Visible Emissions Program Operations Manual

Stationary Source Enforcement Series

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U.S. ENVIRONMENTAL PROTECTION AGENCY
REGION IV AIR SURVEILLANCE BRANCH
SURVEILLANCE & ANALYSIS DIVISION
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Visible Emissions Program Operational Manual

by

Victoria Scott

Pacific Environmental Services, Inc.
1930 14th Street
Santa Monica, California 90404

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EPA Project Officer: John R. Busik

Task Manager: Tom Rose

Prepared for

U.S. ENVIRONMENTAL PROTECTION AGENCY
Region IV Air Surveillance Branch
Surveillance & Analysis Division
Athens, Georgia 30601

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1.0 INTRODUCTION

This manual was prepared for use by the instructors and smoke generator operators who conduct EPA Region IV visible emissions (VE) training programs. It describes the specific smoke generators owned by Region IV, but is otherwise generally applicable to training programs throughout the nation. The instructor should always emphasize the meteorological and other parameters pertinent to the area where candidates will be evaluating smoke.

Section 2.0 is devoted to the lecture phase of the training program. It outlines the general content of each suggested talk and includes a sample agenda for the course. Both lectures and agenda may be modified or expanded depending on the needs of the class, since the program described in this manual is a minimal one. The films and slide shows referred to in this section can be obtained through the Air Surveillance Branch of Region IV EPA.

Section 3.0 discusses the procedures involved in conducting the certification phase of the program. Generator setup, calibration, shutdown, and maintenance are included, as well as training and testing procedures.

Section 4.0 deals with certification criteria and confidence limits. The appendices include a copy of Method 9, "Visual Determination of the Opacity of Emissions from Stationary Sources," and further details on smoke generator design, specifications, and testing.

This manual is not intended to be a comprehensive source of information presented in visible emissions lectures (student manuals and other references fill that need). Rather, it is a general guideline for instructors, including both an outline of key issues that should be addressed by the speakers and a step-by-step outline for smoke generator operators in Region IV.

2.0 THE LECTURE COURSE

2.1 INTRODUCTION

Figure 2-1 gives a suggested timetable for the three-day visible emissions evaluation course. Time allotments and order of presentation may be modified to accommodate guest speakers, but the amount of material to be covered requires that a relatively strict schedule be maintained. Less than three days does not provide sufficient time for both a complete lecture course and the minimum 10 test runs to which students are entitled when attempting to qualify as VE evaluators.

The purposes of the lecture course are:

- To provide a working knowledge of the principles behind the method of evaluating emissions by the concept of opacity.
- To familiarize the student with the legal rights and restraints involved in reading visible emissions and in defending his observations in court.
- To prepare the student for the certification training and test phase of the program.

These goals are accomplished by a series of lectures, films, and work sessions conducted on the first day of the visible emissions program. A quiz is administered at the end of the first day to determine the effectiveness of this lecture course.

2.2 REGISTRATION AND ORIENTATION

Registration is usually conducted by the training officer, although the course instructor may perform this task if necessary. A brief welcoming address should be given, which is usually presented by a higher level staff member. Registration and orientation, which consist primarily of introductions, welcome, and completion of trainee registration forms (Figure 2-2), involve the following preliminaries:

		Time (minutes)
DAY ONE		
8:30	Registration and orientation	30
9:00	Lecture 1: Goals and principles	60
10:00	Break	10
10:10	Lecture 2: Sources of visible emissions	
	1. "The Three T's of Combustion" (film)	20
	2. Combustion sources	25
	3. Noncombustion sources	25
11:20	Lecture 3: Field operations	40
12:00	Lunch	60
1:00	Lecture 4: Meteorology	60
2:00	Break	10
2:10	"Role of the Witness" (film)	45
2:55	Break	15
3:10	Lecture 5: Testing procedures	60
4:10	Quiz, discussion, and closing	40
DAY TWO		
8:30	Generator familiarization and calibration	30
9:00	Practice sessions	75
10:15	Break	15
10:30	Training session	30
11:00	First test	30
11:30	Second test	30
12:00	Lunch	60
1:00	Third test	30
1:30	Continue testing (at least two tests per hour)	
DAY THREE:		
8:30	Lecture 6: Legal aspects	60
9:30	Break	15
9:45	Generator calibration	30
10:15	Training session	30
10:45	First three tests	90
12:15	Lunch	60
1:15	Continue testing (at least two tests per hour)	
	Final recalibration	30

Figure 2-1. Sample Agenda for Visible Emissions Evaluation Course

TRAINEE REGISTRATION RECORD – Technical Course

COURSE TITLE | COURSE NUMBER (1-3)

LAST NAME (4-23) (Please Print) | FIRST NAME (24-33) | INITIAL (34) | U.S. CITIZEN (35) YES ☐1 NO ☐2

Mr._Mrs._Miss_

Position Title

Civil Service or PHS Commissioned Grade

Local Residence During Course

EMPLOYER

Name __________

Address __________

__________ Zip ______

EDUCATION (Check highest degree obtained) (36)

Bachelor ☐1 Master ☐2 Doctor ☐3

Years of College Training (Check correct box) (37)

None ☐1	4 years ☐3	7-8 years ☐5
1-3 years ☐2	5-6 years ☐4	9 or more ☐6

YEARS OF PROFESSIONAL EXPERIENCE (40)

0-1 year ☐1	5-7 years ☐3	11-15 years ☐5
2-4 years ☐2	8-10 years ☐4	16-20 years ☐6
21 years or over ☐7		

EMPLOYER CATEGORY (For U.S. and Foreign Trainees) (41-42)

GOVERNMENT			
FEDERAL (NATIONAL)		UNIVERSITY	
EPA (U.S. only)	☐01	Faculty	☐06
Dept. of Defense	☐02	Student	☐07
Other Federal	☐03	INDUSTRY	☐08
STATE	☐04	CONSULTANT	☐09
LOCAL	☐05	OTHER	☐10

PROFESSIONAL OR OCCUPATIONAL CODE (38-39) ☐☐

INSERT MOST APPROPRIATE CODE NUMBER. ONE DIGIT IN EACH INDIVIDUAL BOX.

01 Administrator	04 Health Educator	08 Sanitarian
02 Chemist	05 Industrial Hygienist	09 Statistician
03 Engineer	06 Meteorologist	10 Technician
	07 Physical Scientist	11 Other

NAPCA-94 (Durham) 11-68

FOR MODERATOR'S USE ONLY

Course starting date ______ (43-48)

______ (49-50)

SEE REVERSE SIDE FOR CODE NUMBER

Figure 2-2. Sample Trainee Registration Record

1. Introduce yourself and welcome the class to the facility and to the course.

2. State the purpose for and method of conducting the training course in evaluation of visible emissions.

   a. The purpose is to train the student so that he or she can qualify as a certified visible emissions evaluator, i.e., can determine the opacities of both gray-black and nonblack plumes within 7.5 percent of the correct reading on the average, with no reading incorrect by more than 15 percent.

   b. Half the time is devoted to lectures and half the time to training and test runs using a smoke generator.

      i. Lectures include instruction on the sources of visible plumes, the effects of weather on these plumes, the legal basis for visible emissions regulations, and certification and field procedures.

      ii. Training includes instruction in correctly identifying plume opacities, training runs, and actual test runs to establish or re-establish certification.

3. Have each student introduce him or herself, giving a short background as to where he is from, with whom he is affiliated, and so on.

4. Hand out registration materials and any other student materials not previously distributed, giving any necessary instructions for filling out registration cards.

5. Point out the locations of restrooms, explain arrangements for coffee during break periods, and so on.

6. Check that all students have adequate transportation for the remainder of the session.

7. Suggest convenient restaurants or cafeterias for lunch and mention local spots of interest and scenic attractions in the area.

8. Give the names and affiliations of any guest speakers who will be contributing to the course.

9. Collect the completed registration forms.

10. If time permits and such a show is available, present a "sound-slide" introduction to the facility.

11. Have a secretary prepare a class roster to hand out to the students at the end of the first day.

2.3 LECTURE 1: GOALS AND PRINCIPLES

The purpose of this lecture is to introduce the student to the history, principles, and practice of conducting visible emissions evaluations. Visual aids include a 2 x 2 slide projector, screen, and Visible Emissions Slide Show No. 1.

Begin by re-emphasizing the purpose of conducting the course, expanding upon and clarifying the introductory remarks made during orientation. Explain that certification is necessary to assure accurate VE evaluations, and that it will be discussed in more detail later in the day (refer to Sections 2.3.3 and 2.8). Then start the slide talk, covering each of the following points.

2.3.1 HISTORY OF THE METHOD

The official standard for visible emissions evaluation procedures is the current Method 9, "Visual Determination of the Opacity of Emissions from Stationary Sources," published in the Federal Register, Volume 39, No. 219, on November 12, 1974 (refer to Appendix A). All students should have a copy of this document for study during the training course and for reference during future field operations.

Explain that Method 9 is the standard method used and approved by the U.S. Environmental Protection Agency to test for visible emissions (slide No. 1). It is just as valid as stack testing methods: in fact, its accuracy is much higher.

The entire visible emissions evaluation system is loosely based on the principles devised by Maximillian Ringelmann around the turn of the century in an attempt to measure air polluting waste from coal-fired boilers (slide No. 2).

The Ringelmann Chart, a method by which the densities of columns of smoke rising from stacks may be compared, was one of the first tools used to measure emissions to the atmosphere (slide No.

3). The chart consists of a scheme by which graduated shades of gray that vary by five equal steps between white and black can be accurately reproduced by means of a rectangular grid of black lines of definite width and spacing on a white background.

In the 1950's, the term "equivalent opacity" was introduced and the principle of visible emissions evaluation was extended to other colors of smoke. The modern term is simply "opacity," which is defined as the obscuring power of the plume.

The Federal government has discontinued the use of Ringelmann numbers in Method 9 procedures and in Federal New Source Performance Standards (NSPS), basing the determination of the optical density of visible emissions from stationary sources solely on opacity (refer to Section 2.3.2). Some state regulations have not made this change, however, and so continue to operate under a dual system in which the Ringelmann Chart is used in the evaluation of black and gray emissions and equivalent opacity is used for all other visible emissions.

Certified evaluators must be familiar with both systems of measurement, but all smoke readings conducted by EPA personnel in Region IV must be in percent opacity only.

Students should be told that the Ringelmann Chart is actually unnecessary and that the training they are receiving will enable them to evaluate the opacity of smoke plumes without such artificial aids.

2.3.2 OPACITY

The concept of "equivalent opacity" made possible the application of the Ringelmann principle to white and other nonblack colors of smoke. One of the first applications of this concept was in the 1945 air pollution control ordinances of the County of Los Angeles, which specified that nonblack plumes be judged by the amount of light that they obscure. The 1947 California Health and Safety

Code was subsequently amended to limit visible emissions for a given period of time not only to Ringelmann No. 2 shade of gray, but also to any opacity that obscures an observer's view to a degree equal to or greater than Ringelmann No. 2.

Opacity simply means the degree to which an image or background viewed through the plume is obscured. A good working definition of opacity is "the obscuring power of the plume expressed in percent." (Thus reference to an opacity as "equivalent" to a given Ringelmann number is no longer required or desirable.)

2.3.3 CERTIFICATION

The concept of opacity and the training through which evaluators learn to apply it are presented in a series of smoke schools that are held all over the country (slide No.4).

Qualifying trainees are certified for 6 months following the date they successfully complete the lecture and test portions of the visible emissions evaluation course. Recertification may be obtained without repeating all of the classroom part of the course (refer to Section 2.10).

To become certified, observers must read 25 white and 25 black smoke plumes of varying opacities with a deviation of not more than 7.5 percent for each set of 25 readings and without erring by more than 15 percent opacity on any single reading. Testing procedures are explained in detail in Sections 2.8 and 3.6.

The standard of accuracy that students must demonstrate to become certified is necessary to assure the quality of visible emissions observations. Only currently certified evaluators can perform field operations (Section 2.5) and act as expert witnesses in court (Section 2.10).

2.3.4 SMOKE GENERATORS

In order to train personnel to evaluate visible emissions, a smoke generator that produces both black and white smoke and an instrument that measures the transmission of light through this smoke are necessary.

The instrument that measures light passing through the plume is a transmissometer, which consists of a light source and photocell combination; the percent transmission is indicated by a strip chart recorder calibrated from 0 to 100 percent opacity. Calibration is accomplished by means of neutral-density filters. Further details on the design, calibration, and operation of the smoke generator are included in the field portion of the course (refer to Section 3.0).

Black smoke is generated by the incomplete combustion of toluene or other organic hydrocarbons in a specially designed, insulated combustion chamber (slide No. 5). Smoke density is varied by adjusting the fuel injection rate. The smoke is pumped through a fan and up the stack past the transmissometer, which reads the opacity of the smoke.

White smoke is generated by vaporizing kerosene or No. 2 fuel oil on a heated plate or in a hot box (slide No. 6). Smoke density is controlled by adjusting the fuel flow rate. The white smoke is also pumped through a fan and past the transmissometer.

The opacity of the smoke depends upon several mechanisms (slide No. 7):

- Reflection: the return of a ray of light after striking the surface of the smoke particles.
- Refraction: the change of direction of a ray of light in in passing from one medium (air) into another (smoke particles) in which its speed is different. This is similar to a lens or prism effect.

- Absorption: the reduction in energy in the form of electromagnetic radiation by a medium or by a reflecting surface. Dark-colored smoke particles absorb the energy of the light, thus preventing it from getting to the detector. (The detector in this case is a phototopic photocell much like that in a camera.)

2.3.5 ADVANTAGES AND DISADVANTAGES OF OBSERVER EVALUATION OF VISIBLE EMISSIONS

Observer evaluation of visible emissions has numerous advantages over stack testing. These include:

- Short training time (24 to 32 hours)
- No extensive technical background needed
- No expensive equipment required
- Many readings per observer per day
- Source testing not necessary in order to cite violators
- Questionable emissions easily located
- Cannot practically test many sources by any other method

One of the main reasons for using the visible emissions method is its low cost (slide No. 8). Comparison of the cost of the minimum equipment needed for the VE inspector versus that of a conventional stack testing system reveals the truth of this statement: a sun visor and a compass add up to around $8.35, whereas the sampling procedures, tests, scaffolding, and so on required for Method 5 stack testing can very easily cost about $17,000. The amount of time for the VE inspection is approximately 1 hour; the time for a stack test is about 9 man-days.

Moreover, there are numerous facilities that cannot be practically tested by any method other than smoke reading. A battery of coke ovens is one such source: a VE inspection would take about 2 days, but stack testing would require all year (slide No. 9).

There are, however, several criticisms of visible emissions control regulations and the ability of evaluators to enforce them objectively. In addition to the variables mentioned in relation to viewer position (refer to Section 2.3.6), these criticisms concern the difficulties of accurately evaluating smoke under the following conditions:

- When the emissions are gaseous at stack temperature but condense after plume expansion
- At night
- When condensed water vapor is present in the plume
- From within the building housing a point source
- When polluters circumvent regulations by adding more air to the effluent or by building a new stack of smaller diameter for emitting the same quantity of effluent
- When opacity is not well correlated with the amount of material emitted
- In the presence of weather constraints such as raindrops, inclement weather, and high winds that shear the plume

While these objections have a certain degree of validity, they are mitigated by the following points:

- Opacity is not influenced by night time per se. The light source should be behind the plume when making VE observations during hours of darkness. The light source can be the moon, a star, a street light, or city lights. The densest part of the plume should be between the observer and the lighted object.
- Visible emissions evaluation programs teach inspectors how to identify the presence of water vapor in plumes and how to read such plumes so as to avoid looking through the "steam" or condensed water vapor.
- Other methods of measuring emissions may be preferable within the building housing a point source, but this does not invalidate the method of observer evaluation.
- Circumvention can be detected by comparing current readings with past VE records, which include the location and stack diameter of all observed emission points.
- Opacity limits are enforceable independent of mass emission limits and other standards. Studies such as those by Ensor and Pilat have attempted to calculate smoke plume opacity from particulate air pollutant properties (Reference 1), but

this remains a complex and controversial issue. Refer also to the EPA Response to Remand in Portland Cement Association v. Ruckelshaus (Reference 2).

- Certified inspectors are aware of the influences of weather constraints and do not attempt to make VE observations under inappropriate conditions.

The validity of observer evaluation of visible emissions is also attested to by the ability of students to learn to read smoke (slide No. 10). Judging opacity is no different than judging shades of color. The human eye is capable of selecting a very narrow range of the electromagnetic spectrum and identifying its frequency of light. The VE training program consists of calibrating this type of ability to a scale that distinguishes opacity in increments of 5 percent. This is done by first teaching the student to recognize 25, 50, and 75 percent opacity, and then giving readings in between these standards.

2.3.6 OBSERVER POSITION

Opacity or smoke density observations may vary according to the position of the sun, atmospheric lighting, background of the plume, and size of particles in the plume (slide No. 11). This variability can be minimized by reading plumes under the following conditions:

- With the sun in the 140 degree sector to the observer's back, and preferably in a 90 degree sector
- With the wind blowing at approximately right angles to the observer's line of sight and from a point not less than two stack heights and not more than 0.25 miles from the source
- Against a background that contrasts with the color of the plume
- With the longer axis of rectangular outlets at approximately right angles to the observer's line of sight
- Through the densest part of the plume and where the plume is approximately the diameter of the stack
- With summertime readings avoiding the hours between 10:00 a.m. and 1:30 p.m. (when the sun is high in the sky)

The major rule is to keep the sun directly over the observer's back. This and the other guidelines are illustrated by the following scenario:

- The deputy comes out to read smoke in the morning and what does he see (slide No. 12)? Can he read smoke? Why not?
- He comes back after about 4 hours and the sun has moved across the sky (slide No. 13). Now, should he look through line A or line B? Obviously, he should look through line B.
- In fact, the only thing that would make it easier for the deputy to read smoke would be to get a good background (slide No. 14).

Emphasize once again that the correct line of vision is perpendicular to the long axis of the plume (slide no. 15). The best viewing spot is one stack diameter above the stack exit, where the plume is densest.

Encourage students to observe plumes using different backgrounds and with the sun located at different angles in order to demonstrate the effects that these parameters have on observed opacity (slides No. 16 - 19).

Illustrate what happens to a smoke plume when the wind is blowing (slide No. 20). Also show how the plume can look very thick if it is observed along the long axis instead of through it, and discuss the effects of background (slides No. 21 - 23).

The smoke reading situation is somewhat akin to that of David and Goliath (slide No. 24), in that the lowly smoke reader, equipped only with his eyes and clipboard, must face the mighty giant of industry. However, it is not so much the tool you use (slide No. 25), as how well you use it! The importance of correct observer position cannot be overemphasized. Refer to Section 2.5, Figures 2-3 and 2-4.

2.3.7 CONDENSED WATER VAPOR PLUMES

Condensed water vapor or "steam" plumes are a potential problem due to aesthetic considerations, visibility reduction, and the possibility of their masking atmospheric contaminants. Condensed water vapor is not a pollutant, however, so opacity observations must be made either beyond or prior to the point where it is visible in the plume (refer to Appendix A, Sections 2.3.1 and 2.3.2). The lecture on meteorology (refer to Section 2.6) gives details on how steam plumes are formed, how to identify and evaluate them, and how to predict their occurrence through use of a psychrometric chart (refer also to Appendix C, Figure C-2).

The importance of correctly identifying condensed water vapor plumes is illustrated by the following example (slide No. 26). Say you have two plumes, plume No. 1 and plume No. 2. Which one is dirtier? Without knowledge of what is contributing to those plumes, it is impossible to make a judgment. Based on sheer opacity, plume No. 2 may appear dirtier. However, its white material could be—and probably is—condensed water vapor, in which case it is not pollution. Thus plume No. 1 appears to be much cleaner, but it is in fact all particulate and is probably the dirtier of the two.

Condensed water vapor plumes can either be attached to or detached from the stack exit (slide No. 27). Detached plumes occur when the entrained water vapor is at too high a temperature and condenses above the plume, or when sulfuric acid forms above the plume. This is particularly prevalent where vanadium-containing fuel oils, such as come from South America, are used in oil-fired boilers.

2.4 LECTURE 2: SOURCES OF VISIBLE EMISSIONS

This lecture may be given either by an enforcement branch staff member or by the training course instructor. Visual aids include a 16 mm movie projector, 2 x 2 slide projector, screen, the film "The Three T's of Combustion," and slides illustrating combustion and noncombustion sources of visible emissions.

Begin by discussing the importance of particle size to plume visibility, the various types of visible air contaminants, and the effects of particulate air pollutants. Then introduce the film "The Three T's of Combustion," which is 20 minutes long and gives a short introduction to the physics of combustion. Next, while showing the appropriate slides, discuss the problems of and techniques for accurately evaluating the different types of sources of visible emissions. Special emphasis should be given to the topics discussed in the following subsections.

2.4.1 COMBUSTION SOURCES

Combustion sources of visible emissions are classified as fuel combustion, transportation, and solid waste disposal, and include fuel oil, natural gas and coal burning, incineration, agricultural burning, and mobile sources. Stress the differences between complete and incomplete combustion, black and nonblack smoke, types of fuel, combustion equipment and methods, major emission points, and other variables affecting visible emissions.

2.4.2 NONCOMBUSTION SOURCES

Industrial process losses, such as fumes, dusts, mists, gases, and vapors, are classified as noncombustion sources of emissions. Such emissions cannot truly be called "smoke" because this term refers only to the visible effluent resulting from incomplete combustion, which consists mostly of soot and fly ash. Operations that emit noncombustion pollutants to the atmosphere include grinding, melting, cooking, materials handling, and so on.

Because a wide variety of industries produce visible process emissions, this lecture should be tailored to the industries in the area where the students will be evaluating smoke. Limit this part of the lecture to a few examples of the problems and techniques involved in identifying, evaluating, and controlling visible emissions from noncombustion sources. Give particular attention to ways of distinguishing between noncombustion emissions—particularly condensed water vapor plumes—and smoke. This is most important to the visible emissions evaluator because condensed water is not a pollutant (refer to Sections 2.3.7 and 2.6).

2.4.3 OTHER SOURCES OF VISIBLE EMISSIONS

Emphasize the pertinence of fugitive emissions, types of vents, and other factors that affect observer evaluation of stationary sources. During recertification, review any problems in the area where observers are evaluating smoke (e.g., coke ovens; refer to Section 2.10.1).

