes in any hour was constitutional. The Appeals Court also ruled that the original judges had not abused their authority by admitting the testimony of inspectors with only two day's training in the evaluation of visible emissions who had been recertified shortly before making the evaluation.

CASE 13: PORTLAND CEMENT ASSOCIATION VS. RUCKELSHAUS 486 F 2d 375, U.S. COURT OF APPEALS, DISTRICT COLUMBIA CIRCUIT (JUNE 29, 1973)

EPA's response to the "unreliability" challenge to Section 111 opacity standards was held sufficient justification for such regulations to measure pollution and to aid in control of emissions, and were therefore validated on remand by the Court in Portland Cement Association vs. Train, Administrator, No. 72-1073 D.C. Cir. May 22, 1975. While this validation of opacity regulations is binding only for Section 111 purposes, it will serve as valuable precedent for challenge to opacity standards within the State Implementation Plans.

CASE 14: NATIONAL ASPHALT PAVEMENT ASSOCIATION VS. TRAIN, U.S. APP. D.C. - NO. 74-1332 (1975)

This case deals with opacity issues similar to those contained in Case #13, and will be heard by the Court in the fall of 1975.

CASE 15: STATE OF NEW JERSEY VS. FRY ROOFING Docket No. C-3682-72 New Jersey Superior Court, Trenton, New Jersey. (1974)

Fry Roofing contended that the procedures for determining opacity "1)....were scientifically inaccurate in that they were simply estimates obtained by the unaided eyes of field observers, and that the investigators did not distinguish visible water vapor from the particulate plume; and 2) that the investigations were conducted without a warrant, without notice to and without consent of the defendant, constituting unreasonable searches in violation of the Fourth and Fourteenth Amendments to the U.S. Constitution."

Violations of the opacity regulation were observed on two separate occasions; once from a location on company property and once from off company property. For both cases the company contended that the visual inspections violated the Fourth Amendment to the U.S. Constitution. Citing the Air Pollution Variance Board of the State of Colorado vs. Western Alfalfa Corporation (Case 1, above), the court concluded that the company's constitutional rights had not been violated.

The company contended that the observations were made without prior warning, violating the right of due process under the law. The court concluded that no prior warning is necessary.

The company also contended that the observers' training was inadequate since they had not received any training in the evaluation of plumes containing visible water vapor. Evidence was introduced to demonstrate that it is not difficult to determine if a steam plume is present and the observers testified that a "steam plume" had not been present. Using representative data for the stack exit conditions and actual meteorological observations, the witnesses demonstrated by use of a psychrometric chart that a steam plume would not be formed. The court concluded that the observers were fully qualified and the court was satisfied that there was no steam plume present at the time the observations were made.

The case was remanded, and at the time of publication of this manual the case had not reached the courts.

6.4 PRESENTATION OF TESTIMONY

6.4.1 GENERAL

Whether the case is to be heard before an administrative body or in a regular court of law, the witness must be prepared to properly convey to a board, jury, or judge his competency to testify, and his credibility as an evaluator of visible emissions.

The witness must have had adequate and proficient training as a result of attending a smoke-reading school operated in the manner prescribed in EPA Method 9 and from which he has received a certificate. He should be familiar with moisture laden plumes and understand how to evaluate them. He must be able to evaluate weather conditions by visual observations and with simple measuring devices.

The witness should have some familiarity with courtroom procedures. This can be acquired by attending actual trials or by participating in mock trials. He should be familiar with all aspects of the law that pertain to his responsibilities.

Given his expertise and knowledge of the case under review, the attitude of the witness is crucial to the effectiveness and acceptability of his testimony. His objective should be to provide accurate and complete facts in as clear a manner as possible in response to direct questions. He should not offer his opinions and judgments of the source being tried or of official programs or policies, nor should he be concerned with justifying his infallibility as an expert in his field. He should not argue with or "talk down" to the examiner, or give the impression that he is an expert in a specialized area when he is not. He should avoid exaggeration of the facts and boasting of his accomplishments.

The witness should be prepared for the proceeding. He should know the exact substance of what he will be called upon to testify. He should be rested and alert. Fatigue can affect concentration and the precision of answers to a marked degree. He should be able to quickly think through his answers before responding, and avoid saying anything that he does not mean.

6.4.2 WITNESS BEHAVIOR

Personal appearance in the courtroom is quite important. The witness should come to the courtroom in conservative dress (preferably a business suit, or in uniform, if applicable). He should be well-groomed with neatly trimmed hair. The witness should always arrive on time or a little ahead of time so as not to hold up the proceedings. In general the witness should avoid any behavior that might tend to create an unfavorable impression in the mind of the court.

When called to the stand, the witness should walk with assurance. When being sworn in, he should hold his right hand high with fingers extended and look directly at the person administering the oath. After the oath has been administered he should say "I do" in a loud voice, and generally behave in a confident manner.

6.4.3 TESTIMONY

The two main categories of witness testimony is the direct examination by his own counsel and the cross-examination by the opposing counsel. The direct examination is usually started with a line of questioning which will provide a foundation for the qualifications of the witness. The following list of questions which will be asked by the agency counsel will give some idea of how this is achieved:

1. State your full name and home address, please.
2. By whom are you employed?
3. How long?
4. Prior to your employment with (agency or company), did you have any college or university work? What kind of work? Graduate work? Degree?
5. Have you had any prior employment which might be relevant to this case?
6. Have you ever attended a training course which might be referred to as "Smoke School" or "Smoke-reading School"? When? Were you certified?
7. Describe briefly the training you received.
8. Did you learn to evaluate black smoke?
9. Did you learn to evaluate any color other than black?
10. Did you learn to evaluate emissions without the use of the Ringelmann Chart?
11. Were you required to attain a certain degree of proficiency before being certified?
12. What were the standards?
13. Do you recall your own personal proficiency?
14. Have you testified in court before as an expert?

The foundation of the case is then laid with questions similar to the following:

1. On date and location, were you on duty as a representative of (agency or company)?
2. What directed your attention to this location? (Routine observation, citizen's complaint, etc.)
3. Where were you when you first saw it?
4. Could you determine the source of emission?
5. Describe the premises.
6. Did you make any readings. What time did they begin? What time

did they end? What were the times, duration and densities of the emissions?

7. Did you see the source of the emissions?
8. Were any representatives of the defendant present and were there any conversations?

These are the types of questions that will be asked by the counsel in order to present the case to the court. The witness may use notes including the observation and summary forms, he has personally made in order to refresh his memory on any facts, but may not read from them directly. The answers to the questions should not be memorized but they should be accurate, factual and truthful.

After the direct examination is finished, the opposing counsel will cross-examine the witness. In this phase, he may try to discredit the witness, or present conflicting technological evidence. The witness must be knowledgeable in his field and be prepared to respond to such questions.

Re-direct examination by the witness' counsel may be necessary to rebut some points brought up in the cross-examination. Opposing counsel may then want to make an additional refutation. This type of questioning could go on indefinitely except that it will usually be terminated by the judge when he feels it is no longer useful to the trial.

