DOCUMENT RESUME

ED 187 556 SE 030 942

TITLE	Visible Emissions Evaluation. APTI Course 439. Final [Edition].
INSTITUTION	Environmental Protection Agency, Research Triangle Park, N.C. Air Pollution Training Inst.
SPONS AGENCY	Environmental Protection Agency, Research Triangle Park, N.C. Control Programs Development Div.
REPORT NO	EPA-450/3-78-105
PUB DATE	Sep 78
CONTRACT	68-02-2374
NOTE	177p.; Not available in paper copy due to marginal legibility of original document.
AVAILABLE FROM	National Technical Information Service, 5285 Port Royal Road, Springfield, VA 22161 (no price quoted).
EDRS PRICE	MF01 Plus Postage. PC Not Available from EDRS.
DESCRIPTORS	*Air Pollution; Chemical Analysis; Environment; Environmental Education; *Environmental Influences; *Evaluation Methods; Instructional Materials; Meteorology; Pollution; *Postsecondary Education; Science Education; Teaching Guides; *Technical Education
IDENTIFIERS	*Analytical Techniques; *Smoke; Smoke Generators

ABSTRACT

This manual has two parts: (1) Instructor Manual, and (2) Operator Manual. The Instructor Manual aids instructors who conduct visible emissions training for the new smoke reader trainee and for the smoke reader seeking recertification. It describes the appropriate sequence of lessons for the course, discusses necessary equipment and instrumentation, and calibration and positioning. Testing and evaluation methods for student performance are included. Example lesson plans are provided for 15 lessons. The Operator Manual describes the components, principles, and procedures that are directly applicable to a typical generator. (Author/RE)

United States
Environmental Protection
Agency

Air Pollution Training Institute
MD 20
Environmental Research Center
Research Triangle Park NC 27711

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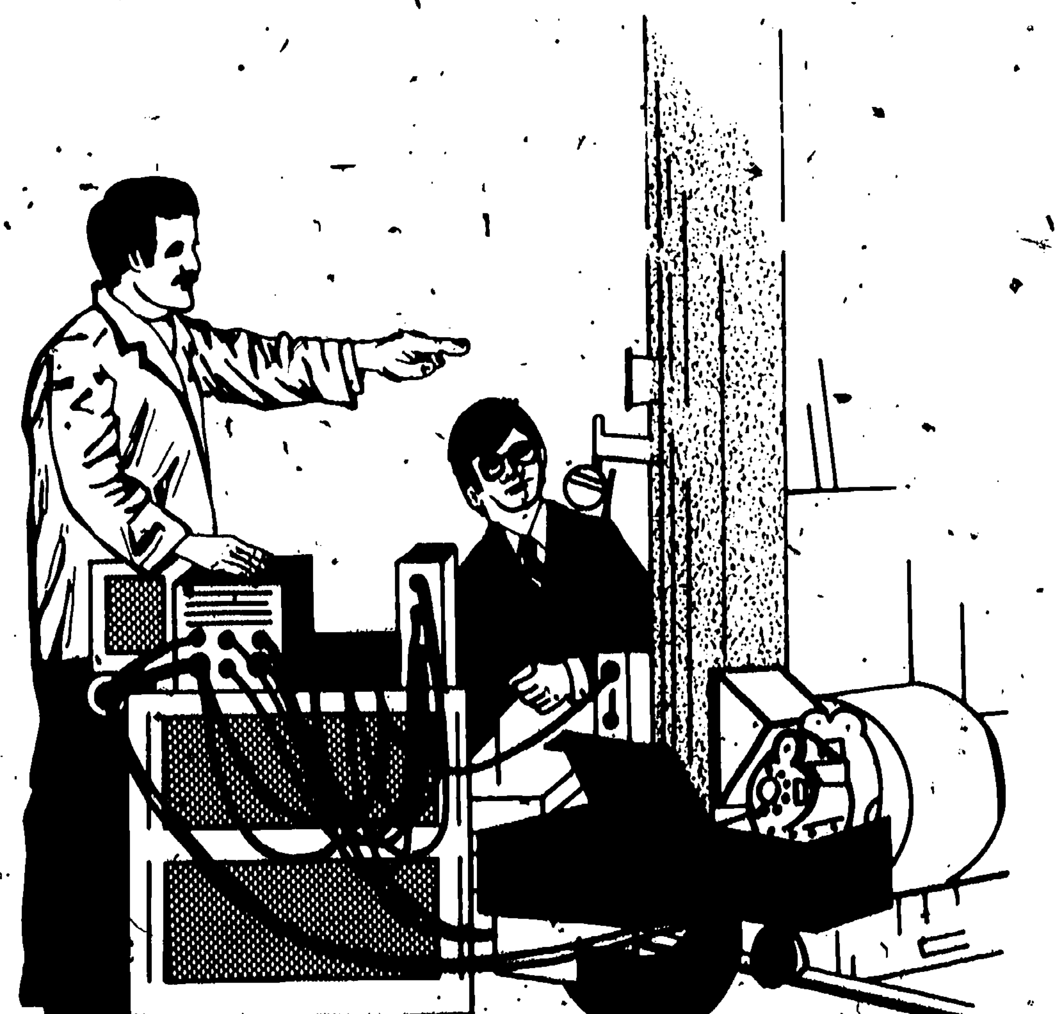
Air

EPA

APTI Course 439 Visible Emissions Evaluation

Final

Instructor Manual



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APTI Course 439 Visible Emissions Evaluation

United States Environmental Protection Agency
Office of Air, Noise, and Radiation
Office of Air Quality Planning and Standards
Research Triangle Park, NC 27711

US/EPA

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EPA

AIR POLLUTION TRAINING INSTITUTE
MANPOWER AND TECHNICAL INFORMATION BRANCH
CONTROL PROGRAMS DEVELOPMENT DIVISION
OFFICE OF AIR QUALITY PLANNING AND STANDARDS

The Air Pollution Training Institute (1) conducts training for personnel working on the development and improvement of state, and local governmental, and EPA air pollution control programs, as well as for personnel in industry and academic institutions; (2) provides consultation and other training assistance to governmental agencies, educational institutions, industrial organizations, and others engaged in air pollution training activities; and (3) promotes the development and improvement of air pollution training programs in educational institutions and state, regional, and local governmental air pollution control agencies. Much of the program is now conducted by an on-site contractor, Northrop Services, Inc.

One of the principal mechanisms utilized to meet the Institute's goals is the intensive short term technical training course. A full-time professional staff is responsible for the design, development, and presentation of these courses. In addition, the services of scientists, engineers, and specialists from other EPA programs, governmental agencies, industries, and universities are used to augment and reinforce the Institute staff in the development and presentation of technical material.

Individual course objectives and desired learning outcomes are delineated to meet specific program needs through training. Subject matter areas covered include air pollution source studies, atmospheric dispersion, and air quality management. These courses are presented in the Institute's resident classrooms and laboratories and at various field locations.

Robert G. Wilder
Program Manager
Northrop Services, Inc.

Jean J. Schueneman
Chief, Manpower & Technical
Information Branch

FOREWORD

The Federal government has discontinued the use of Ringlemann Number in Federal new source performance standards and based the determination of the optical density, or opacity of visible emissions from stationary sources, solely on opacity. Many State regulations have not made this change and continue to operate under a dual system in which the Ringlemann Number is used in the evaluation of black or gray emissions and Equivalent Opacity is used in the evaluation of all other visible emissions.

This manual is designed to serve as wide an audience as possible and so continues to refer to both the Ringlemann Number and the Equivalent Opacity methods of evaluation. If Opacity is now the only type of visible emission regulation in your State, please make the proper adjustments in the manual curriculum to reflect this regulation. If Ringlemann and Equivalent Opacity are currently viable in your State, your trainees should at least be aware of the Federal regulation. A copy of the current Method 9 as published in the Federal Register is included in the last pages of the Student Manual for this course.

Battelle-Columbus Laboratories is credited for most of the material in this manual. Under contract with EPA, they prepared a training package. Because much time has elapsed since completion of their contract and due to many changes in regulations and techniques, EPA has found it appropriate to modify the training package prepared by Battelle.

Course directors should conduct their training activities in accordance with the appropriate parts of "Guidelines for Development of a Quality Assurance Program: Volume IX - Visual Determination of Opacity Emissions from Stationary Sources," EPA-650/4-74-0051, USEPA, Washington, D. C., November 1975.

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CONTENTS

APPENDIX

PART 1 INSTRUCTOR MANUAL

INTRODUCTION AND PURPOSE

This Instructor Manual has been prepared to aid instructors charged with conducting a visible emissions training and testing program for the new smoke reader and for the smoke reader that needs to be recertified. The aim of this program is to train air pollution inspectors in the skill of measuring the shade of visible emissions by eye. For the new smoke reader, this program will require an initial course of three days' duration. These three days include one and one-half days of classroom instruction followed by field sessions devoted to letting the student practice the determination of correct shades of black and white smoke produced by a smoke-generating device. The criterion against which the student is graded is a measurement made by an optical system in the generator's smoke stack. The outdoor sessions are conducted in a fashion so that the student is repeatedly tested on his ability to correctly measure the shade of the smoke. When he has achieved a skill which meets the specified requirements, he is qualified as a smoke reader. It is expected that with each repeated trial the student will be perfecting his skill until he can pass the test. The number of repetitions allowed the student in his effort at passing is up to the instructor. It has been found in past courses that two-thirds of the students can usually meet the standard after eight series of 25 black and 25 white shades. After additional trials a higher percentage of the students can be expected to qualify.

For the previously certified smoke reader that needs to be recertified, the program is set up so he can enter the course on the second day, at noon. According to EPA Method 9, the inspector will requalify every 6 months or more frequently if a particular agency so desires. During the morning of the second day, the requalification classroom sessions can be devoted to review of one of the topics introduced in the inspector's initial training. It is not imperative that the inspector attend all of these morning sessions on the second day in order to be recertified but he should at least try to attend the sessions on the emission generator just prior to the session on reading visible emissions. Following this, the inspector will have at least a day and a half outside to requalify. There should also be a period during which the inspectors can discuss with the instructors, the agency heads, and each other the problems that have come up in their enforcement duties or to be briefed about any special topics such as regulation changes or agency policies.

The Instructor Manual, the Instructor Lesson Plans, and the visual aids in the Student Manual constitute a training package that an agency can use to give the Evaluation of Visible Emissions Course. The only other requirements are a smoke generator, a classroom, and visual aid equipment. However, one or more of the members of the instructional staff should have taken a course similar to this one and be qualified as smoke inspectors.

With repeated sessions the instructor will become more familiar with the material presented here and should take upon himself the task of adapting and improving the course content and the course preparation with the aim of better training his own staff in the duties that are unique to the locality where they work. He will emphasize the sources and types of emissions found in his state or locality and disregard the other types that are not found there. He will gather information and visual aids that are applicable to these local sources. He will go into detail about the regulations of his city, county, or State. He will obtain as guest instructors local experts in the topics covered in the course.

It has been found in presentation of the 3-day course that more lecture outlines are provided in this manual than can be covered in a day and a half of lectures. The extra lecture outlines therefore allow the course director the option of cutting out portions of lectures or entire lectures to better tailor the course to the needs of his agency. For instance, if no coal is burned in your area, the Coal Combustion lecture can be dropped. However, if the sample agenda shown in the appendix is followed, all except one of the lecture outlines will be utilized. The quizzes and course examination (see Appendix) are based on the assumption that all lectures are presented. If all lectures are not presented in a given course, examination questions relating to the omitted material should not be counted in grading the exams.

Quizzes or less important lectures can be eliminated from the agenda during the presentation of the course if it is found that some topics have run longer than anticpated. The extra material can be held in reserve by the instructor for presentation in case bad weather prevents the outdoors portion of the class from proceeding as scheduled.

COURSE OBJECTIVES

This manual is intended for use by instructors to teach students that have not been certified as a qualified observer. The contents of this manual will help the instructor to provide the qualified observer with adequate background knowledge needed to help substantiate any violation that he may record.

At the conclusion of this course the student should be able to:

1. Visually measure (i.e., without the use of devices) the shade or opacity of visible air pollution emissions for a set of 25 shades of white smoke and 25 shades of black smoke:
   a) With an average error not to exceed 7.5 percent opacity in each category;
   b) With an error not to exceed 15 percent opacity (or 3/4 of Ringelmann Number) on any one reading in each category.
2. Define Ringelmann Number and Equivalent Opacity in the following manner:
   a) The Ringelmann Number gives shades of gray by which the density of columns of smoke rising from some source may be compared. It is a system whereby graduated shades of gray, varying by five equal steps between white and black, may be accurately reproduced by means of a rectangular grill or by black lines of definite width and spacing on a white background.
   b) Equivalent Opacity is an extension of the Ringelmann Chart method of quantifying visible emissions. The opacity or degree to which a non-black or gray plume obscures an observer's view is related to the extent to which a black or gray plume of a particular Ringelmann Number obscures an observer's view. For example a Ringelmann Number 2 plume is equivalent to a plume having 40 percent opacity. The U. S. EPA Federal regulations for visible emissions standards consider only the use of opacity and does not link opacity standards with Ringelmann.
3. List the following essential conditions for correctly evaluating the plume:
   a) Keep the sun in the 140° sector at your back.
   b) Try to have a contrasting background.

c) Readings should be taken at approximately right angles to the plume direction and at any distance to obtain a clear view of the emissions.

d) Readings should be made through the most dense part of the plume and in that portion of the plume where condensed water vapor is not present.

e) When observing emissions from rectangular outlets, readings should be at approximately a right angle to the longer axis of the outlet.

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

4. List the following essential items to be recorded on the training form:

a) Name
b) Date
c) Time
d) Wind speed
e) Wind direction
f) Sky condition

and properly fill out these items for his field recording form.

5. List at least four of the following techniques (even though not generally in use) for measuring visible emission without the aid of references:

a) Smoke Guide
b) Umbrascope
c) Photo-electric cell
d) Smokescope
e) Smoke tintometer

6. Differentiate between the plumes emitted from combustion processes and industrial processes.

7. Identify condensed water vapor plumes and break-point.

8. Make application of his knowledge of meteorology in the following manner:

a) Estimate wind speeds from 0 - 18 mph using the Beaufort Scale;
b) Define wind direction and estimate wind direction;
c) Estimate sky condition (percentage of cloud cover);
d) List the distinguishing characteristics of high and low pressure areas;
e) Identify on a weather map the symbols for the following: high pressure area, low pressure area, cold front, warm front, occluded front, stationary front;
f) List at least two points of information obtained from a weather map which the smoke inspector could find useful in planning his activities.

9. Testify in court as an effective expert witness concerning visible emission observations. To demonstrate his capability he should be able to:
   a) Identify 8 of the 10 criteria for being an expert witness;
   b) List 5 of the 8 rules for behavior on the witness stand;
   c) Cite the legal precedents set in the California appeal cases concerning visible emission regulations.
10. State the essential elements of his local or state visible emission code.
11. List the primary components of the emission generator:
   a) Combustion chamber for generating black smoke;
   b) Generator's exhaust manifold for white smoke;
   c) Transmissometer;
   d) Auxiliary blower;
   e) Recorder or indicator.

REQUIRED FACILITIES AND EQUIPMENT

The chief requirement for the presentation of this training course is a device for the production and measurement of shades of black and white smoke. An instrument for this purpose can be constructed by the air pollution control agency staff or its contractors or, as is generally done, it can be purchased. As of November 1977, Environmental Industries, P. O. Box 441, Cary, N. C. 27511 (Tel 919-467-1500) is the only known manufacturer of smoke generators.

Suggestions for locating the smoke generator are given in Part II section of this manual. Its site should not be too far from the classroom where the indoor portion of the course will be presented unless arrangements for transportation are provided. A building near the generator site should be available in case a change in weather drives the students and instructor inside.

The size of the required classroom will be determined by the size of the expected class. The classroom should be capable of being darkened for the showing of movies and slides. It should have electric outlets which are convenient for attaching the cords from the various projectors or extension cords that will reach from an outlet to the projector.

Equipment for the room should include a screen on which to project the movies and slides, auxiliary tables for supporting the projectors, a blackboard including chalk and eraser, and a lectern or table on which the instructor can place his notes and demonstration materials. There should be another table at the rear of the room or in an adjacent room for the instructors to use in storing materials, grading examinations, etc.

The visual aids suggested for this course include motion pictures and 35 mm (2" x 2") transparent slides. The longest movie ("The Role of the Witness") that is suggested for possible presentation requires a 1600 foot take-up reel, which may take a special effort to obtain. Other movies suggested as alternatives or supplements to lectures can be run on the reel normally furnished with projectors. A list of suppliers for materials is provided in the Appendix.

In place of the prescribed fuel oil lectures, the agency can request a prepared film strip entitled "Combustion Testing." (See lesson plan #4 and the list of sources of course materials in the Appendix.) For presentation this requires a tape recorder which will play at 3-3/4 inches per second and a film strip projector.

CLASSROOM EQUIPMENT

- Desks or chairs and tables for the students
- Lectern or table for the speaker
- Table for the instructors at rear of the classroom
- One or two tables (preferably on wheels) for holding the projection equipment
- Blackboard, chalk, and eraser
- Extension cord
- Screen for showing slides and movies
- 16 mm movie projector with tape-up reel to hold 1600 feet of film and normal size
- 35 mm (2" x 2") slide projector (e.g., carousel projector), preferably with a cord for remote operation.
- Overhead (vu-graph) projector for showing large transparent figures (optional)
- Pointer
- Tape Recorder--3-3/4 inches per second--and film strip projector (optional, depending upon Combustion of Fuel Oil lecture)
- Ringelmann Chart (Available from the U. S. Bureau of Mines)
- Recommended, but not essential: USPHS Smoke Guide Umbrascope, Smokescope, Smoke tintometer, Microringelmann Charts

INSTRUCTIONAL FACULTY REQUIREMENTS

To present the full course it is recommended that at least three speakers be used. For a requalification course one instructor may be capable of handling the classroom portion. If the two courses are presented concurrently, all three instructors would lecture to the new students on the first day; then on the morning of the second day, two would stay with the new students. The third instructor would conduct the classroom portion of the review training for the inspectors who were going to take their requalifying test. In the afternoon both groups would go outside for familiarization and testing runs with the smoke generator.

Thus, a group of three instructors who can each give several lectures is the desirable staff for the continuing training and requalifying of inspectors as smoke readers, although two people could possibly get by with some detriment to course quality. To make the course more interesting and give it variety, the person in charge could arrange to have guest lecturers speak on selected topics in the course. He can give these guests the material in the Student Manual and in the Instructor Lesson Plans as guides to what they should cover, but tell them to expand on any topic which is likely to be of particular interest to the students.

Potential candidates for guest lecturers are attorneys who are with the Prosecutor's Office or who have a special interest in air pollution, representatives of fuel oil or coal distributors, engineers or managers from local industrial firms, and staff members of the local National Weather Service Station. The representatives from industry or fuel distributors will probably not be in complete agreement with the aims and policies of the air pollution agency with respect to the visible emissions regulations. However, it has been found in past courses that controversial speakers are often more interesting. At any rate, all of these speakers--lawyers, fuel distributors, industry representatives, and meteorologists--have information and experience which is beneficial to the student-inspector. Encourage questions from the class for all speakers. The exchange helps both the student and the lecturer.

Always thank the guest lecturer and give him a round of applause. At the completion of the course send him a thank you note. Traveling expenses or an honorarium are topics that should be discussed with the guest when you first approach him. Some industrial and governmental representatives will decline and charge off expenses to public relations.

The agency instructional staff should have several talents. Someone should be able to operate (and repair if necessary) the projection equipment, especially the movie projector. Someone must know how to operate and maintain the smoke generator. It has been found in the past that a man familiar with electrical equipment and the checking of electrical circuits is invaluable.

PRECOURSE PLANNING

You should make your plans for presentation of the course at least a month before the date of the course. The local preparations will include:

- Scheduling classroom facilities
- Arranging for visual aid equipment
- Obtaining guest lecturers
- Giving staff and guest lecturers copies of the instructional guides and visual aids they will need in preparing their lectures
- Sending out announcements to the prospective students
- Checking over the smoke generator for proper operation.

It is assumed that prior to this final month of preparation you have on hand or have made arrangements for:

a) A smoke generator
b) Instructional materials, manuals, visual aids, etc., for use by students and instructors.

COURSE LENGTHS

The new inspector or the inspector qualifying as a smoke reader for the first time should be given the full lecture and field course lasting at least three days--one and a half days of classroom lectures and one and a half days of familiarization and qualification runs. The lecture portion of the course should be reduced to one-half day for inspectors who are requalifying.

One and a half days of familiarization and qualifying runs is a minimum figure. To ensure that a high percentage of the students become trained well enough to meet the smoke reader requirements, another one-half to one day may be added to the field portion of the course. After a full day of trying to qualify, the student becomes fatigued and tense. He will probably do better after a night's rest. This additional time also allows for bad weather or for smoke generator malfunction.

A full schedule of one and one-half days of classroom lectures has been given for the suggested course agenda in this manual. This full schedule gives an over supply of material. Thus, some may be eliminated or the extra material may be presented when inclement weather keeps the class inside during the time they are scheduled for outside work.