2.5 LECTURE 3: FIELD OPERATIONS

This section refers to the actual evaluation of visible emissions by certified VE observers during field inspections. This presentation should be made by an experienced inspector, if possible, or it can be made by the course instructor.

Begin by emphasizing the importance of doing preparatory research prior to making actual field observations of a particular plant. Such research should include information on process operating conditions, type and location of control equipment, probable location of source emissions, possible observation sites, regulations applicable to the source, presence of water vapor plumes, and other pertinent data.

Pass around the equipment that should always be taken along by the inspector (e.g., inspection forms, field logs, a stopwatch, a sling psychrometer, a compass, and a camera with a telephoto lens). Other equipment may be necessary, depending on the type of source and the observational conditions (such equipment might include topographic maps, a hand-held anemometer, binoculars, a range-finder, and a machete). It is also good practice to take along a hard hat and safety boots; other safety equipment might include safety goggles or a respirator.

Explain observer pcsition (Section 2.3.6) in further detail, including the use of a pencil shadow form (Figure 2-3). A line drawn through the shadow of the pencil toward the sun must fall within the triangular 140° sector when the pencil is placed upright at the point that represents the observer's position in relation to the plume.

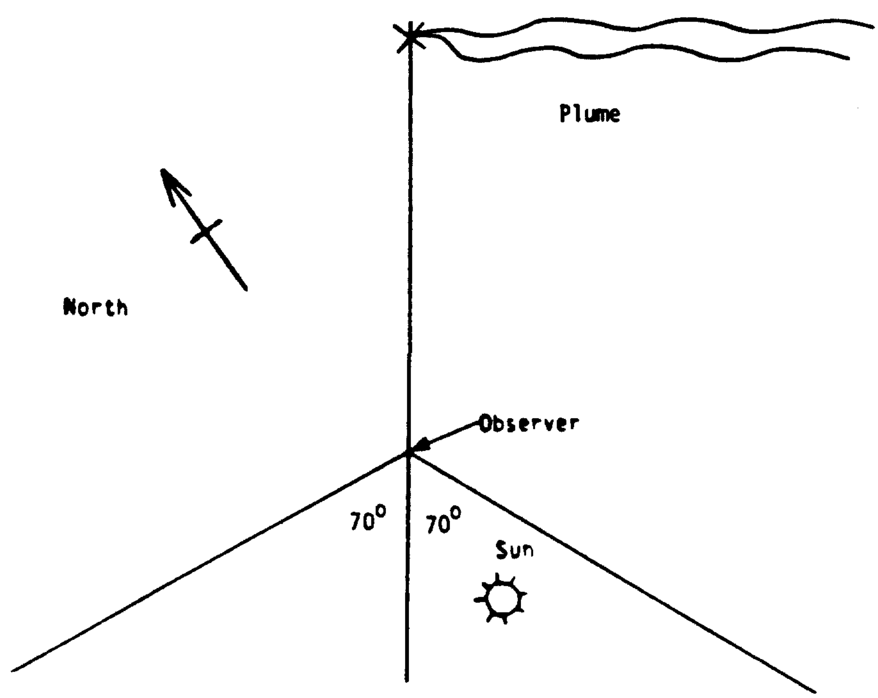


Figure 2-3. Pencil Shadow Form

Illustrate the correct use of the pertinent observation form, field log, and inspection data sheet, pointing out that observation forms are source specific, i.e., different for different facilities. In general, the following items should be performed by the inspector in the field in conjunction with completing observation forms and field logs. These items are necessary to meet Method 9 requirements and to improve documentation of the VE evaluation:

- Take readings every 15 seconds
- Take at least 24 readings (6 minutes)
- Divide the observations into sets of 24
- Obtain the average opacity for each set
- Record the average opacity for each set
- At the beginning and at the end of the observation, record the following:
    - Estimated distance to the emission point
    - Direction of observer to the source
    - Height of observation point
    - Wind speed
    - Wind direction
    - Ambient temperature
    - Wet bulb temperature
    - Relative humidity
    - Description of sky condition
    - Plume background
    - Distance plume is visible
- Indicate whether a steam plume is present. If there is a steam plume, note whether it is attached or detached, where the breakpoint occurred, and where the opacity readings were made.
- Draw a sketch showing observer location in relation to the emission point, the wind direction, and the location of the sun. Use symbols, as indicated in Figure 2-4.

- Record the operational data at the time of the evaluation for the source being evaluated. Such data includes actual operating rate, design operating rate, materials or fuels being used, types of air pollution control equipment, and so on.

Wherever possible, these items should be measured with the appropriate instrumentation. The minimum amount of equipment necessary consists of a sling psychrometer, an anemometer, a compass, and a stopwatch.

If time permits, briefly illustrate the steps of photo documentation, using a single lens reflex camera or one with automatic photocells. These steps are given in Appendix B. Conclude by emphasizing the importance of following up the visual observation with an in-plant inspection.

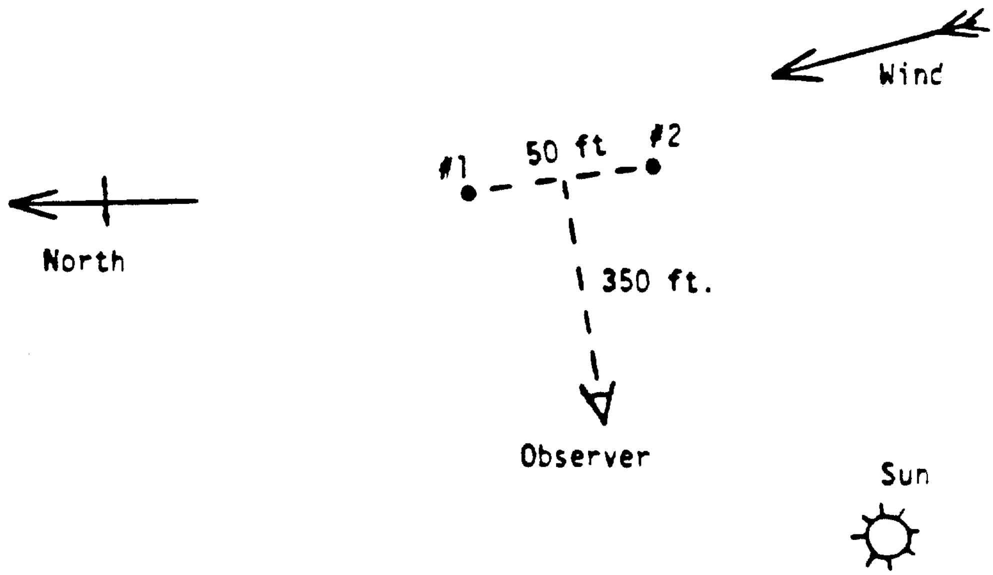


Figure 2-4. Sample Sketch of VE Observation

2.6 LECTURE 4: METEOROLOGY

This lecture is designed to introduce students to the basics of air pollution meteorology, and may be presented either by a guest speaker or by the course instructor. Visual aids may include slides, transparencies, or handouts illustrating major weather influences on pollutants.

Give a brief synopsis of the air pollution cycle of release, transport and dilution, and reception of air pollutants, pointing out that diffusion and transport are the major weather influences on pollutants after their release. Describe the structure of the earth's atmosphere, including definitions of lapse rate (the rate of decrease in temperature with increase in height) and inversion. Point out the effects of temperature inversions on atmospheric processes and hence on the dispersion of air pollutants.

Explain dry adiabatic lapse rate—the lapse rate of a parcel of dry air as it moves upward in a hydrostatically stable environment and expands slowly to lower environmental pressure without exchanging heat with its environment (it is also the rate of increase in temperature for a descending parcel).

Next, discuss diffusion and vertical and horizontal transport in some detail, as well as how climatic zones affect when and where inversions occur (particularly in the area where students will be evaluating smoke, if applicable). Also include other meteorological parameters that affect plume shape and type, e.g., radiation, fronts, pressure areas, water in the air, turbulence, eddies, and so on.

Give a brief synopsis of the meteorological conditions that interfere with or prohibit smoke reading. These include:

1. Rain: Rain not only creates a hazy background, but actually obscures the vision and may knock down part of the plume.
2. Position of the sun: Although this is not specifically meteorology, the position of the sun is very important. If the sun is not at the observer's back, then the plume can be enhanced in appearance due to the characteristic called forward scatter.

3. Wind: If the plume is being sheared off at the stack, the observer will probably read the smoke as less opaque than it actually is. Smoke should not be read under these conditions.

4. Time of day: If it is dark, it is very hard to read smoke. Although people have been certified in California reading smoke after dark by the use of a light, it is very impractical. Night vision scopes and other sorts of devices have been tried, but smoke reading at night is still a problem.

5. Clouds and haze: Clouds and haze also interfere with smoke readings. A very strong gray cloud cover will tend to make the observer underread the smoke due to the lack of contrast between the particles of the smoke and the background of the clouds. It is impossible to tell that something is being obscured if it is the same color as the obscuring body.

6. Cold temperatures and condensed water vapor plumes: Cold temperatures can cause the condensation of water vapor in the plume. This reduces the observer's ability to read smoke accurately.

The four most important aspects of condensed water vapor (or "steam") plumes are:

- How condensed water vapor plumes are formed
- How to identify condensed water vapor plumes
- How to read condensed water vapor plumes
- How to predict the occurrence of condensed water vapor plumes through the use of a psychrometric chart (refer to Appendix C, Figure C-2)

A sling psychrometer is a device that is operated by moistening the wick on one thermometer ("wet bulb") and swinging it around in the air along with a dry bulb thermometer until a differential temperature is evolved. Either the chart on the sling psychrometer (if present) or the a relative humidity table such as the one shown in Appendix C, Figure C-1 can be used to determine the relative humidity of the air. This number is plotted at one point on the psychrometric chart. The water vapor percentage of the plume (derived from emissions information) is recorded at a second point. If a line drawn through the two points enters the nongridded area of the chart, then there is a good chance that a condensed water vapor plume will form. This is the only method short of stack testing that can predict the presence of condensed water. A sample calculation using the psychrometric chart is contained in Appendix C.

It is also important to note whether a given plume rises or is dispersed, whether it stays compact, and so on. There are several kinds of plumes:

1. Looping plume: This occurs on a superadiabatic day, i.e., a day on which the temperature cools as air rises in the atmosphere. Due to the temperature of the plume and the change in temperature of the earth, the plume varies and loops.
2. Fanning plume: A fanning plume occurs when the lapse rate is inverted, that is, when warm air is above the cold air. In this case, the plume can travel for many hours in an unaltered state.
3. Fumigation plume: This type of plume occurs when the temperature inversion is breaking up and the sun warms the earth, so that the air between the temperature inversion and the earth becomes the same temperature as the plume. When this happens, the plume mixes very strongly with the air below the inversion and fumigates the area.
4. Coning plume: A coning plume occurs when the adiabatic lapse rate is normal and extremely good mixing occurs along with some wind. This type of plume gives maximum dispersion.
5. Lofting plume: A lofting plume occurs when the smoke is emitted above stagnation or above an inversion level.

Another point that ought to be emphasized in the meteorology lecture is how to estimate cloud cover. This can be done with a piece of blue cardboard and a sheet of white paper of equal size. Illustrate 100 percent cloud cover, then tear the white page in half, tear the half into smaller pieces, and illustrate 50 percent cloud cover. Next, take half the pieces away and illustrate 25 percent cloud cover. This shows that people tend to overestimate cloud cover.

A final point that should be stressed is the use of a wind instrument to determine wind velocity. Both small rotameters and hand-held anemometers are available. The Beaufort scale of wind-speed equivalents may also be used (Figure 2-5).

General Description	Characteristics	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 vane	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 pot 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

Figure 2-5. The Beaufort Scale of Wind-Speed Equivalents

2.7 FILM: "ROLE OF THE WITNESS"

Show the film, "The Role of the Witness" (this requires a 16 mm projector and screen). This 45-minute film is a dramatization of proper courtroom procedures when giving testimony as an expert witness. Explain that the discussion of legal aspects of visible emissions evaluation will take place on the morning of day three, so that observers who are being recertified can hear the review of current cases given by the speaker (refer to Section 2.10).

2.8 LECTURE 5: TESTING PROCEDURES

The testing procedure for obtaining certification is illustrated by Visible Emissions Slide Show No. 2, which should be shown at the beginning of this lecture. Other visual aids include a 2 x 2 slide projector, overhead projector, screen, transparencies, china marking pencils, and a practice and a test form (Figures 2-6 and 2-7) for each student. This lecture is crucial because if students do not understand the proper procedures, they will use valuable testing time to ask questions.

Distribute the practice forms (Figure 2-6) and explain that they are used to introduce different opacities to the students. Tell the class that the training sessions will consist of sets of four readings, preferably of 25, 50, 75, and 100 percent opacities (in random order) for the first few sets of four. After each set, the instructor or generator operator will give the actual opacities and have students grade their own papers.

Stress the fact that the students' ability to distinguish these standard values accurately will build their confidence at the outset, thus facilitating discrimination between smaller and smaller increments of opacity. Explain that readings will continue to be given four at a time until all students are reasonably confident of their ability to read all four opacities correctly.

ENVIRONMENTAL PROTECTION AGENCY
REGION IV
SURVEILLANCE AND ANALYSIS DIVISION
ATHENS, GEORGIA 30601

Visible Emissions Evaluation

Practice Run Sheet

READING	ACTUAL	DIFFERENCE	READING	ACTUAL	DIFFERENCE

Figure 2-6. Practice Form

NAME ____________________ RUN# ____________________

COURSE LOCATION ____________________ TIME ____________________

DATE ____________________ SKY ____________________ WIND ____________________

DISTANCE AND DIRECTION TO STACK ____________________

READING NUMBER																						ERROR
1	0	5	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95	100	1
2	0	5	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95	100	2
3	0	5	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95	100	3
4	0	5	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95	100	4
5	0	5	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95	100	5
6	0	5	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95	100	6
7	0	5	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95	100	7
8	0	5	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95	100	8
9	0	5	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95	100	9
10	0	5	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95	100	10
11	0	5	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95	100	11
12	0	5	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95	100	12
13	0	5	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95	100	13
14	0	5	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95	100	14
15	0	5	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95	100	15
16	0	5	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95	100	16
17	0	5	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95	100	17
18	0	5	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95	100	18
19	0	5	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95	100	19
20	0	5	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95	100	20
21	0	5	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95	100	21
22	0	5	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95	100	22
23	0	5	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95	100	23
24	0	5	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95	100	24
25	0	5	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95	100	25

WHITE DEVIATION ____________________

26	0	5	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95	100	26
27	0	5	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95	100	27
28	0	5	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95	100	28
29	0	5	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95	100	29
30	0	5	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95	100	30
31	0	5	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95	100	31
32	0	5	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95	100	32
33	0	5	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95	100	33
34	0	5	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95	100	34
35	0	5	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95	100	35
36	0	5	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95	100	36
37	0	5	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95	100	37
38	0	5	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95	100	38
39	0	5	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95	100	39
40	0	5	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95	100	40
41	0	5	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95	100	41
42	0	5	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95	100	42
43	0	5	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95	100	43
44	0	5	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95	100	44
45	0	5	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95	100	45
46	0	5	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95	100	46
47	0	5	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95	100	47
48	0	5	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95	100	48
49	0	5	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95	100	49
50	0	5	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95	100	50

BLACK DEVIATION ____________________

Figure 2-7. Certification Form

The number of readings per set will then be increased to eight, 12, 16, and so on, as time permits.

Give a brief list of the equipment needed during testing, i.e., a clipboard, a large rubber band (to keep the test paper from flapping in the wind), a small piece of cardboard (to keep one's place on the form), ballpoint pens, a sun visor, appropriate clothing, and perhaps a folding chair, thermos of coffee, and so on.

Also mention the use of sunglasses. If a candidate intends to wear sunglasses while making visible emissions evaluations, he must qualify wearing the same pair of glasses. Glasses that change density with changing sunlight and red or blue sunglasses are not acceptable. The best sunglasses for reading smoke are gray neutral sunglasses or those in the green light range; the latter optimize the visibility of smoke in the same way a transmissometer does.

Now distribute the certification forms (Figure 2-7), pointing out the fact that the certification form is a "no carbon required" (NCR) form that allows students to grade their own papers while prohibiting cheating. Stress the necessity of using ballpoint pens (not felt tip ones) on these forms.

Explain that in the actual test situation, the instructor will hand out the certification forms and announce the run number. Each set of 50 readings, 25 white and 25 black, is one test run. Students then fill out the entire top part of the form, giving the following information:

- Name
- Course location (including area, city, and state)
- Run number (provided by the instructor or generator operator)
- Time of day
- Date
- Sky conditions (in percent of cloud cover)

- Wind speed and direction
- Observer distance and direction to stack

Inform students that a compass board will be placed between the testing area and the generator so they can determine the direction the wind is coming from and their own direction to the stack.

Next, discuss the actual testing procedures, covering the following topics:

- When to make readings
- How to mark the paper
- How to correct a reading
- How to grade a paper

The first thing the generator operator will say once the certification run begins is "number one." This indicates that the smoke is steady as it comes out of the generator. When students hear these words, they are to glance up at the plume and make a judgment as to how opaque it is by looking through the plume and estimating the percentage of the background that is obscured.

Stress that students are not to write anything on their papers until they hear the word "mark." At this time, they should make a slash from the upper right to the lower left through the value that most closely approximates the opacity they observed when the operator said "number one." This procedure will be repeated for the remaining 24 white and 25 black readings (slide No. 1).

Occasionally, something will happen beyond the operator's control, e.g., the smoke shifts or a bubble occurs in the fire box so that the smoke changes in opacity. When this occurs, instead of saying the word "mark," the generator operator will say the word "scratch." When students hear the word "scratch," they are not to mark on their papers. Thus the generator operator validates the steadiness of the smoke at the same time students are making their readings (slide No. 2).

If the student wishes to change a reading, he can do so by circling the incorrect answer and making a new mark on the correct answer (slide No. 3). More often than not, however, the first impression is the best.

When the test run has been completed, students turn in the top copy of their papers and grade their own carbons. Using a pen of a different color, they mark down the answers given by the instructor or generator operator by making slashes from the upper left to the lower right through the correct values (slide No. 4). They then add their "increments of error:" each error of 5 percent opacity, either positive or negative, is counted as one increment.

In order to qualify, no one reading can be in error by more than three increments, and the total error (without regard to sign) must be 37 or less both for the 25 white and for the 25 black readings (slide No. 5). If a student thinks he or she has qualified, he turns in his carbon to the instructor, who matches it up with the original test paper and grades the run according to the method described in Section 4.1.

A student who thinks that he has qualified should nevertheless take the next test because his paper will be graded during that test. Thus if the student made a mistake in his grading, he will not miss the next chance to qualify.

At the end of the slide talk, if time permits, have the students fill out the certification forms as though a real certification test were being conducted. Then give 50 readings, instructing the class to record them as though they were doing so during a test; follow this with the "correct" values, having the students grade their own papers as they would during a test. Then show an overhead transparency of a correctly graded sheet, emphasizing the 7.5 percent average deviation and 15 percent error limitation for passing the test and thus qualifying for certification.

Conclude by entertaining any questions, repeating the entire exercise if necessary. This is more efficient than having to answer questions individually in the field on day two.

2.9 QUIZ

Figure 2-8 is a sample quiz on the lecture part of the course. This quiz or one similar to it should be given and graded at the end of day one.

2.10 LECTURE 6: LEGAL ASPECTS

This lecture should be given on the morning of the third day, so that observers who are becoming recertified can hear it. It should be presented by a staff lawyer from the regional office, although a legal support branch staff member may deliver it if necessary.

2.10.1 METHOD 9 AND LEGAL PRECEDENT CASE HISTORIES

The visible emissions regulations—Ringelmann numbers and equivalent opacity—and their enforcement by certified observers have been established for a number of years in various states and their constitutionality has been supported by numerous appeals cases. Summarize a few specific court cases, preferably both in the region where the course is being given and nationwide (refer to "Guidelines for Evaluation of Visible Emissions," EPA-340/1-75-007, April 1975). Emphasize how these cases have affected the subjects discussed in the following sections. Also discuss any currently pending enforcement cases that involve VE observations and touch on the highlights of Method 9.

2.10.2 LEGAL RIGHTS OF INSPECTION

Various courts in the country have found that visible emissions may be evaluated from either inside or outside the plant

NAME ____________________
1 point

Smoke School Quiz

Multiple Choice - 3 points each

1. A certificate is valid for:
   A. 6 months B. 1 month C. 1 year

2. The observer should stand:
   A. Facing the sun B. With the sun on his back C. With sun at his side

3. The opacity scale is used for:
   A. Black smoke B. White smoke C. Red smoke D. Blue smoke
   E. A & B F. All of the above

4. A North wind blows from the:
   A. South B. North C. West D. East

5. The smoke reading should be taken:
   A. One stack diameter above the top of the stack B. At the top of the plume
   C. At the widest part of the plume D. At the narrowest part of the plume

6. The plume axis should be:
   A. Along the reader's line of sight B. At right angle to the reader's line of sight

7. Smoke reading is an (a) ____________________ measurement.
   A. Objective B. Subjective

8. White smoke emitted from the generator consists of:
   A. Talcum powder B. Oil soot C. Oil Vapor D. Steam

Matching - 1 point each

9.	______ 20% opacity	A.	Transmissometer
10.	______ 0% opacity	B.	Not measurable
11.	______ Water vapor	C.	0 Ringelmann
12.	______ 50% opacity	D.	2-1/2 Ringelmann
13.	______ Gaseous pollutants	E.	Steam Ringelmann
14.	______ Wind speed	F.	5 Ringelmann
15.	______ 80% opacity	G.	4 Ringelmann
16.	______ Light scattering	H.	Calibration
17.	______ Photocell	I.	1 Ringelmann
18.	______ Neutral density filter	J.	Beaufort scale
19.	______ 100% opacity	K.	Opacity

Figure 2-8. Sample Quiz

Short answer or listing - 8 points each

20. What is opacity? 25 words or less

21. What are the advantages of the visual method of plume evaluation?

22. What are the limitations of visual plume evaluation?

23. Distinguish combustion versus process sources.

24. How can photographs be useful in smoke reading?

25. List typical sources of BLACK smoke.

26. List typical sources of WHITE smoke.

27. What is a sling psychrometer?

Figure 2-8. Sample Quiz (Concluded)

property. Advance notices or entry warrants are not always necessary, but the consent and cooperation of the owner is of course advisable. Each agency should consult with its own counsel to develop a policy of how and when entries will be made.