For some administrative type hearings direct testimony is written out in narrative form and only the cross-examination is done orally. The opposition is usually given a week or two to study the document before the witness appears. This document usually consists of four parts: (a) his qualifications as an expert, (b) the material from which he fashions his opinion, (c) the reasoning process used to arrive at an opinion from the material, and (d) the conclusion or opinion itself.

Other cases involve discovery or the process by which one side finds out what the factual basis for the other side is. This may be done by deposition or interrogatories. For a deposition the potential witness is placed under oath before a court reporter and asked a wide range of questions designed to prepare the opposing lawyer for his testimony at the trial. The interrogatories are merely written questions served upon the opposition which are to be answered under oath.

In any case, the witness must eventually appear in court to present his testimony. Some guidelines for this presentation are given below.

If at all possible, the witness should be on hand to view the proceedings prior to his testimony. This will give him the "tone" of the hearing and indicate in general what type of questions to expect. Most importantly, it will reassure him.

6.4.4 TYPE OF INFORMATION REQUIRED IN TESTIMONY

The witness may be called upon to present any information that he may have that will be necessary to prove a violation. These tend to fall into two categories:

1. Basic elements
   a. The rule or state code section violated.
   b. The date and location of the violation.
   c. The time or times of violation.
   d. The time, duration, and densities of the violating opacities.
   e. The names and titles of the owners and operators of the equipment emitting the violating opacities.
   f. The names of the enforcement officers observing the violation (usually the witness).

2. Supportive elements
   a. Identity of visible emissions, i.e. "smoke" "fume" "dust" etc.
   b. Description of the equipment and process or processes with their operating cycles.
   c. Ambient atmospheric conditions.
      1. Light conditions and sun position.
      2. Wind direction and velocity.
      3. Temperature and relative humidity.

   d. Background against which observation was made.
   e. Position of observer relative to point of emission; the height of the stack and his distance from it.
   f. Description of surrounding geographic features such as buildings and streets.
   g. Certification date of the observer.
   h. Description of plume appearance, i.e. color, length,

moisture, etc.

While on the stand the witness should always be truthful, fair and frank. Before replying to a question the witness should pause for a while in order to collect his thoughts. A hasty answer may not convey the full facts that should be brought out and an incomplete, or erroneous, reply might place the opposing counsel in a position to discredit the witness, which in turn could seriously jeopardize the case.

Answers should be brief and to the point. Information should never be volunteered--the reply should merely be an answer to the question asked. If an objective is raised the witness should stop speaking at once, and not continue until the court has given its ruling. If the opposing attorney interrupts an answer this should be indicated to the presiding judge. The skillful witness also knows when to concede a point, even if it reflects poorly on his work.

The witness should express himself as lucidly as possible, using simple technical language that the judge, jury and attorneys can understand. The court should not be treated in a condescending manner, however. Mannerisms, witicisms and colloquialisms should be held to a minimum, and no attempt should be made to overimpress the court with irrelevant information.

For the court reporters' benefit, the witness should speak loudly, clearly and slowly, waiting until the question has been completed before beginning the answer. Replies should not be made by a movement of the head to imply a "yes" or "no" answer, since the court reporter may not always be looking at the witness.

When addressing the court, use "Your Honor"; when addressing the attorneys, use their names.

The witness should never lose his composure by becoming flustered or losing his temper, especially when being goaded or aroused by the opposing counsel. The witness also has no obligation to answer a question which he does not feel qualified to answer. An "I am not qualified to answer that" is perfectly acceptable.

If the witness has made a mistake, or a contradictory statement, this should be admitted and corrected. Under no circumstances should any attempt be made to cover up the error, since it is almost inevitable that the true facts will eventually emerge, throwing the witness' credibility into a very poor light.

During recesses the witness should not discuss anything with other witnesses or parties to the case, and should only speak with his own counsel.

The witness should not allow the opposing counsel to suggest facts or an opinion. Under no circumstances should the counsel be engaged in an argument. An answer to a question which is identical to a previous question should be restated as given the first time. Additional statements can be given, however, to help clarify the original statement, if this is indicated by the line of questioning.

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7. EFFECTS OF VIEWING CONDITIONS ON OPACITY READINGS

7.1 WIND SPEED

The stronger the wind speed the more the plume will be diluted, thus reducing the opacity. However, a small finite time must elapse before the plume can mix significantly with the ambient air, with the result that the plume opacity at the emission point is not affected by wind speed to any great extent.

Read at stack exit, or the source point.

7.2 WIND DIRECTION

If the plume is being blown directly toward or away from the observer, the observer tends to read through a longer path length than when readings are taken with the wind blowing perpendicularly to the observer's line of sight. The longer the path length through the plume, the greater the plume opacity will appear.

Difficulties in obtaining good readings, especially for low-level sources, can be experienced under light, variable wind conditions. (This is most likely to occur on hot, sunny afternoons). Wind direction can vary considerably within a very short period of time (360^{o} in less than a minute, for example) with the result that the observer can find himself in a poor position for taking opacity readings at the specified 15- or 30- second time intervals. Under variable wind conditions the observer should watch the plume more or less continually and take readings when the plume is being blown at right angles to the observer's line of sight. (The observer can change the observation point should the mean wind direction change, provided that the sun remains in the proper orientation. Any changes in the observer's location must be indicated on the observation summary form).

Read at right angles to the wind direction.

7.3 VIEWING POINT

As the plume is transported downwind diffusion takes place, reducing the concentration of the effluent and thus reducing the opacity.

An exception to this may occur in the case of an acid mist plume where the greatest opacity can occur a small distance from the stack exit. This is caused by the hygroscopic acid mist particles growing in size by absorbing water vapor as they are transported downwind.

Always read at the point of maximum opacity. For a particulate plume this will be at the stack exit but for an acid mist plume it can be some distance downstream. (Indicate on the observation form where the viewing point is in relation to the stack exit or source point).

7.4 ILLUMINATION

Contrast between the plume and the background will increase with increasing illumination, causing the apparent opacity to increase.

Attempt to take readings with good lighting conditions.

7.5 BACKGROUND

Tests conducted by Hamil, et. al., (1975) indicated that the background used to evaluate the opacity of an emission does have an effect on the observed opacity. Hamil presented data showing that for white smoke the inspectors' readings tended to have a negative bias (i.e. they read low) whenever a non-contrasting background (overcast sky) was used. When a contrasting background (blue sky) was used, the inspectors tended to have a slight positive bias (i.e. they read high) for very low opacities (15% opacity, or lower) and they tended to read low in the 20% to 35% opacity range.

Whenever possible black plumes should be evaluated using blue sky as background and white plumes should be evaluated using a dark background, such as buildings or hills. Evaluating plumes against a non-contrasting background tends to reduce the observed opacity.

A contrasting background should be used if possible.

7.6 ATMOSPHERIC STABILITY

A plume disperses more rapidly in an unstable atmosphere than in stable atmosphere. Although a plume appears less dense downwind in an unstable atmosphere, if readings are taken at the source, atmospheric stability has no significant effect on the opacity.