For the inspectors who are requalifying at three-month to one-year intervals (usually six months, in accordance with EPA Method 9), the course director can plan for their requalification to coincide with the second and third days of a course for new inspectors. On their first morning the requalifiers should be given a refresher course on one topic from the first course. There should also be an open discussion among the inspectors and instructor for 30 minutes to an hour dealing with the inspector's experiences, problems, or complaints.

The refresher or review topics can be rotated among the following portions of the full course:

a) Combustion of coal and oil;
b) Other combustion and non-combustion sources of visible plumes;
c) Legal aspects of air pollution and local regulations;
d) Meteorology.

In presenting these review topics the instructor should try to cover more of the subject than he did in his lecture for the initial course.

CONDUCT OF A THREE-DAY COURSE

CLASSROOM LECTURE

Instructor Lesson Plans

The principal guide to presenting each lecture is the Instructor Lesson Plan (ILP). The ILP's are included in the Appendix of this Manual. With the exception of the first ILP, "Registration and Opening Remarks," all of these guides are based on sections of Part I in the Student's Manual. After studying the Student's Manual, the instructor should be able to use the ILP as a guide for lectures. The 35 mm slides to be used in a lecture are listed in the right-hand column of the ILP in the position where these are to be used. Comments are included for selected slides. If the instructor wants to obtain more information than is given in Part I of the Student's Manual, he can refer to the reading list at the end of each Key Point section in Part I.

The instructor should not feel that he must follow the Introduction, Outline, and Conclusions as given in the ILP. However, whether he does or not, he should keep in mind the lecture objectives and the examination questions when he decides what topics to cover.

Final Preparations

The course director should make last-day checks of the classroom to see that all the manuals, handouts, and other course materials are ready. He may put them on the students' desks the day before the course or distribute them the first thing in the morning.

The director should check to see that he has adequate seating facilities for his expected class and that the room can be darkened for showing movies or slides. He should be familiar with the operation of all light switches that he may need.

All the equipment for showing movies, 35 mm slides, and vu-graph transparencies should be in the classroom and preferably mounted on tables or rolling carts so time will not be taken setting up this equipment during the course. Plug in this equipment ahead of time to discover if the cords will reach to the nearest socket or whether extension cords will be needed.

If microphones are going to be used, they should be checked out before the course. In a classroom situation there is sometimes a tendency for the teacher, if he has a portable microphone, to get in front of the loud speaker causing feedback. The loud speaker should be placed in a position to avoid this.

For some of the lectures a blackboard is necessary. A single portable blackboard, 4 to 5 feet long, should be adequate. Provide chalk and an eraser. Lecture pads can be substituted in small classes.

A copy of the Smoke School Training Form is provided in the Appendix of this manual. This can be removed for duplication if the instructor desires to make overhead transparencies (vu-graph) or have multiple copies printed for use in the course.

Course Opening

Always open the course by welcoming the students, telling them your own name and the name of the course. You can introduce the other instructors at this time, or when they lecture, or both.

For your own records you should have a list of the students attending the course, their affiliations, and their addresses. You should type up a student name and address list in alphabetical order and distribute it before the end of the course. You can use this list for mailing out certificates, maintaining a record of which of your inspectors are due for requalification, etc.

You should arrange to have a short 15 or 20 minute break every morning and afternoon and have coffee available. A short "stretch in place" at hourly intervals is also desirable.

In your opening remarks or at the end of the morning session, suggest to the students a few convenient places for eating lunch. Some agencies try to arrange for the students and instructors to eat lunch (and sometimes supper) together. This is commendable for it adds to the informality of the course and gives the students more time to acquire new information from instructors or other students.

Official Welcome and Course Objectives

If the head of your agency wants to give a few remarks and welcome the students, you can allot several minutes of your course opening to him.

At some point in your course opening, before you launch into the lectures, you should go over with the class the course objectives listed earlier in this Manual.

Time Schedule

Try to keep the course going on its proper time schedule. Some discussion is encouraged, but the students who are not directly involved may be quite bored if the questions and comments continue too long after the lecture. Their favorite topic may be the next one on the agenda.

The instructor may also find himself engaged in conversation at the end of a "break" period when he is due to give the next lecture. Here it is helpful to have two instructors so that the other one can interrupt the conversation to get the course going again.

Guest lecturers (and also staff lecturers) sometimes talk longer than their assigned time. The speaker should be notified prior to lecturing that he should adhere to the assigned lecture time. Without embarrassing him, a gesture should be made that he has gone beyond his assigned time.

The staff instructor should make an effort to rehearse his lecture and check the time. He can identify portions that can be left out if he is running too long.

The material for both the Combustion of Coal and the Noncombustion Emissions lectures is more than sufficient to use up the allotted time. The lecturers in these two topics should cover only the portions that they believe are most pertinent. Some subtopics, such as water vapor and wet plumes, are covered in more than one lecture. The course director can eliminate this duplication if he wants to cut down on the course time. The Basic Meteorology and the Meteorological Factors in Smoke Reading lectures can be combined into a 40-45 minute lecture.

Films

Two 16 mm movies are scheduled as part of this agenda: "The 3 T's of Combustion," which lasts about 30 minutes and "The Role of a Witness," which lasts about 45 minutes. * These are both sound movies and can be shown by normal 16 mm movie projectors. "The Role of a Witness" requires a 1600 foot take-up reel, which is larger than usual, so you should check to see that you have this size reel before the course begins.

Both of these movies are very good and appropriate to the course. The only reason for not showing them might be if all the students have seen them several times.

"The Role of a Witness" has two breaks in the action where the screen goes dark for a few seconds. Some lawyers who have lectured in this course use these places to stop the film and make a few remarks about the proceedings.

Two additional audiovisual packages have been used occasionally in the Visible Emissions course. One is a film covering basic meteorology, approximately 20 minutes long, that can be substituted for a part of the basic meteorology lecture (Lesson Plan 11). Instead of conducting the Combustion of Fuel Oil lecture as outlined in Instructor Lesson Plan 4, you may prefer to use the film strip entitled Combustion Testing. This narrated film strip lasts 45 minutes. You must have a

* ("3 T's of Combustion" - Lesson Plan 3; "Role of the Witness", Lesson Plan 13.)

tape recorder or playback unit that will play at a speed compatible with the film projector and an amplifier sufficient for your class size. The film strip itself requires a special projector and an operator to advance the film at an audible signal on the tape recording. If you have not operated a film strip projector previously, you should make a trial run before the course.

Film, slide, and filmstrip suppliers are listed in the Appendix (Sources of Course Materials). While precourse planning cannot be overemphasized, it is extremely important in audiovisual presentations where a number of components or variables must function properly.

Handout Material

It is suggested that you plan to give each student taking the course for the first time a copy of the Ringelmann Chart and, at your option, a copy of either a Plibrico Smoke Chart or Power's Microringelmann Chart.

The official Ringelmann Chart is published by the Bureau of Mines of the United States Department of the Interior as part of its Information Circular 8333. Copies of the chart may be obtained free from the Publications Distribution Branch, Bureau of Mines, 4800 Forbes Avenue, Pittsburgh, Pennsylvania 15213.

The two small hand-held Ringelmann aids are mentioned in lesson number 9 on the Ringelmann Chart and Equivalent Opacity. These charts are available from:

Tom Berry
1800 Kingsbury Street
Chicago, Illinois 60614
Tel. (312) 549-7014
Cost: No Charge

Power Magazine
McGraw-Hill Publishing Co., Inc.
Power Reprint Dept.
1221 Avenue of the Americas
New York, New York 10036
Tel (212) 997-6794
Cost: $0.75 per copy

Although the use of this is optional, it may not be needed since EPA and several state regulations are stated in opacity only and omit any reference to the Ringelmann Chart.

Quizzes and Examination

The suggested course agenda calls for three quizzes and an examination. A passing grade on these tests is not required for qualification as a smoke reader.

The written tests are to be used to help the student learn the material presented in the lectures and give the instructor clues as to how learning is progressing. To best accomplish these objectives, the instructor should go over the answers to the quizzes and examination in class and discuss those answers which the students do not understand or with which they disagree.

Copies of Quiz I, Quiz III, the final examination, and the answers to these tests are given in the Appendix. The quizzes should take only 5 to 7 minutes to complete and 5 to 7 minutes to discuss. It is suggested that the final examination be given to the student on the second afternoon of the course to use as a "take-home" exam. It can be discussed the first thing in the morning on the third day. If you want to check on how the students are doing, you can collect the examinations, grade them and hand them back on the third day before discussing them. Students attending for recertification are not required to take the examinations.

Quiz I covers combustion principles and the combustion of coal and oil. Quiz II is an identification of source types. The quiz included in the Appendix is an example. The instructor should pick out ten 35 mm slides of different sources of major interest in the home area of the students. These are to be projected on a screen with the students asked to write down the correct answers. Quiz III covers meteorology. The final examination has been made up from the material in Part I of the Student Manual and covers items from the entire course.

As part of the Qualification Procedures lecture, instructor lesson plan 10 provides an Exercise in Recording for Qualification. This consists of ten 35 mm slides, five showing shades of black smoke and five showing white plumes (The same slides used in Quiz II). The student is supposed to put down on a modified training form as shown in slide no. 1 his evaluation of the plume, check it against the instructor's estimate of shade and then determine the deviations and average deviation. This manual should contain one of these forms, or just use the regular smoke school training form.

OUTDOOR SMOKE READING
QUALIFICATION PORTION

The primary objective of this course is to qualify or requalify the students as expert smoke readers. Not only should the student meet a standard set of requirements for qualification, but he should also believe that these requirements are sufficiently difficult and that the smoke generator calibration and measurement system against which he is tested gives accurate and objective readings.

It is the duty of the instructor to train the student in proper smoke reading techniques, to give the student sufficient practice time to refine his reading abilities, to require a high standard of performance from the student, and to maintain the smoke generator and transmissometer so that the smoke shades produced are accurate.

Precourse Preparation

It is important that the smoke generator be operated and checked out far enough in advance of the course to allow time for major repairs (perhaps 2 weeks) and again one or two days before the course begins. The preferred agenda calls for the operation of the generator during the last hour of the first day of the course. A previous checkout would assure good operation and increase the student's faith in the smoke generator.

Especially with mobile smoke generators, there are numerous difficulties that can arise owing to the vibration of the parts of the generator during transit. It is always embarrassing for the instructor and frustrating for the student when major adjustments or repairs must be made on the generator at the time when the outdoor readings are supposed to commence. With experience the instructional staff will learn the problems that may arise with the generator and how to correct them. However, it is best to set aside some time before the course begins for checking the operation of the generator. Some of the points that should be checked include the following:

a) Sufficient fuel in the fuel tanks or in reserve: Toluene - 5 gallons (Formerly benzene was used but this material has been placed on the toxic substances list), #2 fuel oil - 5 gallons, Gasoline - 2 gallons.
b) Different shades of black and white smoke can be produced by the combustion systems.
c) Exhaust fans in transmissometer pipe are running.
d) Induced draft fan is operating.
e) Horn is operating
f) Light source in transmissometer is operating.

g) The transmissometer readout system should be calibrated before each course using neutral density filters having a nominal opacity of 20, 50, and 75 percent. The zero and 100 percent opacity conditions are also calibrated. Check that these calibration points will remain stationary by running through several shades returning to the zero and 100% points during the procedure (refer to EPA Method 9 for full explanation of calibration procedures).

h) The smoke shade readings of the transmissometer seem reasonable when compared with the actual shades as judged by an expert smoke reader (the instructor).

i) No electrical connections are loose or broken. A vacuum tube voltmeter would be a good device to have for this check.

j) The smoke plume will be relatively unaffected by downwash from buildings, trees, etc.

k) Contrasting backgrounds for the smoke are available in several viewing directions from the smoke generator or with a minimum of moving of the generator.

In addition to the generator checks, the instructor should verify that he has a sufficient supply of training forms (copy in the Appendix) for the students to make their readings during the tests. The students should be requested to bring their own clip boards, but the course director may have some extra available for those that don't have them.

The instructor should also determine from a map where the direction of north is from his generator site. This will be necessary for the student when he makes his wind direction observations.

Training and Testing Procedures

Explanation of Emission Generator Operation. After the students have moved to the smoke generator site the instructor should review the operation of the generator and point out the different parts.

Two peculiarities of the smoke-generating system should be understood by the instructor so that he can be forewarned in planning his testing procedures. First, the gasoline engine for producing white smoke makes considerable noise. It is desirable to shut off the engine when you are talking to the class. It can easily be restarted. Second, the fire in the combustion chamber that produced black smoke takes several minutes to burn out after the fuel supply is turned off. It is standard practice to run the white and then the black test series. The fuel supply to the combustion chamber can be cut off so that the fire will burn out during the time when the correct readings are being announced.

After explaining the generator operation have the students station themselves at any distance necessary to obtain a clear view of the generator and start the familiarization runs.

Familiarization Runs. In familiarizing the student with the smoke shades you should take one color at a time. Run up and down the shade scale announcing the correct reading to the class. You may prefer to sound the horn to train them that the reading is to be made at this time.

There are generally some student questions as to whether the sounding of the horn has some effect on the plume shade. There are times when they see, or believe they see, a change in a shade just after the horn sounds. There is no reason why the horn should affect the plume shade. At most its drain on the electrical power might affect the transmissometer reading. You should be able to see any change of this type on the indicator dial or recorder.

Another recurring question concerns the time for the smoke to travel from the transmissometer, where it is measured, to the top of the stack, where the student sees it. This time is less than 0.5 second. If the student looks up at the top of the stack when the horn sounds, he should be observing the smoke that passed the transmissometer when the instructor pushed the horn button. Of course, the instructor should strive to blow the horn only when the transmissometer reading is steady. He should also hold the horn button down for a second.

After two or three runs up and down the scale, give the students several practice tests of 5 or 10 shades each during which they mark their readings on a portion of the training form and then check them against the correct reading as announced by the instructor at the conclusion of the practice test.

At the completion of these short practice tests, switch to the other smoke color and repeat the same procedure.

Next, run through a complete practice run of 25 white shades and 25 black shades. Give the correct readings to the class at the completion of the entire set of 50 shades.

Suggestions to the Generator Operator. In a series of smoke shades for either the familiarization or qualifying runs you should try to cover the entire scale with most emphasis on the shades just above or just below the legal limit.

During the course of the training and testing readings, one of the instructors who is a qualified smoke reader should join the students in making observations. In this way, he can notice, and later describe to the students any prevailing conditions which might have influenced their recorded observations.

Qualification Runs. After completing the practice runs, most of the remainder of the course is devoted to conducting series of runs for qualification of the students. Each run consists of 25 different white and 25 different black plumes. Each qualification run of 25 should have a number such as 1-W or 1-B. A complete qualification series would consist of the combination of run 1-W and run 1-B. The training forms are designed so that the student's readings, the transmissometer readings, the deviations, the calculations, and the supplementary identification information are all included on a single sheet of paper.

A student will complete a qualification series successfully when he has made the 50 readings and has:

a) An average error not to exceed 7.5% opacity in each category. All readings, even if the Ringelmann standard is still in force, should be given in percent.
b) No error to exceed 15% opacity (or 3/4 of a Ringelmann number) on any one reading in each category. (That is, on any run a single reading that is incorrect by one whole Ringelmann number or more or 20% opacity or more disqualifies the student from that series.)

The student cannot use a successful white smoke run from one series (e.g., 1-W) with a successful black smoke run from another series (e.g., 3-B). They must be in succession.

Once the student has a run in which he has fulfilled the maximum deviation requirement (part b above), he should calculate his average deviation. If this is also within the limit, he should fill out the remainder of his training form and give it to the instructor for the files. These training forms are kept by the air pollution control agency as a record of the number of expert smoke readers on their staff and the time when the inspector must requalify. They can also be presented in court as verification of the expert smoke reader's qualifications.

After the observer has read 25 white and 25 black plumes, the instructor reads the correct values to the students so that they may compare the correct readings with their own observations. The students should make two copies of their readings by using a carbon paper. They should hand in the original sheet before the correct readings are given out. They check the carbon copy and then hand it to the instructor if they have qualified.

Training Forms. The forms for recording the readings may be of several designs. One convenient design is presented in the Appendix.

Practice in Continuous Evaluation of Plumes. When the expert smoke reader is operating in the field he will be observing emissions continuously and making readings at 15-second intervals in order to determine how many minutes out of an hour the emissions are in excess of a specified shade. To give the student practice in this observing procedure two parts of the field portion of the course have been designated for continuous evaluation – one for white smoke and one for black. These exercises are optional with the instructor and can be excluded if time is short.

If the continuous evaluation sessions are used, the instructor should run the generator on one color of smoke for either 15 or 30 minutes, varying the shade at intervals during the session. At 15-second intervals the horn should be blown and the reading recorded. At the end of the interval each student must decide whether the smoke generator was in violation of the local regulation and compare his readings with those of the transmissometer. The student can be provided with a visible emission observation form as shown in the Appendix or the agency conducting the course can use their own form.

Operation in Inclement Weather

It has been found that operation of the smoke generator during rain subjects the operators to shocks from the electrical system. It is recommended that outside training and testing sessions not be conducted in the rain.

Extremely strong winds cause rapid dilution of the plume and down-draft conditions in the lee of the stack. Students find it almost impossible to qualify under these conditions. If the wind is cold, there is the additional problem of discomfort. If the winds are not too strong, it may be possible to move the generator to a location in the lee of a building where plume, students, and instructor are all protected from the elements. Otherwise it is better to discontinue outside operations.

If inclement weather forces the cancellation of part of the outdoor portion of the course, the class can be taken inside. At this time some of the extra materials or movies can be presented.

In case the weather forecast appears unpromising for the afternoon of the second day, but not for the morning, the indoor and outdoor portions of the class may be switched.

STUDENT COURSE EVALUATION

It is helpful to the instructional staff to obtain some feedback from the students regarding the course and its presentation. You should always be trying to improve the course; many good suggestions can come from the students. One means of doing this is to give the students a course evaluation form on which they can answer pertinent questions about the course content and instructor's presentation. Do not take their criticisms as a personal affront but accept them as helpful suggestions.

You are free to devise any evaluation form that will give you the comments that will help you. A copy of a sample course evaluation form is included in the Appendix.

LECTURE PREPARATION AND REHEARSAL

Preparation

The Instructor Lesson Plans are designed to closely follow the material presented in Part I of the Student Manual. Use Part I as your principal reference and consult Part II and the other suggested readings for additional information.

Try to keep your lecture material up-to-date by reviewing new sources of information for their coverage of topics that are part of this course. Maintain a complete library of appropriate publications and guidelines published by the Federal air pollution agency. Review the articles in the Journal of the Air Pollution Control Association. Keep informed about the current visible emissions regulations.

Rehearsal

In preparing for giving a lecture the first time, the instructor should go over the Instructor Lesson Plan and the visual aids that can be used with the lecture. He should plan to rehearse his lecture aloud at least once, checking the time and content. If you need to cut the lecture shorter or expand it or change the content, you should revise the Instructor Lesson Plan and go through another rehearsal. Some pointers on rehearsing and delivering your lecture follow.

Your rehearsal will serve two purposes: (1) to check your terminology to be sure it fits the audience's vocabulary and (2) to time yourself.

To check content: You'll want to consider how much the audience knows about the topic and, while you rehearse, jot down any words you use that you think the audience might not know. You should define these words for them in your lecture.

To time yourself, present each part of the lecture (introduction, body, conclusion) and watch the clock. Write down the number of minutes for each part — write the time on the outline itself so you'll have it later.

Since you must imitate the actual lecture situation as closely as possible, get yourself a clock, a pencil, and a lectern if you'll be using one at the lecture hall. Set up all your presentation aids. And you'll need to TALK OUT LOUD and use gestures—don't let your aids stand idle, either.

Rule 1. READ the introduction. (You will not want to read it during presentation unless your mind goes blank.)

Rule 2. TALK the body of the lecture.

Rule 3. PRESENT all aids.

Rule 4. READ the conclusion. (You will not want to read it during the presentation unless your mind goes blank.)

Rule 5. WRITE DOWN the time.

Now clear your throat, conquer the butterflies, STAND UP, and rehearse ALOUD.

PART 2 OPERATOR MANUAL

INTRODUCTION

The training and testing of smoke observers requires the use of a device for generating black and non-black smoke and for controlling the opacity of this smoke. The U. S. Environmental Protection Agency has published specifications for smoke generators as part of "Method 9 - Visual Determination of the Opacity of Emissions from Stationary Sources" (40 CFR Part 60, Appendix A). (A copy of this Federal regulation is included in the student manual.) 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 with 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 tuning the fluid control valve until the photoelectric cell system measuring the density indicates on a dial or recorder that smoke of the desired density is going up the stack.

It is possible for an air pollution control agency to build its own smoke emission equipment for training its smoke inspectors. Several agencies including Los Angeles County, Bay Area, and the State of Colorado have done this and prepared stationary units.

As of this time portable emission generators are produced commercially only by one company — Environmental Industries, Cary, N. C. 27511. These are mounted on trailers and can be hauled from city to city behind an automobile or truck.

This guide will describe the components, principles, and procedures which are directly applicable to a typical generator. Agencies which own another type of unit can probably apply many of the instructions and comments to their own unit without much alteration. Agencies which have built or will build their own unit should also find this Manual useful as a guide to principles and correct operational practices.