2.10.3 LEGAL RESTRAINTS

Different types of sources and different areas of the country require different visible emissions restrictions. Certain operations may be exempt from the regulations, and exceptions may be allowed for others (such as agricultural burning) during certain periods of time. Discuss the specific variations applicable to the location where the course is being held.

2.10.4 HOLD HARMLESS AGREEMENTS

Hold harmless agreements (also referred to as indemnity agreements, waivers, and visitors' releases) are statements that certain firms require inspectors to sign as a condition to entry onto their industrial facilities. EPA employees cannot be denied entry for refusal to sign such agreements and, in fact, should be instructed not to sign them under any circumstances. For further details, refer students to pages 12 - 15 and Attachment 3 (John Quarle's 1972 memo) of the 1975 EPA Visible Emission Inspection Procedures (Reference 3).

The situation may vary for state and local inspectors. If so, tell students what the appropriate policy is or from whom they can obtain this information.

2.10.5 BEHAVIOR DURING INSPECTIONS

Briefly discuss the importance of establishing and maintaining courteous relations with plant owners and operators, of doing background research prior to making the actual field observations, and of completing all observation records and field logs at the time of observation. Only by complying with the proper procedures can the visible emissions inspector truly be an expert witness.

2.10.6 BEHAVIOR IN COURT

The film "Role of the Witness" (shown on day one; refer to Section 2.7) elaborates on proper preparation for and behavior when giving testimony as an expert witness. Familiarity both with courtroom procedures and with all aspects of the law that deal with the witness' responsibilities is imperative, as is a calm but confident demeanor.

References for Section 2.0

1. Ensor, D.S., and Pilat, M.J. "Calculation of Smoke Plume Opacity from Particulate Air Pollutant Properties." Journal of the Air Pollution Control Association (APCA), Volume 21, No. 8, August 1971, pp. 496-501

2. EPA Response to Remand in Portland Cement Association v. Ruckelshaus, Appendix III, Part A: Opacity Standards, 1973

3. Malmberg, Kenneth B. EPA Visible Emission Inspection Procedures. Division of Stationary Source Enforcement (DSSE), U.S. Environmental Protection Agency, Washington, D.C. 20460, August 1975

4. Rose, Thomas H. Unpublished draft procedures for Region IV VE Programs, 1978

5. Gerjuoy, Edward. "Common Legal Challenges to Agency Enforcement Proceedings." Talk presented at the Region X Visible Emissions Workshop, Seattle, Washington, October 11-13, 1978

3.0 CERTIFICATION PROCEDURES

This section includes procedures for calibrating and operating the smoke generator and for conducting the certification part of the training program. For maximum efficiency, this part of the course should be conducted by two persons—one to operate the generator and the other to instruct the students, keep the generator fueled, and ensure that the smoke is readable.

3.1 GENERATOR FAMILIARIZATION

Allow students to examine the smoke generator. At the same time, give a brief explanation of its construction, including the following points:

- White smoke production: White smoke is generated by vaporizing fuel oil in a heated chamber.
- Black smoke production: Black smoke is generated by burning toluene or other organic hydrocarbons in a combustion chamber.
- Cost of the generator: A generator that meets the specifications listed in Method 9 (Appendix A) costs about $15,000.
- Calibration: The smoke generator is routinely calibrated according to the procedures specified by Method 9 (refer to Section 3.3).
- Design and performance specifications: This smoke generator meets the design and performance specifications listed in Method 9.
- Strip charts: A strip chart record will be made of each test run.
- Transmissometer: This device monitors the generator's smoke output by means of a light source and a photocell.

Emphasize that for their own safety, students must stay away from the smoke generator during training and test runs, because once it is operating, (1) it has hot surfaces that can cause bad burns, and (2) there are numerous electrical cables and fuel lines which, if accidentally disconnected, could shut down the generator and delay the entire program for several hours.

3.2 GENERATOR OPERATION

Use the generator setup checklist (Figure 3-1) prior to assembling the generator. Allow the students to observe the steps involved (Figure 3-2); refer to Figure 3-3 for the locations of the parts referred to by number below:

1. Connect the generator console fuel lines, which are stored in the base of the control console (3). Connect them first to the console input and then to their color-coded connections on the generator.
2. Connect the generator console electrical lines, which are stored in the rear storage compartment (not illustrated). The two sets of electrical lines—a three-conductor and a multiple-conductor—are combined in a single electrical umbilical cord. Connect the umbilical first to the console and then to the generator.
3. Connect the power line (usually yellow) to the generator and to a source of 15 amp 115 VAC power.
4. Turn on the propane tank (7) and adjust the pressure to 8 pounds with the regulator (9).
5. Light the toluene igniter (14) and the white smoke vaporizer torch (11) with a small propane torch.
6. Crank up the smoke stack by removing the stack strap and pumping the hydraulic jack at the base of the stack.
7. Turn on the main power.
8. Connect the microphone to the "mike 1" input on the back of the generator console.
9. Connect the speakers to the yellow jacks on the back of the generator console.
10. Open the toluene valve for black smoke (2). To prevent damaging the generator, do not keep the black smoke at 100 percent for more than 3 minutes.
11. Open the oil valve for white smoke (1). Do not open this valve fully or too quickly or it will flood the vaporizer with oil and start a fire. If this does happen, simply shut off the valve, let the fire in the vaporizer burn out, and then open the valve more slowly.

GENERATOR	FIELD FILE	SPARE PARTS
Toluene (2 tanks)	China marking pens	Box fuses 15 amp main
Kerosene (1 tank)	Filter calibration log	Box fuses 10 amp blower
Funnel	Calibration log	Box fuses 3 amp fans
Extension cord	Roster log	Box fuses 1 1/2 amp light
Ground fault interrupter	Test forms	Box fuses 3/4 amp amplifier
Power cord	Practice forms	Box fuses 1/2 amp recorder
(2) Fuel interconnects	Grading acetates	Torch tip (white smoke)
Electrical interconnect	Certification stamp	Torch tip igniter
Propane torch	Stamp pad	Tank "O" rings
Propane (20 lb)	Felt tip pens	Valve
Striker	Extra ball point pens	(5) Bulbs TS67 (12 volt)
Tip for vaporizer	Clipboards	(1) 1 K linear pot 10 turn
Vaporizer	Large rubber bands	Spare tire 14 1/2 X
Calibration filters		Hydraulic jack
Calibration staff		(2) Disconnects
Calibration stamp		Chart paper (1 roll)
Digital voltmeter		Recorder pens
Flag and staff		
Control console		
Table		
Chart paper		
Pen for recorder		
Speaker		
Microphone		
Fire extinguisher		
Tool box		
SOP manual		

Figure 3-1. Generator Setup Checklist

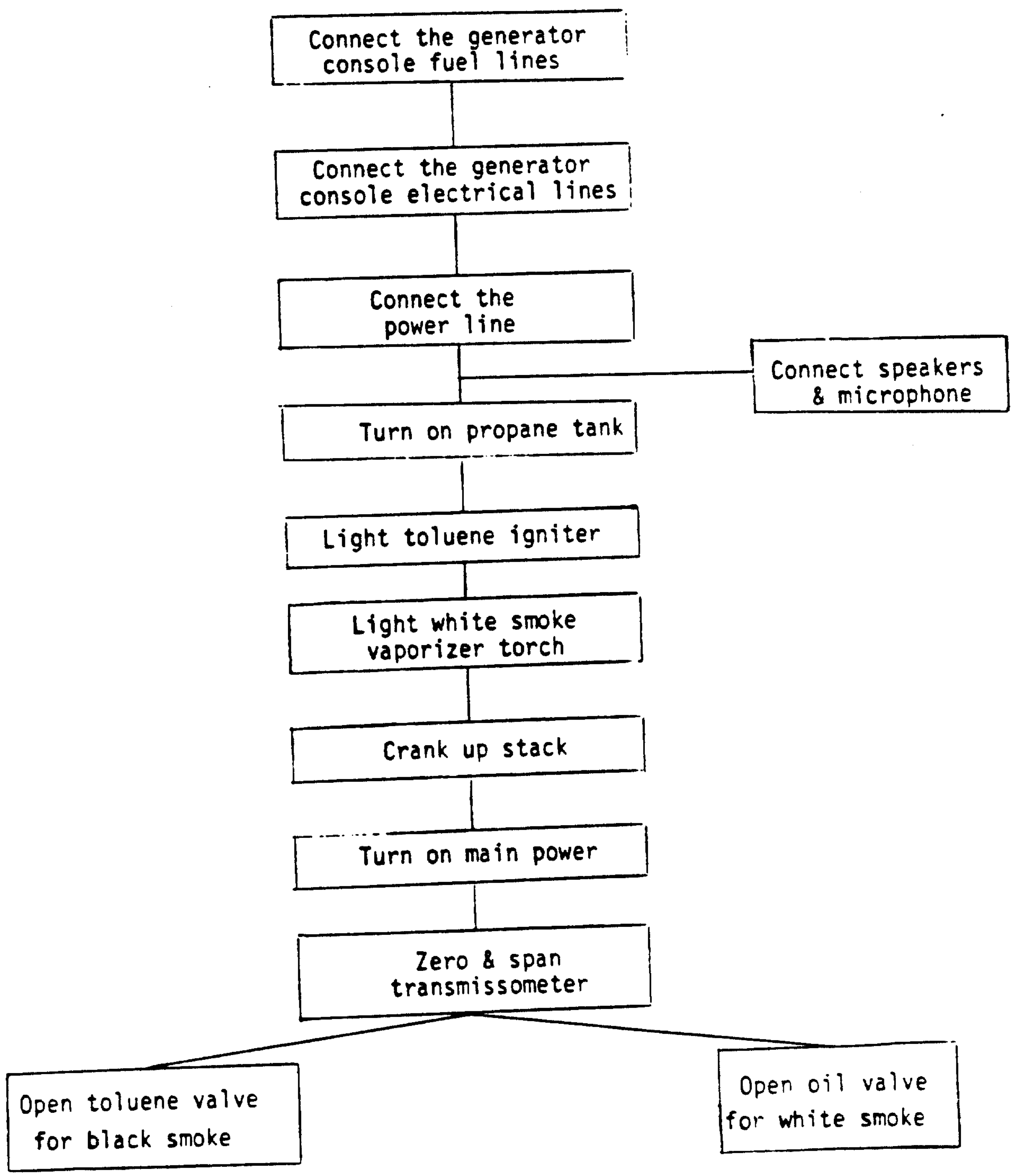
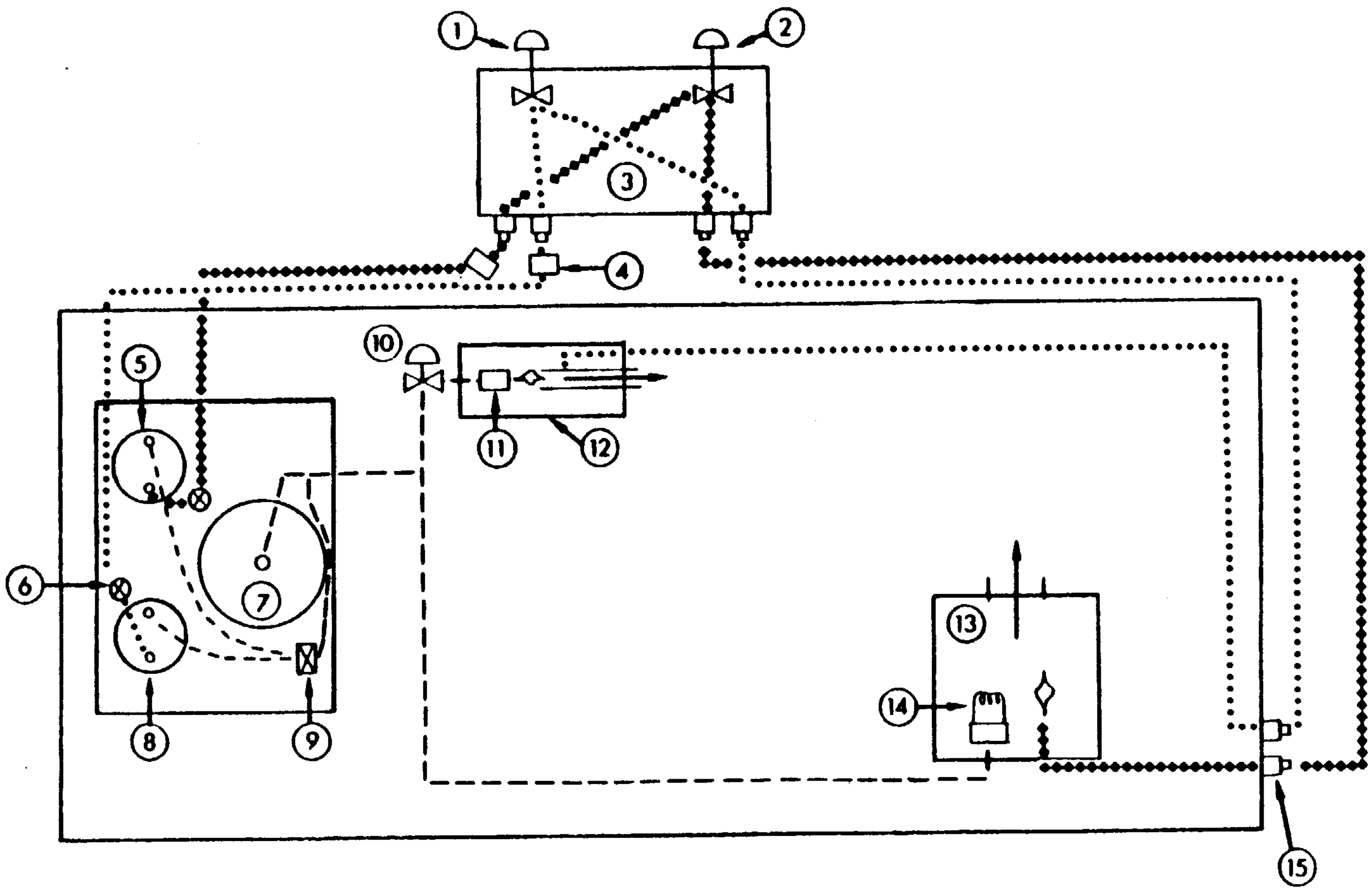


Figure 3-2. Generator Operation Procedure



1. White smoke control
2. Black smoke control
3. Control console
4. Fuel line shutoffs
5. Toluene tank
6. Fuel filters
7. Propane tank
8. Fuel oil tank
9. Propane regulator
10. Torch control valve
11. Vaporizer torch
12. White smoke vaporizer
13. Black smoke firebox
14. Toluene igniter
15. Connectors

- ●●●●●●●● Toluene lines
- •••••••• Fuel oil lines
- ——— High pressure propane lines
- - - - - Low pressure propane lines

Figure 3-3. Smoke Generator Schematic

A brief explanation of the smoke generator console (Figure 3-4) may also be in order. Refer to Appendices D (Smoke Generator Specifications) and E (Operator's Manual) for further information.

3.3 GENERATOR CALIBRATION

Calibration of smoke generators includes checking both zero and span transmissometer drift and the accuracy of intermediate opacity readings. The procedures involved are described in Sections 3.3.1 and 3.3.2, respectively, and are listed together in Section 3.3.3 (refer also to Appendix F). Calibration error should be checked prior to practice, training, and testing sessions to save time during these portions of the program. Zero and span drift must be checked at the beginning of each test run.

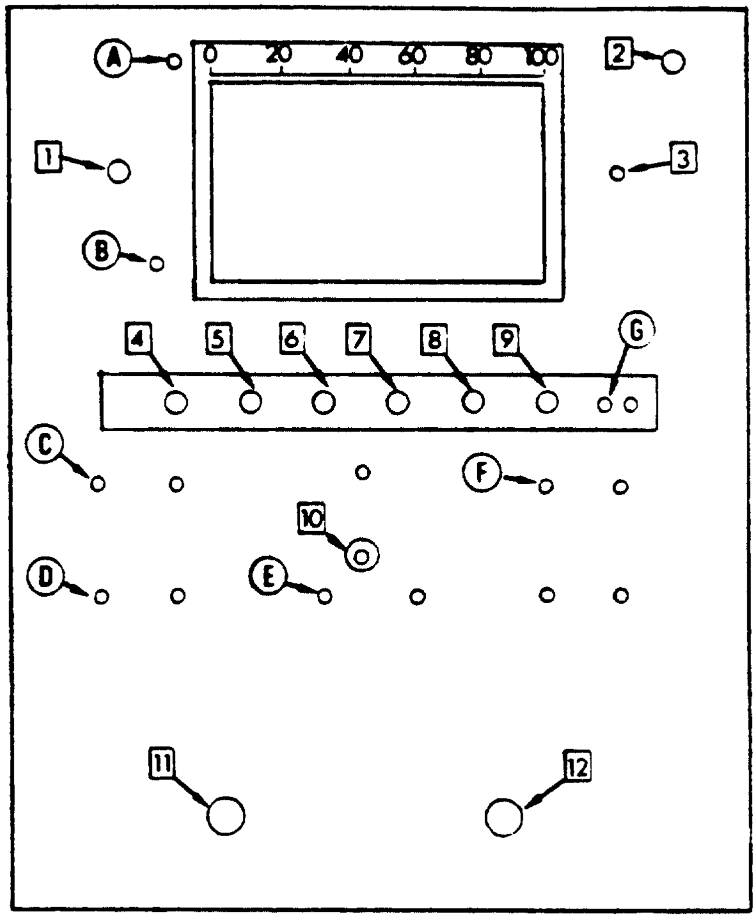
3.3.1 ZERO AND SPAN DRIFT

Method 9 (Appendix A) specifies that:

> 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.

This procedure is referred to as a "zero and span" check and must be performed at the beginning and at the completion of each test run (Reference 1).

If the zero or span drift exceeds ±1 percent opacity at the end of a smoke reading run, the condition must be corrected prior to any further test runs. In order to comply with Method 9, the zero and span drift must also be checked following repair or replacement of the photocell, chart recorder, output meter, and so on, or every 6 months, whichever occurs first.



SWITCHES

A. Chart marker
B. Recorder
C. Main blower
D. Main
E. Tansmissometer source
F. Speaker
G. PA system

KNOBS

1. Chart speed
2. Recorder attenuation
3. Recorder span
4. Mike 1
5. Mike 2
6. Aux
7. Bass
8. Treble
9. Master
10. Transmissometer zero
11. Black smoke
12. White smoke

Figure 3-4. Smoke Generator Console

3.3.2 CALIBRATION ERROR

The second calibration procedure that must be periodically performed checks the error between the actual response of the photocell and the theoretical linear response of the smoke meter. Neutral-density filters that are of known opacity and National Bureau of Standards (NBS) traceable should be used. They must be calibrated within ± 2 percent.

The smoke meter must first be calibrated for 0 and 100 percent opacity readings (refer to Section 3.3.1). A series of three neutral-density filters with nominal opacities of 20, 50, and 75 percent are then inserted into the smoke meter pathlength; care must be taken to prevent stray light from affecting the meter. Method 9 specifies that five nonconsecutive readings are required for each filter; the maximum error allowed on any one reading is 3 percent opacity. If such an error occurs, troubleshooting procedures, including checks for recorder and photocell malfunction, should commence (Reference 1).

Also check the intensity of the light bulb with a digital voltmeter to ensure that it is operated within ± 5 percent of the nominal rated voltage, as specified by Method 9 (refer to Appendix F, Section 1.0).

3.3.3 CALIBRATION PROCEDURES

The zero and span drift and calibration error may be checked separately or together, as in the following step-by-step procedure. Refer to Figure 3-4 for the various switches and controls referred to throughout.

1. Set up the generator's electrical system and raise the smoke stack. Keep all switches turned off.
2. Turn on the recorder switch (B), with the chart advance set to zero.
3. Turn on the transmissometer (E) and readjust the recorder to zero percent with the zero control (10).

4. Turn off the transmissometer (E) and adjust the recorder to 100 percent using the span control (3).
5. Repeat steps 3 and 4 and adjust, if necessary.
6. Turn on the transmissometer (E).
7. Set chart speed (1) to 30 inches/hour.
8. Insert the "calibration staff" (Figure 3-5) into the stack from the back of the generator and sequentially block the light with each filter for one minute. If the generator has only a needle meter rather than a strip chart, it is necessary to record these readings manually.
9. Repeat step 8 four times (i.e., take five readings, inserting the filters in a random order, for each filter).
10. Withdraw the calibration staff.
11. Turn off the chart advance (1).
12. Record the strip chart values on the calibration form (Figure 3-6) and plot the average of the five results for each filter on the calibration log. Include location, data, and calibrator's signature. The form shown in Figure F-1 of Appendix F may also be used.
13. Stamp the strip chart with the calibration stamp (Figure 3-7a), fill in the calibration information, and mark each calibrated point.
14. If the error for any individual reading is more than 3 percent opacity from the calibrated filter opacity, recheck the zero and span, reinsert the appropriate filter, and repeat steps 2 to 14. If the discrepancy persists, check for chart recorder and photocell malfunctions.