Read at stack exit or source point.

7.7 ATMOSPHERIC HAZE

The presence of haze, either natural or man-made, in the atmosphere will reduce the contrast between the plume and its background, and hence will reduce the opacity reading. Atmospheric haze should not significantly affect the opacity reading if the visibility is greater than about three miles and the observation point is within ¼ mile of the emission point.

Readings should not be taken in poor visibility conditions.

7.8 SUN ANGLE

The particles in the plume scatter more light in the forward direction (at small angles with reference to the direction of the sun's rays). A plume viewed such that the observer is looking toward the sun appears to be more dense than a plume viewed with the sun located behind the observer. A reading taken with the sun directly behind the observer will produce the lowest opacity reading possible with the existing conditions, but it has been found experimentally that the observed opacity is not particularly sensitive to the sun's location provided the sun is behind the observer, within an angle of about 70^{o} with the line of sight.

The sun should be within a 140^{o} sector oriented behind the observer's back.

7.9 EFFECT OF OBSERVER DISTANCE ON OBSERVED OPACITY

As the observer moves closer to the base of the stack of an elevated source the pathlength through the plume increases, so that the observed opacity increases with decreasing observational distance, even though the cross-plume opacity remains constant. (See Figure 7.1.) Table 7.1 below compares the variation of the observed opacity with distance from the base of the stack which is emitting a plume of 20% opacity. As shown in the table the observed opacity, as evaluated from a distance of one stack height (H) is 28%, whereas this value drops to 22% from a distance of 2H, and 21% from a distance 3H.

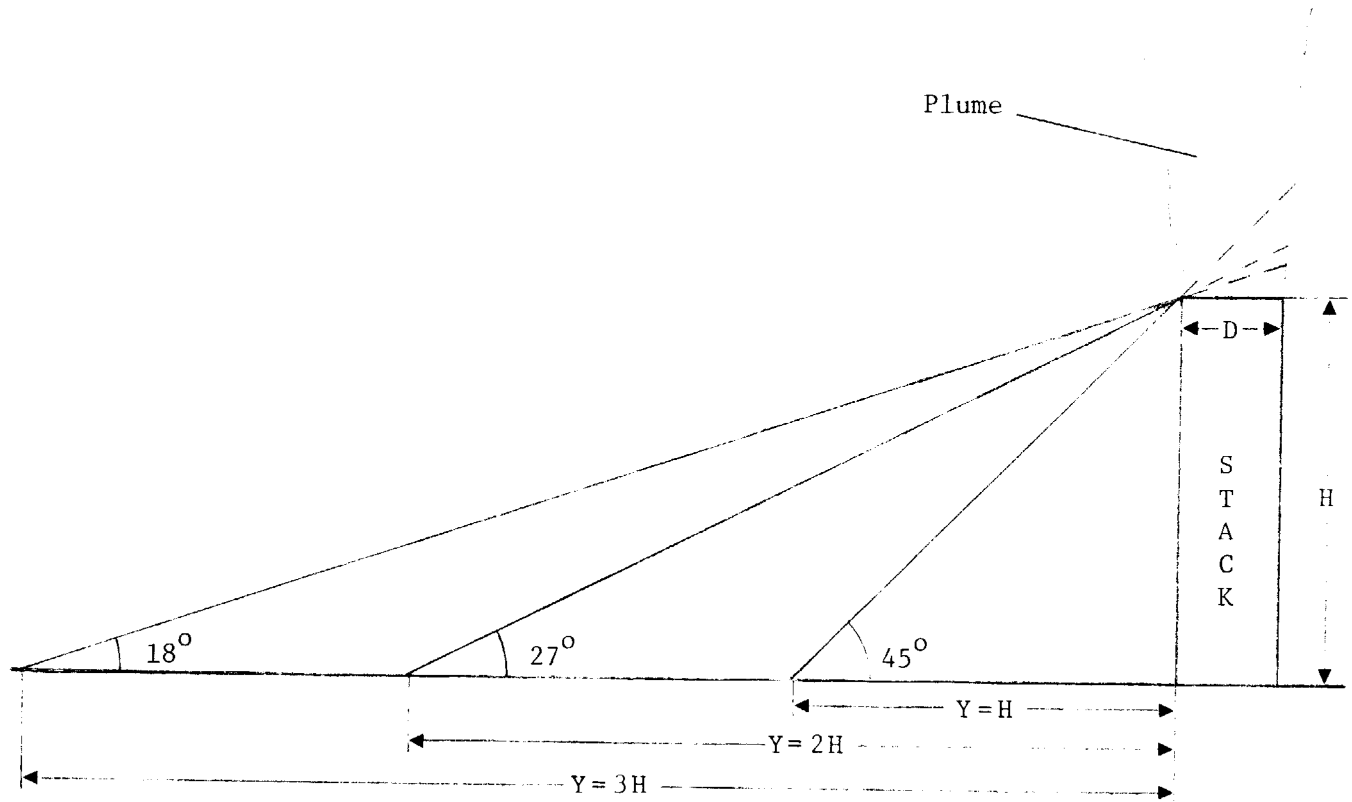

Figure 7.1: EFFECT OF OBSERVER LOCATION ON OBSERVED PATHLENGTH

Table 7.1: VARIATION OF OBSERVED OPACITY WITH DISTANCE FROM AN ELEVATED SOURCE

OBSERVER DISTANCE (Y)	OBSERVED PATHLENGTH	ACTUAL OPACITY %	OBSERVED OPACITY %	DEVIATION %
H	1.41D	20	28.2	8
2H	1.12D	20	22.4	2
3H	1.05D	20	21.0	1

Significant increases in the observed opacity can therefore be introduced if the observer selects an observation location that is very close to the base of the stack. If observations are made from positions that are very close to an elevated source the effect that this has on the opacity readings should be carefully weighed if the readings are to be used as testimony in subsequent legal proceedings.

As the observer moves further away from the source, the contrast between the plume and the background decreases, causing a decrease in the observed opacity. This is due to light scattering by the particles in the air between the source and the observer, and it is particularly noticeable when the visibility is not very good.

Earlier versions of Method 9 recommended that the observer should be between two stack heights and a quarter or a mile from the source. While these requirements are no longer valid, they do indicate approximately what the distance between the source and the observer should be.

When evaluating an elevated source the observer should be at a suitable distance from the source. ≃ 2-3H

7.10 TIME INTERVAL BETWEEN READINGS

Staring continuously at the plume will result in eye fatigue resulting in reduced visual acuity. For this reason the observer should glance at the plume and make the opacity determination at regular intervals. The recommended time interval between readings is 15 seconds. If longer time intervals between readings are taken, the reasons for this should be shown on the observation form.

Read at 15-second time intervals.

7.11 SUMMARY OF RECOMMENDED OBSERVATIONAL PROCEDURES

Opacity readings should be taken:

- at 15-second intervals
- through the densest part of the plume
- under good lighting conditions
- with a contrasting background, if possible
- with the sun behind the observer
- with the plume being blown at right angles to the line of sight
- at a suitable distance from the source.