Portions of this Operator Guide have been reproduced or adapted from the Instruction Manual for the Mark II Smoke Observer's Training Unit, prepared by Dr. Robert Sholtes of the Environmental Specialties Company. Although, this unit is no longer manufactured, it is typical of those portable units still being produced.

THE SMOKE GENERATOR PARTS

Photographs of the Mark II smoke generator appear on the next three pages and the various components are numbered and listed below:

(1) Trailer hitch
(2) Wires for connecting trailer tail lights to electrical system of vehicle used to haul the trailer
(3) Auxiliary box for carrying recorder and extra parts during transit
(4) Stack support with tie-down bolt
(5) Toluene container
(6) Toluene fuel pump
(7) Power generator
(8) Furnace
(9) Furnace wind shield
(10) #2 Fuel oil container
(11) Recorder; control panel on top contains:
  (a) light source switch
  (b) light intensity control
  (c) main blower switch
  (d) fans switch
  (e) oil fuel pump switch
  (f) benzene fuel pump switch
  (g) horn switch
  (h) fuses
(12) Lower portion of stack
(13) Hinge
(14) Upper portion of stack
(15) Light source
(16) Junction box
(17) Transmissometer cross pipe
(18) Photocell
(19) Fans for exhausting air from transmissometer arms
(20) Hydraulic pump
(21) Vent for hydraulic system
(22) Bleed valve (hidden) for hydraulic system

(23) Housing connector on fuel tank
(24) Spare tire
(25) Main blower
(26) Main blower inlet
(27) Toluene metering valve
(28) Fuel oil metering valve
(29) Panel board
(30) Amphenol connectors
(31) Damper control
(32) Damper in main blower inlet
(33) Example of Fiberfrax
(34) Example of fire brick
(35) Stop switch for gasoline engine
(36) Exhaust manifold of generator
(37) Hypodermic needle in place, for injecting #2 fuel oil into manifold
(38) Oil filler plug
(39) Plastic tubing attached to hypodermic needle
(40) Choke
(41) Gasoline container for power generator

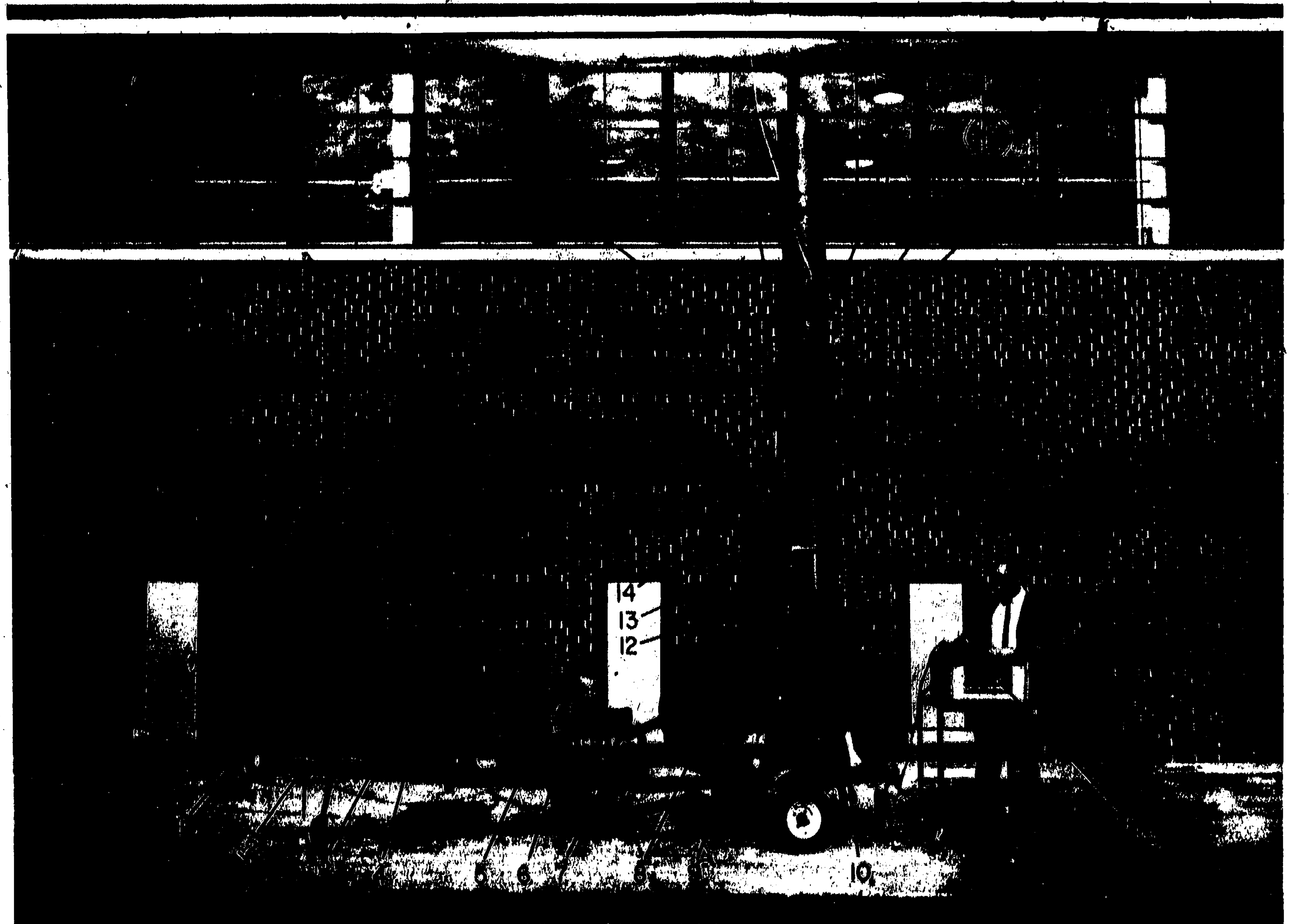
(A list of component specifications is given in the Appendix.)

OPERATING PRINCIPLES OF THE SMOKE GENERATOR

Two different operating principles are used in the production of white and black smokes. In the case of white smoke, it is sought to vaporize #2 fuel oil in the absence of oxygen and subsequently condense this vapor into an aerosol cloud, which is the "white smoke." In the Mark II smoke generator, the white smoke is obtained by injecting the oil into the hot exhaust manifold of the generating set.

Black smoke is produced by the combustion of toluene with a deficiency of air. When any carbonaceous fuel is burned with insufficient air, a smoky flue gas is produced, consisting of carbon-containing particulates suspended in the gas. In the Mark II smoke generator, a special furnace is provided in which the combustion air is limited to a fixed amount. Using a fine metering valve, fuel is fed into the combustion chamber where it is poorly mixed and burned in the limited air. By decreasing the fuel flow one can produce a lesser or greater density of smoke.

In the production of both white and black smokes, the smoke produced is diluted with ambient air. The degree of dilution is controlled by means of dampers installed in the main blower inlet.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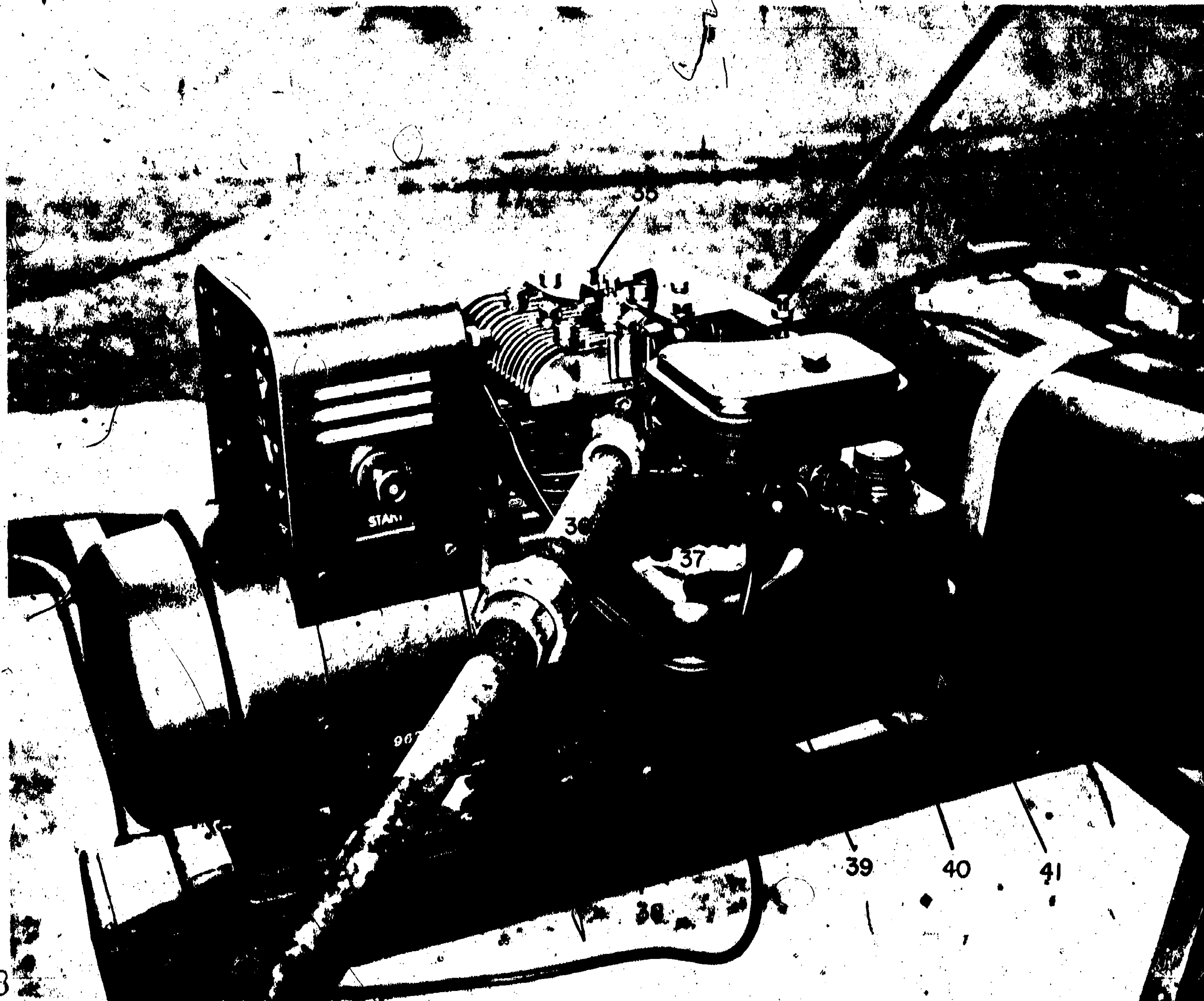
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The transmissometer is a simple light source and photocell combination, which measures the light transmission permitted by the particular smoke being produced. The light to photocell path is approximately 4 feet long, but only 1 foot of length is exposed to the smoke. The remaining 3 feet are continually flushed with ambient air to prevent fouling by smoke of transmissometer components. The apparatus can be calibrated over the entire density scale by using several grades of neutral density filters.

SETUP ~~AND~~ OPERATING PROCEDURES

If desired, the unit can be operated while attached to the towing vehicle. If the smoke generator is to be operated separately, the trailer frame should be leveled and the wheels chocked to prevent movement.

1. Check levels of all fuels and lubricants.
   a. Toluene (CAUTION - do not use benzone since it has been classified as a toxic substance);
   b. #2 fuel oil;
   c. Gasoline for the engine;
   d. Oil in engine crankcase.
2. Elevate stack.
   a. Remove tie-down bolt and nut at upper end (forward end of trailer) of lowered stack.
   b. Close bleed valve and open vent on hydraulic pump and commence pumping. Note. As the stack is being elevated, it is possible to pump at a rate that results in resonant vibration of the stack assembly. This condition should be avoided by changing pumping rate.
   c. When the stack reaches the approximate upper limit of its travel, the geometry of the design will cause it to quickly move to the completely erect position. After this has occurred, pump a few more strokes to apply a holding force. (CAUTION - do not exceed a reasonable holding force as this cylinder can cause permanent distortion to stack if pumping is continued.) Close vent. No further attention should be necessary, although a C clamp can be placed over the lips of the top and bottom portions of the stack as an additional guard against the stack toppling over in strong winds.

A gasket may be inserted between the upper and lower portions of the stack or masking tape may be used to cover the crevice between the top and bottom. Covering this opening reduces the tendency for pulsations in the plume by preventing the ambient air from entering the stack.

3. Make electrical connections between the panel mounted on the stack and the meter or recorder using the amphenol connectors.
4. Supply electrical power.
   a. The electrical power for the Mark II can be supplied by the gasoline-powered generating set provided. The generator's gasoline engine is started in a manner similar to starting a power lawn mower. If the engine has a shorting mechanism, fuel valve, and choke, these should be in the proper position before the rewind starter is pulled.
   b. Alternatively, electrical power can be obtained by plugging the three-prong plug into an available 115 volt 60 cycle current using an extension cord. By using this electrical power one is assured of a steadier current than that supplied by the generator.
5. After allowing a minimum of 30 minutes warmup, set Transmissometer for total opacity and then for total transparency. (This calibration shall be done prior to conducting each smoke reading test.)
   a. Check zero reading of meter, adjusting with facescrew if necessary (use zero adjust if recorder model).
   b. Move light intensity control to the counterclockwise limit of travel.
   c. Switch light source on and adjust intensity control in clockwise direction until readout meter indicates 0 Ringelmann (100% transmission).
   d. If unit has been out of service for an extended period, it would be well to recheck this calibration after 10 minutes.
6. Generate White Smoke
   a. Start gasoline engine (unless it is already being used to generate power).
   b. Start main blower, fans, and oil fuel pump in that order using switches on control panel.

c. Open oil valve (the right-hand valve) mounted on the panel to supply the appropriate quantity of fuel.

   CAUTION. The metering valves provided are of the precision needle type and should never be forcefully closed. Only a light pressure is required for tight closure.

d. Turn off the fuel oil metering valve, the oil fuel pump, and short out the engine when switching to black smoke.

7. Generate Black Smoke

   a. Start main blower, fans, and toluene fuel pump in that order using switches on control panel.

   b. Open toluene valve (left-hand valve) mounted on panel board to supply the appropriate quantity of fuel.

      CAUTION. The metering valves provided are of the precision needle type and should never be forcefully closed. Only a light pressure is required for tight closure.

   c. Quickly ignite toluene with a match or piece of waste paper thrown in through furnace opening.

   d. Place the wind shield over furnace opening.

   e. Turn off toluene valve and let fire in furnace die out when switching to white smoke.

8. Shutdown Procedure

   a. Close fuel valves to both white and black smoke generators.

   b. Cut off power to fuel pumps.

   c. Allow a 5-minute cooldown period and then cut off power from main blower.

   d. Turn off light source.

   e. Stop gasoline engine and disconnect outside electrical power, if used.

   f. Disconnect electrical connections between panel and meter or recorder.

9. Lowering the Stack

   a. Open vent and slightly open bleed valve.

   b. Push stack over to start its descent.

   c. After stack has been lowered into the support and tied down, close the bleed valve and the vent.

TRANSMISSOMETER CALIBRATION

The transmissometer-recorder or transmissometer-meter system should be recalibrated prior to each training course and after any repair or replacement involving the photocell, light source, or associated electronic circuitry. Procedures for this calibration are given in EPA Method 9. A set of neutral density filters having nominal opacity of 20, 50, and 75% is needed. These filters, when placed one at a time in the horizontal pipe between the light source and the photocell, will give the true values of transmission for three points. Two more points on the curve can be obtained when no filter is in the pipe and the light source is turned on (0% opacity), and when the light source is turned off (100% opacity).

These readings establish five points on the meter or or recorder. From these the additional 1/4 Ringelmann or 5% opacity readings can be determined by subdividing the spaces between the five points established with the neutral density filters and the 0% and 100% opacity.

AUXILIARY EQUIPMENT

A smoke generator may have several major components that are purchased as a unit and installed in the smoke generator system. The Mark II generator includes a four-cycle engine, a 2000-watt electrical power plant run by the engine, and a recorder. Each of these units is supplied with an instruction manual giving directions for operation and care of the unit. The smoke generator operator should be familiar with the contents of these manuals and should plan to do the preventative maintenance prescribed in the manuals. A few of the items mentioned in the manuals are listed here for further emphasis.

TECUMSEH FOUR-CYCLE HORIZONTAL CRANKSHAFT ENGINE

1. Keep the engine clean and see that no dirt or water enters the engine while filling it with gasoline or oil.
2. Use MS classification oil. Do not use oils marked only MM, ML, or unmarked.
3. Above 32°F use SAE 30. Below 32°F use SAE 10w.
4. Do not mix oil with gasoline.
5. Keep the oil reservoir filled to the top of the filler plug opening.
6. Oil should be changed after every 25 hours of operation.
7. Clean the air cleaner occasionally.

8. Use a good grade of regular gasoline. Keep the small vent hole in the gasoline tank cap clear so that the air pressure can push the gasoline into the carburetor.
9. Filling the gasoline tank up to only the 3/4 level will prevent gasoline from being thrown out the cap hole when the engine vibrates.

DAYTON POWER GENERATOR

1. Under ordinary circumstances commutator brushes should be inspected after every 50 hours of operation.
2. If brushes are worn to a length of 3/8 inch or less, replace the entire set.
3. Keep the commutator free from carbon dust or other dirt by cleaning it with a lint-free cloth.
4. Keep the surface of the collector rings in a high state of polish by shining them occasionally with a crocus cloth.

HYDRAULIC SYSTEM

1. The shaft supporting the stack may need to be lubricated periodically.
2. Additional fluid should be added to the system as needed.

EXPERIENCE WITH THE OPERATION AND MAINTENANCE OF THE SMOKE GENERATOR

During the past several years, there has been a rapid increase in the number of smoke generators made and used for the training of air pollution inspectors. These generators have been operated under many different weather conditions and have been hauled many miles for the presentation of smoke reader training.

It is the purpose of this section to relate some of the problems that have arisen in the use of smoke generators and how these problems were handled. Many of the difficulties will occur again. By citing some of these past experiences, we hope to pass on to future generator operators the knowledge that previous operators have acquired. Most of the information related here was obtained by the EPA operators with their portable smoke generators.

It is hoped that each user of this manual will take time to write down in his manual any troubleshooting experiences he has had with his generator. In this manner he can pass on to his associates and successors the maintenance and service recommendations that may be pertinent to the generator that his agency owns and operates. You might compile a listing of agencies in your region that own a smoke generator. By exchanging information with other operators or contacting them when you have a problem, you should be able to improve the performance of your own smoke generator.

NOTE: It is recommended that whenever a portable smoke generator has been moved, the operator should make a trial run with it at the earliest possible time. This will allow him to discover any problems that may have occurred in transit and will give him time to solve them. After moving the generator to a course site this trial run should be made before or during the first day if possible.

LOOSE PARTS

The portable smoke generator is very prone to having problems caused by loose wires, nuts, etc. Even when the trailer is hauled over good roads, there is sufficient vibration to cause small parts to come loose. Poor roads and minor collisions increase the probability. The generator operator should always carry a roll of fiber tape (and a knive or scissors) with him to tape securely pieces such as the furnace windshield, the #2 fuel pipe, and the door of the control box. The plastic fuel oil pipe, the hypodermic needle and all other loose tools, parts and electrical connections should be detached and carried separately in the hauling vehicle or in a large box welded to the trailer frame.

The electrical connections to the photocell, the light source, and those into the junction box on the stack may come loose. If necessary, these connections can be soldered for added security.

Shaking has resulted in:

(a) The tie-down nut holding the stack in place coming off and requiring a replacement nut for good tightness during transit.
(b) A wire in the variac (in the recorder box) coming loose and shorting out the rectifier. The result was no response of the recorder (or indicating dial) to change in smoke density and the blowing of fuses. The problem was finally discovered by using a vacuum tube voltmeter and the wiring diagram for the smoke generator to check out all the connections for breaks in the line.
(c) The printed circuit in the recorder developing a hairline crack that resulted in fluctuations in the recorder reading. As a consequence the recorder would at times indicate increases and decreases in smoke density when there were none.

This was a particular problem when the smoke density was low (the high end of the recorder). The hairline crack was eventually discovered and mended; however, it has been suggested that a duplicate printed circuit board might be an item that should be carried with the generator.

(d) Bulb in the transmissometer being loosened or moved out of line. This appears as no response of the transmissometer to variations in smoke density. The solution is to remove the cap from the bulb end of the transmissometer pipe and check the bulb for tightness or alignment. In the case of alignment it might be a good idea for the generator operator to become familiar with the proper placement of the elements of the transmissometer when the generator is running satisfactorily so that he can identify any irregularities if difficulties arise later.

OTHER PROBLEMS ARISING FROM MOVING AND HANDLING

(a) The power generation unit can be shaken during moving. The manufacturer has put on better bracing with rubber cushions and coil springs to help reduce the effects of vibration.

(b) Handling and vibration have caused the stack to be thrown out of line so that it does not exactly fit into the brace that holds it in its lowered position. This has prevented the stack from being held tight and the constant vibration during traveling has worn a dent in the area where the stack bumps against the brace.