3.4 PRACTICE SESSIONS

Before test runs are conducted, students must be made familiar with testing procedures and attain proficiency in evaluating visible emissions. The usual procedure is to generate standard 25, 50, and 75 percent opacity plumes and then conduct several practice runs, giving the actual values generated immediately after the students have recorded their readings. This helps establish standards of comparison and reinforces accurate judgments. Figure 3-8 is a flow chart of the practice procedure, which consists of the following steps:

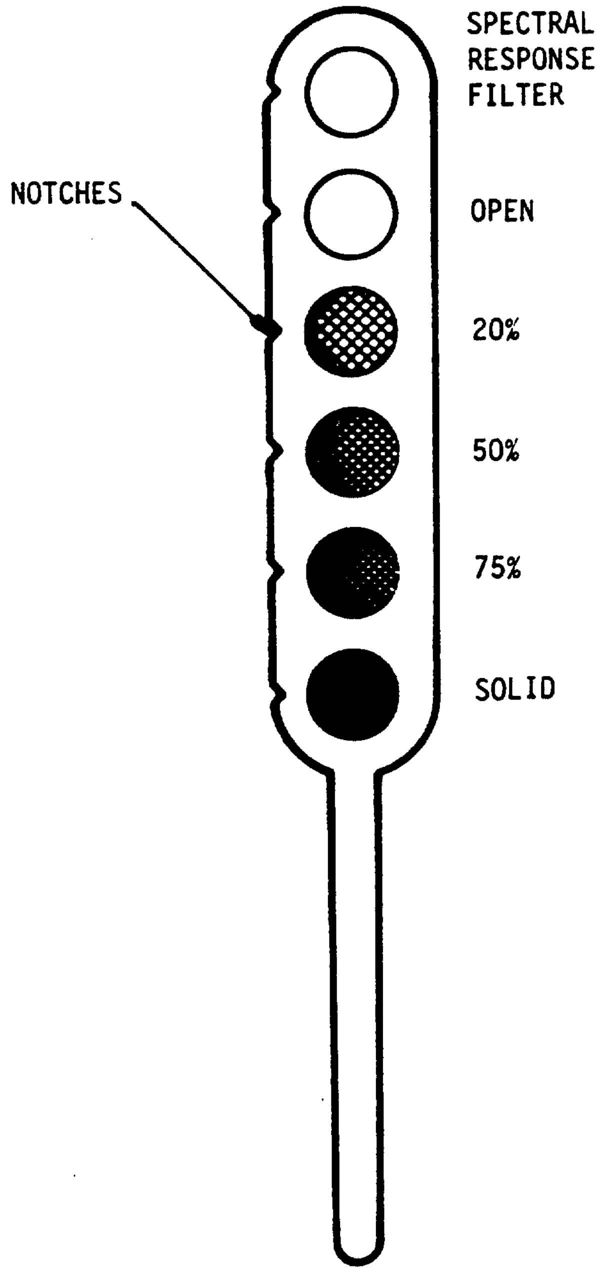
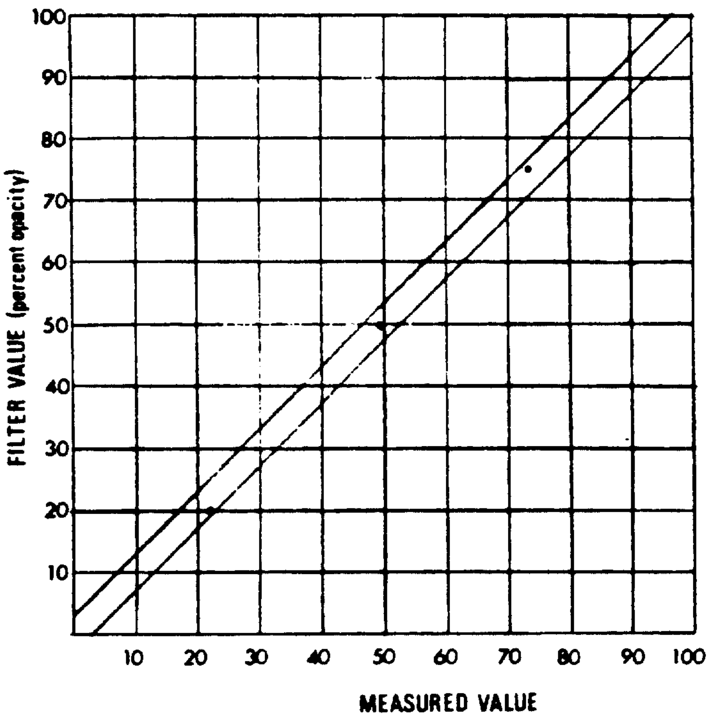


Figure 3-5. Calibration Staff

CALIBRATED BY: Tom Rose

DATE: 3 July 1976

LOCATION: Athens, Georgia



CHART

FILTER VALUE	MEASURED VALUE				
0	0	0	0	0	0
100	100	100	100	100	100
20	22	22	22	22	22
50	49	49	49	49	49
75	73	75	73	73	73
0					
100					
20					
50					
75					

LOG

Figure 3-6. Sample Calibration Form

LOCATION ____________________

DATE _____ RUN # _____ TIME _____

1-25 ____________ 26-50 ________

GENERATOR # ________________

OPERATOR ___________________

VERIFIED BY _________________

a. Calibration stamp (applied to strip chart following calibration procedures)

QUALIFIED

Graded by ________________

Verified by ________________

b. Certification stamp (applied to qualifying certification forms)

Figure 3-7. Calibration and Certification Stamps

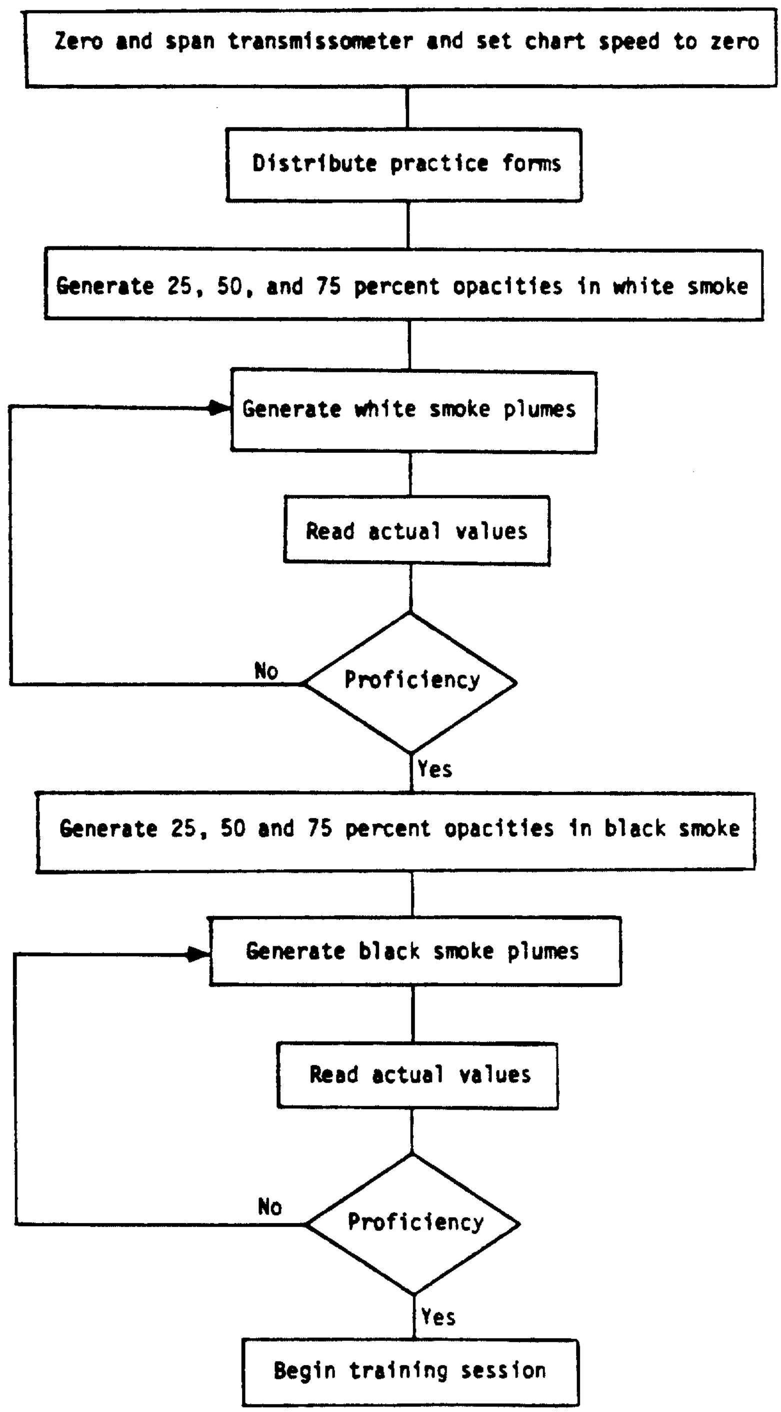


Figure 3-8. Practice Procedure

1. Perform steps 1 to 6 given in Section 3.3.3 (i.e., set up the generator and perform the zero and span checks).
2. Set the chart speed (Figure 3-4, no. 1) to zero.
3. Distribute the practice forms (Figure 2-6).
4. Generate a 25 percent opacity white smoke plume.
5. Encourage the students to walk around and view this opacity value at different angles to the sun. Run this value for at least 10 minutes.
6. Generate a 50 percent opacity white smoke plume for at least 5 minutes.
7. Generate a 75 percent opacity white smoke plume for at least 5 minutes.
8. Generate a white smoke plume around the 25 percent opacity level and:

   a. say "ready" when the smoke is steady
   b. wait at least one second
   c. say "mark"

   The students estimate the opacity of the plume between the words "ready" and "mark," but record this observation on the form only when the instructor announces "mark."
9. On a duplicate practice form, record the transmissometer value for the same period.
10. Repeat steps 8 and 9 for values around 50 and 75 percent opacity.
11. Read the actual values recorded from the transmissometer and have the students check their answers.
12. Repeat steps 8 to 11 with smaller shifts in opacity until the students become proficient at judging opacity in increments of 5 percent.
13. Shut down the white smoke generator.
14. Start up the black smoke generator.
15. Repeat steps 4 to 12 for black smoke plumes.
16. Shut down the black smoke generator.

3.5 TRAINING SESSIONS

Training sessions are identical to test runs except that students may compare answers and grade their own papers to see where they erred (the carbon copies are not turned in). Figure 3-9

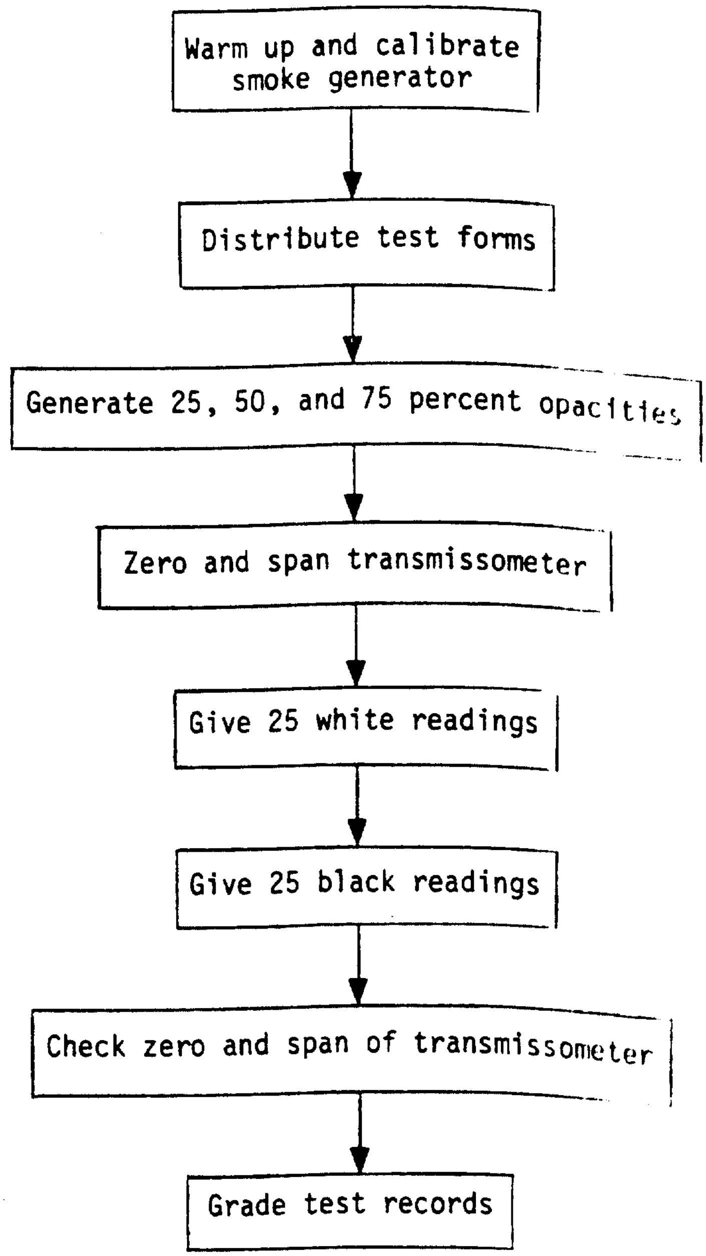
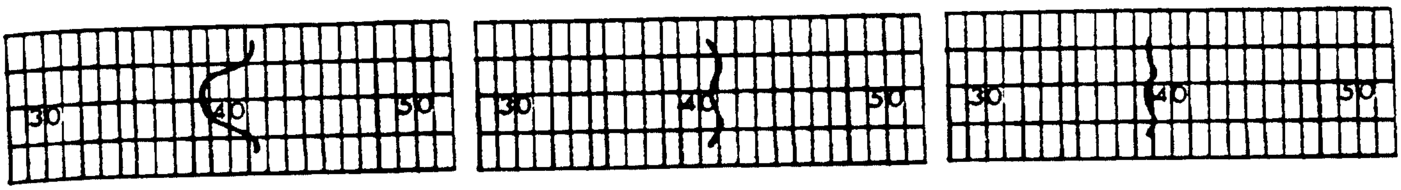


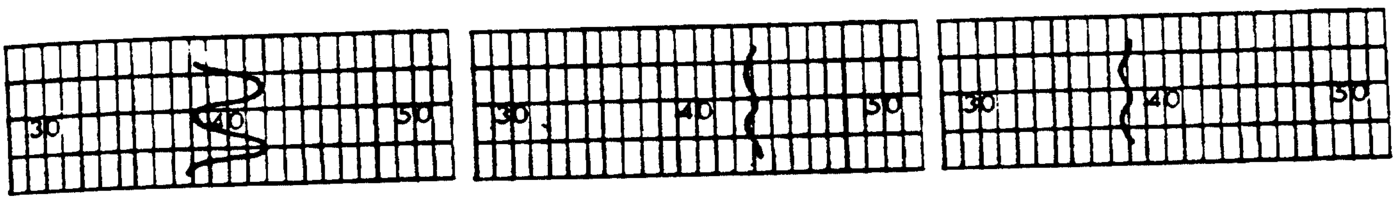
Figure 3-9. Training and Testing Procedure

illustrates the following steps in the training session (refer also to Appendix G):

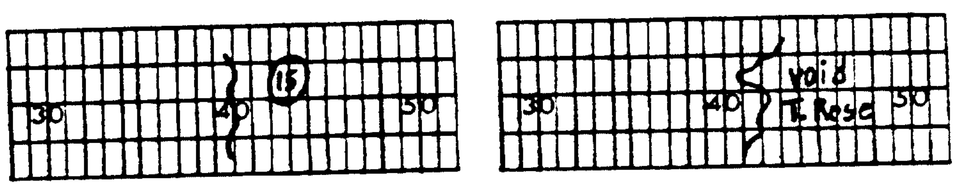
1. Perform steps 1 and 2 given in Section 3.4 (i.e., set up the generator, perform the zero and span checks).
2. Distribute the certification forms and have the candidates fill out the top (Figure 2-7).
3. Generate standard 25, 50, and 75 percent opacity white smoke plumes.
4. Turn off all valves. Wait until no emissions are visible and the transmissometer trace is flat.
5. Repeat steps 1 and 2 given in Section 3.4 (i.e., set up generator and perform zero and span checks).
6. Announce the start of the test and give the run number and time.
7. Open the oil valve and allow the smoke to become steady within 1.5 percent opacity of a 5 percent scale line (Figure 3-10a).
8. When the smoke has stabilized, say "number one" and press the record button on the generator console.
9. After one to two seconds, say "mark" <u>if</u> this reading stayed within 1.5 percent opacity limits. Then release the record button and number the reading. If unacceptable, say "scratch" and repeat the reading (Figure 3-10b). (Students do not mark their papers unless the word "mark" is announced.) Mark the unacceptable reading "void" on the chart and initial it (Figure 3-10c).
10. Repeat steps 7 to 9 for the remaining 24 white smoke readings. The opacity of these readings must be selected in a random order.
11. Shut off the white smoke valve.
12. Check the zero and span transmissometer drift. If the values are within 1 percent of 0 and 100, go on to step 13. Otherwise, wait 15 seconds and repeat the check.
13. Open the black smoke valve and proceed with steps 7 to 10 for readings 26 to 50. The opacities must again be selected at random.
14. Give the correct readings. Candidates should check their own papers so they can see where they erred.



a. Acceptable readings for 40 percent opacity, i.e., trace remained within 1.5 percent opacity of the 5 percent scale value.



b. Unacceptable readings for 40 percent opacity.



c. Examples of how to mark valid and invalid readings.

Figure 3-10. Acceptable and Unacceptable Smoke Readings

3.6 TESTING PROCEDURES

A valid test run consists of 25 white and 25 black smoke plume readings. The candidate must demonstrate the ability to assign opacity readings in 5 percent increments, meeting the following criteria:

- No one reading must be in error by more than 15 percent opacity
- Average error must not exceed 7.5 percent for either white or black smoke

Plumes within each set of 25 readings must be presented in random order. If the candidate fails to qualify, the complete run of 50 readings must be repeated. Certification is valid for 6 months, after which the qualification procedure must be repeated, although the full lecture and training course need not be.

Students must stay in the testing area with the sun at their backs and at least 20 feet from the generator. Smoke school personnel will come into this area to collect test papers. Remind students that they will have to shift position to maintain optimum viewing conditions as the sun moves across the sky (i.e., as the earth turns).

Testing procedures follow the order shown in Figure 3-9 and described in Section 3.5, using the certification form shown in Figure 2-7. These NCR (no carbon required) forms automatically produce a carbon copy as the observations are recorded. The crucial difference between the training session described in Section 3.5 and the testing procedure is that in the latter the originals must be collected prior to announcing the correct readings; the carbon copies are then checked by the students themselves.

Test runs must comply with the specifications given in Method 9. The following points are particularly important:

- Allow a 30-minute warmup period for the smoke generator
- Instruct students to follow field operation procedures in selecting their observation points (refer to Section 2.5)
- Instruct students to record their observations with ball-point pen (not pencil)
- Instruct students not to compare observations among themselves at any time during the test
- Select the opacity of the emissions in a random order
- Record each of the 50 readings on the strip chart recorder (for invalid readings, refer to Section 3.5 and Figure 3.10)
- Make three calibration error readings (one for each of the three filters) inbetween two of the certification runs (refer to Section 3.3.3)

It should not be necessary to review the contents of the lecture on testing procedures (Section 2.8), since its purpose was to prepare students so that they need not ask time-consuming questions in the field.

The grading procedures to be used by smoke school personnel are presented in Section 4.0, which also discusses certification letters and confidence limits procedures for those students who qualify as visible emissions inspectors. Passing papers should be stamped "Qualified" and the grader should sign his name (refer to Figure 3-7b).

Repeat the testing procedure as often as time permits so that students have as many chances as possible to qualify during the training program. A minimum of 10 test runs should be given.

3.7 GENERATOR SHUTDOWN

Once the training session is over, the generator must be shut down. Figure 3-11 is a flow chart of the following major steps involved in this procedure:

1. Repeat the calibration procedures (Section 3.3.3, steps 3 - 14).

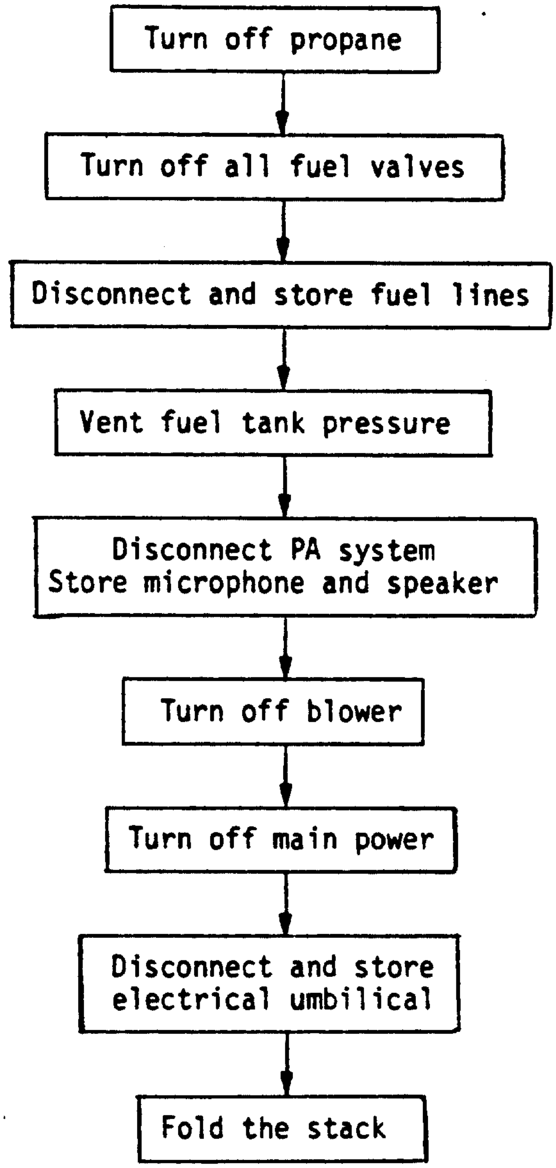


Figure 3-11. Generator Shutdown Procedure

2. Turn off the propane tank valve at the tank (Figure 3-3, no. 9).
3. Turn off the kerosene and toluene valves at the back of the console (Figure 3-3, nos. 1 and 2).
4. Disconnect the console inlet fuel lines from the console (the valves stay on the lines), and store them in the front storage compartment.
5. Disconnect the pressurization lines from the fuel tanks.
6. Vent the pressure from both fuel tanks by depressing the button on the pressure inlet.
7. Store the console inlet fuel lines in the front compartment, and close the compartment.
8. Disconnect the generator inlet fuel lines.
9. Attach the loose ends to the inlet console fittings, making a closed loop.
10. Coil the attached lines in the base of the console.
11. Turn off the propane torch in the vaporizer (Figure 3-3, no. 11)
12. Turn off the toluene igniter in the burner (Figure 3-3, no. 14).
13. Turn off the PA system (Figure 3-4, G)
14. Unplug the speaker jacks (yellow).
15. Wind the speaker wire around the base of the speaker and store it in the rear storage box.
16. Disconnect the microphone from the cable and place it in the accessory box (blue).
17. Disconnect the microphone cable from the console, and coil and store it in the rear storage box.
18. Unscrew the microphone stand from the console and store it in the rear storage box.
19. Turn off the recorder (Figure 3-4, B).
20. Turn off the transmissometer (Figure 3-4, E).
21. Turn off the main blower (Figure 3-4, E).
22. Turn off the main power (Figure 3-4, D).
23. Unplug the generator.
24. Disconnect the amphenol connector (power) from the console.
25. Disconnect the amphenol connector at both ends of the electrical umbilical.