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8. APPLICABILITY OF VISIBLE EMISSIONS EVALUATIONS

8.1 ADVANTAGES

Opacity regulations (formerly Ringelmann and equivalent opacity method) have been the foundation for the vast majority of particulate control or enforcement actions in this country. The task of visible emission compliance would be much more difficult without this simple but effective means of source surveillance.

From the standpoint of the responsible air pollution control agency, some of the advantages of the use of opacity regulations are:

(1) The validity of using the Ringelmann Chart and opacity provisions has been well established in the field of air pollution legislation by the courts.

(2) Observers can be qualified in about three days of training and it is not necessary that the observers have an extensive technical background. Recertification can be achieved in one day, or less, every six months.

(3) No expensive equipment is required in comparison to alternative source measurement procedures.

(4) A qualified inspector can make several observations per day, enabling a wide area to be inspected, particularly for those agencies equipped with a helicopter or light aircraft, allowing potential violators to be quickly located and identified.

(5) Violators can be cited without resorting to time-consuming and costly source testing.

(6) Opacity regulations serve as an effective screening process to reduce the number of expensive source tests required for informational and enforcement requirements.

(7) Although it is usually not possible to accurately quantify the reduction in mass emissions by visual observations, there is a definite relationship between reducing visible emissions and improvements in particulate air quality.

(8) Control can be achieved for those operations not readily suitable to regular source testing methods, such as dust and other leakage from process equipment, visible automobile exhaust, and bulk loading, unloading, or storage of dusty materials (grains, coal, ores, etc.).

(9) Opacity regulations provide an expedient means for sources to conduct self-appraisals and monitor their operating conditions.

(10) The presence of visible emissions is prima facie evidence that something other than clean air is present in the atmosphere.

(11) It provides an excellent tool to bring minor or marginal sources of pollution under control that would normally be exempt under process weight restrictions.

(12) In most cases, a trained observer can distinguish smokes and mists by color, behavior and dissipation point. He can distinguish between emissions of smoke resulting from rubbish burning, fuel-oil burning and even natural gas, when gas-fired boilers are severely out of adjustment, by color and escape velocity of the body of the plume.

(13) The results of such regulations provide an indication to any observer (officials, citizens, etc.) that the agencies maintain good operating practices and procedures.

(14) Opacity can be monitored and recorded automatically by means of bolometers, photoelectric cells, etc., to ensure compliance with the applicable regulations.

(15) Visible emissions are easily observed by laymen who can act as "spotters" for the air pollution agency. Although laymen cannot be considered as expert witnesses, they can serve to inform the agency of possible violations of the regulations.

8.2 OBJECTIONS

The most common objections to the use of equivalent opacity, and rebuttals to these objections, are given below:

1.1 "The opacity observed is a subjective measurement, varying with the position of the observer in relation to the sun and sky, with the size of particles in the plume, stack diameter, and with atmospheric lighting and background of the plume."

1.2 This objection has been used for many years against the use of the Ringelmann Chart for gray smoke, but to date no other method has been found to be as practical and useful. It has been shown that with adequate training, using consistent observational procedures, an experienced observer can learn to weight the opacity readings according to various conditions, with good accuracy and reproducability.

2.1 "Opacity has not as yet been successfully correlated in detail with other methods of measurement."

2.2 In recent years several plume opacity models have been developed that have shown good correlation between predicted and observed opacity. The models do require that the input parameters, such as grain loading and particulate size distribution, be well defined.

The particles causing the light scattering are in the submicronic range and normally constitute a small percentage of the total particulate emissions, whereas the particles causing light absorption are primarily greater than 10 microns in diameter. Reducing the plume opacity therefore would result in a reduction of the total particulate emissions, although not necessarily in the same ratio.

3.1 "Gaseous emissions cannot be determined by equivalent opacity."

3.2 This is generally true since most, although not all, gaseous emissions are invisible. However, the use of a visible emission regulation should not be regarded as the only enforcement regulation available to an air pollution agency and it does not eliminate the need for qualified technical personnel, source testing capability, a thorough understanding of the processes leading to air pollutant emissions, and sound engineering and administrative judgment.

4.1 "Visible emission observations are difficult to make at night."

4.2 Provided the observer has been properly qualified to make opacity determinations at night and the approved procedures are followed, opacity observations can be made during the hours of darkness. However, EPA does not have a procedure for night-time evaluation at the present time.

5.1 "Water droplets interfere with the equivalent opacity observations."

5.2 Air pollution control regulations exempt visible emissions which violate the opacity rule because of the presence of water droplets in the plume, so that some allowance must be made for those plumes whose opacity is derived from the presence of condensed water vapor. It is relatively simple to identify the presence and exact location of a steam plume, and the problem is easily handled by making the evaluation at a point in the plume where condensed water is not present.

6.1 "The regulations concerning the opacity of emissions are arbitrary and capricious."

6.2 There are many legal precedents including a U.S. Supreme ruling (Air Pollution Variance Board of the State of Colorado vs. Western Alfalfa Corporation, - U.S. - 94 S. Ct. 2114. 1974) which indicate that this is not the case. If a reading is made in a proper manner by a trained observer, this is considered to be a perfectly legal and valid measurement of the degree of pollution created by visible emissions from a given source.

7.1 "It is difficult to secure guarantees from vendors that a control system can be designed to ensure that a source will achieve compliance with the visible emission regulation."

7.2 For a given set of stack conditions it is possible to obtain good correlation between opacity and grain loading. Vendors can therefore design control equipment for a specific source that will ensure compliance.

8.1 "Visible emission regulations can be circumvented by the introduction of dilution air, or by reducing the exit diameter of the stack."

8.2 Normally the introduction of air in order to bring a source into compliance is a contravention of the regulations. Reducing the stack diameter may not be a contravention of the regulations, however, this may not be a very wise strategy for the source to undertake, since compliance with the process weight and grain loading regulations must still be achieved.

8.3 SUMMARY

While the arguments continue and positions remain polarized, the fact remains that opacity regulations and their enforcement have unquestionably proven to be an effective and dynamic abatement and compliance tool for use in the control of air pollution.

The general public is probably more aware aware and concerned with visible emissions than with any other aspect of the air pollution problem, and the application of an opacity standard is a very effective means of demonstrating that measures are being taken to ameliorate the problem.

While enforcement actions based on opacity observations have been, and probably will continue to be, challenged in the courts, if the observations are made according to the approved procedures by a properly qualified inspector the courts will probably continue to accept opacity observations as a valid measure of the emissions from a source.

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9. PARTICLE SIZES AND THEIR CHARACTERISTICS

9.1 GENERAL

A particle is defined as any dispersed material, either solid or liquid, in which the individual aggregates are larger than single small molecules (0.002 microns in diameter) but smaller than 500 microns. Particles have a life-time in the suspended state varying from a few seconds to several months. Chemically they are a most diverse class of substances, although physically they do have a number of properties in common. Table 9.1 gives a brief summary of the types of particles and their characteristics.