(c) The refractory firebricks fall out of their places in the combustion chamber and break. This necessitates extra bricks being carried along for relining after the trip is finished. One solution was to rebuild the combustion chamber of double-walled steel and doing away with firebrick. However, the steel floor does not retain fuel like the brick and the fire sometimes goes out when the fuel flow is slow. "Fiberfrax" or refractory brick can be used on the floor to retain the fuel.

(d) The trailer has been involved in automobile accidents. This can require major repairs and rebuilding. Thus, the operator should have a good idea of all the components of the generator and how they fit together so that he can have them put back together. Keep all the descriptive material, diagrams, and photographs supplied with a portable smoke generator. Then take additional photos from different angles to be used for reference.

(e) In moving and handling, several parts have been knocked off or lost. The exhaust fans on the transmissometer assembly are quite susceptible to being knocked off. Fenders have also been lost. The operator should inspect these parts to see how they are attached so that he can have them replaced. He should also know how to obtain replacements for these parts.

(f) A spare tire is supplied for replacement of flat tires. A combination of an automobile jack and some support such as a concrete block can hold the trailer off the ground while the tire is being changed. You should check to see that you have the proper wrench for loosening the lug nuts.

FUEL PROBLEMS

(a) Toluene is the fuel of preference for black smoke replacing benzene, which is considered toxic. Toluene will not freeze in cold weather. The freezing point of toluene is -95°C.

(b) Fuel pumps have failed. It is a good idea to carry an extra one along in the tool box and know how to install it.

(c) Suspicions of improper fuel flow can be checked visually by seeing if the toluene or fuel oil is flowing out of the fuel pipe. There may be some obstruction in the pipe that needs cleaning out.

(d) Fuel flow may deteriorate the "O" ring in the housing on top of the fuel tank causing an unsteady fuel flow. A replacement housing can be purchased at a marine supply store.

(e) To produce the black smoke, the toluene flows out over the floor of the combustion chamber where it is lighted and burned. This is not an entirely satisfactory procedure. One operator has constructed a bowl on the chamber floor into which the fuel flows.

As mentioned in the discussion of "Other Problems Arising from Moving and Handling" the refractory brick floor does retain some of the fuel within its surface and prevents the fuel from evaporating too rapidly. If a steel floor is installed, the operator may turn his fuel flow down to obtain a low Ringelmann number and discover that his fire has gone out. This is the result of the evaporation and burning of the fuel exceeding the rate of incoming fuel. CAUTION. Be careful when relighting the fire in a hot combustion chamber whether it is steel-lined or fire-brick lined. The heat vaporizes the incoming fuel and may provide an explosive atmosphere. Keep your head and body away from the opening when you hold or throw the match in. Explosions have never yet damaged the combustion chamber but they have singed some arms. Do not be in too much of a hurry; let the chamber cool down a little.

One solution to these problems of fuel flowing out over the combustion floor is to install some material with good absorptive characteristics. One operator suggests a piece of 3/4" "Fiberfrax". This is used as insulation in furnaces and can be purchased at a furnace supply store.

Note: When moving around with a portable generator, the operator should always check his supplies of regular gasoline, toluene, and #2 fuel oil prior to operating the generator. If any of these are low, he should make immediate arrangements to obtain additional quantities.

PAINTING AND PREVENTION OF DAMAGE FROM THE ELEMENTS

(a) For overall good maintenance the smoke generator should be kept painted. However, there are portions of the breeching system between the combustion chamber and the stack that will not retain paint because of the high temperatures of the exhaust gases.

(b) If water accumulates in the housing for the blower fan, you should drill a small drain hole in the bottom of the housing.

PILFERAGE, VANDALISM, AND LARCENY

(a) To discourage the stealing of any of the loose items used with the smoke generator, you should disconnect all electrical wires and recorders when the generator is not in use (including overnight during a course) and place these items in the storage box or the trunk of an automobile.

(b) It is hoped that the public association of pollution fighters with "good guys" will prevent any vandalism. To identify the smoke generator, in this respect one operator has placed on his generator a sticker supporting smog eradication. Another aid may be to explain the instrument and its purpose to any curious bystanders.

(c) The power generation unit and the fuel tanks are portions of the smoke generator that have other uses and can be removed from the generator if the thief brings the proper tools. If community conditions warrant, the smoke generator should be kept inside or under guard.

PULSATING PLUMES

One of the recurring criticisms by students of the smoke generator's performance is that sometimes the shade of the smoke produced is not constant during the few seconds over which a reading takes place. During normal operation the horn should be blown at a time when the recorder or indicating dial shows that operation is stable. If it suddenly changes by more than 5% opacity or 1/4 Ringelmann after you have blown the horn the student may have legitimate cause for complaint. You can mark those readings in case complaints come up when the correct readings are given to the students.

In some cases there are complaints that the transmissometer readings are in error by significant amounts. To ensure that this is not a valid complaint, the operator should reduce the smoke output to zero once or twice during every run and check his recorder or indicator for a zero reading. If an adjustment is required, he should make it.

An additional precaution may be taken if recorder or indicator fluctuations are suspected. The operator or his assistant can take visual observations of the readings along with the students and check their expert ability against the transmissometer value after each reading.

One generator developed a problem of an unsteady and nonreproducible zero* opacity or Ringelmann reading on its recorder. Several components were checked for malfunction (recorder, photocell, and loose wires) and found to be performing acceptably. The deduction was that the

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*The zero opacity is in reality the highest reading for the recorder since the scale is reversed during calibration. The problem was eventually found to be a broken connection in the printed circuit board. However, the suggestion concerning the use of the variac might still be followed.

light source was varying. One suggestion was not to use the variac to adjust the light, but to calibrate for zero opacity by varying the input signal from the light to the recorder.

HAULING PROCEDURES

The Mark II Smoke Observer Training Unit can be pulled behind an automobile or truck equipped with the proper trailer hitch. Some agencies hire commercial trailer hauling firms to transport their smoke generators. Others own station wagons or light trucks with permanently installed trailer hitches. For occasional moving, trailer hitches for attachment to rear bumpers can be rented from some (but not all) trailer rental agencies. If renting, you must tell the rental agency what kind of vehicle will do the pulling and specify the ball size you need.

The ball size for the Mark II smoke generator is 1-7/8". This is one of the standard sizes for boat trailers. Some owners have switched their hitches to the 2" size.

ELECTRICAL CONNECTIONS

When pulling a trailer on the highway, the tail lights and turning signals of the trailer must be electrically connected to the hauling vehicle. A commercial hauler or someone who hauls a boat trailer regularly will have these connectors permanently attached to the vehicle's tail light system. The trailer lead wires consist of three wires that are color coded and should be attached to similar colors leading to the tail lights of the hauling vehicle.

The black and red wires are for the running lights. The third wire on the trailer and the automobile may be white, green, or yellow and it is for the turn signals.

If the hauling vehicle is not permanently equipped for pulling trailers it will be necessary to obtain three pieces of insulated wire (bell wire will do) which are 3 to 4 feet long for connection between the trailer lead wires and the automobile tail lights. Clamps are available from trailer rental agencies for attaching the wires joining the trailer and hauler. These clamps simplify the operation and relieve you from having to peel off insulation and then tape over the peeled portion. If you do cut through the insulation make certain that any exposed wires are wrapped with friction tape. In addition to friction tape the generator operator should have pliers and a knife when he is working on the electrical hookups.

The trunk lid of an automobile can be closed on the connecting wires without breaking through the insulation.

ATTACHING THE TRAILER TO THE HAULING VEHICLE

It will probably take two people to lift up the trailer tongue and lower it onto the ball. Some operators and experienced commercial haulers can do it alone. Some agencies have installed a dolly wheel on their trailer by which the front end can be raised or lowered with the attached jack. This also aids in the leveling of the smoke generator before it is used in a training course.

When lowering the trailer tongue over the ball be sure that the lips of the hitch are in the proper position to accept the ball. After the hitch is fitted over the ball, turn the mechanism to the lock position and place a nail or metal wire through the mechanism to hold it in place.

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LOCATION OF THE SMOKE GENERATOR FOR CONDUCTING TRAINING SESSIONS

Several factors must be considered in choosing a place to park a mobile smoke generator or a place to construct a stationary generator.

VIEWING DIRECTIONS AND BACKGROUND

In order for the student to follow the correct procedures for plume watching, the generator should be placed in a position so that:

(a) The student can view the plume in both morning and afternoon without facing into the sun.
(b) The student has room to shift his viewing position so that he may, at times, get a contrasting background for either white or black smoke. (See discussion on contrasting background in EPA Method 9.)
(c) The student can view the plume from a direction perpendicular to the wind and has room to shift his position in case the wind direction changes. (In some cases of wind direction shifts it may be better to delay the testing sequence for a few minutes until the wind returns to its original direction. In extreme cases the operator may have to consider moving the smoke generator.)
(d) The student can stand at least 50 feet away from the stack in any direction from which he may need to view the plume.

A good setup for a smoke generator would be in a position where the students are located south of the stack with room to move eastward and westward. By this arrangement the sun would be behind the student for east or west winds. The student could adjust his position for north or south winds.

Additional ideal conditions would be to have trees south of the students as a shade and protection and trees several hundred feet north of the generator to serve as a background for the white smoke. The sky above these trees would be the background for the black smoke. Trees or buildings several hundred feet east and west of the generator could shield the area from strong winds. Some athletic fields have been found to fit the ideal conditions.

BUILDINGS

Under moderate wind and temperature conditions the only needs for nearby buildings are as possible places to connect electrical power and as places to which to retire if additional classroom discussion is required. Generally, the operator has only one 100-foot extension cord and can borrow only one or two more at the training site. Thus, the availability of electrical power is important in determining the outdoor training site unless the smoke generator power generation unit is used.

Under less ideal conditions the presence of nearby buildings can aid as a shield against strong winds, which play havoc with the smoke plume and chill the students and instructor in cold weather. One must remember that there is a downwash effect of buildings which can result in high plume concentrations coming to the ground. However, it has been the experience of past visible emissions course instructors that the shielding effect of a nearby building far outweighs the downdraft problems it may cause. The generator can be moved to a spot where the eddy effects pass above the plume and the students are instructed to make their readings just above the stack — a point where the turbulent dispersion of the smoke is just beginning.

The smoke produced by the generator is generally not obnoxious to anyone living or working in the neighborhood where the training is taking place. Any objectional effects have disappeared within 50 feet of the generator site and generally the whole operation is just an object of curiosity for passersby during the days of outdoor training. (This "effects limit" of 50 feet does not exclude the generator operators unfortunately. They will have to endure the nuisance of black soot fallout during high Ringelmann readings and fuel oil odors during white smoke.)

ACCESSORY EQUIPMENT AND SUPPLIES

The generator operator should always have with him a copy of the operating and maintenance instructions for the generator and its components as well as a set of tools and selected replacement parts for the generator. A tool box should be obtained for carrying tools, replacement parts, the hypodermic needle, and the plastic tubing.

SUGGESTED REPLACEMENT PARTS TO BE KEPT ON HAND

- Light bulbs for transmissometer
- Fuel pump
- Fuses
- Plastic tubing

DESIRABLE TOOLS AND EQUIPMENT TO BE KEPT IN TOOLBOX

- Pliers
- Screwdriver
- Pocket knife
- Pipe wrench for loosening the transmissometer cap (The handle may be sawed off to make the wrench fit in the tool box.)
- Glass fiber tape
- Friction tape
- Roll of paper towels
- Matches
- Vacuum tube voltmeter (This is necessary for checking for breaks in the wiring, but may be difficult to transport safely.)
- Wiring diagram for generator, control box, and recorder (if recorder is used)
- Crescent wrench
- Hand cleaning fluid
- 100' extension cord
- Cutters for trimming wire
- C clamps

APPENDIX

Sources of Course Materials

COMBUSTION TESTING
Filmstrip with tape

Source: National Oil Fuel Institute
60 E. 42nd Street
New York, New York 10017

ORIGINS OF THE WEATHER
16 mm Film, Color

Source: Encyclopaedia Britannica Educational Films, Inc.
425 North Michigan Avenue
Chicago, Illinois 60611

ROLE OF THE WITNESS
16 mm Film, Color

Source: National Audio Visual Center, GSA
Sales Branch
Washington, D.C. 20409

THREE T's OF COMBUSTION
16 mm Film, Color

Source: Rodel Productions
1028 33rd Street, N.W.
Washington, D.C. 20007

RINGELMANN SMOKE CHART
Information Circular 8333

Source: Publications Center
Bureau of Mines
4800 Forbes Avenue
Pittsburgh, Pa. 15213
Tel.(412) 721-8342
Cost: FREE

GUIDELINES FOR EVALUATION OF VISIBLE EMISSIONS
EPA-340/1-75-007
U.S. Environmental Protection Agency
Washington, D.C.
April, 1975

and

GUIDELINES FOR DEVELOPMENT OF A QUALITY ASSURANCE PROGRAM:
VOLUME IX - VISUAL DETERMINATION OF OPACITY EMISSIONS FROM STATIONARY SOURCES
EPA - 650/4-74-005-i
U.S. Environmental Protection Agency
Washington, D.C.
November, 1975

Source: Library (MD-35)
U.S. Environmental Protection Agency
Research Triangle Park, N.C. 27711

or

National Technical Information Service
5285 Port Royal Road
Springfield, Virginia 22161

Sample Agenda

VISIBLE EMISSIONS EVALUATION

May 17-19, 19__

COURSE LOCATION:
USEPA Environmental Research Center
Research Triangle Park,
North Carolina 27709

MODERATOR: J. Doe

Day and Time	Subject	Speaker
Tuesday, May 17	First Day (For New Smoke Readers Only)	
8:30	Registration and Opening Remarks	J. Doe
9:00	Visible Emissions, Their Cause and Regulation	J. Doe
9:30	Principles of Combustion - Introduction to Movie: "3 T's of Combustion"	R. Jones
10:00	Break	
10:20	Combustion of Fuel Oil - Correct Practices	R. Jones
11:00	Combustion of Coal - Correct Practices	R. Jones
11:45	Quiz	
12:00	Lunch	
1:00	Other Combustion Emissions: Open Burning, Incinerators, Internal Combustion Engines, and Jet Aircraft	R. Jones
1:30	Noncombustion Emissions and Water Vapor Plumes	R. Jones
2:10	Break	
2:20	Ringelmann Chart & Equivalent Opacity	J. Doe
3:00	Qualification Procedures and Exercise in Recording for Qualification	J. Doe
3:30	Demonstration of Emission Values with Emission Generation (outside)	J. Doe
4:30	Adjourn	

Day and Time	Subject	Speaker
	Second Day	
Wednesday, May 18	(For New Smoke Readers and Those Needing Recertification)	
8:15	Review and Discussion	J. Doe
8:30	Basic Meteorology	J. Doe
9:00	Meteorological Factors in Smoke Reading	J. Doe
9:30	Quiz	
9:45	Break	
10:00	Legal Aspects of Visible Emissions and Local Regulations	E. Law
10:45	Film - Role of a Witness	E. Law
11:30	Citation Forms for Violations	E. Law
11:45	Emission Generator	J. Doe
12:00	Lunch	
1:00	Emission Generator (outside)	J. Doe
1:30	Black Smoke (Read and Record)	R. Jones
1:50	White Smoke (Read and Record)	
2:10	Black Smoke (Read and Record)	
2:30	White Smoke (Read and Record)	
2:50	White Smoke (Read and Record)	
3:10	Black Smoke (Read and Record)	
3:30	Black Smoke (Read and Record)	
3:50	White Smoke (Read and Record)	
4:10	Black Smoke - Continuous Evaluation for Violation Citation	J. Doe R. Jones
4:30	Adjourn	

Day and Time	Subject	Speaker
Thursday, May 19	(For new smoke readers and those needing recertification)	
8:15	Exam	J. Doe
9:00	Black Smoke (Read and Record)	J. Doe and R. Jones
9:20	White Smoke (Read and Record)	
9:40	White Smoke (Read and Record)	
10:00	Black Smoke (Read and Record)	
10:20	Break	
10:40	Black Smoke (Read and Record)	
11:00	White Smoke (Read and Record)	
11:20	White Smoke (Read and Record)	
11:40	Black Smoke (Read and Record)	
12:00	Lunch	
1:00	Exam Review	
1:30	White Smoke - Continuous Evaluation for Violation Citation	J. Doe and R. Jones
2:00	White Smoke (Read and Record)	
2:20	Black Smoke (Read and Record)	
2:40	Black Smoke (Read and Record)	
3:00	White Smoke (Read and Record)	
3:20	Black Smoke (Read and Record)	
3:40	White Smoke (Read and Record)	
4:00	Course Evaluation and Closing	J. Doe

INSTRUCTOR LESSON PLAN 1

Subject: REGISTRATION AND OPENING REMARKS
Objective: Student should be able to identify the purpose of this course and to find and have read the Course Objectives listed in the beginning of the Student Manual.
Suggested Time: 15 minutes
Required Equipment: None

LESSON OUTLINE	Aids & Cues
I. Make a final check of pre-class preparations	
A. Lighting and lighting controls	
B. Student manuals, handouts, and registration materials	
C. Projection equipment	
1. 35 mm projector	
2. movie projector and take-up reels (1 for 1600 ft. film)	
3. projection screen	
4. blackboard, chalk, eraser	
5. overhead projector (optional)	
6. wax pencil (if needed)	
II. Preliminary remarks	
A. Welcome class	
B. Introduce self and the name of the course	
C. Hand out any registration materials and any other student materials not previously distributed	
D. Give students any necessary instructions about filling out registration cards	
E. Mention the names and affiliations of other speakers who will be appearing during the course	
F. Point out the location of the restrooms	
G. Explain any arrangements for coffee during break periods	

LESSON OUTLINE 1	Aids & Cues
H. Suggest locations of restaurants or cafeterias where the students can eat lunch I. Collect the registration cards when they are completed. III. State the <u>purpose for</u> and the <u>method of</u> conducting this short course in <u>Evaluation of Visible Emissions</u> A. Purpose 1. To train the student so that he can qualify as an expert smoke reader who can determine the opacities of both grey-black and non-black plumes within 7.5% of the correct reading on the average and with no reading incorrect by as much as 20%. 2. To instruct the student in the causes of visible plumes, the effects of weather on these plumes, the legal basis for visible emissions regulations, and the proper procedures in enforcing these regulations. B. Method 1. A day and a half will be devoted to lectures on the various topics associated with visible emissions and their evaluation. 2. During the last 1 1/2 days the course will be conducted outside. First, you will be given training in correctly identifying (use whichever is appropriate for the agency involved) the shade of black plumes according to the Ringelmann scale and white plumes according to the equivalent opacity scale or the opacity of black or grey and white plumes according to USEPA Method 9 . Then, there will be a series of qualification runs testing whether you can identify the correct opacities or densities of	

LESSON OUTLINE 1	Aids & Cues

25 shades of black smoke and 25 shades of white smoke. To qualify, you must read one of these sets of 50 shades within the prescribed accuracy.*

3. There will also be several short quizzes and one examination during the course to test what you have learned from the lecture portion.

C. Qualification

If you successfully pass the qualification test for evaluation of visible emissions, you will be given a certificate by the agency conducting the course stating your qualification and the date of this course. (A diploma may also be given for attending at least 95% of the sessions without the requirement of qualification.)

IV. An official of the sponsoring air pollution control office may be invited to give a short welcome talk at this point.

*Plume - readings will be based on current state regulations.

Subject: VISIBLE EMISSIONS, THEIR CAUSE AND REGULATION	
Objective: The Student should be able to define micron, list the types of visible air pollutants, and give an example of each, describe the effects of particulate air pollutants, including the scattering of light by 0-1μ particles, and list the types of air pollution regulations.	
Suggested Time: 30 minutes	
Required Equipment: 35 mm slide projector	
LESSON OUTLINE	**Aids & Cues**

Introduction:

To begin this course, I would like to explain why we see some plumes while others are invisible. Although many pollutants are visible and can hurt us, the ones we cannot see can also have damaging effects to health, vegetation, and materials.

We are here to learn how to make visual measurements of the shade of visible plumes so that we can enforce one type of law on regulation against air pollution— the visible emissions regulation are (depending on regulations of the agency involved):

(1) Ringelmann Numbers for regulating gray and black emissions;

(2) Equivalent Opacity for regulating non-black emissions;

or (3) Opacity regulations for all visible emissions.

There are other types of regulations for restricting air pollutants and we will say a few words about them. In the course of this talk there will be several terms introduced. These will be used frequently throughout these lectures to make sure you understand them.

I. Discuss the importance of particle size to plume visibility and introduce the micron as a measurement of particle size.

A. Composition of visible plumes

LESSON OUTLINE 2	Aids & Cues
1. particles	
a. solid	
b. liquid	
2. gases	
B. Particle size	
1. micron	
2. behavior	2-1*
a. large - fall out of the air	
b. 5-100μ - suspended particulates	
c. 0.1 - 1.0μ cause haze	
3. effect on light rays	
a. 0.4 - 0.7μ scatter light	
b. larger particles reflect	
c. smaller - invisible	
II. List and define the names of the various types of visible air contaminants	2-2
A. smoke	2-3
B. soot	2-4
C. flyash	2-5
D. fumes	2-6
E. dust	2-7
F. mist	2-8
G. condensed water vapor	
H. gas - visible	2-9
1. NO_2	
2. chlorine	
3. water vapor	
III. Describe the effects of particulate air pollutants	
A. materials	2-10
B. visibility	2-11
C. incoming sunlight	2-12

*These are slide-numbers. The first number indicates the lesson number and the second number indicates the series of numbers in the lesson.