26. Store the electrical cables in the rear storage box.
27. Turn the hydraulic valve so that it is horizontal.
28. Release the stack hold-down clamp.
29. Tip the stack.
30. Close the stack hold-down clamp and lock it with a bolt.
31. Put the back on the console and store it.
32. Store the fire extinguisher, torch, and torch igniter.
33. Break down the calibration staff and store it in the rear storage box.
34. Close the rear storage box.
35. Lock the front and rear storage boxes.

3.8 MAINTENANCE PROCEDURES

At the end of each smoke school and prior to the beginning of the next, the following routine maintenance procedures should be performed:

1. All electrical cables should be checked to be sure that there are no frayed parts, that all contact points are clean, that the connectors are not bent, and that the cables have good integrity.
2. All fuel lines should be checked to ensure that they are unkinked, that there are no weathered spots, splits, or leaks, and that there is nothing wrong with the connectors. It is very easy to lose the ferrules inside of connectors, so make sure that these are present.
3. The integrity of the fittings to the torch box with the white smoke vaporizer should be checked with snoop.
4. The propane gas cylinder that supplies the propane for the white smoke vaporizer and the pressure for the fuel system should be refilled.
5. The "O" rings on the fuel tanks should be checked to make sure that they have not become deformed due to the absorption of organics.
6. The PA system should be assembled and checked out to ensure that all wires are still good, particularly the mike wires.

7. There is a small drain hole in the bottom of the stack. This should be checked to make sure that it is open and that the stack has not accumulated water prior to the school.

8. Calibration of the generator should be performed to ensure that the light bulb has not aged and that the calibration curve is still good.

9. Check the recorder pin assembly and ensure that the recorder pin is operating correctly. This can be performed by turning on the transmissometer and turning the signal attenuator to the right and left to make sure that the recorder pin will travel up and down the scale. An alternate procedure would be to turn the transmissometer on and off to ensure that the pin will drive back and forth smoothly from one side to the other. Time of travel from 0 to 100 percent should be approximately 4.2 seconds but less than 5 seconds.

10. Safety inspection of the trailer should be performed whenever the trailer is to be moved:

    - Make sure that the trailer running lights and electric brake package are all functional.
    - Check that there are no loose parts in the stack hinge area; make sure that all of that is secure and solid.

11. After the fire box has cooled off, it should be inspected by inserting an inspection mirror in the side and making sure that the torch and the deflector plate are good and that there has been no damage to the fire box in transit.

12. A drop of oil should be placed on each of the bearing surfaces and in the oil drop slot on either side of the electric motor at the beginning of each smoke school.

3.9 RECORDKEEPING

A bound log book should be kept to record all events that bear on the performance of the smoke generator. Such events include records of all repair and maintenance work, spectral response checks, calibration checks, response time checks, the number of observers attempting each test, the number of observers passing each test, their names, addresses, and so on. Appendix F includes a form (Figure F-1) for recording this information.

3.10 RECERTIFICATION PROCEDURES

Recertification procedures are identical to testing procedures. Inspectors must be recertified every 6 months. They are not required to repeat the entire lecture portion of the course, although a one-hour presentation on legal aspects and other specific topics of interest to visible emissions evaluators should be offered (refer to Section 2.10).

References for Section 3.0

1. Wohlschlegel, P. and Wagoner, D.E. "Guidelines for Development of a Quality Assurance Program: Volume IX - Visual Determination of Opacity Emissions From Stationary Sources." EPA-650/4-74-005-i. Research Triangle Institute, Research Triangle Park, N.C. 27709. Prepared for U.S. Environmental Protection Agency, Office of Research and Development, Washington, D.C. 20460, under Contract No. 68-02-1234, November 1975

2. Rose, Thomas H. Unpublished draft procedures for Region IV VE Programs, 1978

3. Lee, William S. Personal communication

4.0 DATA REDUCTION

4.1 GRADING THE CERTIFICATION FORM

Figure 2-7 is a copy of the certification form. If another form is used, it should include the same information and be designed so that the average deviation for each run of 25 readings can be entered on the form. Both black and white smoke deviations must be less that 7.5 percent and no reading may err by more than 15 percent to meet the Method 9 criteria.

To grade the certification form, follow the procedures illustrated in Figure 4-1 and enumerated in the following steps:

1. At the end of the test run, collect the original (top white) copy of each student's certification form (Figure 2-7). Place these in the field file in the first section.
2. Take a blank certification form and remove the carbon copy. Place the test form on a clipboard.
3. Write "master" in the space for the observer's name. Fill in the run number, date, location, and time the test was begun.
4. Record the actual values on the form as they are read from the strip chart. Have the students grade their carbon copies as this is done.
5. Place a grading acetate over the master, being careful to align it correctly.
6. With a "china marking pencil," make a diagonal slash from upper left to lower right (\) over each marked number on the grading master. File the acetate with the originals.
7. Turn the grading master over and record the names of the students who think they have qualified. These are the only papers that will be graded.
8. Remove the papers to be graded from the file. Select one and align the acetate over it.
9. Count from the mark on the acetate to the mark on the student's paper. Counting to the left, record a negative value (-); counting to the right, record a positive one (+). Each 5 percent is counted as one. For example,

	(3)	(2)	(1)		
30	35	40	45	50	Error = -3
	Student			Actual	

10. Add all of the negative errors for the 25 white smoke readings and record "-10," or whatever the sum may be, on the line marked "White Deviation."

11. Add all of the positive errors and record on the same line used in step 10, e.g., "-10 +6."

12. Ignore the signs and add the two numbers, placing the absolute value in brackets on the same line used in steps 10 and 11, e.g., "-10 +6 [16]."

13. If no single error has an absolute value of more than 3 and the number in brackets is 37 or less, repeat steps 9 to 12 for the 25 black smoke readings.

14. If no single error among the black smoke readings has an absolute value of more than 3 and the number in brackets is 37 or less, stamp the paper "Qualified" (refer to Figure 3-7b).

15. Sign the line marked "Graded by," and have the supervisor verify the grade.

16. Enter the student's name, address, and qualifying run number in the VE program roster, which is a bound log book (Figure 4-2).

17. Compute the deviation on the white readings by multiplying the number in brackets by 0.2 or by reference to Figure 4-3, and record this value on the test paper and under "Deviation White" in the roster.

18. Repeat step 17 for the black smoke readings.

19. Compute the bias on the white readings by combining the positive and negative percentages, first multiplying each positive and negative error by 5 percent (refer to step 9). Record this value under the "Bias White" column in the roster.

20. Repeat step 19 for the black smoke readings.

21. Inform the students who certified.

22. Follow up by sending a certification letter to each student who qualified.

4.2 CERTIFICATION LETTERS

Wall certificates are provided to all students who attend the course. Each passing test must be regraded by the instructor prior to issuance of a letter stating that the observer is a certified visible emissions evaluator. The letter should be mailed within one month of the date on which the observer qualified.

DATE ______

LOCATION ______

GENERATOR # ______

NAME AND ADDRESS	FEE PAID	TRAINING	RECERTIFY	QR #	DATE	DEV. WHITE	DEV. BLACK	BIAS WHITE	BIAS BLACK	CERTIFICATE	COMMENTS:

Grader: Sig______ Init.______ | Instructor ______

Sig______ Init.______ | Signature ______

Sig______ Init.______ | Date ______

Sig______ Init.______

Figure 4-2. Sample VE Program Roster

Increment of Error[a]	Percent Deviation	Increment of Error	Percent Deviation
1	0.20	26	5.20
2	0.40	27	5.40
3	0.60	28	5.60
4	0.80	29	5.80
5	1.00	30	6.00
6	1.20	31	6.20
7	1.40	32	6.40
8	1.60	33	6.60
9	1.80	34	6.80
10	2.00	35	7.00
11	2.20	36	7.20
12	2.40	37	7.40
13	2.60	38	7.60
14	2.80	39	7.80
15	3.00	40	8.00
16	3.20	41	8.20
17	3.40	42	8.40
18	3.60	43	8.60
19	3.80	44	8.80
20	4.00	45	9.00
21	4.20	46	9.20
22	4.40	47	9.40
23	4.60	48	9.60
24	4.80	49	9.80
25	5.00	50	10.00

[a] Each error of 5 percent opacity, either positive or negative, is counted as one increment.

Figure 4-3. Average Deviation Chart

4.3 MEAN DEVIATION AND CONFIDENCE LIMITS

If confidence limits are required for use in court or to otherwise demonstrate the accuracy of a given visible emissions evaluation, they should be calculated as follows.

The objective of this calculation is to find the confidence limits about the observer's mean deviation. This mean deviation or bias is the amount, on the average, the observer has differed from the "true" opacity of the emission he has observed. The confidence limits tell us that in future tests, each consisting of 25 observations taken under the same conditions, the observer's mean deviation is expected to be, 19 times out of 20, within the confidence limits calculated from the data of the original test.

In order to calculate the mean deviation we must find the difference between the "true value" and the evaluator's observed and recorded opacity. Finding the opacity value the observer recorded is easy. Finding the true value of the opacity is more demanding because we must consider the introduction and the propagation of errors.

The starting place in the search for the "true value" is the value recorded on the strip chart or other recording device of the smoke generator. In fact we can use this value as the "true value" if we are sure that any and all errors in this value are small; small compared to the mean differences (deviation) between the observer's recorded values and the "true value."

Possible errors that could influence the value as recorded on the strip chart are drift, calibration and random error. Random error might come from, for example, a large motor nearby turning on and lowering the voltage of the electrical supply, or the pen of the chart recorder mechanically sticking. The operator of the smoke generator must be alert to many possible interferences and take steps to minimize these effects or to eliminate the interference if possible and keep this type of error small.

Drift of zero and span are checked both at the beginning and at the end of every test run. If either is found to exceed ± 1 percent opacity at the end of a smoke run, the condition must be corrected. The operator of the smoke generator must keep this kind of error small by replacement of the electrical circuits of the unit if necessary.

Calibration error is checked before and after every run series. This is done by inserting a series of low, median, and high neutral density filters that are of known opacity and National Bureau of Standards (NBS) traceable. The maximum error allowed as measured between the pen of the chart recorded and the "known" opacity of the filter should not exceed 3 percent opacity. If the limit is exceeded, then the operator of the smoke generator should correct the problem before proceeding with the work of testing visible emission evaluators. He should check each filter before use for any smudges on the filter or visible deterioration of the filter. Here again the operator must keep this kind of error small.

The mean deviation and confidence limits should be calculated from the data taken for each filter. This should be done as follows:

1. Determine the difference between the measured value of the filter and the certified value for the filter:

   d_1 = Certified value - Measured value_1

   d_2 = Certified value - Measured value_2

   . . . . .

   . . . . .

   . . . . .

   d_N = Certified value - Measured value_N

   where N is 5 or greater.

2. Calculate the mean difference $\bar{D}$ and the standard deviation SD as follows:

$$\bar{D} = \frac{d_1 + d_2 + \ldots + (d_N)}{N}$$

$$SD = \sqrt{\frac{(d_1 - \bar{D})^2 + (d_2 - \bar{D})^2 + \ldots + d_n - \bar{D})^2}{(N - 1)}}$$

3. Calculate the confidence limits as follows:

$$\text{Low confidence limit} = \bar{D} - \frac{t\ (SD)}{\sqrt{N}}$$

$$\text{High confidence limit} = \bar{D} + \frac{t\ (SD)}{\sqrt{N}}$$

where "t" is the Student t value for N data points or (N-1) degrees of freedom taken from standard statistical tables.

The value "zero" should be between the low confidence limit and the high confidence limit. In other words, the low confidence limit should be negative and the high confidence limit should be positive. If this is not true, then the filter should be examined for deterioration or smudges and the test repeated.

4. The calculations outlined in Steps 1 through 3 should be repeated for each filter used in the calibration check of the smoke generator.

The mean and confidence limits for each student can be calculated by a similar procedure as follows:

1. Determine the differences between the 25 white smoke determinations as follows:

d_1 = Observer $value_1$ - Chart $value_1$
d_2 = Observer $value_2$ - Chart $value_2$

. . . . .

. . . . .

d_{25} = Observer $value_{25}$ - Chart $value_{25}$

The Chart value is taken to the nearest percent opacity.

2. Calculate the mean difference $\bar{D}_w$ and the standard deviation as follows:

$$\bar{D}_2 = \frac{d_1 + d_2 + \ldots + d_{25}}{25}$$

$$SD_w = \sqrt{\frac{(d_1-\bar{D}_w)^2 + (d_2-\bar{D}_w)^2 + \ldots + (d_{25}-\bar{D}_w)^2}{24}}$$

3. Calculate the confidence limits as follows:

$$(\text{Low confidence limit})_w = \bar{D}_w - \frac{t(SD_w)}{\sqrt{25}}$$

$$(\text{High confidence limit})_w = \bar{D}_w + \frac{t(SD_w)}{\sqrt{25}}$$

4. Repeat Steps 1, 2, and 3 for the 25 black smoke determinations and calculate $\bar{D}_B$, SD_B, and the confidence limits.

The preceding calculation should be made for every student observer's final passing test paper and the information should be made available to the student.

There is another statistic that should be calculated for each run (25 white and 25 black readings) of the smoke generator. This value is an indication not of the performance of the student observer, but rather is an indication of how well the operator ran the smoke generator. This calculation is done in a similar manner as the preceding calculation except Step 1, which is modified as follows:

1. Determine the differences between 25 white smoke determinations as follows:

$$d_1 = \text{Announced value}_1 - \text{Chart value}_1$$
$$d_2 = \text{Announced value}_2 - \text{Chart value}_2$$
$$\cdot \quad \cdot \quad \cdot \quad \cdot \quad \cdot$$
$$\cdot \quad \cdot \quad \cdot \quad \cdot \quad \cdot$$
$$d_{25} = \text{Announced value}_{25} - \text{Chart value}_{25}$$

The Announced Value is the value announced to the students for the purpose of grading their test papers and is in units that are multiples of 5; for example, 10, 25, 65, etc.

The remainder of the steps 2 through 4 are done as specified in the preceding calculation. These values are retained in the records of the "smoke school."

References for Section 4.0

1. Spiegel, Murray R. Schaum's Outline of Theory and Problems of Probability of Statistics. New York: McGraw-Hill Book Company, Schaum's Outline SEries, 1975, pp. 109-111, 194-195.

2. Rose, Thomas H. Personal communication.

3. Smith, Miles. Personal communication.

APPENDIX A

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

APPENDIX A

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.

FIGURE 9-1
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 Start--End	Opacity Sum	Opacity Average

Readings ranged from ____ to ____ % opacity

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

FIGURE 9-2 OBSERVATION RECORD PAGE ___ OF ___

COMPANY ______________ OBSERVER ______________
LOCATION ______________ TYPE FACILITY ______________
TEST NUMBER ______________ POINT OF EMISSIONS ______________
DATE ______________

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

FIGURE 9-2 OBSERVATION RECORD PAGE ___ OF ___
(Continued)

COMPANY ______________ OBSERVER ______________
LOCATION ______________ TYPE FACILITY ______________
TEST NUMBER ______________ POINT OF EMISSIONS ______________
DATE ______________

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

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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 ± 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° maximum total angle.
d. Angle of projection	15° maximum total angle.
e. Calibration error-	± 3% opacity, maximum
f. Zero and span drift	± 1% opacity, 30 minutes.
g. Response time---	5 seconds.

3.3.1 CALIBRATION

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

3.3.2 SMOKE METER EVALUATION

The smoke meter design and performance are to be evaluated as follows:

3.3.2.1 LIGHT SOURCE

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

3.3.2.2 SPECTRAL RESPONSE OF PHOTOCELL

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

3.3.2.3 ANGLE OF VIEW

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

3.3.2.4 ANGLE OF PROJECTION

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

3.3.2.5 CALIBRATION ERROR

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

3.3.2.6 ZERO AND SPAN DRIFT

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

3.3.2.7 RESPONSE TIME

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

4. REFERENCES

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

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

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

APPENDIX B

CAMERA INSTRUCTIONS

APPENDIX B

CAMERA INSTRUCTIONS

(Minolta)

Accurate photographs can be taken with a single lens camera or one with automatic photocells by performing the following steps:

1. Check the ASA of the film (listed on the box) to ensure that it matches the ASA reading on the camera. (On a Minolta, the ASA number is located under the film speed dial.)
2. Set the film speed for .01 second.
3. Point the camera at the subject, placing the subject in the center of the frame, and turn the focus ring until the picture appears sharp.
4. Note the "lollipop-shaped" line on the right side of the viewer and the needle that fluctuates when the camera is moved. Turn the "F-stop" dial until the needle is squarely in the center of the circle at the top of the "lollipop stick." (This sets the Irish diaphragm or F-stop.)
5. Hold the camera steady and press the shutter.

If in the correct position to view opacity, this method ensures clear, accurate photographs of the facility.

To take telephoto pictures, perform the following steps:

- Locate the red button on the upper left side of the camera face next to the lens, and slide it down.
- Rotate the lens counterclockwise with the camera facing toward you; then remove the lens.
- To insert the telephoto lens, turn it clockwise and then slide the red button up.

The remainder of the procedure consists of steps 1 to 5 given above.

APPENDIX C

THE PSYCHROMETRIC CHART

APPENDIX C

THE PSYCHROMETRIC CHART

The following discussion and example are from Reference 1, pp. 5.3 to 5.7.

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. Either the chart on a sling psychrometer or the one shown in Figure C-1 can be used to determine the relative humidity of the air.
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 C-2. 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.

Toward the lower end of the ambient temperature range it takes very little moisture to fully saturate the air, and thus the possi-

Directions for Use of Relative Humidity Tables.

For Example:

To find the Relative Humidity for the reading of the "Dry-Bulb" at 55° and the "Wet-Bulb" at 45°, subtract the "Wet-Bulb" reading (45°) from the "Dry-Bulb" reading (55°), which gives a difference of 10°. Follow down the column headed (10°) and read across the table from "Dry-Bulb" reading (55°), we find the relative humidity 43%

READINGS DRY-BULB THERMOMETER	DIFFERENCE BETWEEN READINGS OF "WET-BULB" AND "DRY-BULB" THERMOMETERS															
	1°	2°	3°	4°	5°	6°	7°	8°	9°	10°	11°	12°	13°	14°	15°	16°
20°	85%	70%	55%	40%	26%	12%										
21°	85	71	56	42	28	15	1%									
22°	86	71	58	44	31	17	4									
23°	86	72	59	46	33	20	7									
24°	87	73	60	47	35	22	10									
25°	87	74	62	49	37	25	13	1%								
26°	87	75	63	51	39	27	16	4								
27°	88	76	64	52	41	29	18	7								
28°	88	76	65	54	43	32	21	10								
29°	88	77	66	55	44	34	23	13	2%							
30°	89	78	67	56	46	36	26	16	6							
31°	89	78	68	58	47	37	28	18	8							
32°	89	79	69	59	49	39	30	20	11	2%						
33°	90	80	70	60	51	41	32	23	14	5						
34°	90	81	71	62	52	43	34	25	16	8						
35°	91	81	72	63	54	45	36	27	19	10	2%					
36°	91	82	73	64	55	46	38	29	21	13	5					
37°	91	83	74	65	57	48	40	31	23	15	7					
38°	91	83	75	66	58	50	42	33	25	17	10	2%				
39°	92	83	75	67	59	51	43	35	27	20	12	5				
40°	92	83	75	68	60	52	45	37	29	22	15	7				
41°	92	84	76	69	61	54	46	39	31	24	17	10	2%			
42°	92	85	77	69	62	55	47	40	33	26	19	12	5			
43°	92	85	77	70	63	55	48	42	35	28	21	14	8	1%		
44°	93	85	78	71	63	56	49	43	36	30	23	16	10	4		
45°	93	86	78	71	64	57	51	44	38	31	25	18	12	6		
46°	93	86	79	72	65	58	52	45	39	32	26	20	14	8	2%	
47°	93	86	79	72	66	59	53	46	40	34	28	22	16	10	5	
48°	93	86	79	73	66	60	54	47	41	35	29	23	18	12	7	1%
49°	93	86	80	73	67	61	54	49	42	36	31	25	19	14	9	3

Figure C-1. Relative Humidity Tables[a]

[a]These values are correct only for an air velocity of not less than 600 feet per minute and a barometric pressure of 29.92 inches. Temperature readings in degrees Fahrenheit, humidity in percent.