The usual means of classifying particles is by their "size". Size may be defined in several ways, although the most usual definition is to classify particles by their "Stokes" or aerodynamic diameter, which is a measure of their settling velocity. This settling velocity depends on the configuration of the particle, so that a non-spherical particle is classified by the Stokes diameter of a spherical particle that has the same settling rate.

Although the distribution of particle sizes usually encountered in the atmosphere closely approximates a log-normal distribution (Volz,1959), shown in Figure 9.1 with a median size of 1 micron, the particle size distribution in a plume is usually very different from this, and in addition the distribution is different for each type of source.

9.2 SIZES OF PARTICULATE MATTER EMISSIONS

Particles are produced by two mechanisms: those below 1 micron are formed principally by condensation, while larger particles result from comminution.

Combustion of fuels is a complex source of particulate emissions with particles being formed in the following ways:

1. The heat may vaporize material which subsequently condenses to yield particles in the size range between 0.1 and 1 microns.

Table 9.1: PARTICLE SIZES AND CHARACTERISTICS

Size (microns) (mm)	0.1 0.0001	0.5 0.0005	1 0.001	10 0.01	100 0.1
Light Light Scattering	UV Some	Visible Yes	Near IR Yes	IR Some	Far IR Little
Examples	Carbon Black, Fume, Combustion Nuclei	Tobacco Smoke, Smog, Oil Smoke	Sulfuric Acid Mist, Talc, Clay	Cement Dust, Fog, Bacteria	Human Hair, Mist, Sand
Settling Velocity cm/sec.	0.0002	0.002	0.007	0.6	50

From: Sheehy et al. (1968)

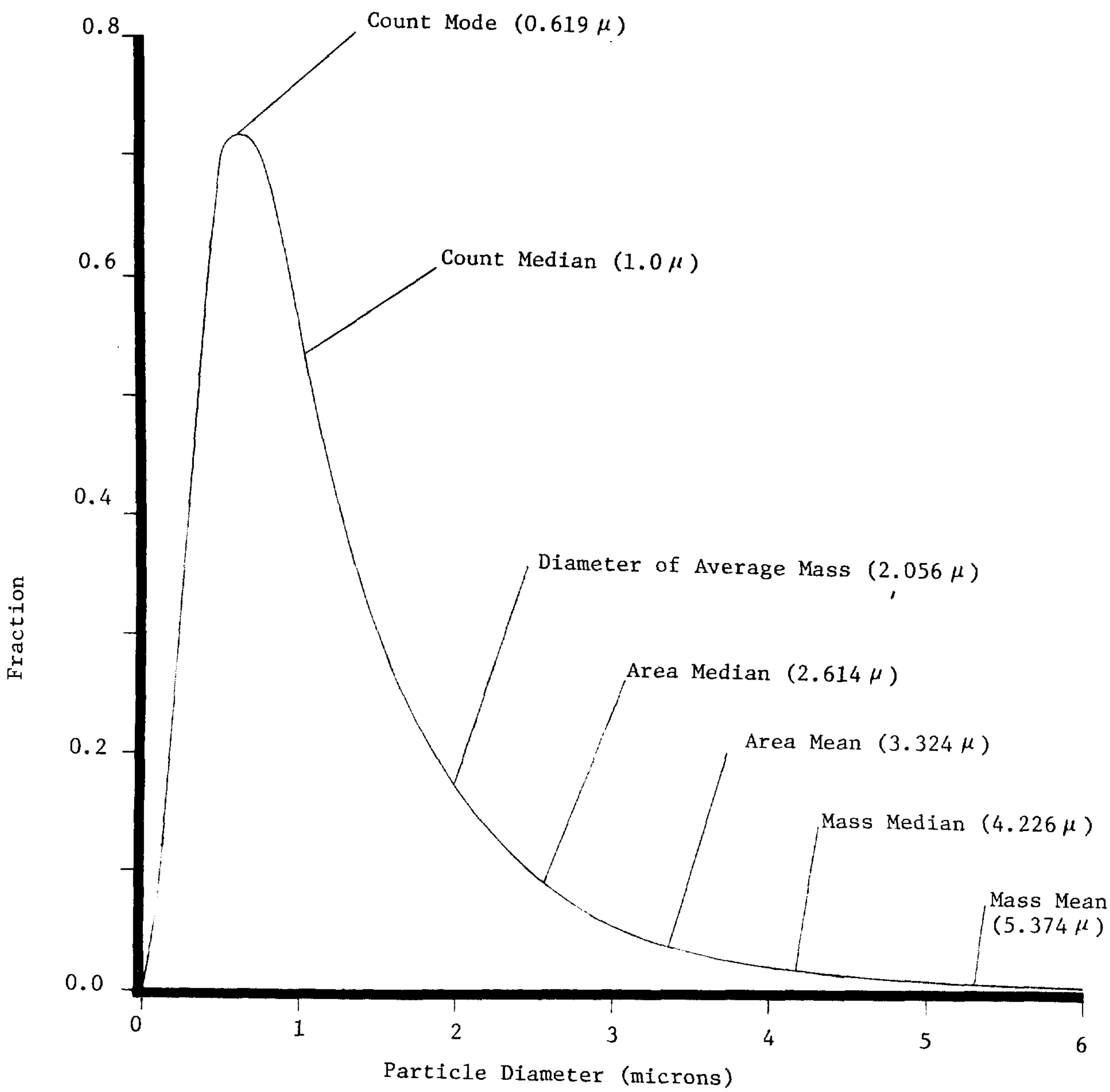

Figure 9.1: TYPICAL SIZE DISTRIBUTION OF PARTICLES IN THE ATMOSPHERE SHOWING VARIOUS AVERAGE DIAMETERS (VOLZ, 1959)

2. Particles of very small size are also produced (below 0.1 microns); these particles may be of short life as a result of their being simply unstable molecular clusters.
3. Mechanical processes may reduce either fuel or ash to particle sizes larger than 1 microns and may entrain it.
4. If the fuel is itself an aerosol during combustion, a very fine ash may escape directly.
5. Partial combustion of fossil fuels may result in soot formation.

Particles larger than 10 microns frequently result from mechanical processes such as wind erosion, grinding, spraying, etc., although natural precipitation is obviously not produced in this way.

NAPCA (1969) has given the size distributions of particulate emissions from several major source categories:

Open-Hearth Furnaces (Silverman, 1955)

Majority of particles by number $<$ 0.1 microns

About 46% by weight $<$ 5 microns

Municipal Incinerators (Chass and Rose, 1953)

About 30% by weight $<$ 5 microns

Sulphuric Acid Manufacture

Chamber Process (NAPCA, 1969)

About 10% by weight $<$ 3 microns

Contact Process (U.S. Department of HEW, 1965)

About 63% by weight $<$ 3 microns

Cement Plants (Kreichelt, Kemnitz and Cuffe, 1967)

About 30% by weight $<$ 5 microns

About 20% by weight $<$ 2 microns

Automobiles (Mueller, Helwig, Alcocer, Gong, and Jones, 1964, and Lee, Patterson, Crider and Wagman, 1968)

About 70% by weight $<$ 2 microns

About 90% of lead emissions is contained in particles $<$ 0.5 microns

Fuel Oil Combustion

The size distribution of particulate emissions from large oil burning units Table 9.2, was given by Smith (1962).