LESSON OUTLINE 2

Aids & Cues: 2-13, 2-14, 2-15, 2-16

D. health

E. vegetation

IV. Identify and give examples of the types of regulations that can be used to control pollutants

A. weight per unit weight of stack gas (lbs/1000 lbs)

B. grain loading (0.04 grains/scf or 90mg/scm)
process weight (40 lbs per hour per 60,000 lbs per hour of process weight)

C. limitation on basis of thermal input (lbs/10^6Btu of heat input)

D. boundary line measurements of air quality (200µg/m^3 at or beyond property line)

E. Ringelmann Number and Equivalent Opacity

1. advantages 2. disadvantages

V. Summary

Thus, although we may commonly call the emissions from a stack "smoke," they may not strictly be smoke for that term is reserved for products of incomplete combustion. To be sure of what name to call emissions we should know how they were created.

Generally, the particles that make a plume visible are extremely small. They can be seen only with a microscope, if we look at them individually. The larger particles that we can see individually with the naked eye do not remain in the plume, but fall to the ground relatively soon after they leave the stack.

The alternatives to regulating emissions by visual observations are measurements of the weight of material coming from the stack. These measurements take time and expensive equipment and can be done on only a single stack at a time.

Regulation through the use of a visible emission regulation can offer a means to cleaner air with the expenditure of smaller amounts of manpower, time, and money by the enforcement agency.

35 mm Slide List for Visible Emissions, Their Cause and Regulation

Slide Number	Topic	Comment
2-1	Sizes of atmospheric particulate matter (from Criteria Document for Particulates)	Note classifications of particulates between 0.1μ and 10^2 μ
2-2	Types of effluent plumes (from L.A. Field Operations Manual)	All of these include some visible pollutants
2-3	Wood products manufacturing plant Columbus, Ohio (wood waste burning).	Smoke
2-4	Air pollution training smoke generator (smoke from burning toluene)	Soot
2-5	Steam-electric power plant Lawrenceburg, Indiana (coal-fired)	Fly ash
2-6	Open-hearth furnaces Lorain, Ohio - 1970 (metallurgical fume)	Iron oxide fumes
2-7	Grain elevators, Columbus, Ohio (grain dust)	Dust
2-8	Contact process sulfuric acid plant Columbus, Ohio (sulfuric acid mist)	Sulfuric acid mist from tall stack; water vapor from lower cooling tower
2-9	Nitric acid plant (NO_2 plume)	Nitrogen dioxide gas (brownish plume)
2-10	Cleaning of City Hall Cincinnati, Ohio	Effect of particulates on materials
2-11	Skyline (Cincinnati, Ohio)	Effect on visibility
2-12	Measurements of amount of sunlight (0.5μ) reaching different heights in urban and rural areas (from Criteria Document for Particulates)	Effect on incoming sunlight
2-13	Human respiratory system (from Criteria Document for Particulates)	Divides system into nasopharyngeal, tracheo-bronchial, and pulmonary parts
2-14	Fraction of particles deposited in the three parts of the respiratory tract system as a function of particle diameter	Larger particles stop in naso- portion; Most of smaller ones get to the pulmonary portion (compare with slide No. 2-1)

Slide Number	Topic	Comment
2-15	Frequency of Individual Symptoms Experienced by Residents of Donora Area during October, 1948 smog	Note the percentages of respiratory symptoms. Lower respiratory symptoms due to smaller size particles as shown in slide No. 2-14
2-16	Effect of Particulate on Vegetation	Fly ash damage to Hydrangea

Subject: PRINCIPLES OF COMBUSTION - INTRODUCTION TO THE MOVIE

Objective: The student should be able to list the four items necessary for efficient combustion, list the chemical elements which combine with oxygen when fuels burn, and identify the causes of poor combustion shown in the movie, "3 T's of Combustion."

Suggested Time: Movie and remarks - 45 minutes (Movie alone - 30 minutes)

Required Equipment: 35 mm Slide Projector; 16 mm sound movie projector with a take-up reel of 12" diameter.

LESSON OUTLINE	Aids & Cues
Introduction:	
We are next going to watch a movie that describes how to obtain efficient burning without producing black smoke. It is called "The Three T's of Combustion" and what it says about the necessity for time, temperature, and turbulence plus oxygen or air is true for any type of combustion, whether it be the burning of coal in a furnace, gasoline in an automobile engine, trash in an incinerator, or jet fuel in an airplane.	
Before we see the movie, I want to mention some of the main points you should watch for in the film.	
I. Point out that most fuels contain carbon and hydrogen plus small amounts of unwanted sulfur and nitrogen, all of which combine with oxygen in burning.	
A. Hydrogen plus oxygen gives water vapor and heat	
B. Carbon plus oxygen gives carbon dioxide and heat	
C. Sulfur plus oxygen gives sulfur dioxide and a small amount of heat	
D. Nitrogen plus oxygen gives nitrogen oxides	
E. Except for some forms of carbon in coal and free nitrogen in some gaseous fuels, none of these elements occur in pure form in most fuels. Thus, to get the	

LESSON OUTLINE 3	Aids & Cues

full output of the combustion, we need to control the conditions of burning - the 3 T's and air (or oxygen).

II. Describe the parts of a kerosene lamp and how alterations in the burning conditions within the lamp will produce incomplete combustion.

A. Parts of the lamp
   1. glass container for holding the fuel
   2. wick
   3. grate
   4. diffuser or tuyere (pronounced "tweer")
   5. lamp chimney

B. Conditions producing incomplete combustion or inefficient burning in the lamp
   1. no tuyere - lack of mixing (turbulence)
   2. no chimney - too much cool air (time & temp.)
   3. cold chimney - lack of heat in the combustion area (temperature)
   4. too much air - wasted heat
   5. too little air - unburned fuel

C. Methods of increasing air and eliminating smoke
   1. taller chimney - increased draft
   2. raise bottom of lamp - overfire air

III. Show Movie "The Three T's of Combustion."

IV. Summary and application of the 3 T's to furnaces

A. For all the carbon and hydrogen to combine with oxygen. The needs are:
   1. sufficient time
   2. adequately high temperature
   3. sufficient turbulence
   4. these conditions prevent formation of CO and smoke.

LESSON OUTLINE 3	Aids & Cues
B. Methods for increasing the 3 T's in furnaces	3-1
1. temperature	
a. preheat air	
b. insulate combustion chamber	
c. design chamber to reflect heat inward	
2. turbulence	
a. baffles	
b. air jets	
3. time	
a. baffle design	
b. adequately sized combustion chamber	
C. Principles to check if there is a smoky flame	
1. too much air	
2. too little air	
3. insufficient mixing	
4. cold furnace	
D. All fuels or combustible materials burn as a gas. Solids or liquids must be transformed into gaseous state by sufficient heat.	

INSTRUCTOR LESSON PLAN 4

Subject: COMBUSTION OF FUEL OIL - CORRECT PRACTICES

Objective: The student should be able to differentiate between the characteristics of distillate and residual oil, define fractionation and cracking, identify the types of boilers, list the types of draft systems, explain the necessity for soot blowing and the recommended frequency, identify the causes of poor burner operation, and identify the composition of the different colors of emissions that may accompany fuel oil combustion and the combustion conditions associated with each.

Suggested Time: 40 minutes

Required Equipment: 35 mm Slide Projector

LESSON OUTLINE	Aids & Cues
Introduction:	
The incomplete combustion of carbon-containing fuels is the cause of black smoke. The three principal hydrocarbon fuels today are coal, oil, and natural gas. Generally the burning of natural gas does not produce a black plume. Complete combustion of coal and oil will not produce a black plume either. However, complete combustion of these two fuels is not always achieved.	
We will now discuss in two lectures the burning of fuel oil and coal. You, as an air pollution control officer should know something about the composition of these fuels and the mechanics of burning them. If black smoke is emitted something is wrong in the combustion operation. You will have to go into the boiler room for an inspection. While these next two lectures will not make you a combustion engineer, they will discuss some of the basics and relate them to the three T's of combustion.	
The first lecture will cover the burning of fuel oil.	
I. Explain the refining of oil and the classification of fuel oils produced by the fractionation	
A. Refining of crude oil-distillation and cracking	
1. composition of crude oil	
2. distillation or fractionation	4-1

LESSON OUTLINE 4	Aids & Cues
a. boiling to separate the fractions	
b. products	
1) distillates	
2) residuals	
3. cracking	
a. change in hydrocarbon structure	
b. heat, pressure, and most often catalysts, are required	
c. redistillation	
B. Grades of fuel oil	
1. classification by number	
a. distillates: 1 and 2	
b. residual: 4,5, and 6 (Bunker C)	
c. Number 3 no longer used	
2. Each grade must meet standard specifications	4-2
a. list the specifications	
3. Characteristics affecting air pollution	
a. viscosity	
1) define and discuss	
2) variation between residual and distillate	
b. sulfur content	
1) range	
2) limited for distillates (Bureau of Standards)	
3) desulfurization	
c. ash content	
1) maximum of 0.3%	
d. types of hydrocarbon compounds in crude oil and their characteristics	
1) paraffins - burn easily.	
2) aromatics - cracking	
3) olefins - hard to burn	

LESSON OUTLINE 4	Aids & Cues
II. Discuss the equipment used in burning fuel oil and transforming its energy into useful heat	
A. Requirements for complete combustion - 3 T's	
1. all fuel burns as a vapor (gas)	
a. vaporization of fuel - time and turbulence	
b. atomization of fuel	
2. flame in combustion chamber must be hot - temperature	
a. combustion chamber size - time	
1) too large - cooling (poor mixing)	
2) too small - insufficient time	
3. oil drop burns in layers	
a. mixing is required - turbulence and sufficient air	
B. Burners	
1. vaporizing	
a. heat oil in burner	
b. used for residential furnaces and water heaters	
2. atomizing	
a. steam or air	4-3, 4-4
1) break up fuel oil stream at burner tip	
2) steam keeps temperature high	
b. oil pressure	
1) high pressure breaks up the droplets	
c. rotary cup	4-5
1) tear oil film into drops by centrifugal force	
2) vertical rotary - domestic burners	
3) horizontal rotary - residual oil	
d. mechanical	4-6
1) use both high oil pressure and centrifugal force	
2) steam - electric power plants	
3. burners and viscosity	

LESSON OUTLINE 4	Aids & Cues
a. proper operation only between narrow viscosity limits 1) air to fuel ratio must be correct b. preheaters 1) most residual oil must be warm to allow pumping 2) location 4. Hydrocarbon combustion a. hydroxylation 1) blue flame 2) molecules combine with oxygen b. decomposition (cracking) 1) yellow flame 2) hydrocarbons decompose into lighter compounds c. mixture of hydroxylation and decomposition is ideal for good combustion C. Combustion Chamber 1. ~~heat~~ release is important factor a. too high - excessive furnace temperature b. too low - excessive cooling and smoking 2. size determines heat release 3. shape prevents flame from hitting chamber sides D. Boilers 1. used to heat or vaporize water 2. fire-tube a. heated gases inside tubes b. water outside tubes c. used for small and medium-size industrial boilers 3. water-tube a. heated gases outside tubes b. water inside tubes	

LESSON OUTLINE 4	Aids & Cues
c. used for all large steam-electric power plants and many industrial boilers	
4. sectional	
a. sections may be joined together	
b. neither water-tube or fire-tube	
E. Draft systems	
1. natural	
a. difference in pressure between stack and outside air	
b. back pressure	
1) too small stack	
2) too large stack	
2. induced	
a. fan pulls combustion products from the combustion chamber and through other passages	
3. forced	
a. fan pushes combustion products through the combustion chamber	
F. Soot blowing	
1. carbon and inorganic ash solids adhere to heat exchange surfaces in boiler	
a. deposits must be removed for good heat transfer	
b. soot blower - jets of steam or air	
c. particles are picked up by gases and cause excessive opacity	
2. frequency	
a. recommended every 2 or 4 hours	
1) little increase in opacity	
2) dust collector (if any) not as badly overloaded	
b. 8 to 24 hours - not recommended	
1) increase in plume density; dust collector (if any) overloaded	

LESSON OUTLINE 4	Aids & Cues
III. List the different emissions arising from fuel oil combustion and explain which ones can be controlled by proper burning practices	
A. air pollutants from fuel oil burning	
1. attributable to fuel grade	
a. sulfur oxides	
b. ash	
2. affected by burner design and operation	
a. carbon	
b. carbon monoxide	
c. aldehydes	
d. organic acids	
e. hydrocarbons	
f. nitrogen oxides	
3. poor burner design or operation	
a. signs	
1) appreciable odor	
2) smoke	
3) eye irritation	
b. causes	
1) burner and fuel not compatible	
2) burner not properly adjusted	
3) poor draft	
4) improper fuel-to-air ratio	
5) poor mixing	
6) insufficient turbulence	
7) low furnace temperature	
8) insufficient time for burning in the combustion chamber	
9) flame hitting side of combustion chamber	
10) improper fuel temperature	
11) improper fuel or steam pressure	
12) dirty, worn, or damaged burner tips or rotary cup.	

LESSON OUTLINE 4	Aids & Cues
B. black smoke and white smoke 1. black a. carbon particles b. unburned hydrocarbons 2. brown or white a. finely divided particulates - usually liquid 1) result from vaporization and condensation of the oil without combustion 2) caused by excessive combustion air (cooling) or loss of flame 3. visible plumes accompanying complete combustion a. large oil-fired steam generators b. causes 1) inorganic ash particulates 2) sulfuric acid mist c. particulates 1) dependent upon type of fuel a) distillate - low ash b) residual - higher ash content 2) size a) ash - 85% are less than 1 micron (except during soot blowing) b) unburned carbon or hydrocarbons - larger particles 3) cenospheres a) carbon particles resulting from incomplete combustion of residual oil b) hollow, black, spherical, low density c) size range - 0.1 to 1.0 micron 4) distribution by type a) ash - 10 to 30% b) sulfates - 17 to 25% c) cenospheres - 25 to 50%	

LESSON OUTLINE 4	Aids & Cues
5) Ash and sulfates are controlled by fuel content while cenospheres are controlled by efficient combustion. Modern steam generators burning fuel oil produces very little combustible material. Visible emissions from these plants are essentially attributed to finely divided inorganic materials - notably sulfur trioxide and inorganic materials.	
d. sulfur oxides	
1) distribution in exhaust gases	
a) SO_2 - 95% - colorless.	
b) SO_3 - 5% - can combine with water vapor and condense to form visible sulfuric acid mist	
2) sulfur trioxide	
a) concentrations are negligible in small equipment and increase as equipment sizes, firebox temperature, and sulfur content of fuel increase	
b) acidifies particulate matter - acid spotting	
c) causes of increase in SO_3 emissions-high combustion temperature, too much excess air, fuel sulfur content, dirt on heat exchanger tubes and small quantities of metallic metals contained in the fuel acting as an oxidation catalyst (V, Mn, Fe, and Ni)	
d) shade of plume - varies with weather and particulate composition	

LESSON OUTLINE 4	Aids & Cues
e) detached plume - caused by SO_3 reaching its dew-point at some small distance downstream from the lip of the stack.	
C. Control equipment for residual oil-fired combustion	
1. centrifugal or cyclone collectors	
a. not efficient in removing particles less than 5 microns	
b. used primarily for control during soot blowing	
2. electrostatic precipitators	
a. can cut particulate loading by 90%	
b. SO_3 emissions cut by 50%	
3. fabric filters - potentially important in the future	
IV. Summary	
Fuel oils used in combustion are of two types—distillate and residual. The distillate oils are low in ash and sulfur content and thus produce visible plumes only when there is incomplete combustion. Residual oils are higher in sulfur and ash so that even under good combustion conditions visible plumes consisting of inorganic ash or sulfuric acid mist may be emitted. These visible emissions can be controlled by electrostatic precipitators and fabric filters may come into increasing use.	
With careful attention to such things as burner maintenance and adjustment, proper fuel usage, preheating of fuel, and correct soot blowing schedules, there should be no illegal black plumes from the combustion of residual fuel oil.	
Note: At his option the course director may replace this lecture with the film strip entitled "Combustion Testing." This film strip is included in the Sources of Course Materials listing.	

INSTRUCTOR LESSON PLAN 5

Subject: COMBUSTION OF COAL--CORRECT PRACTICES

Objective: Student should be able to list the types of coal, differentiate between proximate and ultimate analyses, differentiate between the causes of the various colors of coal combustion emissions, list the different types of particulate collection equipment, and identify the effects of the following on the creation of smoke from coal combustion; coal factors; combustion equipment; combustion factors (time, temperature, and turbulence).

Suggested Time: 40 minutes

Required Equipment: 35 mm Slide Projector

LESSON OUTLINE	**Aids & Cues**
Introduction: Through the years most of the black plumes emerging from chimneys have been caused by the burning of coal. As gas and oil replaced coal as the fuel heating many homes and other establishments, the amount of black smoke on the horizon decreased. The installations that burn coal have increased their use of more efficient collection devices in order to reduce the emission of ash and unburned carbon. In recent years, much emphasis on air pollution control of coal combustion has been given to the reduction of sulfur oxides. However, the burning of coal is still a principal source of energy for the production of electric power, and coal is used in numerous larger plants. Vast reserves of coal remain to be mined and burned. You should understand the methods that have been developed for burning coal and what effect they have on the visible emissions. The composition of the coal varies. For example, mines in Wyoming produce coal that has characteristics different from West Virginia coal. These differences require changes in the combustion equipment. Finally, if coal combustion is producing a plume of an illegal opacity; you must also suspect that somewhere in the burning operation one of the 3 T's of combustion is not being	

LESSON OUTLINE 5	Aids & Cues

fulfilled sufficiently, or there is trouble with the dust collector.

This lecture will cover the classification of coals, coal burning methods and equipment, and some of the causes of visible plumes and the preventive practices to avoid black smoke.