barometric pressure of 29.92 inches. Temperature

READINGS "DRY-BULB" THERMOMETER	DIFFERENCE BETWEEN READINGS OF "WET-BULB" AND "DRY-BULB" THERMOMETERS																													
	1°	2°	3°	4°	5°	6°	7°	8°	9°	10°	11°	12°	13°	14°	15°	16°	17°	18°	19°	20°	21°	22°	23°	24°	25°	26°	27°	28°	29°	30°
50°	93	87	80	74	67	61	55	49	43	38	32	27	21	16	10	5														
51°	94	87	81	75	68	62	56	50	45	39	34	28	23	17	12	7	2													
52°	94	87	81	75	69	63	57	51	46	40	35	29	24	19	14	9	4													
53°	94	87	81	75	69	63	58	52	47	41	36	31	26	20	16	10	6	1												
54°	94	88	82	76	70	64	59	53	48	42	37	32	27	22	17	12	8	3												
55°	94	88	82	76	70	65	59	54	49	43	38	33	29	23	19	14	9	5												
56°	94	88	82	76	71	65	60	55	50	44	39	34	30	25	20	16	11	7	2											
57°	94	88	82	77	71	66	61	55	50	45	40	35	31	26	22	17	13	8	4											
58°	94	88	83	77	72	66	61	56	51	46	41	37	32	27	23	18	14	10	6	1										
59°	94	89	83	78	72	67	62	57	52	47	42	38	33	29	24	20	16	11	7	3										
60°	94	89	83	78	73	68	63	58	53	48	43	39	34	30	26	21	17	13	9	5	1									
61°	94	89	84	78	73	68	63	58	54	49	44	40	35	31	27	22	18	14	10	7	3									
62°	94	89	84	79	74	69	64	59	54	50	45	41	36	32	28	24	20	16	12	8	4	1								
63°	95	89	84	79	74	69	64	60	55	50	46	42	37	33	29	25	21	17	13	10	6	2								
64°	95	90	84	79	74	70	65	60	56	51	47	43	38	34	30	26	22	18	15	11	7	4								
65°	95	90	85	80	75	70	66	61	56	52	48	44	39	35	31	27	24	20	16	12	9	5	2							
66°	95	90	85	80	75	71	66	61	57	53	48	44	40	36	32	29	25	21	17	14	10	7	3							
67°	95	90	85	80	75	71	66	62	58	53	49	45	41	37	33	30	26	22	19	15	12	8	5	2						
68°	95	90	85	80	76	71	67	62	58	54	50	46	42	38	34	31	27	23	20	16	13	10	6	3						
69°	95	90	85	81	76	72	67	63	59	55	51	47	43	39	35	32	28	24	21	18	14	11	8	5	1					
70°	95	90	86	81	77	72	68	64	59	55	51	48	44	40	36	33	29	25	22	19	15	12	9	6	3					
71°	95	90	86	81	77	72	68	64	60	56	52	48	45	41	37	33	30	27	23	20	17	13	10	7	4	1				
72°	95	91	86	82	77	73	69	65	61	57	53	49	46	42	38	34	31	28	24	21	18	15	12	9	6	3				
73°	95	91	86	82	78	73	69	65	61	57	53	50	46	42	39	35	32	29	25	22	19	16	13	10	7	4	1			
74°	95	91	86	82	78	74	69	65	61	58	54	50	47	43	40	36	33	30	26	23	20	17	14	11	8	5	2			
75°	96	91	86	82	78	74	70	66	62	58	54	51	47	44	40	37	34	30	27	24	21	18	15	12	9	7	4	1		
76°	96	91	87	82	78	74	70	66	62	59	55	51	48	44	41	38	34	31	28	25	22	19	16	13	11	8	5	3		
77°	96	91	87	82	79	74	71	67	63	59	56	52	48	45	42	39	35	32	29	26	23	20	17	14	12	9	6	4	1	
78°	96	91	87	83	79	75	71	67	63	60	56	53	49	46	43	39	36	33	30	27	24	21	18	16	13	10	8	5	3	
79°	96	91	87	83	79	75	71	68	64	60	57	53	50	46	43	40	37	34	31	28	25	22	19	17	14	11	9	6	4	1

Figure C-1. Relative Humidity Tables (Continued)

DIFFERENCE BETWEEN READINGS OF "WET-BULB" AND "DRY-BULB" THERMOMETERS (columns 1–25)

ADINGS "DRY-BULB" THERMO-METER	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
80°	96	91	87	83	79	75	72	68	64	61	57	54	50	47	44	41	38	35	32	29	26	23	20	18	15
82°	96	92	88	84	80	76	72	69	65	61	58	55	51	48	45	42	39	36	33	30	28	25	22	20	17
84°	96	92	88	84	80	76	73	69	66	62	59	56	52	49	46	43	40	37	35	32	29	26	24	21	19
86°	96	92	88	84	81	77	73	70	66	63	60	57	53	50	47	44	42	39	36	33	31	28	26	23	21
88°	96	92	88	85	81	77	74	70	67	64	61	57	54	51	48	46	43	40	37	35	32	30	27	25	22
90°	96	92	89	85	81	78	74	71	68	65	61	58	55	52	49	47	44	41	39	36	34	31	29	26	24
92°	96	92	89	85	82	78	75	72	68	65	62	59	56	53	50	48	45	42	40	37	35	32	30	28	25
94°	96	93	89	85	82	79	75	72	69	66	63	60	57	54	51	49	46	43	41	38	36	33	31	29	27
96°	96	93	89	86	82	79	76	73	69	66	63	61	58	55	52	50	47	44	42	39	37	35	32	30	28
98°	96	93	89	86	82	79	76	73	70	67	64	61	58	55	53	50	48	45	43	40	38	36	34	32	29
100°	96	93	89	86	83	80	77	73	70	68	65	62	59	56	54	51	49	46	44	41	39	37	35	33	30
102°	96	93	90	86	83	80	77	74	71	68	65	62	60	57	55	52	49	47	45	42	40	38	36	34	32
104°	97	93	90	87	83	80	77	74	71	69	66	63	60	58	55	53	50	48	46	43	41	39	37	35	33
106°	97	93	90	87	84	81	78	75	72	69	66	64	61	58	56	53	51	49	46	44	42	40	38	36	34
108°	97	93	90	87	84	81	78	75	72	70	67	64	62	59	57	54	52	49	47	45	43	41	39	37	35
110°	97	93	90	87	84	81	78	75	73	70	67	65	62	60	57	55	52	50	48	46	44	42	40	38	36
112°	97	94	90	87	84	81	79	76	73	70	68	65	63	60	58	55	53	51	49	47	44	42	40	38	36
114°	97	94	91	88	85	82	79	76	74	71	68	66	63	61	58	56	54	52	49	47	45	43	41	39	37
116°	97	94	91	88	85	82	79	76	74	71	69	66	64	61	59	57	54	52	50	48	46	44	42	40	38
118°	97	94	91	88	85	82	79	77	74	72	69	67	64	62	59	57	55	53	51	49	47	45	43	41	39
120°	97	94	91	88	85	82	80	77	74	72	69	67	65	62	60	58	55	53	51	49	47	45	43	41	40
122°	97	94	91	88	85	83	80	77	75	72	70	67	65	63	60	58	56	54	52	50	48	46	44	42	40
124°	97	94	91	88	85	83	80	78	75	73	70	68	65	63	61	59	57	54	52	50	48	47	45	43	41
126°	97	94	91	88	86	83	80	78	75	73	70	68	66	64	61	59	57	55	53	51	49	47	45	44	42
128°	97	94	91	89	86	83	81	78	76	73	71	68	66	64	62	60	58	56	54	52	50	48	46	44	42
130°	97	94	91	89	86	83	81	78	76	73	71	69	67	64	62	60	58	56	54	52	50	48	47	45	43
132°	97	94	92	89	86	84	81	79	76	74	71	69	67	65	63	61	58	56	55	53	51	49	47	45	44
134°	97	94	92	89	86	84	81	79	76	74	72	69	67	65	63	61	59	57	55	53	51	49	48	46	44
136°	97	94	92	89	86	84	81	79	77	74	72	70	68	65	63	61	59	57	55	54	52	50	48	46	45
138°	97	94	92	89	87	84	82	79	77	75	72	70	68	66	64	62	60	58	56	54	52	50	49	47	45

DIFFERENCE BETWEEN READINGS OF "WET-BULB" AND "DRY-BULB" THERMOMETERS (columns 26–50)

ADINGS "DRY-BULB" THERMO-METER	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50
80°	12	10	7	5	2																				
82°	14	12	10	7	5	2																			
84°	16	14	12	9	7	5	3																		
86°	18	16	14	11	9	7	5	3	1																
88°	20	18	15	13	11	9	7	5	3	1															
90°	22	19	17	15	13	11	9	7	5	3	1														
92°	23	21	19	17	15	13	11	9	7	5	3	1													
94°	24	22	20	18	16	14	12	10	9	7	5	3	1												
96°	26	24	22	20	18	16	14	12	10	8	7	5	3	2											
98°	27	25	23	21	19	17	15	14	12	10	8	7	5	3	2										
100°	28	26	24	22	21	19	17	15	13	12	10	8	7	5	4	2	1								
102°	30	28	26	24	22	20	18	16	15	13	11	10	8	7	5	4	2	1							
104°	31	29	27	25	23	21	20	18	16	14	13	12	10	8	7	5	4	2	1						
106°	32	30	28	26	24	23	21	19	17	16	14	13	11	10	8	7	5	4	3	1					
108°	33	31	29	27	25	24	22	20	19	17	16	14	12	11	10	8	7	5	4	3	2				
110°	34	32	30	28	26	25	23	21	20	18	17	15	14	12	11	10	8	7	6	4	3	2	1		
112°	35	33	31	29	27	26	24	23	21	19	18	16	15	14	12	11	9	8	7	6	4	3	2	1	
114°	35	34	32	30	28	27	25	24	22	20	19	18	16	15	13	12	11	9	8	7	6	5	3	2	1
116°	36	34	33	31	29	28	26	25	23	22	20	19	17	16	14	13	12	11	9	8	7	6	5	4	2
118°	37	35	34	32	30	29	27	25	24	23	21	20	18	17	16	14	13	12	11	9	8	7	6	5	4
120°	38	36	34	33	31	29	28	26	25	23	22	21	19	18	17	15	14	13	12	10	9	8	7	6	5
122°	39	37	35	34	32	30	29	27	26	24	23	22	20	19	18	16	15	14	13	11	10	9	8	7	6
124°	39	38	36	34	33	31	30	28	27	25	24	22	21	20	18	17	16	15	14	12	11	10	9	8	7
126°	40	38	37	35	33	32	30	29	27	26	25	23	22	21	19	18	17	16	15	13	12	11	10	9	8
128°	41	39	37	36	34	33	31	30	28	27	25	24	23	22	20	19	18	17	16	14	13	12	11	10	9
130°	41	40	38	37	35	33	32	30	29	28	26	25	24	22	21	20	19	18	16	15	14	13	12	11	10
132°	42	40	39	37	36	34	33	31	30	28	26	25	24	22	21	21	20	19	17	16	15	14	13	12	11
134°	43	41	39	38	36	35	33	32	30	29	27	26	25	24	22	21	20	19	18	17	16	15	14	13	12
136°	43	41	40	38	37	35	34	33	31	30	28	27	26	25	23	22	21	20	19	18	17	16	15	14	13
138°	44	42	40	39	37	36	34	33	32	30	29	28	27	25	24	23	22	21	20	19	17	16	15	14	14

Figure C-1. Relative Humidity Tables (Concluded)

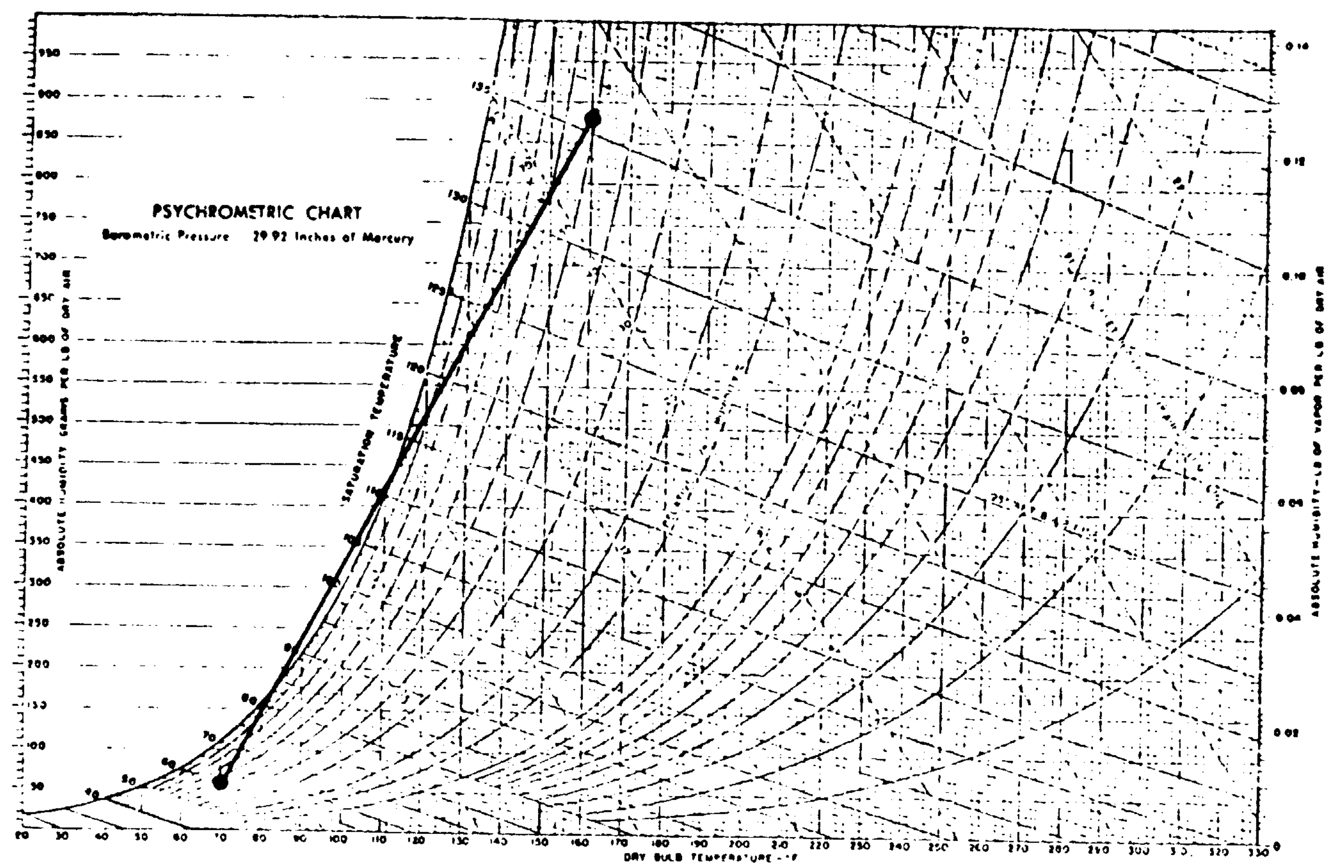


Figure C-2. Sample Psychrometric Chart

bility of the moisture in the plume condensing is very high, no matter what the stack exit conditions may be. The possibility of a steam plume being formed is smallest on hot, dry days.

The psychrometric chart may be used to determine whether 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) consists of 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:

$$\text{Humidity ratio} = \frac{4354\ (\text{M.C.})}{1 - \text{M.C.}} \quad \frac{\text{grains}}{\text{lb of dry air}}$$

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 (stack conditions)

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 C-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.

However, stack gas is not a pure air water mixture, but generally contains gases such as SO_2 and SO_3, and fine particulates. These substances can alter the dew point and affect the visibility of the plume.

Reference for Appendix C

1. Missen, R. and Stein, A. "Guidelines for Evaluation of Visible Emissions: Certification, Field Procedures, Legal Aspects, and Background Material." EPA-340/1-75-007. Pacific Environmental Services, Inc., Santa Monica, Cal. 90404. Prepared for U.S. Environmental Protection Agency, Office of Enforcement, Washington, D.C. 20460, under Contract No. 68-02-1390, April 1975, pp. 5.3-5.7

APPENDIX D

SMOKE GENERATOR SPECIFICATIONS, MODEL 3000-A

SPECIFICATIONS

Smoke Generator

Model 3000-A

1975

GENERAL

The generator shall be capable of producing constant black and white smoke plumes with an opacity range of 0 to 100%. The unit shall be mounted on a single axle trailer to facilitate transportation. The smoke generator shall include the following major component systems:

1. Single axle trailer
2. Benzene combustion chamber
3. White smoke generator
4. Stack assembly
5. Transmissometer
6. Fuel pump system
7. Dilution manifold
8. Main blower assembly
9. Automatic benzene ignition
10. Operator's console
11. Storage compartment
12. Accessories

The unit shall meet the specifications as outlined in the Federal Register Volume Number 39, No. 177 - dated Wednesday, September 11, 1974.

SPECIFICATIONS

A. Single Axle Trailer

The trailer shall be constructed to withstand a load capacity of no less than 2,000 pounds. The trailer size shall be 6 ft. wide by 14 ft. long. All components of the smoke generator shall be mounted on a solid sheet metal bed attached to the trailer frame. The bed shall be constructed of 14 guage cold rolled steel. Turn signals shall be included to meet all state and federal regulations concerning towed trailers in the 2,000 pound load range. The trailer shall be equipped with a 1 7/8 inch coupler and safety chains for towing. To insure adequate trailer road stability, 14" automotive-type tires shall be used to support the trailer bed.

B. Benzene Combustion Chamber (Black Smoke)

Shall be constructed with double metal walls (14 guage) with a minimum of 2.0 inches of castable insulation between the walls. The insulation material shall be rated at 2000°F or greater. Internal baffling and liner will be included in the combustion chamber to insure proper benzene combustion to produce a plume opacity of 0 - 100%. Baffling and liner will be constructed of No. 304 stainless steel.

C. White Smoke Generator

White smoke shall be generated by injecting #2 fuel oil into a propane heated coil. The fuel vaporization chamber will be constructed from stainless steel. The vaporization chamber and coil will be mounted to the generator mixing chamber. The fuel vaporization assembly shall be capable of producing a white smoke plume from 0 to 100% opacity.

D. Stack Assembly

The stack shall be 12 inches in diameter with a minimum height of (16) feet in the raised position. The stack shall be constructed of 14 guage cold rolled steel. The hydraulic cylinder utilized to raise the stack shall have a minimum load capacity of 2500 pounds. For travel purposes the stack shall be capable of being lowered to a maximum height of (8) feet or lower and the stack shall be held in position by a cradle supported from the trailer frame. The hydraulic cylinder shall have a minimum stroke of 18.0 inches and be at least 2.0 inches in diameter.

E. Transmissometer

The transmissometer shall be stack mounted and will consist of a light source and a solid state photodetector. Both the light source and the photodetector shall be shock mounted (spring loaded) to prevent damage while in transit. The transmissometer shall be equipped with two positive pressure fans to prevent smoke interference with the light source and photodetector. Calibration of the transmissometer will be accomplished by the insertion of neutral density filters between the light source and photodetector. The neutral density filters will not be furnished by Environmental Industries.

F. Fuel Pump System

Two direct current operated fuel pumps (AC type EP-1 or equal) shall be provided to supply fuel to the black smoke combustion chamber and the white smoke vaporization chamber. Two six gallon fuel tanks shall be included to furnish the fuel for the generator. Fuel flow shall be adjusted using two needle valves (Whitey No. B-1RS-4) or equal. The benzene fuel line shall be equipped with a (3) way drain valve to prevent freezing during extreme cold weather. Color-coded fuel lines throughout: black for benzene, white for fuel oil and quick disconnect fittings with double end shut off feature on all fuel lines.

G. Dilution Manifold

The generator shall be equipped with a dilution manifold between the black smoke combustion chamber and the main blower. The dilution chamber shall be constructed of 14 guage cold rolled steel. A manually operated damper shall be included to control volume of ambient air allowed to pass through the main stack assembly. The dilution chamber shall be at least 8.0 inches in diameter.

H. Main Blower Assembly

The unit shall be equipped with a 1430 cfm paddle wheel type blower to insure proper air flow to the main stack. The blower assembly shall be located between the dilution chamber and the stack assembly. All components of the main blower shall be fabricated of 14 guage cold rolled steel, except the blower blade and the motor housing. Power to the main blower shall be supplied by a (3/4) HP 117 volt AC motor. Maximum RPM of the blower motor shall be 1725 RPM.

I. Automatic Benzene Igniter

The benzene combustion chamber shall be equipped with an automatic fuel igniter. The igniter shall be propane operated and include a trailer mounted 20 lb. propane gas bottle. A propane regulation valve shall be inserted between the propane tank and the igniter head as an added safety factor.

J. Operator's Console

A remote operator's console shall include the following components:

1. Digital Printer

The digital printer will be included to accept the transmissometer output. The digital printer shall include all necessary input jacks for the transmissometer output and digital printer calibration.

2. Operator's Control Panel

The function of the operator's panel shall be to supply control voltages to all operating systems on the generator. Control switches shall be included for main blower, main power, stack fans, (2) DC fuel pumps, light source and a 12 volt horn. The panel shall also include a variable 10 turn potentiometer for calibration of the transmissometer. Three isolated 12 volt DC power supplies shall be mounted behind the control panel to supply power to the fuel pumps, horn and light source. The light source DC supply circuit shall also include a constant voltage transformer to prevent interference from AC-line voltage fluctuations. All console electrical circuits shall be individually fused to prevent power overloads. A 16 ft. cable shall be supplied to interconnect the console and generator trailer. Amphenol mil spec connectors or equal shall be used on the control panel and the interconnect cable. The control panel shall not exceed 8.5"H x 19.0"W x 15.0"H.

The control panel will include three isolated power supplies as follows:

a. Light Source Power Supply

(1) Output voltage: 11.5 - 12.5 VDC
(2) Output current: 1.8 amps
(3) Input voltage range: 108 - 132 volts, or 216 - 264 volts
(4) Input frequency range: 50 - 400 Hz
(5) Regulation-line and load combined: ± 0.1%
(6) Temperature coefficient: 0.03% C
(7) Polarity: May be used positive or negative
(8) Short circuit protection: automatic circuit protects the power supply if the output is shorted continuously. Automatic return upon removal of short circuit.
(9) Operating temperature: 0°C to 55°C
(10) Storage temperature: minus 20°C to plus 85°C

b. Fuel Pump Power Supply

(1) Output voltage: 12.0 - 14.0 VDC
(2) Output current: 3 amps
(3) Input voltage range: 110 - 120 VAC
(4) Input frequency: 60 Hz
(5) Filtered
(6) Operating temperature: 0°C to 55°C

c. Horn Power Supply

(1) Output voltage: 12.0 to 14.0 VAC
(2) Output current: 8.0 amps
(3) Input voltage: 110 to 120 VAC
(4) Input frequency: 60 Hz
(5) Operating temperature: 0°C to 55°C

3. <u>Fuel Control Panel</u>

The fuel control panel shall be console mounted to facilitate remote fuel adjustments to both the white and black smoke generators. The panel shall include two DC fuel pumps (AC EP-1 or equal) and two fuel control valves (Whitey No. B-IRS-4 or equal). Fuel line connectors shall be accessible from the console rear and fuel line size shall not exceed .250 inches in diameter. The console shall be designed to operate in any location up to 16 feet from the smoke generator trailer. The entire operator's console shall be housed in a sheet metal cabinet.