Table 9.2: SIZE DI^TRIBUTION (% BY NUMBER) FROM OIL COMBUSTION

Case	0-1μ	1-2μ	2-5μ	>5μ	Largest μ
1	48.4	28.8	16.7	6.1	15
2	64.2	18.8	10.0	7.0	15
3	93.5	3.2	2.0	1.3	20
4	94.8	2.2	1.5	1.0	20

Coal Combustion

Size distributions for four coal-burning furnace types were given by Smith and Gruber (1966) and are reproduced below in Table 9.3.

Table 9.3: WEIGHT PERCENT LESS THAN STATED SIZE FROM COAL COMBUSTION

Particle Size (μ)	Pulverized Fuel Fired Furnace	Cyclone Furnace	Spreader Stoker-Fired Furnace	Stoker-Fired (Other-than Spreader)
10	30	76	10	7
20	50	83	20	15
40	70	90	37	26
60	80	92	47	36
80	85	94	54	43
100	90	95	60	50
200	96	97	-	66

9.3 EFFECT OF ATMOSPHERIC PARTICULATES ON CLIMATE

Particles in the atmosphere play several roles in the behavior and determination of the weather. One of the more obvious ways is the effect they have on solar radiation, by scattering and absorbing the incoming light to greater or lesser extents in different wavelengths depending upon particle size, character and concentration, providing not only colorful sunsets, but also dense urban palls and reducing the amount of solar energy reaching the ground.

They play an essential role in the formation of clouds and in causing precipitation from these clouds. The question has also been raised in recent years of the long-term effects of high particulate loading in the atmosphere. It has been suggested that a high atmospheric particulate loading would lead to a reduction of the Earth's temperature, effected by the particles absorbing the solar radiation before it is allowed to reach the surface, although no conclusive evidence has been produced to date to either prove or disprove this suggestion.

During the winter period there is increased usage of fossil fuels for heating purposes, particularly in the colder areas of the country, resulting in greater emissions of particulates to the atmosphere which has the effect of reducing the amount of sunlight reaching the surface. Sheleikovskii (1949) presented figures to show that in Leningrad this reduction could be as high as 10% during the summer and 70% during the winter.

9.4 ATTENUATION OF SOLAR RADIATION

Solar radiation is attenuated during its passage through the atmosphere by four physical factors:

1. Scattering by the air molecules and particles which are smaller than the wavelength of light. This is known as "Rayleigh scattering." Scattering is inversely proportional to the fourth power of the wavelength so that light of shorter wavelength is scattered most, accounting for the blue color of the sky.
2. Selective absorption by the gases present in the atmosphere (Ozone, Carbon Dioxide, water vapor, etc.)
3. Scattering by particulate matter which is roughly the same size as the wavelength of light. This is known as "Mie scattering."
4. Absorption by particulate matter which is the same as, or larger than, the wavelength of light.

Mie scattering is the dominant form of attenuation in the atmosphere, and for plumes the other three factors may usually be ignored.

Visible light has a wavelength of between about 0.4 and 0.7 microns. Particles within the 0.1 to 1 micron range scatter light more efficiently than particles of other sizes. When light is scattered, more is scattered in the forward direction (parallel to the direction of the light) than in other directions.

Scattering of light in the atmosphere reduces the contrast between a target and its background i.e. visibility is reduced by the presence of small particles in the atmosphere. Because of the forward scattering mentioned above, visibility is greater when measured away from the sun than when measured toward the sun.

9.5 HEALTH EFFECTS OF ATMOSPHERIC PARTICLES

Experiments by various workers, Dautrebande, Bechmann and Walkenhorst (1957) and Findeisen (1935), for example, have shown that particles of small diameter settle out in the passageways of the human lung. It has been shown that virtually all particles larger than 1 micron become trapped in the respiratory system, and moreover, for particles of about 1 micron in diameter, 80% are deposited in the alveolar region with a corresponding value of 50% for 0.5 micron particles. It is in the alveoli that oxygen from the air is transferred into the bloodstream, and waste gases are transferred into the air, and if the subject is exposed to continually high concentrations of these particles they will tend to decrease the lung efficiency and eventually can lead to lung disease.

It should be noted here that the particles in the 0.5 to 1 micron range, which do the most damage in the alveolar region, are also those particles which are of the same size as the wavelength of light and have the greatest effect on scattering the light, and therefore the greatest effect on plume opacity. There is then a correlation between the plume opacity, as determined by the observer in the field, and the amount of lung-damaging particulate being emitted.

9.6 REMOVAL MECHANISMS

9.6.1 GRAVITATIONAL SETTLING

This is an important removal mechanism primarily for those particles larger than about 20 microns, when settling occurs within a fairly short distance from the source.

For a 50 micron particle the settling velocity is about 12 cm/sec, so that if the release point is 100m above ground level the particle would reach the ground after about 14 minutes. With a wind speed of 5m/sec. the particle would therefore reach ground level some 4 km from the emission point.

For a 0.5 micron particle emitted from the same stack with the same wind speed the settling velocity is only about 0.002 cm/sec. and ground impact would not occur until some 250,000 km downwind, so that to all intents and purposes these very small particles would remain in the atmosphere almost indefinitely, being transported across State and international borders, unless there existed some other removal mechanism. Fortunately there are other processes available for removal, such as coagulation, rainout, washout and impaction.

The above times and distances should not be taken as absolute values since the particles are affected by the turbulent eddies in the atmosphere, with the result that some particles will settle out before the distances given above, and some particles will settle out at considerably further distances.

9.6.2 COAGULATION

When particles come into contact and adhere to one another the process is called coagulation. Particles can come into close proximity because of their Brownian motion, resulting in thermal coagulation, or superimposed on this there can also exist an orderly motion produced by electrical, gravitational or other forces.

After coagulation has occurred the new particle has a larger gravitational settling rate and different light scattering properties, compared to the original.

9.6.3 RAINOUT

If there is sufficient water vapor present in the air, particles that are 0.2 microns or larger in diameter act as nuclei for the formation of raindrops.

9.6.4 WASHOUT

Particles that are larger than about 1 micron can collide with and be absorbed by raindrops. Particles smaller than about 1 micron have such small inertia that the pressure forces surrounding a falling raindrop are sufficiently large to prevent the particle from contacting the raindrop.

9.6.5 IMPACTION

When particles come into contact with a surface, such as a building or vegetation, present in the atmosphere, they can settle out from the flow and become loosely attached to the surface. This attachment can be strengthened by any electrostatic attraction between the particle and the surface.

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10. AIDS FOR EVALUATING VISIBLE EMISSIONS

10.1 INTRODUCTION

A number of aids for evaluating the opacity of visible emissions has been developed, ranging from a simple hand-held Ringelmann chart to sophisticated laser techniques. The aids vary in price from a few cents to tens of thousands of dollars. Although some are useful for research purposes, none of them produces any significant improvement over an inspector who has been properly trained to evaluate emissions.