I. List the various methods for classification of coal and point out the importance of a coal's volatile matter, ash, sulfur, and heating value to air pollution emissions

A. Types of coal
1. anthracite
2. bituminous
3. lignite
4. preparation of coal

B. Composition of coal
1. proximate analysis — 5-1
a. volatile matter
b. fixed carbon
c. ash
d. moisture content
e. other
1) sulfur content
2) heat content

2. ultimate analysis — 5-2
a. hydrogen
b. carbon
c. oxygen
d. nitrogen
e. sulfur
f. ash
g. moisture

3. size
a. screen analysis

C. Coal composition and air pollution

LESSON OUTLINE 5	Aids & Cues
1. volatile matter—incomplete combustion results in partially burned particles: soot and black smoke 2. ash a. particulate emission b. high ash coals—power plants c. low ash coals—retail usage d. some can be removed in preparation plants 3. moisture a. reduces coking in stokers b. reduces dust 4. sulfur a. pyritic sulfur 1) some can be removed 2) most of the sulfur is in this form b. organic sulfur—cannot be removed economically c. combined sulfur 1) in sulfate form 2) cannot be removed economically d. high sulfur coal—high in all three forms of sulfur II. Introduce several terms that are commonly used in discussing coal combustion A. Furnace system characteristics 1. fuel bed a. grate 2. fuel feeding method a. underfeed stoker b. overfeed stoker c. spreader stoker d. pulverized 3. air a. underfire air b. overfire air 4. arch a. refractory material	

LESSON OUTLINE 5	Aids & Cues
5. heat exchange equipment a. radiant heat absorbers b. boilers 1) fire tube 2) "fire box" 3) water tube c. superheaters	5-3
d. economizers e. air preheaters 6. breeching a. originally, the connecting link between the furnace and the chimney b. now, may contain several pieces of equipment	"
7. draft a. forced b. induced c. natural d. furnace e. draft losses 8. coke 9. carbon in the ash 10. slagging III. Discuss the basic principles of coal combustion and describe the principal types of mechanical coal firing equipment A. Burning of coal 1. combustion process a. vaporize solid by addition of heat b. burn the gas	5-4

LESSON OUTLINE 5	Aids & Cues
2. burning on grates a. overfeed 1) coal from top 2) air from below 3) burning from bottom to top in layers a) layer of ash b) oxidation zone c) reduction zone d) top layer — hydrocarbons and tars driven off 4) top layer produces smoke a) "secondary" or "combustion" air can oxidize the volatile matter and reduce smoke b. underfeed beds 1) coal from below 2) air from below 3) volatile matter is driven off at bottom of bed and burned in ample air 4) comparatively little smoke produced	

LESSON OUTLINE 5	Aids & Cues
B. Mechanical coal-firing equipment	
1. overfeed stokers	
2. underfeed stokers	
a. single retort—used with smaller boiler	5-5
b. multiple retort	5-6
3. traveling grate stoker	5-7
4. vibrating grate stoker	5-8
a. increase in fly ash because of agitation	
5. spreader stoker	5-9
a. coal thrown into furnace	
b. partially burned in suspension	
c. overfire jets required to reduce smoke from the overfeed type of burning	
d. particulate collector required	
6. pulverized-coal firing unit	5-10
a. types	
1) wet bottom	
2) dry bottom	
b. median size of particles—5 microns	
c. used in steam-electric power and other large plants	
1) 50-80% of the ash in the coal leaves boiler as fine fly ash	
2) requires high efficiency dust collectors	
7. cyclone furnace	5-11
a. used in large steam-electric power plants	
b. fires crushed coal	
c. coal and air circle around a cylindrical chamber	
d. 85% of the ash is retained as slag	
e. ash escaping is very fine	

8. fly ash reinjection
   a. used with some types of coal-firing equipment
   b. cinders are returned to grate for reburning
   c. increases total flyash

IV. Itemize the causes of particulate emissions and visible plumes arising from the combustion of coal and give some methods for reducing the visible emissions

A. Plume composition and plume colors
   1. condensed water vapor—white
   2. sulfur trioxide and sulfuric acid mist—detached bluish-white plume that does not readily dissipate
   3. organic liquids or solids—white, yellow, or brown
   4. particulates (including fly ash)—light grey, brown, or black
      a. black smoke
         1) small unburned or partially burned solid carbon or liquid hydrocarbon particles
         2) caused by incomplete combustion of volatile part of the fuel followed by cooling of these unburned gases until particles are formed—soot
      b. light grey or brown
         caused by the ash of the coal; very little free carbon

B. Causes of emissions of smoke and particulates
   1. coal factors
      a. coal size—smaller sizes are more easily swept up the chimney
      b. volatile content
         1) high volatile coal
            a) greater portion of hydrocarbons which, when not completely burned, produce soot and smoke

LESSON OUTLINE 5	Aids & Cues
b) long flame that may strike cool surfaces of furnace and produce soot	
2) low volatile coal	
a) burns with short transparent flame	
c. ash content— greater the ash content of the coal, the higher the emission of fly ash	
2. combustion equipment and methods	
a. type of firing	
1) least generation-underfeed stokers	
2) greatest generation-pulverized fuel unit	
b. firing rate	
1) higher rate results in increased gas velocity, which causes more and larger particles to be carried out of furnace	
c. furnace design	
1) smaller quantity of emission from larger furnaces	
d. secondary air jets	
1) tend to reduce emissions	
e. fly ash reinjection	
1) accumulation of ash resulting in increased emissions	
3. improper combustion — 3 T's of combustion	
a. possible reasons for insufficient turbulence	
1) insufficient overfire air	
2) plugged overfire air nozzles	
3) improperly aimed nozzles	
4) incorrect burner adjustment	
b. possible reasons for insufficient temperature	
1) too much air (usually overfire air), which chills flame	
2) cold fire box - often caused by excessive furnace draft; start up or rapid load	

LESSON OUTLINE 5	Aids & Cues
increase	
3) furnace too large (low firing rate-low load)	
c. possible reasons for improper distribution of fuel and air	
1) uneven depth of fuel bed	
2) plugged air holes in grate	
3) clinker that shuts off air flow	
4) leaky seals around edges of grate	
5) incorrect burner adjustment	
d. proper fuel-to-air ratio and the furnace flame	
1) good burner adjustment	
a) yellowish orange color	
b) no black tips	
c) soft	
2) too much air	
a) whiter color	
b) harder	
3) too little air	
a) black color	
b) lazy	
c) soot may form	
C. Control Equipment for collecting particulates from coal combustion	5-12 5-13
1. settling chamber	
a. used for natural-draft stoker units	
b. efficiency— 20 to50 %	
2. large-diameter cyclones	
a. stoker-fired units— 70-85% efficiency	
b. cyclone furnaces— 20-30% efficiency	
3. small-diameter cyclones	
a. used as precleaners for electrostatic precipitators or final cleaners	
b. stoker-fired units— 85-95% efficiency	

c. cyclone furnaces — 30-40% efficiency

4. wet scrubbers

a. used only to control emissions during soot blowing

5. electrostatic precipitators

a. most commonly used device for large stationary combustion sources

b. best adapted to pulverized-coal units

V. Summary

You now know that time, temperature, turbulence, and sufficient oxygen, when properly regulated, can reduce or eliminate the black smoke from the burning of coal. However, you also realize that these keys to good combustion are not the entire answer to the elimination of visible plumes. The composition of the coal--its volatile content, ash content, and size--is important. Some types of coal-firing equipment are more susceptible to visible emissions than other types. Also, there are several kinds of devices for collecting particulate matter, but these devices have different efficiencies and some can do a better job on particular types of firing equipment. You need to be alert to all these possibilities when making your investigations of emissions from coal combustion.

Subject: OTHER COMBUSTION EMISSIONS: INCINERATORS, AGRICULTURAL BURNING, NATURAL GAS, AND MOBILE SOURCES

Objective: The student should be able to identify the types of incinerators and the kinds of agricultural burning, state the basic points of a visible emission regulation for mobile sources, and identify the causes of visible plumes originating from the following: incinerators, natural gas combustion, gasoline engines, diesel engines, and jet engines.

Suggested Time: 30 minutes

Required Equipment: 35 mm slide projector

LESSON OUTLINE	Aids & Cues
Introduction: The preceding two lectures discussed emissions from the burning of coal and of fuel oil. The Ringelmann chart for judging the shade of black plumes was originally devised and used for smoke from coal and fuel oil fires. There are other kinds of burning that takes place involving materials other than coal and oil. Some of this combustion is done to dispose of solid waste and the energy produced is not used, although efforts are being made to utilize the heat from the incineration of solid waste materials. Other combustion from which the energy is not used included the intentional burning of weeds and cuttings in agricultural fields and the accidental burning of buildings and forests. A considerable portion of the combustion of fuels today involves gasoline, diesel oil, and jet fuel used in transportation. All of these other combustion processes will produce visible plumes sometimes continuously and sometimes intermittently depending upon the type of fuel, the condition of the engine or combustion device, and the atmospheric conditions. In many cases, the plume will not be a shade	

LESSON OUTLINE 6	Aids & Cues

of black or grey, but white or bluish of various densities. Often all or part of the white will be caused by water vapor. Sometimes, as in the case of structural building fires or forest fires, there is no offender that can be charged with a violation under the visible emission regulations.

Thus, the combustion of materials other than coal and oil are going to generate visible plumes that will present problems for the air pollution inspector besides the question of whether their density does or does not exceed a prescribed Ringelmann Number or equivalent opacity. You will also have to judge their composition, whether the local regulations apply to them, and whether any change can be made in their sources which will reduce the visibility. You may have to defend your judgments before a judge, a legislative group, the public, or the operator of a source.

I. Describe the use of burning to dispose of waste material and the types of visible emissions that are related to incineration.

A. Types of incinerators and their characteristics

1. chambers

a. single — 6-1

b. multiple — 6-2

2. incinerators, classified as to size and use

a. backyard

b. apartment house

c. commercial or industrial

d. tepee burner

e. municipal

f. pathological

B. Plume colors and their relation to fuel type

1. dark and light colored plumes

2. moisture in the waste and lighter colored plumes

LESSON OUTLINE 6	Aids & Cues
3. large fly ash particles and submicron particles	
4. results of a study of smoke density in relation to material burned in a teepee incinerator	6-3
C. Particle Collectors used on Incinerators	
D. Application of higher standards to Municipal Incinerators	
E. Incineration for Agricultural purposes	
1. Burning that can be scheduled for best dispersion conditions	
a. meteorological factors, forecasts, and permits	
b. removal of logging slash	
c. pre-harvest clearing	
c. weed and brush removal	
2. Unscheduled burning	
a. burning for frost prevention	
b. disposal of diseased animals or vegetation	
3. Relation of plume density to burning conditions	
a. combustion temperature	
b. residence time	
c. moisture content of the fuel	
F. Operation methods to reduce smoke	6-4
II. Discuss emissions from combustion of natural gas	
A. Composition of natural gas	6-5
1. very low in sulfur	
2. very low in ash	
3. promote good combustion since it has a hydrogen-carbon ration > 0.26	
B. Burners	
1. atmospheric	
2. mechanical draft	
C. Visible Plumes	
1. white	

LESSON OUTLINE 6	Aids & Cues.
a. water vapor caused by high amount of hydrogen b. occurs more frequently when relative humidity is high—more moisture in air, lower atmospheric temperature 2. black a. caused by improper operation of burner b. insufficient combustion air 1. other indications 2. causes	
III. Identify the types of engines used in surface vehicles and aircraft, explain their operating principles, and tell why they sometimes produce visible smoke. A. Types of mobile engines 1. internal combustion a. gasoline and diesel engines 1. cars, trucks, airplanes 2. large trucks, busses, locomotives, ships, earth-moving equipment	
b. four-stroke and two-stroke cycles 1. intake 2. compression 3. expansion 4. exhaust c. ignition 1. spark - gasoline 2. compression - diesel 2. aircraft - gas turbine or jet a. compressor, combustor, turbine, and tailpipe	6-6, 6-7
b. principles of different types of jet engines 1. turbojet 2. turboprop 3. turbofan	6-8

LESSON OUTLINE 6	Aids & Cues
B. Visible emissions from mobile sources	
1. gasoline engines	
a. particulate emissions	
1. source	
2. composition	
3. size	
b. colors of smoke and their causes	
1. white - water vapor	
2. blue - burning oil	
3. black - incomplete combustion of gasoline	
2. diesel engines	
a. composition of smoke and size of particles	
b. engine power related to fuel injected	
1. open throttle	
2. rich fuel-to-air ratio	
c. observance of manufacturer's specifications and maintenance of fuel system	
d. improper setting - more power and more smoke	
C. Jet engines	
1. fuel-to-air ratios	
a. low during flight	
b. high during takeoff and landing	
2. composition of emissions	
3. amount of emissions related to power settings	6-9
4. only Federal standards for aircraft; enforced only by Federal government	
D. Visible emission ordinances and mobile sources	
1. applied to automobiles, trucks, locomotives, and ships	
a. limitations on interstate commerce	
b. smoke that "draws attention" to vehicle	
2. not applied to aircraft — Federal enforcement on emissions preempts state regulations	

LESSON OUTLINE 6	Aids & Cues
a. Inspectors not required to make visible emission evaluations b. smoke emissions measured by Federal Government using reflectance test of withdrawn filtered sample	

IV. Summary

The shade of smoke from incineration is often related to the type of material that is being burned. Some materials should not be burned, and much less smoke will be created if those that are burned are disposed of in multiple-chamber incinerators.

Agricultural burning should be controlled as much as possible by restricting it to days when atmospheric conditions will aid dispersion but will not increase the risk of accidental fires.

Under high humidity and low atmospheric temperature conditions, the burning of natural gas will produce dense white plumes composed of water droplets.

Most of the emissions from gasoline engines are invisible. However, during warmup on cold days there will be a water vapor plume. Black or blue smoke indicates that the engine is in need of repair. Continuous emissions from a diesel engine also mean an engine adjustment is required. However, sometimes the diesel engine has been adjusted deliberately to give more power at the expense of increased fuel usage and waste.

Jet aircraft engines are not evaluated for visible emissions. Instead, smoke emissions are evaluated while the jet engine is being certified on a test stand by the Federal Government. An exhaust filter sample is collected and the filter is measured by a reflectance test to meet a specified smoke number.

INSTRUCTOR LESSON PLAN 7

Subject:	NON-COMBUSTION EMISSIONS AND WATER VAPOR PLUMES
Objective: The student should be able to list several industrial operations in his region that emit visible plumes; describe the points in these processes at which the emissions occur, and describe the exterior appearance of the source of the plume. He should also be able to define relative humidity, identify a wet plume, list several sources of wet plumes, and explain the effects of temperature and relative humidity on wet plumes.	
Suggested Time: 40 minutes	
Required Equipment: 35 mm Slide Projector	

LESSON OUTLINE	Aids & Cues
Introduction:	
If air pollutant emissions are categorized, many of the sources fall in the classifications of fuel combustion, transportation, and solid waste disposal. All of these can be filed under combustion. The one major class of sources that does not fall in combustion is called "industrial process losses." The process pollutants are emitted in several forms: fumes, dusts, mists, gases, and vapors. They cannot truly be called smoke since smoke should be used to describe only the visible effluent resulting from incomplete combustion and consisting mostly of soot and fly ash.	
These non-combustion pollutants may be emitted from many operations including grinding, melting, cooking, and handling. Whether they are visible or not will depend on their nature, their size, and whether they emerge in solid, liquid, or gaseous form.	
Most industries make some provision for limiting the amount of these process losses reaching the atmosphere. Thus cyclones, wet scrubbers, electrostatic precipitators, and fabric filters are standard equipment in many plants. The removal of particulates, vapors, gases, and heat from the exhaust stream by	

LESSON OUTLINE 7	Aids & Cues
washing with water is used in many industries. In this process, large quantities of water vapor are emitted to the air and result in very visible white plumes. While these wet plumes are primarily made up of condensed water vapor, they will also generally contain some of the pollutants since no collector is 100% efficient.	
Of the many industrial sources of visible non-combustion plumes, I will discuss a few that are located in and around this area with additional comments concerning some of the industries that are considered as major, nationwide, air pollution problems.	
The emissions from many of these industries are regulated primarily by ordinances other than Ringelmann or opacity; such as, process weight rules. However, the visible emissions regulations are generally written to be all encompassing so that they cover fumes, dusts, vapors, etc. The smoke inspector may thus be required to make density evaluations on plumes from sources where the problem is not incomplete combustion.	
I would like to speak first about some equipment and terminology that is used in several industries and then go into the description of several industries. (The Instructor Lesson Plan outlined here contains more material than can be covered in the allotted time.)	
The instructor should tailor this lecture to the industries of his area, discussing the ones that the smoke inspector will see. Information is given on several typical industries and associated equipment. If there are industries in the area that emit visible plumes but are not described in the text, the instructor should plan to take pictures of these sources and learn about their operational processes. He should use whatever information is available from the company itself, engineering books and other	

LESSON OUTLINE 7	Aids & Cues
reference books.	
I. List and briefly describe some metallurgical terms, several types of furnaces, and several types of driers.	
A. Metallurgical terminology	
1. metals industry	
a. primary	
b. secondary	
2. smelting	
3. electrolytic reduction	
4. roasting or calcining	
5. sweating	
6. sintering	
7. quenching	
8. refractory material	
B. Furnaces	
1. reverberatory - open hearth	
2. cupola - used for iron castings	
3. electric furnaces	
a. direct arc	
b. indirect arc	
c. resistance	
d. induction	7-1
4. crucible	
5. pot	
C. Types of driers	
1. rotary	7-2
a. direct	
b. indirect	
2. flash	7-3
3. spray	
4. tray or compartment	

LESSON OUTLINE 7	Aids & Cues
II. Describe several of the following industries pointing out the sources of atmospheric emissions, the composition of the pollutants (for example, dust, iron oxide, fume, etc.) the size of the aerosols, any identifying color, and the emissions that are combined with water vapor.	
A. Iron and Steel Mills	7-4, 7-5
1. blast furnace	
a. the smelting process — continuous operation	
b. operation	
c. emissions	
1. particulates — dust catcher, "slips"	
2. carbon monoxide — used as fuel for the stoves	
2. sintering plant	
a. the process	
b. emissions	
3. open hearth furnace	7-6
a. the process (see description of reverberatory furnaces)	
b. emissions	
1. composition	
2. size	
4. basic oxygen furnace	7-7
a. the process - faster than open hearth	
b. emissions	
1. comparison with open hearth	
2. newer and more economical process, thus additional and better pollution control is used	
5. electric arc furnace	7-8
a. special uses	
b. emissions	
1. composition	

LESSON OUTLINE 7	Aids & Cues
2. control	
6. By-product coke ovens	
a. process	7-9
1. charging	
2. coking	
3. discharging	
4. quenching	
b. emissions	
1. composition	
2. emission controls	
c. by-product gas processing	
d. visible emission regulations	
B. Gray Iron Foundries	
1. gray iron and white iron - definitions	7-10
2. melting and casting of iron	
3. emissions	
a. dust, smoke, oil vapor, fumes	
b. size	
c. control	
4. coke oven emissions	
C. Non-Ferrous Metallurgical Industry	
1. aluminum	7-11
a. primary	7-12
1. electrolytic reduction process	7-13
2. emissions	
3. control methods	
b. secondary recovery	
1. process	
2. emissions	
3. control methods	
2. lead and zinc - often done at same factory	
a. primary	

LESSON OUTLINE 7	Aids & Cues
1. roasting, sintering, smelting, and electrolytic reduction	
2. emissions	
3. control methods	
b. secondary	
1. raw materials	
2. emissions	
3. control methods	
3. copper	
a. primary	
1. recovery from copper sulfide ore	
2. emissions	
b. alloys — boiling temperatures and pouring temperatures	
1. bronze — limited emissions	
2. brass — considerable emissions	
D. Petroleum Refining	
1. processes	7-14
a. separation — fractionation	
b. conversion — catalytic cracking	
c. treating	
d. blending	
2. catalyst regeneration	
a. fluid catalytic cracking	7-15
b. thermofor catalytic cracking	7-16
c. emissions	
d. FCC - new source performance standard of EPA	
3. airblowing of asphalt	7-17
a. process	
b. emissions	
4. sludge burning	
5. flares	
a. need	

LESSON OUTLINE 7	Aids & Cues
b. emissions and control	
E. Cement and Lime manufacture	7-18, 7-19, 7-20, 7-21
1. cement manufacture	
a. wet mixing	
b. dry mixing	
c. production of clinkers in kiln	
d. grinding	
2. process emissions	
a. dusts	
b. control	
3. lime manufacture	7-22
a. process	
b. dust emissions and their size	
F. Manufacture of paper pulp in kraft mills	7-23
1. process - separation of cellulose from lignin	
a. cooking in digester	
b. blow tank	
c. cellulose to finished paper or pulp	
d. recovery of chemicals from lignin	
2. emissions	
a. odors	
1. gases	
a) hydrogen sulfide	
b) methyl mercaptan	
c) dimethyl sulfide	
2. sources	
a) digester blow systems	
b) evaporators	
c) recovery furnaces	
d) lime kilns	

LESSON OUTLINE 7	Aids & Cues
b. particulates	
1. types	
a) sodium sulfate	
b) sodium carbonate	
c) carbon particles	
d) lime dust	
e) water vapor	
2. sources	
a) recovery furnace — chimney	
b) lime kiln	
c) smelt tank, causticizer, blow tank, and digester — mists	
d) bark burning — chimney	
G. Sulfuric acid manufacture	
1. basic process	
a. generation of SO_2	
1. burning of S	
2. oil refinery H_2S	
3. primary smelters	
4. power plants — experimental	
b. oxidation to SO_3	
c. hydration to H_2SO_4	
2. methods	
a. chamber process — little used	
b. contact process	7-24
1. sulfur burning	
2. four-stage converter — vanadium pentoxide catalyst	
3. economizer — cooling	
4. absorption tower	
3. contact process emissions	
a. sulfuric acid mist	
b. tall stack from absorption tower	

LESSON OUTLINE 7	Aids & Cues
c. particle size	
H. Nitric acid manufacture	7-25
1. process	
2. emissions	
a. sources	
b. colors	
1. NO — colorless	
2. NO_2 — red-orange-brown.	
c. control	
I. Phosphoric acid manufacture	
1. thermal or phosphorous burning process	7-26
a. operations	
1. oxidizing	
2. hydrating	
3. absorption	
b. emissions — mist	
1. source	
2. composition	
2. wet process	7-27
a. operations	
1. decomposition of phosphate rock by sulfuric acid	
2. filtering of gypsum from phosphoric acid	
3. concentration	
b. emissions	
1. composition — phosphate rock contains fluorine	
a) dust	
b) fluoride	
c) fluoride particulates	
d) acid mist	
2. sources	

LESSON OUTLINE 7	Aids & Cues
J. Phosphate fertilizer manufacture	
1. process and fertilizers — % phosphorous pentoxide	
a. normal superphosphate	
1. mixing of phosphate rock and sulfuric acid	
2. "denning"	
3. drying	
b. triple superphosphate	7-28
1. mixing of phosphate rock and phosphoric acid — continuous process	
2. alternate treatments	
c. diammonium phosphate	
d. granulation of the fertilizer	
2. emissions	
a. gases	
1. silicon tetrafluoride	
2. hydrogen fluoride	
b. particulate dusts — visible	
1. sources	
a) drying	
b) handling	
c) drying and storing	
d) granulation and blending	
2. control methods	
K. Paint and varnish manufacture	
1. process — cooking of ingredients at high temperatures	
2. emissions	
a. type	
b. causes	
c. size	

LESSON OUTLINE 7	Aids & Cues
L. Hot-mix asphalt batching	7-29
1. operations	
a. conveying aggregate	
b. drying aggregate	
c. heating asphalt	
d. measuring out aggregate	
e. mixing	
f. delivering to trucks	
2. emissions — dust	
a. sources	
b. sizes	
c. control	
1. cyclones	
2. scrubber — wet plume	
M. Soap and detergent manufacture	
1. soap making process	
a. hydrolysis	
b. boiling	
c. drying	
2. detergent manufacture process	7-30
a. sulfonation	
b. neutralization	
c. drying	
3. emissions	
a. sources of particulate matter	
1. spray drying	
2. handling of dry materials	
b. control	
1. cyclone	
2. wet scrubber	7-31
3. wet type precipitator	
c. dense white plume	
1. primarily water vapor	

LESSON OUTLINE 7	Aids & Cues
N. Water vapor plumes	
1. water in the air	
a. vapor (gaseous state) — invisible	
b. liquid or solid — visible	
2. relative humidity	
a. definition	
b. how it can be increased	
1. add moisture	
2. cool the air	
c. saturation	
1. 100% humidity	
2. more water vapor or cooler temperature results in condensation to liquid	
3. wet plumes	
a. white	
b. occurrence and duration are dependent upon relative humidity	
c. identification	
1. wispiness	7-32
2. detached plume in hot weather will not appear detached in cold weather	7-33
3. effect of atmospheric humidity	7-34
4. plumes containing water and dust	7-35
a. particulate trail remains after evaporation of water	7-36
b. regulatory problems	
1. where to read the plume	
2. uncombined water	
3. difficulties in judging a violation (may call for a source test)	
5. objections to wet plumes	
a. ground fog and decreased visibility	
b. icing in cold weather	

LESSON OUTLINE 7	Aids & Cues
c. combination to form harmful pollutant	
d. aesthetics	
6. sources of water vapor plumes	
a. drying operations	
b. combustion	
c. air pollution control devices using water	
d. cooling to remove combustion or chemical reaction heat	
7. elimination of visible wet plumes	
a. methods	
1. dilution	
2. superheating	
3. condensing the water	
b. expensive	
III. Summary	
We have discussed a cross section of industries that have visible process emissions. In some areas these may be major sources; in other areas the size of the manufacturing output may be small and the emissions may be minor. Some of these processes, like asphalt batching, can be found in almost every city; others, like primary smelting, may be in only a few states.	
Some processes, like drying in rotary kilns, and equipment, such as cupola furnaces, as well as controls, such as wet scrubbers, are found in several industries. By learning that all of these put out visible plumes of particulates or water vapor, you can transfer your understanding of causes of visible emissions from one process to another and know what to expect at different types of factories.	
When viewing an industrial plant for the first time, you may see one or more stacks. These may or may not be visible plumes coming from these stacks. There may be visible emissions that are not coming from stacks. The emissions may	

LESSON OUTLINE 7	Aids & Cues
be continuous or intermittent. They may be put out 24 hours a day or only 8 hours a day. They may or may not be accompanied by odors.	