K. <u>Storage Compartments</u>

Two trailer mounted storage compartments 24"W x 26"L x 28"H shall be furnished for accessory storage. The storage compartment covers shall be hinged and equipped with hasp for locking. The two compartments shall be fabricated from 14 guage cold rolled steel.

L. <u>Accessories</u>

The following accessories shall be furnished with the Smoke Generator:

1. Trailer spare tire
2. Trailer dolly and leveling jack
3. (2) spare light source bulbs
4. Parts list and instruction manual
5. Towing vehicle wiring harness
6. Folding table for operator's console
7. Fire extinguisher 5 lb. dry chemical type
8. One set neutral density filters 2 x 2 - Wratten Gelatin - set includes .1 to 1.0.

M. <u>Stipulations</u>

1. One-year warranty for parts and workmanship.

2. Three-year availability of parts.

MODEL 3000 SERIES

SMOKE GENERATOR

OPTIONS

Option #1

Trailer Options

(A) The heavy duty trailer is recommended if the smoke generator is moved to various locations very frequently or over rough terrain. Load capacity 2000 pounds.

(B) Electric Brakes

(C) Dual Axle Trailer - capacity 4000 pounds with brakes.

Option #2

Automatic Benzene Ignition System

This option includes a propane ignition system to automatically ignite the benzene fuel required to produce the black smoke plume. This is a much needed safety feature not included on prior smoke generators.

Option #3

Electrical (AC) Generator

This option allows the smoke generator to be operated in areas where commercial AC power is not available.

Option #4

Remote Fuel Control Panel

The standard Model 3000 has the fuel pumps and fuel control valves mounted on the generator trailer. The remote fuel control option includes a console mounted panel equipped with fuel pumps and control valves. This option permits the smoke generator operator the flexibility of moving the operator's console and fuel tanks inside a building while conducting a class if adverse weather conditions so dictate.

Option #5

Cold Weather Package

The cold weather package is recommended for customers who may be conducting visible emissions courses under extreme cold weather conditions. The fact that benzene freezes at 37°f is the basic reason for the package. The cold weather package includes an insulated fuel storage compartment and all benzene fuel lines are wrapped with heat tape and insulated to prevent freezing.

Option #6

Transmissometer Readout Systems

(A) Digital Readout/Printer - Option 6A includes a panel mounted digital voltmeter and an eleven column digital printer. The transmissometer readout is printed directly on an IBM computer card by simply pressing a manual print switch.

(B) Recorder Readout - Option 6B includes a rack mounted 10 inch strip chart recorder. Specifications will be furnished on request.

Option #7

Public Address System

The PA system shall be portable and capable of operation on 120 volts AC or battery. Unit will consist of amplifier, microphone, speaker cabinet and a 40 foot speaker extension cable. The amplifier will be solid state with 40 watt output and external jacks for auxiliary equipment.

Option #8

One-Day Orientation and Maintenance Course

Environmental Industries can also provide a one-day orientation course for training smoke generator operators. The cost of the course can also be included in the cost of the generator if desired. The course includes the basic requirements for a visible emissions course and the operation, calibration and maintenance of the Model 3000 Series Smoke Generators. We feel that this service is a very important aspect of establishing a visible emissions course.

Option #9

Accessory Package

Includes the following:

- Tire & Rim
- Manual & Schematics
- Table - Console
- Neutral Density Filters
- Bulbs & Fuses & Parts
- Vehicle Wiring Harness
- Fire Extinguisher
- Filter Holder & Calibrator

Option #10

White Smoke Generator

The White Smoke Generator is designed to replace the air cooled engines presently employed on smoke generators to produce the white smoke plume. The White Smoke Generator is compact and does not have any moving parts to produce the noise associated with air cooled engines.

References for Appendix D

1. Lee, William S. "Specifications, Smoke Generator Model 3000-A." Environmental Industries Air Monitoring Systems, Cary, N.C. 27511, 1975

2. Lee, William S. "Model 3000 Series Smoke Generator Options." Environmental Industries Air Monitoring Systems, Cary, N.C. 27511, 1975

APPENDIX E

OPERATOR'S MANUAL, MODEL 3000

SMOKE GENERATOR

OPERATOR'S MANUAL
MODEL 3000
SMOKE GENERATOR

1976

ENVIRONMENTAL INDUSTRIES
P. O. Box 441
Cary, N. C. 27511

Telephone: 919 + 467-1500

TABLE OF CONTENTS

W A R R A N T Y

Environmental Industries warrants that all products are free from defective workmanship or material for a period extending one year from date of shipment. This warranty shall be applicable only if the products are used in accordance with instructions and recommendations.

A defective product should be returned to Environmental Industries, transportation prepaid. The company will, at its option, repair or replace the defective product and it will be returned freight prepaid.

Environmental Industries shall not be liable for consequential damages nor for labor, loss, or expenses directly or indirectly arising from use of their products or equipment.

INTRODUCTION

The training and testing of smoke observers requires the use of a device for manufacturing black and non-black smoke and for controlling the opacity of this smoke. The production of shades of black smoke can be accomplished by various means of creating incomplete combustion. The non-black emissions can be produced by heating a distillate-type oil so that it vaporizes into a gas and then cooling it so that the vapor condenses into an aerosol cloud. This cloud is white and its opacity varies as the amount of oil that is vaporized. The control of the visual densities of the smoke plumes is accomplished by measuring the densities before the plume is emitted and altering the flow of combustible material (black) or vaporizing liquid (white) until the desired density is achieved. There are no liquid flow control settings which are calibrated to give specified Ringelmann or equivalent opacity readings. One obtains a particular density by turning the fluid control valve until the photo-electric cell system measuring the density indicates on a dial or recorder that smoke of the desired density is passing up the stack.

OPERATING PRINCIPLES

The following describes the two methods employed to produce Black and White smoke with the Model 3000 Smoke Generator.

White smoke is produced by injecting #2 fuel oil into the propane heated vaporization chamber located in the generator mixing chamber. The density of the white smoke aerosol cloud is increased or decreased by adjusting the needle valve (fuel oil) located on the front of the console mounted fuel control panel.

Black smoke is produced by the combustion of benzene or benzol in the double wall combustion chamber. The density of the black smoke plume is determined by increasing or decreasing the Benzene fuel flow. The benzene fuel flow is determined by the needle valve (Benzene) located on the console mounted fuel control panel.

The main blower mixing chamber may also have some effect on the plume density. By adjusting the damper control in the mixing chamber, the amount of the ambient air entering the plume can be increased or decreased - thus changing the density of plume read by the transmissometer.

The transmissometer consists of a photocell and regulated light source. The transmissometer is located in the 4 inch cross arms located on the 12 inch stack. Neutral density filters are used to calibrate the transmissometer.

SET-UP AND OPERATING PROCEDURES

MODEL 3000

1. Unhitch Smoke Generator from towing vehicle. The dolly jack should be adjusted until the front of the trailer is slightly higher than the rear.
2. Check for any damage to generator while in transit.
3. Check levels of all fuels, lubricants and hydraulic fluid.
    a. Lubricate main blower motor prior to each instruction period. Two drops of 3 in One oil should be injected into each oil cup.
    b. Check benzene and fuel oil levels in fuel storage compartment.
4. Electrical Connections
    a. Connect the 16 ft. interconnect cable to the junction box at the rear of the Smoke Generator.
    b. Connect the 16 ft. interconnect cable to the rear of the generator console.

    *The interconnect cable connectors are keyed and cannot be connected incorrectly.

    c. Turn all switches on the generator console to the off position. The fuel control valve should also be in the off position.
    d. Attach the console power cord to the rear panel (3 pin amphenol).

e. Plug the console power cord into a 115 VAC-60 Hz power source. Maximum current required by the console will not exceed 15 amps.

5. Fuel Line Connections

a. Locate the quick disconnect fuel line connectors under the main junction box on the generator trailer and in the rear of the control console (bottom panel).

b. Fuel Line Identification

Two fuel line interconnect assemblies are included with the Model 3000. The shorter set of fuel lines is connected between the fuel storage tanks and the rear of the fuel control panel. The longer fuel line assembly is connected between the fuel control panel and the quick disconnects mounted below the main electrical junction box located on the rear or the generator. Each fuel line assembly is made up of one white and one black fuel line. The white fuel line is for benzene transfer and the black line is for fuel oil transfer. All fuel lines are also identified by colored tape on each quick disconnect.

c. Fuel Line Connections

1. Close both fuel control valves prior to making fuel line connections.

2. Connect fuel lines to the rear of the fuel control panel as per matching color codes. IMPORTANT Always connect the above lines to the fuel control panel prior to making trailer connections or fuel tank connections.

3. Connect two fuel lines to the trailer mounted quick disconnects and complete the fuel line connections to both fuel storage tanks as per color coded tape markings.

4. Vent fuel tanks - loosen filler cap.

7. Operation of Generator Console

a. Main Control Panel (Electrical)

Note: Insure that all electrical switches and fuel control valves are in the off position before starting this procedure.

1. Main power switch should be turned to the (on) position. The amber power indicator light should now be on.

2. Stack fans to (on) position.

3. Main blower to (on) position.

4. Recorder to (on) position zero recorder - see Lab Data Control Operator's Instruction Manual for detailed instructions on recorder.

5. Turn light source to on position and adjust transmissometer output to read zero per cent on recorder scale.

b. Transmissometer Calibration

Note: Allow 30 minutes warm up time for recorder and light source before attempting final calibration.

1. Calibration

The transmissometer is calibrated after allowing a minimum of 30 minutes warm up by alternately producing simulated opacity of 0 percent and 100%. When stable response at 0 percent or 100% is noted, the transmissometer is adjusted to produce an output of 0 percent or 100%, as appropriate. This calibration shall be repeated until stable 0 percent and 100% readings are produced without adjustments. Simulated 0 percent and 100% 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.

2. Response Time

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

c. Fuel Control Panel - Lower Panel

1. Benzene - The benzene control valve should be left in the OFF position (clockwise) until the procedure is followed in the section concerning Black smoke plume production.

2. Fuel Oil - Same as above except White smoke plume production.

8. Elevate Stack

a. Remove nut from stack cradle. Hold down bracket.*

b. Push top half of stack cradle over off the stack.

c. Close hydraulic bleed valve at front of hydraulic cylinder. Turn to up and open vent at top of cylinder.

d. Pump handle on hydraulic cylinder to raise stack.

*e. Do not pump handle after stack reaches the upright position. The stack can be damaged if additional force is applied by the hydraulic cylinder.

9. Procedure for Producing a Black Smoke Plume

Note: Section 1 through 7 of this manual should be completed prior to executing this procedure.

a. Insure that stack fans and main blower are operating properly.

b. Check to insure that both the combustion chamber pilot light control valve and the White smoke generator gas control valve are in the OFF position - (clockwise).

c. Open the main control valve on the 20 lb. propane bottle mounted in the front storage compartment.

d. Remove the heat register plate on the black smoke combustion chamber. Open pilot valve.

e. Using a small propane torch light the pilot inside the combustion chamber.

f. Replace the heat register cover plate with adjustment arm on left.

g. Adjust louvers for proper air flow - Normally down.

h. Turn fuel pump electrical switch to benzene position as indicated on control panel.

i. Open benzene fuel control valve slightly to allow fuel lines to fill with benzene. This can be determined by observing the benzene input line connected to the quick disconnect at the rear of the generator trailer.

j. A small flame should now be evident inside the combustion chamber and the recorder should also be indicating a low level smoke plume less than 20% opacity.

CAUTION: If a flame or plume is not evident close the benzene control valve and turn off benzene fuel pump.

1. Check for possible fuel leaks at all connecting points in fuel lines.
2. Check to insure that the pilot light is burning.
3. Turn OFF pilot light and determine if fuel is entering the fuel tray mounted inside the combustion chamber. Before attempting this make sure pilot light is off.

k. The combustion chamber should be given sufficient time to warm up before proceeding with higher than a #2 Ringleman density reading. 10 to 15 minutes.

l. The desired black smoke density reading can now be continued by adjusting the benzene fuel control valve.

m. Number 4 Ringleman or higher smoke densities should only be held for brief periods to prevent damage to the generator from excessive heat.

n. The pilot light should be left on after the completion of the Black smoke run.

10. Procedure for Producing a White Smoke Plume

<u>CAUTION</u>: Insure that all the benzene is burned out of the black smoke combustion chamber prior to proceeding. The main blower should also be turned on prior to proceeding.

<u>CAUTION</u>: Insure that the front of the smoke generator trailer is slightly higher than the rear of the trailer. This will prevent the possibility of fuel spillage in the vaporizer cabinet area.

a. The vaporizer torch valve should be in the <u>off</u> position (clockwise).

b. Open main valve on propane storage bottle.

c. Open lid on vaporizer assembly cabinet.

d. Turn the main blower switch to the <u>on</u> position. Adjust the vaporizer torch valve until a smooth blue flame exists at the input to the fuel vaporization chamber.

e. Light vaporizer torch with a small propane torch used to light the Black smoke igniter.

f. Allow vaporization chamber a minimum of 5 minutes warm-up time -- longer if operating in extreme cold ambient conditions. Vaporizer chamber should appear slightly red prior to injecting No. 2 fuel oil.

g. Open No. 2 fuel oil valve on console fuel control panel slightly. Allow enough time for fuel interconnect lines to fill with fuel.

h. If the above steps have been followed, a low opacity White smoke plume will now be indicated on the console recorder.

i. The White smoke vaporizer assembly will not produce any desired White smoke plume from 0% to 100% opacity. Caution: To prevent flooding of the fuel vaporization chamber, do not open fuel oil control valve beyond the 100% opacity level indicated on the console recorder.

11. White Smoke Assembly Shut-Down Procedure

a. Turn off fuel pump at control console.

b. Turn off fuel oil control valve.

c. Allow all fuel to be burned from the fuel vaporization chamber. This will be indicated by a 0% opacity reading on the recorder.

d. Turn off vaporization chamber propane torch.

e. Turn off valve on propane bottle if no other runs are to be conducted with either White or Black smoke.

12. Shut-Down Check List

a. Insure that both fuel control valves are completely turned off. Clockwise direction.

b. Insure that all propane control valves are turned to the OFF position.

1. Main bottle valve first

2. White smoke torch valve

3. Benzene igniter valve

c. Disconnect fuel lines at trailer quick disconnect and drop blue connector into benzene storage tank. Also insert green connector into filler neck of kerosene storage tank. The next step should be to pump all fuel lines as free as possible of remaining fuel. Open fuel line control valves completely and allow both fuel pumps sufficient time to clear lines. Remove fuel lines from console quick disconnects and insert caps on male connectors.

d. All electrical control switches can now be turned to the (OFF) position. The power control switches for the recorder should also be moved to the (OFF) position.

e. The electrical system interconnect cable should now be removed from both the trailer main junction box and the rear of the console control panel.

13. Lowering Stack

a. Open cradle hold down bracket.

b. Open hydraulic bleed valve slightly.

c. Insert large screwdriver in slow between upper and lower stack sections.

d. Lift up on screwdriver to tilt stack slightly forward.

e. Adjust bleeder valve to control speed of stack descent.

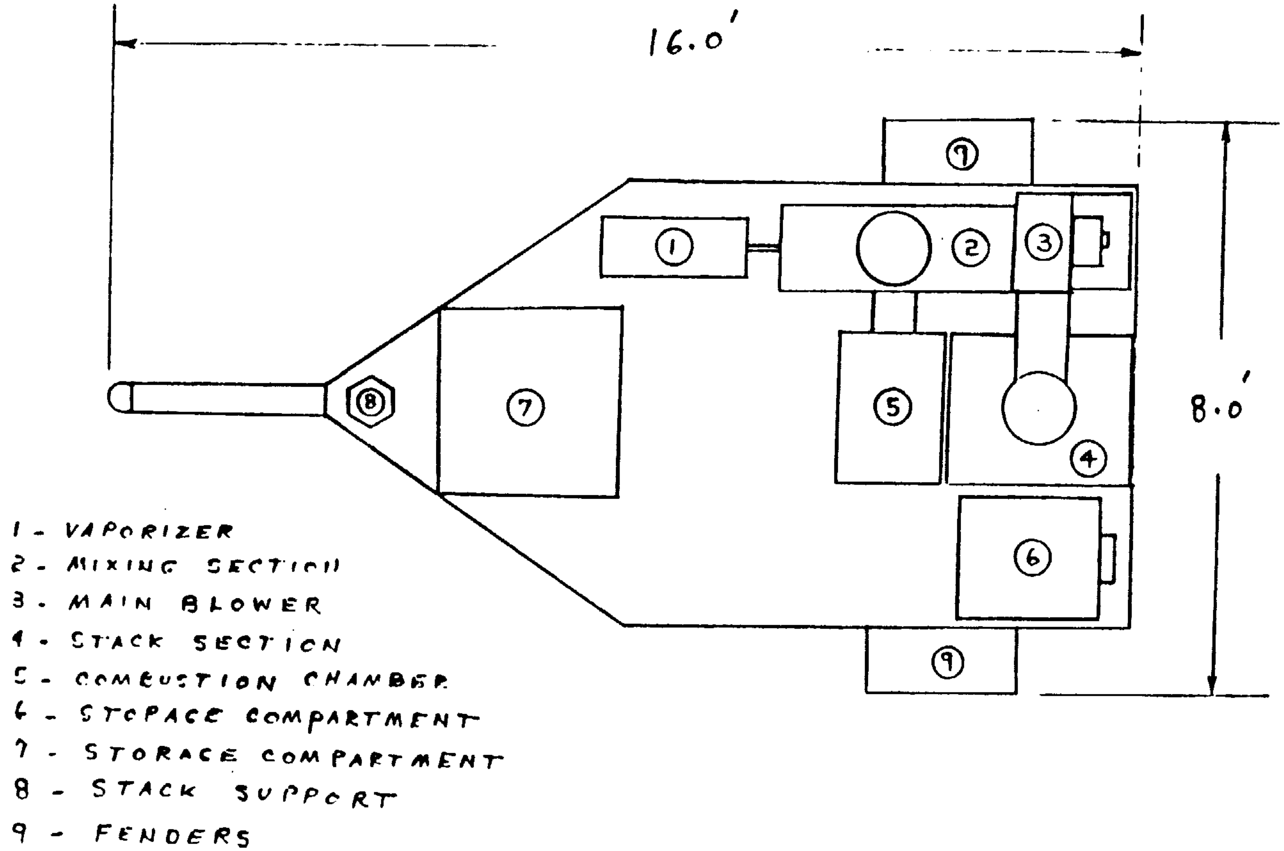
f. Close stack cradle and tighten hold down nut.

g. Bleeder valve should be left open to prevent accidental damage to stack.

Note: Additional information on the operation and maintenance of smoke generators can be obtained from EPA Instructors and Operators Manual on the Evaluation of Visible Emissions. Contact Dennis Holzschuh, NERC, Research Triangle Park, N. C..