10.2 SMOKE CHARTS

The various smoke charts that have been developed work on the Ringelmann principle by comparing shades of gray printed on paper, with the source emission. They are simply smaller, hand held Ringelmann charts, and should be used to evaluate gray or black emissions.

10.3 SMOKE INSPECTION GUIDE

The Public Health Service has developed a film strip comprised of pieces of film with densities of zero, 20, 40, 60 and 80 percent transmission, and which is referred to as a "Smoke Inspection Guide." The inspector views the source through the guide and evaluates the opacity of the source by comparing it to the pieces of film on the guide. Of all the aids available this guide is probably the best from a "cost-effectiveness" standpoint for observations in connection with enforcement proceedings.

10.4 COMPARATORS

These include the smoke tintometer and the umbrascope which use tinted glasses graduated to the Ringelmann scale against which the opacity of the emissions may be compared.

10.5 SMOKESCOPE

This instrument consists of two barrels for receiving incoming light, similar to binoculars, with one eyepiece for viewing. The stack is viewed through one barrel of the instrument. Light from an area adjacent to the stack enters the other barrel and illuminates a circular standard density film. Half of this film is equivalent to No. 2 Ringelmann and the other half is equivalent to No. 3 Ringelmann. The image of these two half discs is projected onto a screen in front of the eyepiece and this image surrounds a small aperture where the smoke is seen. The observer then compares the smoke shade with the two Ringelmann shades. The advantage of this instrument over a Ringelmann Chart used in the field is that the illuminations of the smoke and the reference are both influenced by the same factors. Thus, the smokescope is automatically compensated for varying light conditions. (The amount of light transmitted is used to evaluate plume opacity, while the amount of light reflected is used to evaluate a conventional Ringelmann chart).

10.6 PHOTOGRAPHY

Photographs of the source can be used to evaluate the plume transmittance by placing filters along the side of the camera film plane so that a calibration scale is superimposed on the photograph.

10.7 TELEPHOTOMETERS

Telephotometers are used to measure the luminance of a source, often using a bright light source as a datum.

10.8 TRANSMISSOMETERS

Many permanently installed, in-stack devices are commercially available to continuously monitor and record the emission transmittance. Some are designed to set off an alarm to warn operating personnel when the transmittance reaches a preset level. Others indicate the transmittance on a meter, or record it on a strip chart.

Most of these devices use either a light source-photocell combination to measure the transmission of light through the plume, or remove a sample of the plume and measure the transmission of light through this sample. One problem with the light source photocell system is that both the light source and photocell deteriorate with time and require frequent recalibration. If the light transmission of a sample is measured, it is frequently difficult, especially under varying conditions, to obtain a representative sample.

The bolometer is another device available that uses the same general principal as the light source photocell. This device measures the resistance change across a filament which is proportional to the light that is transmitted through the emission. According to the manufacturer the main advantage of the bolometer over the light source-photocell system is that bolometers do not need to be calibrated as often.

10.9 LASER TECHNIQUES

Laser techniques for measuring the transmittance of plumes have recently been developed. The method is based on the measurement of backscatter signals of a pulsed laser beam by aerosols in the air beyond a plume. The plume's transmittance is obtained by comparing the backscatter signal when the beam is directed through the plume to the backscatter signal obtained when the beam is directed beside the plume.

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11. DEFINITIONS

11.1 POLLUTANT CLOUD

A cloud of air pollution is an emission of air contaminants which has become completely divorced from its source or sources and is gradually being dissipated by the processes of dilution, gravitational settling and diffusion, but may still retain visible boundaries. The cloud is shaped by the direction of air flow, and by dilution which occurs at right angles to this flow. The cloud is the extension or the fanning effect, of the plume and generally occurs under stable atmospheric conditions. Clouds are often produced from large source emissions and from building, brush and forest fires. Generally speaking, the larger the quantity of air pollutants, the longer a cloud remains coherent.

Noting the appearance of clouds in reports, especially as to height, length, breadth and thickness, can be important in determining the severity of a general or local problem.

11.2 HAZE

Hazes are frequently formed by condensation of vapors on atmospheric particles, or by aerosol production in smog formation, and by dusts and pollen. Smog is itself a chemical haze. A haze may also be considered as a more attenuated form of cloud residing at ground level, representing stagnant atmospheric conditions. Notation of the existence of the haze is important, particularly when it is peculiar to a community, since an acute local problem may be present.

11.3 TYPES OF EFFLUENT

The plume represents the form of the air contaminant of primary interest. It is the "discharge" or "emission" regulated or prohibited in most statutes or rules.

Since all substances become liquid, solids and gases at certain temperatures, the plume may consist of a variety of contaminants in various states of matter. Smoke, for instance, contains visible aerosols--carbon particles and solid or liquid particles of partially burned fuels--and such gases as sulfur dioxide, oxides of nitrogen, and unburned vapors.

The identity ascribed to the plume is usually made in terms of its outstanding visual characteristic. For example, even though sulfur dioxide may be the most significant of the pollutants emitted from a given stack, the effluent in which it is contained is frequently described as smoke due to the visible soot, carbon particles and fly ash contained in the plume.

The mere observation of a plume, however, does not result in its conclusive identification. Knowledge of the specific conditions which caused the contaminants is required. The distinction between smoke and fumes cannot be made unless the processes by which they are generated are described.

11.3.1 SMOKE

Smoke is the visible effluent resulting from incomplete combustion. It consists mostly of soot, fly ash and other solid or liquid particles less than one micro-meter in diameter. Depending upon the composition of the fuel or materials being burned and the efficiency of combustion, various volatilized gases and organics such as aldehydes, various acids, sulfur oxides, nitrogen oxides and ammonia may also be emitted. Due to the low vapor pressures and slow settling properties of the particles, the smoke may be carried considerable distances from the source and many submicro-meter particles will remain dispersed in the atmosphere almost permanently.

Smoke will vary in color, but will be generally observed as grey, blue, black, brown and white, and sometimes yellow, depending upon the conditions under which certain types of fuels or materials are burned. The color of smoke is generally a fairly good indication of the type of combustion problem encountered.

Smoke which is grey or black in color may indicate that material is being burned with insufficient air or inadequate mixing of fuel and air.

White smoke usually results when combustion is cooled by excessive drafts of air, or when the materials being burned contain excessive amounts of moisture. In the latter case, of course, a condensed water vapor plume is not subject to the opacity regulation.

Brown or yellow smoke may result from the burning of semi-solid tarry substances such as asphalt or tar paper, resulting from inadequate temperature or poor mixing.

A blue color or light blue color is often associated with the burning of domestic trash consisting mostly of paper or wood products. The light blue color seems to stem from the fine particles of pyroligneous acid due to sulfide treated paper and wood tar constituents. The blue plume contains little or no carbon or soot particles.