I now expect you to be able to look at a plant and be able to make mental comments like:

"That stack is puttong out smoke from a combustion process used to produce heat or power."

"That white plume is coming from a wet scrubber being used to remove the particles from the exhaust gases."

"Although there is no visible plume from that tall thin stack, air pollutants are being emitted. They may be sulfur dioxide or sulfur trioxide."

"That rotary drum must be putting out dust emissions. If I cannot see them, then they are being collected by some device."

These are starters. Keep learning about industrial processes, their emissions, and points of emission. Observe factories in operation and compare them with process flow charts that you can find in engineering books and journals. Ask questions. Little by little your knowledge will increase.

35 mm Slides Describing Water Plumes

Slide Number	Description
7-32	Short water plumes from natural gas power plant stacks and long particulates plume from plant manufacturing refractory materials. Moss Landing, California (Photo by John Maloney, Salinas, Calif.)
7-33	Detached plume, natural gas industrial boiler. Columbus, Ohio
7-34	High humidity on cold autumn morning, brewery. Columbus, Ohio
7-35	Low humidity on warm autumn afternoon, brewery. Columbus, Ohio
7-36	Particulate trail after water has evaporated

Subject: CLASSIFICATION AND IDENTIFICATION OF SOURCES

Objective: The student should be able to list the items he should record in the field when describing a plume, define fugitive emissions, and state the clues that can aid him in identifying the sources of visible plumes.

Suggested Time: 40 minutes

Required Equipment: 35 mm slide projector

LESSON OUTLINE	Aids & Cues
Introduction: There are many sources of air pollutant emissions. For ease in record keeping and in talking about these sources, it is convenient to categorize them. A description or a control device that applies to one member of the category may be applied to all members. A coal-fired industrial boiler in one city is going to have many of the same characteristics as coal-fired industrial boilers in other cities or in other parts of the same city. Emission measurements on a few similar sources are standardized as "emission factors" and used for all sources of this type. The inspector should learn to classify the various sources of visible emission into standard categories and to identify these sources by their outward appearance. Much of this ability for identification can come only by experience. In this lecture we can only suggest some methods for identifying types of industrial and commercial sources.	

2

LESSON OUTLINE 8	Aids & Cues
I. List some categories into which pollution sources could be divided and show an all-inclusive classification system	
A. Source categories	
1. mobile and stationary	
2. point and area	
3. combustion and non-combustion.	
4. industrial, commercial, and residential	
5. subclassification	
a. coal, oil, and natural gas combustion	
b. jet- and piston-powered aircraft.	
B. An all-source classification	8-1
1. Fuel combustion — stationary sources	
2. Fuel combustion — mobile sources	
3. Industrial process losses	
4. Solid waste disposal	
5. Miscellaneous.	
II. Discuss ways in which the inspector can learn how to identify the cause of a visible plume after the plume has been observed.	
A. Information sources	
1. associates	
2. engineering books	
3. EPA publications	show example
4. photographs of similar sources.	
B. Clues for identification of specific sources	
1. company name	
2. Directory of manufacturers	
3. air pollution files	
4. telephone directory	
5. factory surroundings and visible equipment	8-2, 8-3 8-4, 8-5
6. shape of the building	

LESSON OUTLINE 8	Aids & Cues
7. stack or fugitive dust emissions	8-6
8. plume color	8-7
9. odor	8-8, 8-9
10. effects of pollutant	
11. equipment and collection devices	8-10, 8-11
12. variations in plume during the day.	8-12, 8-13
C. Emission description that inspector should make	
1. nature of particulate — dust, fume, etc?	
2. wet plume?	
3. character of emission	
a. plume	
b. cloud	
c. haze	
d. fugitive emissions	
4. plume categories	
a. coning, fanning, etc.	
b. detached	
c. point of dissipation	
d. plume rise	
e. point where it hits the ground.	
D. Identification of causes	
1. If source type is known and inspector understands the process, he may be able to determine the exact cause.	
2. For combustion emission, the color of the smoke may be a help.	
III. Use selected slides to illustrate different sources, process equipment and collection equipment that may help inspector in identifying sources and causes of visible emissions.	select slides from list at end of this lesson
A. Industrial sources	
B. Manufacturing process equipment	
C. Air pollution collection devices.	

LESSON OUTLINE 8	Aids & Cues
IV. Summary The new inspector should use all his detective powers of careful observation and research to gain experience in the types of air pollution problems under his jurisdiction. His knowledge of the sources and causes can aid him in dealing with his associates, with the polluters, and with the public. He should be able to identify and classify in several types of categories all the sources of visible emissions which he will encounter. 1. Type of source — industry, commercial, residential; mobile or stationary 2. Type of emissions 3. Type of plume 4. Part of the combustion or processing system that is causing the problem.	

35 mm Slides for
Classification and Identification of Sources

Slide Number	Topic	Comment
8-1	Example of Comprehensive Source Classification System	Based on System in APTD-1135
8-2	Lead and zinc smelter East Helena, Montana	Large stack, large slag pile
8-3	Portland cement plant Fairborn, Ohio	Note cement hauler in front
8-4	Steam electric plant near Columbus, Ohio (coal-fired)	Note high tension wires and shape of building
8-5	Building housing a basic oxygen furnace, Middletown, Ohio	Note shape of building and red oxide plume
8-6	Plant for removing fluorides from phosphate rock Garrison, Montana	Note emissions from stack and fugitive dust; corroded parts from plant are in field to left
8-7	Steam-electric power plant Lawrenceburg, Indiana (coal-fired)	Note cream color of plume; tall stacks
8-8	Brewery Worthington, Ohio	Odor is distinctive; water vapor plume
8-9	Rendering plant Columbus, Ohio	Odor is distinctive; note stack type and equipment in the yard
8-10	Oil refinery near Houston, Texas	Note plumes from flare and from furnace stack
8-11	Contact process sulfuric acid plant Columbus, Ohio	Note the design of the identifying equipment--the four-stage convertor with the circular pieces on its side
8-12	Asphalt plant, Newtown, Ohio	Uncontrolled
8-13	Asphalt plant, Newtown, Ohio	Controlled with scrubber
8-14	Coke oven battery Toledo, Ohio	Shoving of coke from oven to car has just begun
8-15	Coke oven battery Toledo, Ohio	All of coke has been pushed from oven to quench car

Slide Number	Topic	Comment
8-16	Plant for removing fluoride from phosphate to be used as animal food supplement	Note rotary driers
8-17	Hyperbolic cooling tower and tall stack Steam-electric plant Beverly, Ohio	Water vapor plume
8-18	Warehouse Fire Columbus, Ohio	Note black and brown smoke
8-19	Burning of weeds to clean out water ditches Billings, Montana	Note white smoke caused by burning material containing water
8-20	Plume from jet airplane Columbus, Ohio	Taken while plane was landing
8-21	Diesel-powered bulldozer Columbus, Ohio	Taken while bulldozer operator was feeding fuel to get added power
8-22	Fertilizer manufacture Cincinnati, Ohio	Water vapor plume matches the clouds
8-23	Zinc oxide manufacture Columbus, Ohio	Note color of fugitive dust
8-24	Truck dumping waste material Columbus, Ohio	Dust of fairly large size settles back to earth rapidly
8-25	Open burning at foundry Columbus, Ohio	Note color of smoke and the material being burned
8-26	Plumes from foundry cupola and from open burning at foundry Columbus, Ohio	Note colors of plumes and the small particles that stay aloft
8-27	Conical burner used for incineration Evendale, Ohio (wood wastes)	Note that visible emissions are present even with conveyor feed
8-28	Power plant Wood River, Illinois (coal-fired)	
8-29	Plant for generating steam to heat downtown Toledo, Ohio (oil-fired)	
8-30	Conical ("tepee") burner at lumber mill Bozeman, Montana (burning wood waste)	

Slide Number	Topic	Comment
8-31	Cement plant near New Orleans, Louisiana	Note rotary kiln and four stacks used to emit particles and water vapor from different parts of the kiln
8-32	Fluid catalytic cracking unit at petroleum refinery Los Angeles, Calif.	
8-33	Petroleum refinery Toledo, Ohio	Five narrow towers are fractionating (distillation) units; large diameter unit is a catalytic cracking unit
8-34	Fertilizer manufacture Columbus, Ohio	Water vapor and dust
8-35	Kraft process pulp mill Albany, New York	Tall stack is chimney from black liquor recovery unit
8-36	Asphalt batching plant Worthington, Ohio (Scrubber for control)	Afternoon, good dispersion; water vapor mainly
8-37	Asphalt batching plant Worthington, Ohio (Scrubber for control)	Early morning, poor dispersion, inversion
8-38	Asphalt batching plant Worthington, Ohio (Scrubber for control)	Morning, closeup
8-39	Detergent manufacturing plant St. Bernard, Ohio (near Cincinnati)	Spray tower exhaust gives plume containing considerable water vapor
8-40	Copper smelter near Salt Lake City, Utah	White plume still containing considerable dust by time it reaches the ground
8-41	Lead smelter East Helena, Montana	White plume blends in with the clouds on this day
8-42	Aluminum reduction plant Chalmette, Louisiana	
8-43	Coke plant Middletown, Ohio	Quenching the hot coke with water
8-44	Gray iron foundry Columbus, Ohio	Morning with light wind
8-45	Blast furnace and four stoves Toledo, Ohio	

Slide Number	Topics	Comment
8-46	Steel mill Middletown, Ohio	Blast furnace and BOF
8-47	Steel mill plumes over Gary, Indiana	Wind blowing in from Lake Michigan in the afternoon
8-48	Thermal-process phosphoric acid plant Addyston, Ohio (near Cincinnati)	Plume from tall narrow stack contains some phosphoric acid and much water vapor —emissions from hydrator-absorber after passing through abatement equipment
8-49	Furnace process carbon black plant, Toledo Ohio	No black plume
8-50	Diesel truck	
8-51	Jet emissions	
8-52	Automobile smoke	
8-53	Ferry boat	
8-54	Power plant	
8-55	Open hearth shop	
8-56	Blast furnace and stoves	
8-57	Blast furnace during "slip"	
8-58	Black smoke from oil refinery flare	
8-59	Oil refinery	
8-60	Mist and vapor from paint manufacture	
8-61	Nitric acid plant	
8-62	Phosphate plant, Florida	
8-63	Phosphate plant, Florida	
8-64	Fertilizer manufacture	
8-65	Kraft pulp mill	
8-66	Lumber mill	

Slide Number	Topic
8-67	Cement plant
8-68	Cement plant
8-69	Asphalt batching plant
8-70	Tepee burner
8-71	Open burning
8-72	Open burning

Subject: RINGELMANN CHART AND EQUIVALENT OPACITY
Objective: The student should be able to define Ringelmann Number and Equivalent Opacity, identify the five cards of the Ringelmann chart, describe how an observer is trained to make plume observations in the field without a chart or other aids, identify the advantages of visible emission regulations, and list the aids and alternative methods for evaluating plume shades.
Suggested Time: 45 minutes
Required Equipment: 35 mm Slide Projector Ringelmann Chart

LESSON OUTLINE	Aids & Cues
Introduction: Visible emission laws are written so that plumes of a specified shade or opacity are illegal, but plumes of a slightly lighter shade or opacity are legal. To enforce these laws inspectors must be trained to distinguish between small variations in the optical density of plumes. First a scale must be set up so visible emissions can be graded from no smoke to totally black or totally opaque. Here, air pollution regulation makers have incorporated for gray-black smoke a scale devised in France in the 19th century by an engineering professor, Maximilian Ringelmann. To regulate the optical densities of emissions that were white or other colors besides gray and black, the County of Los Angeles in the 1940's developed the concept of equivalent opacity, which specified that these non-black plumes should be judged by the amount of light that they failed to transmit. Thus a white plume through which an observer could see an object with 65% clarity was considered to be acceptable but one through which the observer could see an object with only 55% clarity was unacceptable. The 65% transmission was termed 35% opacity and the 55% transmission was called 45% opacity. When these regula-	

LESSON OUTLINE 9	Aids & Cues
tions for non-black plumes were devised, the opacities were related to the already established limits set by the Ringelmann scale. Thus the opacities of non-black emissions were equivalent to Ringelmann numbers and the term "equivalent opacity" was derived.	
As time passes, the restrictions on acceptable visible emissions are being lowered so that 20% equivalent opacity is the dividing point for emissions in most jurisdictions or for most sources. In some areas and for some sources, even lower opacities are required. However, until all visible emissions are outlawed there must be inspectors who can distinguish between shades of gray smoke or opacities of white plumes.	
I. Describe the Ringelmann Chart and the extension to equivalent opacity	
A. History of Ringelmann Chart	
1. developed by Ringelmann about 1890	
2. incorporated into Boston law in 1910	
3. originally applied to emissions from coal-fired boilers	
4. excessive emissions for short periods in an hour may be allowed for starting up or soot blowing	
B. Equivalent Opacity	
1. California extended visual standards	
2. Prohibited plume of any color having an opacity that will obscure an observer's view to a degree equal to or greater than smoke of Ringelmann number 2 shade	
3. Observer generally judges amount of light <u>transmitted</u> through both black and non-black plumes	
a. relates transmittance to reflectance from Ringelmann Chart for black plumes	
b. relates transmittance to opacity for non-black plumes	
C. Smoke density and equivalent opacity	

LESSON OUTLINE 9	Aids & Cues
1. definition of density for use in visible emissions — quantity per unit volume or area	
a. Ringelmann Chart — ratio of area occupied by black grid lines to total area	
b. black plume — shade of gray related to the Ringelmann Chart density	
2. opacity — degree to which transmitted light is obscured	
D. Construction of the Ringelmann Chart	show Ringelmann Chart
1. Four cards with black lines of different thickness	
2. Blend into gray areas when viewed from a distance.	(see page 166)
3. Official chart referenced in air pollution law is published by the Bureau of Mines.	
4. If used in field, chart should be 50 feet from observer.	
5. Readings are made to nearest 1/4 Ringelmann.	
E. Opacity expanded to all visible emissions	
1. First appeared in Federal Register in 1971	
2. Concepts behind one measurement system	
II. Discuss the regulating of emissions by setting limits on the opacity of the emissions and the advantages of this method.	
A. Relation of visual observations to actual weight of emissions	
1. For a specific source operating under specified conditions, a correlation has been found between grain loading and opacity but correlation is not transferable to other sources.	
2. Ensor and Pilat have developed a general theoretical relationship between plume opacity and particulate mass concentration for several substances	
3. Visible emission standards can show that more efficient	

LESSON OUTLINE 9	Aids & Cues
combustion may be required 4. If distribution of particle sizes in plume is uniform, then reducing concentration of visible submicron particles will substantially reduce the total weight of emissions B. Cost and comparison with source testing 1. Observer-inspector can be trained in 2 to 3 days. 2. Does not require extensive technical background. 3. One man can make observations of many sources in 1 day whereas it may require as many as 2-4 men to conduct a source test lasting several days including laboratory analysis, calculations, and reports. 4. No expensive equipment is required. 5. Questionable emissions can be located by visual observation and then source tests run if needed. 6. Method for controlling emissions that are difficult to source sample, e.g. fugitive emissions. 7. Can be used for observations of mobile sources a. read at point of maximum density b. use stop watch c. read plume at an angle d. take photo. C. Accuracy 1. With proper training and recertification at least every 6 months, an inspector can maintain his accuracy. D. Criticisms of visible emission regulations. 1. Criticisms a. Opacity or density varies with position of observer and position of the sun. b. Opacity measurements cannot in general be correlated with instruments measuring pollutant mass rate of emission. c. Colorless gaseous emissions cannot be regulated	

LESSON OUTLINE 9	Aids & Cues
by visible emission regulations.	
d. Without proper lighting as a background, visible emissions are difficult to apply at night.	
e. Water vapor plumes may be erroneously judged as violation of air pollution regulations.	
f. Visible emission regulations can be circumvented by diluting with air prior to discharge into the atmosphere or by building a stack of smaller diameter.	
2. Many criticisms may be surmounted if the inspector will always follow standard procedures for observing plumes	
a. keep the sun in the 140° sector to your back.	
b. read plume at a short distance above the stack before it has begun to spread out.	
c. identify whether the plume contains water vapor by its appearance and then read the plume at the point where the water evaporates or if a detached plume, prior to the condensation of the water vapor. If there is a choice between the two, read the one with maximum opacity.	
d. Wait until meteorological conditions improve.	
III. Describe the various (seldom used, except #5 below) smoke reading aids and alternatives to visual evaluation and discuss their advantages and disadvantages.	
A. Aids	
1. smoke tintometer	9-1
2. umbrascope	
a. cannot measure density less than 60%	
3. smokescope	
4. PHS film strip	
a. film may change from body heat when carried in shirt pocket	
b. $15 cost	
5. smoke comparison charts	
a. hold at arm's length	

LESSON OUTLINE 9	Aids & Cues
6. general disadvantages a. applicable only to gray-black smoke b. give only a limited number of Ringelmann numbers c. not significantly more accurate than sight reading B. Alternatives 1. photoelectric cell a. mounted in stack b. problems 1) periodic zeroing 2) emission buildup 2. lidar a. new b. expensive - approximately $50,000	
IV. Sight readings advantages over devices	9-2
V. Summary Most people with normal eyesight can be trained to determine the correct shade of white or black emissions within an average accuracy of 7.5% as compared with transmissometer. With a regular schedule of retesting, air pollution control inspectors who have qualified as visible emission readers can form a strong enforcement arm. By using their visible emission reading capabilities they can maintain particulate emissions below a prescribed standard, can identify sources for which stack tests should be run, and can do these jobs at a smaller cost to their agency and to the taxpayer than any equivalent mechanical methods of regulating visible emissions.	

Subject: QUALIFICATION PROCEDURES AND EXERCISE IN RECORDING FOR QUALIFICATION	
Objective: The student should be able to list the requirements for qualifying as a visible emissions inspection, list the proper procedures for observing visible emissions in the field, and properly fill out the visible emissions training form.	
Suggested Time: 30 minutes	
Required Equipment: 35 mm Slide Projector	
LESSON OUTLINE	Aids & Cues

Introduction:

One and a half days of this course are devoted to observing series of black and white plumes to become a qualified observer. I shall now explain the standards you must meet to qualify and how the testing runs will be conducted. You will record your readings during the test on a training form. If you meet the required standards, you must fill out this form completely and hand it in to be examined and kept on record in the files. During this lecture, I shall also show you how to fill out this form.