Part Number	Description	Manufacturer
101	Trailer	E & I
102	Fuel Tanks	E & I
103	Third Wheel	Jeffries
104	Recorder - Model 2801	Lab Data Control
105	Stack Fans	Dayton
106	Photocell	E & I
107	Light Source	E & I
108	Console Cabinet	Bud
109	Potentiometer	TRW
110	Cable Connectors	Amphenol
111	Fuel Pumps - 12 volt	AC - EPIW
112	Fuel Valves	Whitey
113	Main Blower Fan	Dayton
114	Main Blower Motor	Dayton
115	Vaporization Chamber	E & I
116	Propane Tank - 20 lb.	Universal
117	Igniter Torch - Propane	Keen-Cutter
118	Vaporization Torch #4083	Exact Torch
119	Benzene Combustion Chamber	E & I
120	Quick Disconnects - Body 701	Flo-Lok
121	Flexible Tubing - Nylo-Seal	Imperial Eastman
122	Fire Extinguisher - 5 lb.	Sentry
123	Hydraulic Cylinder 2.0 x 18.0 - 2500lb.	Livingston & Haven
124	Hydraulic Pump - Double Action	Livingston & Haven
125	Hydrualic Line - 48.0"	E & I
126	Control Panel (Elect.) 3000	E & I
127	Fuel Control Panel 3000	E & I

Figure E-1. Parts List



Boston - EPA

Figure E-2. Smoke Generator

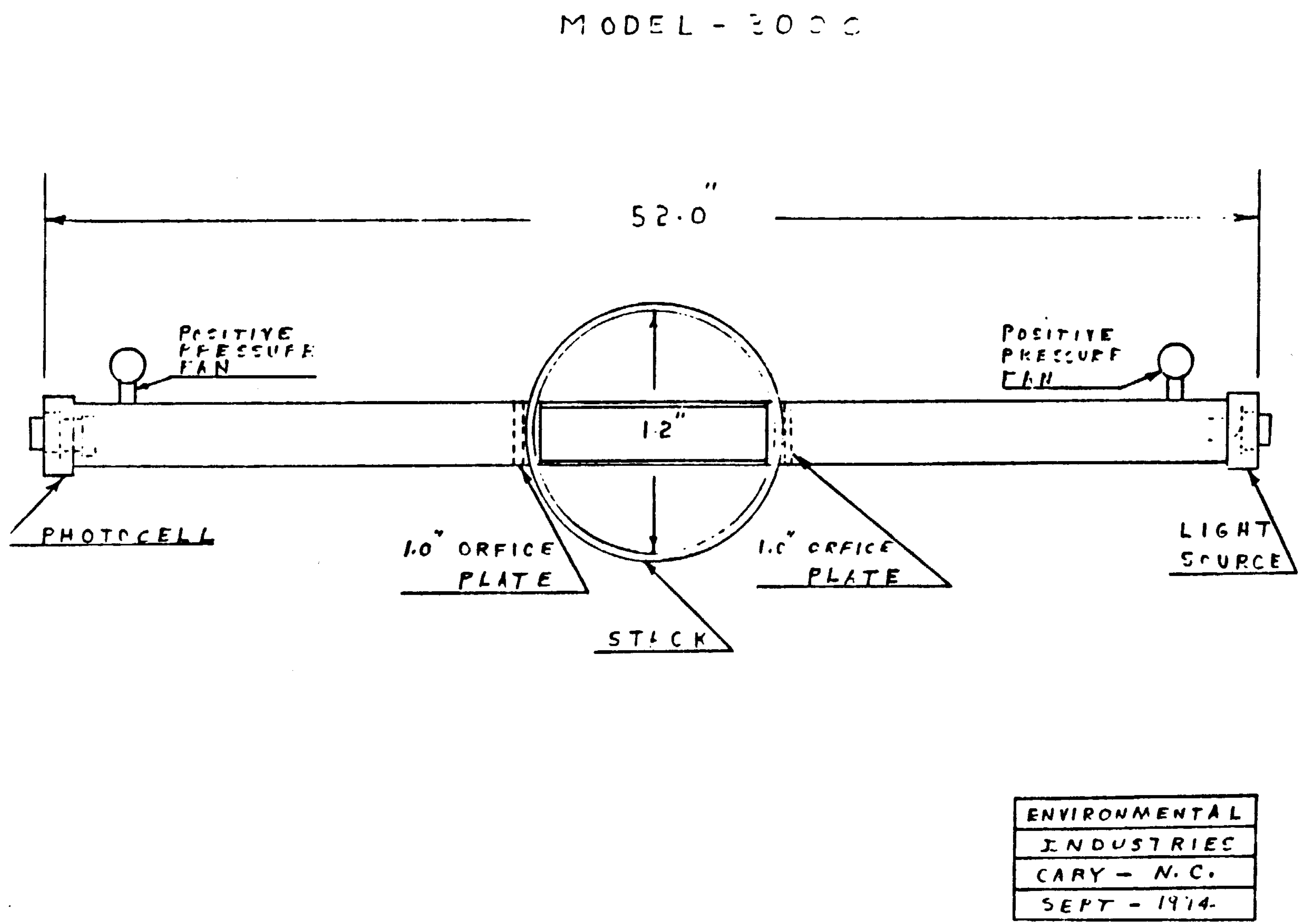


Figure E-3. Transmissometer

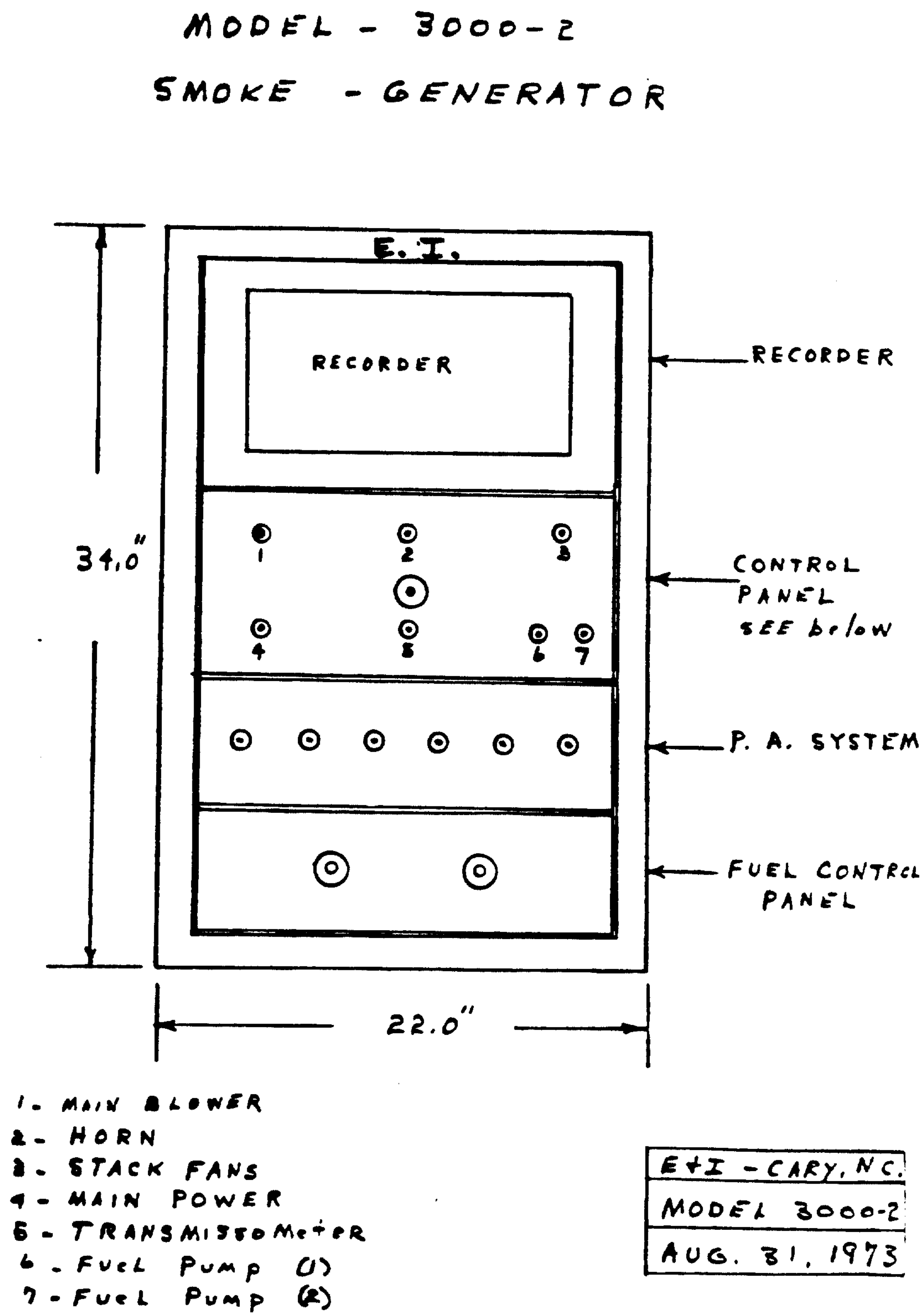


Figure E-4. Control Console

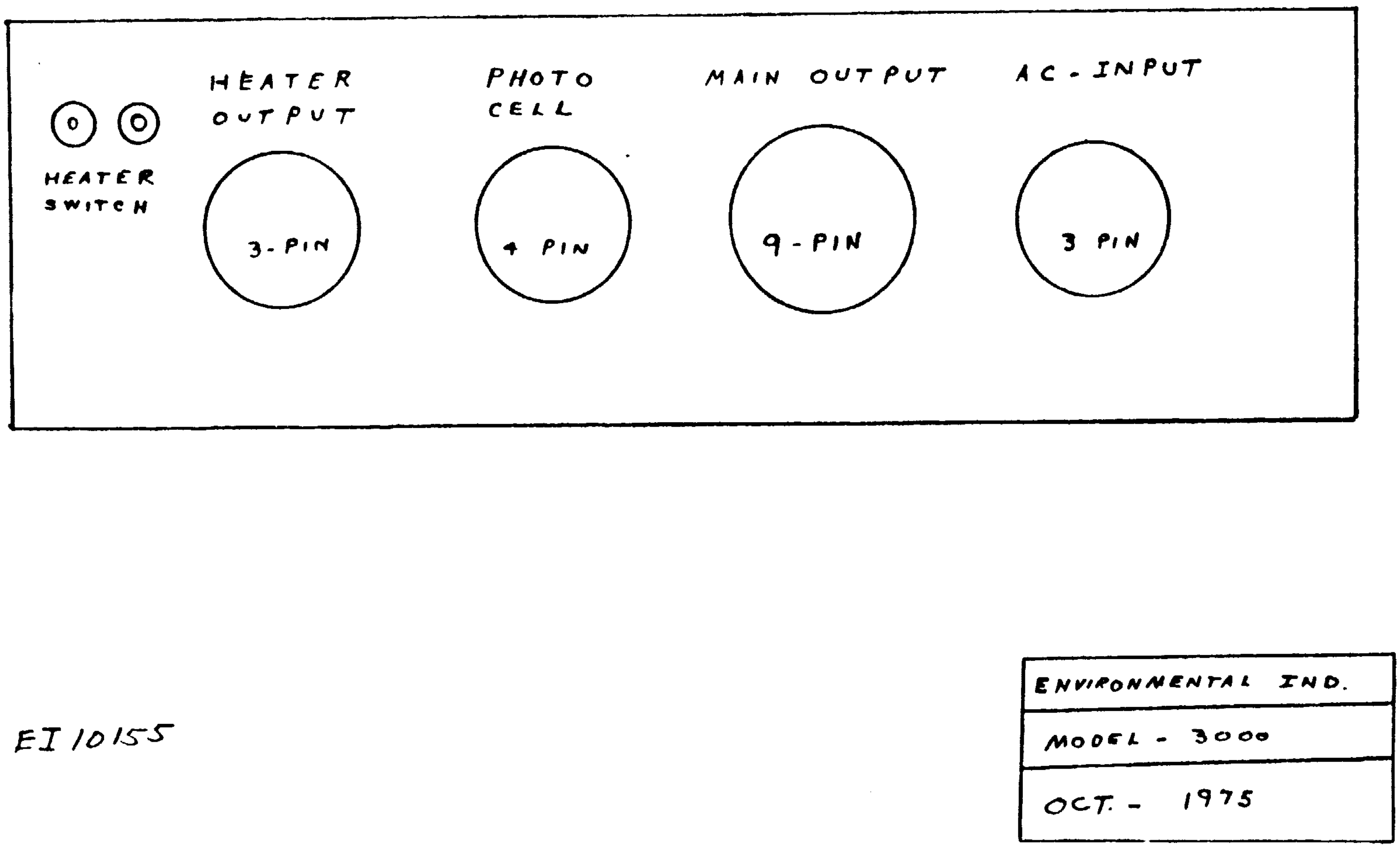
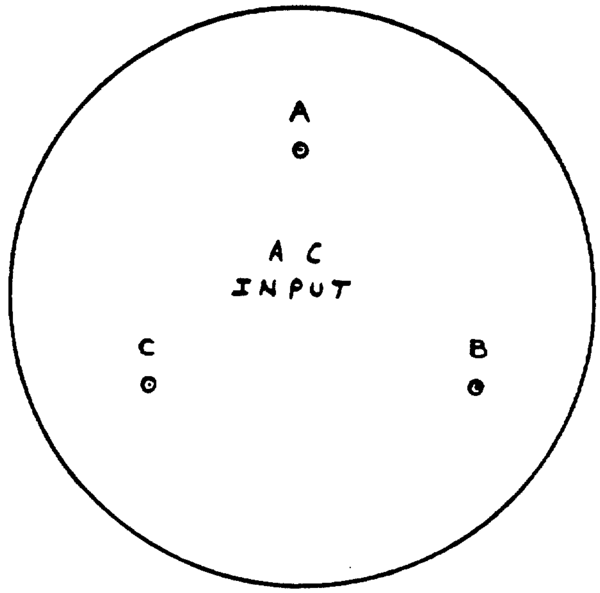


Figure E-5. Console Rear Connector Panel

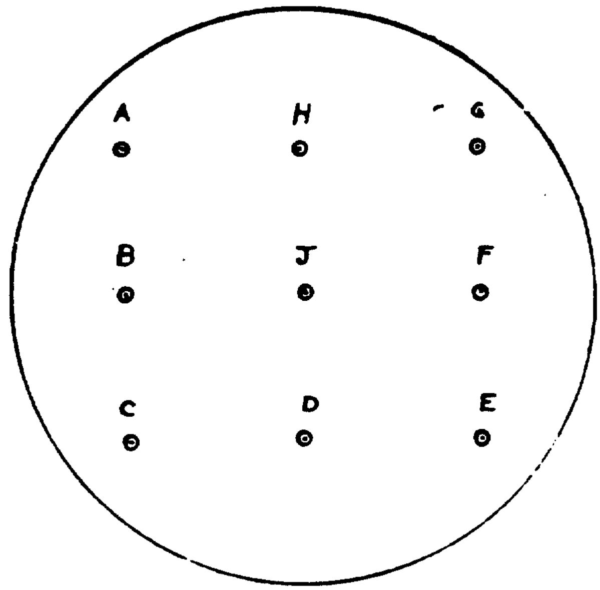


PIN #	WIRE COLOR	VOLTAGE
A	RED	117 VAC (-)
B	BLACK	117 VAC (+)
C	GREEN	EARTH·GROUND

SERIAL #
EI 1055

ENVIRONMENTAL IND
MODEL - 3000
OCT. - 1975

Figure E-6. Console Connector, Three Pin



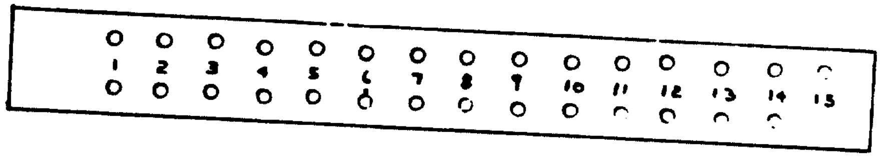
PIN #	SYSTEM	WIRE COLOR	VOLTAGE
A	HORN	GREEN	12V DC (-)
B	STACK FANS	BLACK	117 VAC (+)
C	MAIN BLOWER	RED	117 VAC (-)
D	MAIN BLOWER	BLACK	117 VAC (+)
E	SYSTEM GROUND	GREEN	EARTH GROUND
F	HORN	BLUE	12 VAC (+)
G	FUEL PUMP	BLACK	12 VDC (+)
H	FUEL PUMP	BLACK	12 VDC (+)
J	FUEL PUMP	BLUE	12 VDC (-)

EI 10155

ENVIRONMENTAL IND
MODEL 3000
OCT - 1975

Figure E-7. Console Connector, Nine Pin

EI 10155
MODEL 3000



PIN #	SYSTEM	WIRE COLOR	VOLTAGE
1	PHOTOCELL OUTPUT	BLACK	DC VARIABLE (+)
2	PHOTOCELL OUTPUT	CLEAR	DC VARIABLE (-)
3	LIGHT SOURCE	Black	DC 12.5 V (+)
4	LIGHT SOURCE	White	DC 12.5 V (-)
5	FUEL PUMP	Blue	DC 12.0V (+)
6	FUEL PUMP	WHITE	DC 12.0 V (+)
7	Fuel Pump	Green	AC 12.0 V (-)
8	HORN	BLUE	AC 12.0 V (+)
9	HORN	GREEN	AC 12.0 V (-)
10	BLANK		
11	STACK FANS	RED	AC 117 V (+)
12	STACK FANS	GREEN	AC 117 V (-)
13	MAIN BLOWER	BLACK	AC 117 V (+)
14	MAIN BLOWER	RED	AC 117 V (-)
15	EARTH GROUND	Green	Ground

Figure E-8. Main Junction Box, Trailer-Mounted Terminal Strip

References for Appendix E

1. Lee, William S. "Operator's Manual, Model 3000 Smoke Generator." Environmental Industries Air Monitoring Systems, Cary, N.C. 27511, 1976

APPENDIX F

SMOKE GENERATOR TESTING PROCEDURES

APPENDIX F

SMOKE GENERATOR TESTING PROCEDURES

1.0 LIGHT SOURCE

1. Turn light source on.
2. Using a digital voltmeter, check the lamp voltage at the test points on the rear of the console.
3. Compare the voltage reading obtained with the manufacturer's recommended operating voltage.
4. If the voltage is not within 5 percent, corrective action is required.
5. Record operating voltage on the smoke generator performance data sheet (Figure F-1).

2.0 SPECTRAL RESPONSE

Using the manufacturer's data, verify the photocell's photopic response (400-700 nanometers), or check it with Kodak band pass filters.

3.0 ANGLE OF VIEW OF SMOKEPLUME

1. Remove the source and aperture apparatus from the transmissometer.
2. Set up the apparatus on a flat, horizontal surface making sure that the distance between the light source and aperture is the same as it is in the transmissometer.
3. Turn light source on.
4. Focus the light on a bare surface at a known distance from the aperture (L) and record distance on the performance data sheet.
5. Measure the diameter of the light projected on the bare surface (d) and record distance on the performance data sheet.
6. Using the equation:

   $$\theta = 2 \tan^{-1} \frac{d}{2L}$$

   calculate the angle of view and record the distance on the performance data sheet.

Generator Number________________ Operator__________

Manufacturer________________ Owner__________

____

Light source lamp voltage______________volts.

____

Angle of View $0 = 2 \tan^{-1} d/2L$

L = ________

d = ________

0 = ________

____

Zero drift____________________% Chart

Span drift____________________% Chart

Calibration Error

20%	50%	75%
______% Chart	______% Chart	______% Chart
______% Chart	______% Chart	______% Chart
______% Chart	______% Chart	______% Chart
______% Chart	______% Chart	______% Chart
______% Chart	______% Chart	______% Chart

____

Rise time__________ Fall time______

____

List any corrective action required______

____

____

____

____

____

Tested by____________ Date______

Verified by____________ Date______

Figure F-1. Smoke Generator Performance Evaluation Data Sheet

4.0 ZERO AND SPAN DRIFT

1. Warm up the smoke generator for a minimum of 30 minutes.
2. Place light switch in the off position.
3. Adjust the recorder to read 100 percent chart scale.
4. Place the light in the on position.
5. Adjust the recorder to read 0 percent chart scale.
6. Repeat steps 2 to 5 until a stable response is obtained at 100 and 0 percent recorder chart scale.
7. Perform the calibration error test.
8. At the end of the calibration error test, repeat steps 2 to 5.
9. Record the difference in chart scale for the zero and span on the smoke generator performance data sheet.

5.0 CALIBRATION ERROR

1. After step 6 of the zero and span drift test, place a 20 percent opacity neutral-density filter in the light path of the transmissometer.
2. Record the percent recorder chart scale response.
3. Repeat steps 1 and 2 for neutral density filters of 50 and 75 opacities.
4. Repeat steps 1 to 3 five times for each filter.
5. If any one reading is greater than 3 percent recorder chart scale from the stated value, corrective action is required.

6.0 RESPONSE TIME

1. After a zero setting is obtained, introduce a span into smoke generator.
2. Using a stopwatch, measure the time the recorder takes to reach 100 percent chart scale.
3. Record the rise time on the performance data sheet.
4. Place the smoke generator transmissometer in the zero position.

5. Using a stopwatch, measure the time the recorder takes to reach 0 percent chart scale.
6. Record the fall time on the performance data sheet.
7. If the response time for either test is more than 5 seconds, corrective action is required.

References for Appendix F

1. Rose, Thomas H. Unpublished draft procedures for Region IV VE Programs, 1978

APPENDIX G

QUALITY ASSURANCE TECHNIQUE FOR CERTIFICATION TESTING

APPENDIX G

QUALITY ASSURANCE TECHNIQUE FOR CERTIFICATION TESTING

A strip chart recorder should be purchased and installed if one is not already in operation. The technique described below has been developed by the VE training schools in Region IV and ensures that valid emissions occur for every reading:

1. All zero, span, midrange linearity, and calibration filter readings are recorded on the strip chart, which then serves as a permanent record that these tests were performed and that the Method 9 criteria were achieved for each individual training school.

2. During each test, the chart is permitted to run continuously, but the pen is only activated during the short time intervals when observations are being made by the inspectors.

3. The observation period for each emission is about two seconds, and the beginning and the end of each observation period are signalled by the operator. For example, reading number 7 would be announced "number 7 ... (2 second delay) ... mark!" The observers therefore have two seconds to estimate the opacity of each reading, but more importantly, the instructor has two seconds to determine whether the emission is "valid." If the readings is not valid, the instructor announces "number 7 ... (2 second delay) ... scratch!" and the observers do not make any record on their forms--readings are only recorded when the instructor announces "mark!" The instructor can decide that the readings is invalid for any one of several reasons, for example:

   a. A sudden shift in wind direction.

   b. The plume becomes doubled over.

   c. The opacity is not constant over the two-second observation period. Region IV has developed two criteria for determining whether the opacity is "constant" (refer to Figure 3-10):

      i. The average opacity during the two seconds is within 1.5 percent opacity of the announced opacity.

ii. The variation of the trace does not exceed 1.0 percent opacity from its average position at any time during the two seconds.

A chart recorder of suitable quality costs a minimum of about $1,000, but the subsequent improvements in certification procedures compensate for this. The ability of the instructor to declare readings invalid ensures that observers only take readings under optimum conditions. They can thus qualify more quickly, which means a net savings in labor costs to the agency conducting the training program. In addition, the values reported by the instructor can be validated if the accuracy of the smoke school is questioned.

References for Appendix G

1. Rose, Thomas H. Unpublished draft procedures for Region IV VE Programs, 1978

TECHNICAL REPORT DATA
(Please read Instructions on the reverse before completing)

1. REPORT NO.	2.	3. RECIPIENT'S ACCESSION NO.

4. TITLE AND SUBTITLE	5. REPORT DATE
Visible Emissions Program Operations Manual	February 1979
	6. PERFORMING ORGANIZATION CODE
7. AUTHOR(S)	8. PERFORMING ORGANIZATION REPORT NO.
Victoria Scott	PES275
9. PERFORMING ORGANIZATION NAME AND ADDRESS	10. PROGRAM ELEMENT NO.
Pacific Environmental Services 1930 14th Street Santa Monica, CA 90404	11. CONTRACT/GRANT NO. 68-01-4140 Task No. 32
12. SPONSORING AGENCY NAME AND ADDRESS	13. TYPE OF REPORT AND PERIOD COVERED
U.S. Environmental Protection Agency Region IV Air Surveillance Branch Surveillance and Analysis Division Athens, Georgia 30601	Final 14. SPONSORING AGENCY CODE

15. SUPPLEMENTARY NOTES

16. ABSTRACT

This document contains a set of guidelines for use by officials who are responsible for conducting schools to train inspectors to evaluate the opacity of emissions from stationary sources. The manual specifically addresses the requirements of EPA Method 9 (40CFR, Part 60, Appendix A) as revised on November 12, 1974. For the lecture phase of the training course, suggestions are given for the content of each of six lectures and a sample course agenda is presented. Procedures are given for setup, calibration, shutdown and maintenance of the smoke generator as well as directions for using the generator in training and certification classes. Certification criteria and confidence limits are also discussed.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group
Opacity Visible Emissions Method 9 Transmissometers Smoke Generators Smoke Meters	visible emissions training courses	

18. DISTRIBUTION STATEMENT	19. SECURITY CLASS *(This Report)*	21. NO. OF PAGES
Release Unlimited	Unclassified	75
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	Unclassified	

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