11.3.2 FUMES

In air pollution control, fumes are referred to specifically as "condensed fumes." These are minute solid particles generated by the condensation of vapors from solid matter after volatilization from the molten state, or may be generated by sublimation, distillation, calcination or chemical reaction when these processes create air-borne particles. Fume particles are generally less than one micro-meter in diameter and will behave like smoke. Fumes will more commonly consist of metals and metallic oxides and chlorides. Also contained in the fumes are common solid particulates such as fly ash, carbon, mechanically-produced dust and gases such as sulfur dioxide. The fumes principally emitted, however, are actually dusts condensed from the more volatile elements in the metals melted such as zinc, sulfur, lead and others.

Metallurgical operations are the most common form of fume which consists primarily of the metallic oxide driven from the melting surface when metal is heated to the molten state. Metals such as copper and bronze with relatively high boiling temperatures, as compared to their melting and pouring temperatures, do not readily volatilize and do not constitute an air pollution problem. Copper and tin, for example, have boiling temperatures above 4000^{o}F., but are poured at temperatures at about 2000^{o}F.

Some metals may contain alloys with extreme differences in volatility. Copper-based alloys such as yellow brass, manganese bronze, brazing spelter and various plumbing metals contain from 14 to 40 percent zinc, the boiling temperature of which is around 2200^{o}F. Since the metal must be heated to melt the copper which has the highest pouring temperature, a portion of the zinc will be brought to its boiling point and will volatilize. Copper alloys with high zinc contents may lose from 2 to 15 percent of their zinc through fuming.

When vented to the atmosphere, fumes may have the appearance of smoke. However, all of the sources of fumes may not be practically vented in a large-scale foundry operation, so that fumes in the vicinity of a plant may appear as a haze or a cloud emitted from factory monitors and windows.

Other processes which will produce fumes include calcination, sublimation and distillation.

Calcination consists of heating, roasting or smelting to decompose minerals. Calcination is commercially applied in the manufacture of glass and mineral catalysts through the heating of materials such as sand and limestone. It is variously employed to remove moisture or a volatile constituent by such methods as heating limestone to form carbon dioxide gas and calcium oxide, or to reduce minerals by oxidation.

Sublimation is the process in which a solid substance is converted to a gas without a change in composition and without first going through the liquid state. Iodine, carbon dioxide (dry ice) and many metallic and nonmetallic crystals are examples of sublimed materials. Sublimation of these materials may be accomplished by lowering the pressure, raising the temperature or by changing both temperature and pressure.

Distillation is a cycle of vaporization and condensation in which a liquid is converted to a vapor and condensed to a liquid. Distillation is generally employed to purify a liquid or to segregate components according to relative volatility.

11.3.3 DUSTS

Dusts are minute solid particles released in the air by natural forces or by mechanical processes such as crushing, grinding, melting, drilling, demolishing, shoveling, sweeping, sanding, etc. Dust particles are larger and less concentrated than those in colloidal systems, such as smoke and fumes, and will settle fairly quickly on surfaces. A dust effluent, however, may also contain many submicroscopic particles.

Dusts are produced from virtually every human activity as well as from the natural environment. Some dusty industries include mineral earth processors such as ceramic and cement manufacturing, calcining, and wood-working and feed and flour industries.

Dust particles mainly exceed one micron in diameter and are readily controlled by centrifugal separators, cloth filters and electrostatic precipitators.

11.3.4 MISTS

Mists consist of liquid particulates or droplets, less than the size of raindrops, such as fog, and are formed by condensation of a vapor, or atomization of a liquid by mechanical spraying. Mist droplets may contain contaminant material in solution or suspension. The impregnation and coating of building materials with asphalt or the manufacture or heating of asphalt at batch plants may produce hazes or fogs containing droplets of liquid asphalt. Paint spraying operations emit liquid particulates containing organic solvents, pigments and other materials. Mists may also be emitted from control devices such as cyclones and scrubbers, using a liquid air cleaning medium. Acid particulates, such as chromic and sulfuric acid produced from chrome plating operations, may also form mists when exhausted to the atmosphere.

In large oil-burning installations, sulfur trioxide is formed as a gas, and, after contact with sufficient moisture in the air, forms as a white-to-blue plume several feet above the stack (detached plume). After further contact with moisture in the air, the sulfur trioxide is transformed to a sulfuric acid mist.

11.3.5 GASES AND VAPORS

Most gaseous and vapor plumes are colorless. If they are visible however, e.g. a chlorine or nitrogen dioxide emission, it would probably be wiser for the inspector to report these emissions to a plant official at once rather than to attempt to prove a violation of the opacity regulation. Emissions of some gases in quantities of sufficient magnitude to violate the opacity regulation would very likely constitute a real threat to human health and the local environment, and every attempt should be made to stop the emissions as soon as possible.

11.4 BIBLOGRAPHY

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12. METHOD 9 -- VISUAL DETERMINATION OF THE OPACITY OF EMISSIONS FROM STATIONARY SOURCES

The current Method 9, published in the Federal Register, Volume 39, No. 219 on November 12, 1974 is reproduced below:

"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 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.

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.

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

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

2.3.2 DETACHED STEAM PLUME

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

2.4 RECORDING OBSERVATIONS

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

2.5 DATA REDUCTION

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

3. 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 purpose 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 in-stack opacity based upon a pathlength equal to the stack exit diameter, on a full 0 to 100 percent chart recorder scale. The smoke meter optical design and performance shall meet the specifications shown in Table 9-1. The smoke meter shall be calibrated as prescribed in 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 $\pm$ 1 percent opacity, the condition shall be corrected prior to conducting any subsequent test runs. The smoke meter shall be demonstrated at the time of installation, to meet the specifications listed in Table 9-1. This demonstration shall be repeated following any subsequent repair or replacement of the photocell or associated electronic circuitry including the chart recorder or output meter, or every 6 months, whichever occurs first.

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^{o} maximum total angle.
d. Angle of projection	15^{o} maximum total angle.
e. Calibration error-	$\pm$ 3% opacity, maximum
f. Zero and span drift	$\pm$ 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 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 $\pm$ 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 $\pm$ 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.

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TECHNICAL REPORT DATA

(Please read Instructions on the reverse before completing)

1. REPORT NO. EPA-340/1-75-007	2.	3. RECIPIENT'S ACCESSION NO.
4. TITLE AND SUBTITLE Guidelines for Evaluation of Visible Emissions Certification, Field Procedures, Legal Aspects, and Background Material		5. REPORT DATE April 1975
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15. SUPPLEMENTARY NOTES		

16. ABSTRACT

This report provides guidelines for:

(a) Field procedures to follow in evaluating visible emissions from stationary sources of air pollution. (Procedures are included for evaluation of non-stack emission sources such as are found in the minerals industry as well as specific stack emission sources.)

(b) Visible emissions evaluator regarding specific problems of applicability, including the effects of viewing conditions on opacity readings and the effects of water vapor on plume opacity.

Also included are training and certification procedures for visible emissions evaluation, brief descriptions of affected process operations, general instruction on being a witness during legal proceedings involving opacity evaluations, and the use of aids in evaluating visible emissions

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group
Air Pollution Visible Emissions Evaluations Plume Observations Litigation Water Vapor	Visible Emissions	14B 14D

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