I. Discuss the requirements for passing the visible emissions reading proficiency test.
   A. Observe 25 white and 25 black shades
   B. White recorded in percent equivalent opacity; black in Ringelmann numbers, or both in opacity.*
   C. Deviations allowed
      1. black - none of one Ringelmann or more (20% opacity)
      2. white - none of 20% opacity or more

*depending on your regulations

LESSON OUTLINE 10	Aids & Cues
D. Average deviation for 25 readings is less than 7.5% opacity in black and white categories E. Everything accomplished on one series of runs F. Training Form to be filled out and turned in. II. Describe the conduct of the outdoor proficiency tests A. Familiarization runs — correct readings announced B. Practice run 1. 25 black and 25 white 2. Student to record 3. Correct readings announced at completion 4. Student to figure out his score C. Qualification Runs 1. Repeated for remainder of the course 2. Student fills out form and records observations on original and one copy. Copy handed in; student grades his readings and calculates average deviation. 3. If student qualifies, he should complete entire form and hand it in. 4. No need for qualifying again during this course. D. Practice runs for violation citation — one black, one white 1. Read at 15-second intervals and determine total minutes that plumes were above Number 1 Ringelmann or 20% equivalent opacity. 2. Decide whether smoke generator operator was in violation. E. Read at sound of horn F. Use of aids G. Read under conditions that will exist in the field — dark glasses?	

LESSON OUTLINE 10	Aids & Cues
III. Review proper procedures for observing smoke	
A. Aim is to improve accuracy and maintain a uniform procedure	
B. Instructions	
1. sun in the 140° sector to observer's back	
2. night— light source behind the plume	
3. observer at right angle to the plume	
4. read a foot or two above the stack	
5. contrasting background (see discussion Method 9, Federal Register)	
6. don't stare at plume—in test, look at plume when horn sounds	
7. concentrate on reading; don't be distracted	
IV. Explain how visible emission training form should be filled out	10-1
A. Name, affiliation, date	
B. Time	
C. Location	
D. Wind speed	
E. Wind direction	
1. orientation	
2. 16 points of compass	
F. Sky condition - all levels	
1. clear	
2. scattered	
3. broken	
4. overcast	
5. estimation by quadrants	
G. Observer's position	
1. direction observer is facing	
2. relation to sun	
H. Run Number	

LESSON OUTLINE 10	Aids & Cues
I. Observer's Reading	
1. black – 0 to 100 in 5% increments	
2. white – 0 to 100 in 5% increments	
J. Transmissometer Reading	
K. Deviation columns	
1. explain minus and plus readings	
2. fill out in percent	
L. Sum and Number	
M. Qualification boxes	
1. run number	
2. number correct	
3. excessive deviations	
4. average deviation	
a. explain computation	
b. white and black figured separately	
N. Examiner	
V. Use slides to go through a sample visible emission reading exercise of 5 black and 5 white shades. Have students fill out form and make computations in class or at home in the evening.	10-2, 10-3, 10-4 10-5, 10-6 10-7, 10-8, 10-9 10-10, 10-11
VI. Summary In the visible emission reading proficiency test you will observe a series of 25 shades of black plumes and 25 shades of white plumes and record these in opacity readings. To qualify on this test you are required to complete one series of 50 readings during which you must: A. Read each shade with no deviations of 20% or greater (one Ringelmann or more for black plumes) B. Have an average deviation on both the black and white plumes of no more than 7.5% on the same run. There will be at least eight series of field runs during which you can try to qualify.	

35 mm Slide for
Exercise in Recording for Qualification

Slide Number	Topic	Comment
10-1	Smoke school training form	35%
10-2	Steam electric plant St. Louis, Missouri (coal-fired)	
10-3	Steam electric power plant Columbus, Ohio (coal-fired)	85%
10-4	Pathological incinerator New Orleans, Louisiana	90%
10-5	Feed plant, Sharonville, Ohio	75%
10-6	Industrial boiler at a cigarette manufacturer Durham, North Carolina (coal-fired)	45%
10-7	Fertilizer manufacture Columbus, Ohio	Read at end of water portion of plume 25%
10-8	Portland cement plant Fairborn, Ohio	Read at top of stack 50%
10-9	Aluminum reduction plant Chalmette, Louisiana	Read at point where water evaporated 80%
10-10	Sulfuric acid manufacture Columbus, Ohio	Read at top of tall stack 10%
10-11	University power plant Columbus, Ohio (coal-fired)	Equivalent opacity of wet plume read at top of nearer stack 100%; read at point where water evaporates 0%.

Subject: BASIC METEOROLOGY	
Objective: The student should be able to define temperature lapse rate and temperature inversion, identify the types of lapse rates and inversions, list the types of fronts and pressure areas, and draw the symbols used on weather maps to designate fronts and pressure areas. He should also be able to define turbulence and identify its causes, and describe its effects on plumes.	
Suggested Time: 30 minutes	
Required Equipment: Chalkboard, 35 mm Slide Projector	

LESSON OUTLINE	Aids & Cues
Introduction:	
The problem of air pollution has several aspects. Four important ones are source of pollutants, transport of pollutants, reception of pollutants, and control of pollutants. Meteorological factors enter principally into the transport of pollutants for these factors control the direction the pollutants take away from the source, how fast they travel, and how much they spread horizontally and vertically.	
Since the control of pollution must consider transport and diffusion, meteorology must also be taken into account in planning control strategies. The dispersive characteristics of the atmosphere will determine the relationship between source emissions and ambient air quality. During periods of high air pollution potential, it is the measurements of prevailing weather conditions and the forecasts of future conditions that determine what level of emergency controls should be activated.	
Meteorology can also control certain phases of the emission and reception of pollutants. More fuel is burned in cold weather and more dust is picked up when winds are strong. The formation of photochemical pollutants requires the energy	

LESSON OUTLINE 11	Aids & Cues
from solar radiation. Scavenging of pollutants from the air by precipitation cleanses the air but it can cause contamination problems at the ground. The corrosiveness of air pollutants to metal surfaces is related to atmospheric humidity. Sunlight, temperature, and humidity must be considered in determining the rate at which pollutants affect vegetation.	
I. Discuss radiation, lapse rate, and inversions.	
A. Radiation	11-1
1. solar radiation	
a. wavelengths	
b. maximum - 0.4 to 0.7 microns	
c. reflected, absorbed, transmitted, scattered	
d. clear and cloudy skies	
2. Earth	
a. radiates in longer wavelengths	
b. absorption by water vapor	
c. "greenhouse effect"	
d. surface as source of heat	
B. Lapse Rate	11-2
1. definition	
2. stability and dispersion	11-3
a. neutral stability and dry adiabatic lapse rate	
b. stable - temperature inversion	
c. unstable	
C. Inversions	
1. radiation type	
a. light wind	
b. clear sky	
c. depth	
d. morning break up	

LESSON OUTLINE 11	Aids & Cues
2. subsidence type	
II. Discuss fronts and pressure areas	11-4
A. Fronts	
1. cold	
2. warm	
3. stationary	
4. occluded	
5. movement	
6. relation to pressure areas	
B. Pressure areas	11-5
1. highs — characteristics	
2. lows — characteristics	
III. Discuss particles in the air and their effect on visibility	
A. Removal of particles and particle sizes	
1. settling — >20μ	
2. impaction — <20μ	
3. rainout — 0.1 to 1.0μ at cloud level	
4. washout — >1μ	
5. growth of small particles in moist atmospheres	
B. Scattering	
1. particles similar in size to visible wavelengths	
2. decrease in visual range	
3. dry haze	
4. damp haze	
5. mist	
6. haze layer	
7. forward scattering > backward scattering	

LESSON OUTLINE 11	Aids & Cues
IV. Discuss water in the air. A. Water vapor 1. invisible 2. relative humidity a. relationship to air temperature B. Liquid water 1. condensation a. temperature b. humidity 2. clouds and fog a. particle size b. radiational cooling c. cooling by lifting or convection 3. precipitation	
V. Discuss turbulence and eddies A. Thermal turbulence B. Mechanical turbulence C. Downwash D. Eddies — relationship between stability and their growth	11-6
VI Summary The dispersion of pollutants in the atmosphere is controlled by the wind and the stability of the atmosphere. Atmospheric stability is related to the lapse rate of temperature. The greater the instability, the faster a plume will spread out. Under inversion conditions plumes are prevented from dispersing rapidly. Areas of high pressure are accompanied by inversions, poor dispersion, and hazy conditions. Small particles the size of visible light wavelengths scatter the light and reduce the visibility at these times.	

Subject: METEOROLOGICAL FACTORS IN SMOKE READING

Objective: The student should be able to list the effects that weather elements can have on readings of plume shade, list the procedures the smoke observer should use to compensate for the effects, and to identify the information on a weather map that is important to a smoke inspector. He should also be able to define wind direction, identify the Beaufort specifications for wind speed classes, and make observations of cloud cover, wind direction, and wind speed for entering on the report form.

Suggested Time: 30 minutes

Required Equipment: Chalkboard and 35 mm Slide Projector

LESSON OUTLINE	Aids & Cues
Introduction: The readings that you will make as smoke inspectors may be used as evidence in court. Your testimony should be as objective (just the facts) as possible so that it can stand up under the questioning of a defense lawyer. Anyone who has looked at plumes has observed that they can vary in shape, shade, and brightness even though the rate of emission from the stack does not change. These variations of the plume are due to variations of atmospheric elements such as wind, sunlight, cloudiness, and humidity. You should understand the effects of these elements and, where possible, adjust your observation procedures to compensate for these effects. Whether or not you can compensate for the effects, you should make note of the weather conditions on your observation report so that you will have a record of them for future reference.	

LESSON OUTLINE 12	Aids & Cues
I. Describe the effects of weather elements on the readings of plume shade and point out procedures for compensating for these effects.	
A. Effects	12-1
1. dilution of plume by strong winds	
2. dispersion and downwind configuration of plume related to atmospheric stability	12-2
3. changing wind direction and the observer's line of sight through the plume	12-3, 12-4, 12-5 12-6
4. wind speed, wind direction, and the turbulent eddies caused by buildings and other obstructions	12-7 12-8, 12-9
a. relation of stack height to obstruction height	12-10
b. similarity to looping plume	12-11
5. light scattering, sun angle, and the effect on plume contrast	
6. contrast and effects of weather elements	
a. contrast between plume and background	
b. illumination of plume and background	
c. effect of hazy atmosphere on contrast	
d. effect of different sky shades on contrast	
e. seasons, tree leaves, and background	
B. Procedures for compensating for weather effects	
1. Observe plume at right angles to the wind	
2. Observe portion of plume just above the stack	
3. Observe plume with sun within 140° sector to your back	
4. Pick out background that contrasts with color of plume, if possible.	
C. Make notes on weather conditions	
II. Explain atmospheric humidity, how to estimate the humidity, how it affects wet plumes, and point out that its variations can help the inspector to identify wet plumes.	

LESSON OUTLINE 12	Aids & Cues
A. Relative humidity 1. percentage of saturation 2. water vapor, liquid water 3. saturation and condensation 4. effect of air temperature on amount of water vapor atmosphere can hold 5. Estimates of humidity a. clouds and fog b. moisture on ground c. static electricity B. Relative humidity and wet plumes 1. higher humidity, smaller rate of evaporation 2. higher humidity, greater persistence of wet plume 3. colder temperature, faster condensation 4. detached plumes and their relationship to air temperature 5. methods of identifying plumes containing moisture a. rate of evaporation and wispiness b. persistence of non-water particles after evaporation c. longer plumes on cold moist days d. detached plume on hot days, but not on cold days	
III. Discuss the elements that appear on weather maps and weather forecasts and point out the portions of these that can be useful to the inspector.	12-12
A. Importance of weather report items to smoke inspector 1. fronts, precipitation a. comfort of smoke reader b. shower or steady precipitation c. cleansing of particles by precipitation and improvement of visibility d. precipitation, relative humidity, and wet plumes	

LESSON OUTLINE 12	Aids & Cues
2. temperature a. comfort b. relative need for heating and fuel combustion c. detached wet plumes 3. wind direction a. observer position b. complaints c. downwash 4. wind speed a. dilution b. plume rise 5. relative humidity a. wet plumes 6. lows and highs a. lows — precipitation b. highs (1) low wind speeds (2) clear skies (3) decreased visibility, more haze (4) less clouds 7. cloudiness a. background for plume b. clear skies (1) night — inversions and fanning plumes (2) day — instability and looping plumes IV. Point out the weather observations that the inspector must enter on his observation form and explain how these observations should be made and the units in which they should be entered on the report.	

LESSON OUTLINE 12	Aids & Cues
A. Cloud cover	
1. definition	
2. measured in tenths	
3. terminology	
a. clear	
b. scattered	
c. broken	
d. overcast	
4. estimation by division of sky into quadrants	chalkboard, 12-13
B. Wind direction	
1. direction from which wind blows	
2. 8 or 16 points of the compass	
3. inspector must know his orientation to north	
4. direction from blowing flags, paper, or grass	
C. Wind speed	
1. anemometers and their standard exposure	
2. units — usually miles per hour	
3. Beaufort scale	12-14
a. history	
b. application to land sites	12-15, 12-16 12-17, 12-18 12-19, 12-20
D. Wind variations	
1. variations with height — effect of ground friction	
2. variation during plume observation period	
E. Atmospheric stability observations	
1. not required on form	
2. can be estimated from time of day and plume shape	
3. can help in distinguishing between mechanical and thermal turbulence effects on plume	
V. Summary	
A. Meteorological elements affecting plume observations	

LESSON OUTLINE 12	Aids & Cues
1. Wind speed — dilution 2. Wind variability — dispersion 3. Direction of sun — forward scattering greater than backward scattering 4. Cloudiness — illumination of the plume and the background B. Plume reading procedures to overcome meteorological effects 1. Plume should be viewed with sun within 140° sector to observer's back; 2. Observer should look at the plume from a direction approximately perpendicular to the wind direction 3. Observer should view the portion of the visible plume nearest to the stack; 4. Pick out a background that contrasts with the color of the plume. C. Importance of Contrasting Background as stated in EPA Method 9: "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 effect 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	

LESSON OUTLINE 12	Aids & Cues
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.

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

LESSON OUTLINE 12	Aids & Cues
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."	

35 mm Slides Describing Plume Types

Slide Number	Description
12-3	Looping
12-6	Coning (Cement plant)
12-4	Fanning
12-5	Fumigation (Pulp mill plume, 7 a.m., July, Lewiston, Idaho)
12-11	Downwash caused by building

Subject: LEGAL ASPECTS OF VISIBLE EMISSIONS
Objective: The student should be able to differentiate between common law and statute law, cite the decisions in the appeal cases of the Los Angeles, California visible emissions statute, identify the requirements for a good air pollution law, state the visible emission regulation in effect in his own region, identify the criteria for being an expert witness, and list the rules of courtroom behavior for an expert witness.
Suggested Time: 40 minutes
Required Equipment: Chalkboard and 35 mm slide projector, 16 mm sound movie projector with 14" takeup reel.

LESSON OUTLINE	Aids & Cues
Introduction: The purpose of a visible emissions regulation is to control the amount of air pollutants put out by a stack or tailpipe. The law sets a standard— a specified Ringelmann Number or equivalent opacity percentage— that determines what smoke is illegal. The role of the air pollution control officer or inspector is to enforce this law. He observes the smoke emissions and may issue a citation when he sees a violation of the law. In this procedure he is similar to a traffic policeman who gives out a ticket to a driver who exceeds a specified speed, this speed having been determined as being unsafe for the prevailing conditions such as congestion, population, street width, etc. Like the traffic policeman, you the air pollution officer as part of your job, will sometimes be required to testify in court concerning your observations. In this lecture we will discuss the body of air pollution law that has grown up and which has been tested in appeals cases. To prepare you for your time on the witness stand, we shall discuss several pointers on how to be an expert witness. ("Role of the Witness," a motion picture may serve as the foundation for this portion of your presentation.)	

LESSON OUTLINE 13	Aids & Cues
I. Discuss the development of visible emissions law	
A. Common law and statute law	
1. common — prove injury in each case	
2. statute— black smoke is always a nuisance; injury does not have to be proven in each case	
B. Air pollution regulation power belongs to the States	
1. This power is given to the States by the 10th amendment	13-1
2. The State can grant this power to the city or county.	
3. Only limitations on States' power is in 14th amendment	13-2
C. Ringelmann Standard and Equivalent Opacity Standard	
1. Massachusetts — 1910	
2. Los Angeles — Section 24242	13-3
a. subsections for Ringelmann and Equivalent Opacity	
3. Method 9, Federal Register: Opacity	
D. Constitutionality tests	
1. subsection (a)	
2. subsection (b)	
3. outcome of California appeal cases	
a. code is constitutional	
b. statute may adopt USBM publication for description of prohibited act	
c. smoke inspectors can be considered as experts	
d. layman's uncertainty of the density is no excuse	
d. arbitrary setting of a Ringelmann Number as a standard is matter of discretion	
f. observation of a plume density violation from one direction is sufficient for a court citation.	

LESSON OUTLINE 13	Aids & Cues
II. Describe the requirements for a good air pollution law and list some of the standard and variable terms in visual emissions laws.	
A. Requirements for a good air pollution law	13-4
1. must have power	
2. enforceable	
3. reasonable	
4. clear and precise	
5. no criminal intent is required	
6. there can be different emission standards for different sources.	
B. Variations in visible emission regulations	
1. different shades may be required	
2. different types of sources may be included under these regulations	
3. different types of sources may require different visible emissions restrictions	
4. exceptions to regulations may be allowed during certain periods or for certain sources	
a. new fire	
b. frost prevention	
c. training firemen.	
III. Discuss the visible emission regulation that is in effect in the city or state where this course is being given.	
A. Limitations	13-5, 13-6, 13-7
1. density	
2. equivalent opacity	
3. length of time per hour	
B. Exceptions	
1. source type	
2. new fire	
3. other	

LESSON OUTLINE 13	Aids & Cues
IV. Discuss the role of the expert witness in a court. A. What is special about an expert witness? 1. has special knowledge or talent 2. can testify to his opinions or conclusions. B. Preparation for giving testimony 1. review observations 2. requirement for making out report completely at time of violation since case may not come to court for some time 3. go over your testimony with your attorney prior to your appearance in court 4. photographs a. know plant process that was photographed b. know weather c. know camera and film data 5. telephone conversations should be preceded by a visit with the plant operator 6. Do not become overconfident about court appearances after having made them several times.	Show movie "Role of the Witness"
C. Pointers for the expert witness 1. dress 2. be responsive 3. do not volunteer 4. keep calm 5. be silent if "objection" is called out 6. several examinations may occur a. direct b. cross c. redirect d. recross e. later recall	13-8

LESSON OUTLINE 13	Aids & Cues
V. Summary The visible emission regulations—Ringelmann Number and Equivalent Opacity—and their enforcement by a trained observer have been established for a number of years in various States and their constitutionality has been supported by appeals cases. Therefore, the only additional requirements to make them effective are that the trained air pollution control officer make an observation of a violation, record his observation and the circumstances surrounding it, and when called upon, testify before a judge regarding his observations. In the final analysis, the entire success of the case against a polluter may rest upon the quality of your testimony in court and how convincing you are to the judge in your role as an expert observer. By following the suggestions on preparation and courtroom behavior that I have mentioned, you and your attorney should be able to present a convincing case.	

Subject: OBSERVATION REPORTS FOR VIOLATIONS

Objective: The student should be able to fill out a visible emission observation report form, preferably the one in use in his own locality or state.

Suggested Time: 15 minutes

Required Equipment: 35 mm slide projector

LESSON OUTLINE	Aids & Cues
Introduction	
The purpose of making a visual observation of the degree of blackness or whiteness of a plume is to collect evidence of the violation of a law or regulation. To provide a sufficient basis for court prosecution, the inspector must gather evidence essential for a <u>prima facie</u> case — that is, a case that, unless contradicted, adds up to a violation of the law.	
The inspector should conduct his observation with this end in mind. The report he fills out should be designed so that all the essential information will be recorded. Appropriate observation forms are those used by the U.S. Federal Government as recommended in Method 9, and used to evaluate visible emission standards for NSPS.	Describe forms at end of this lesson plan.
I. Discuss the visible emissions regulation(s) that exists in your State, county, or city.	14-1 (Also used in Legal Aspects LP-13
A. Statement of specifics, each of which must be proven in court	14-2
1. violator	
2. action	
3. source	
4. shade	
5. period of violation	

LESSON OUTLINE 14	Aids & Cues
B. Record and citation form 1. assure that proper data have been collected 2. report is not evidence by itself a. observer's expert opinion b. his testimony 3. facts to be reported on violation a. nature and extent b. date, time, and location c. person(s) responsible d. equipment involved e. cause f. weather conditions g. observation point h. stack involved C. Exceptions and special designations 1. specified sources such as incinerators may be required to meet a lower Ringelmann standard 2. higher emissions may be allowed a. for special periods 1) new fire 2) cleaning fire box 3) blowing tubes 4) equipment breakdown b. for special sources 1) railroad locomotives 2) steamships 3) transfer of molten metals 4) coke ovens 5) gray iron foundries 3. specific sources may be named rather than having designation of "any source" a. fuel-burning equipment b. apartment houses c. process equipment d. diesel motor vehicles e. open fires f. etc.	

LESSON OUTLINE 14	Aids & Cues
II. Explain your report forms or a typical report form used in your State, county, or city.	Make overhead transparency if practical

A. Basic observational information (14-1, 14-2)

1. time intervals for each density or opacity
2. any color changes with time of beginning and ending
3. total violation time for any standard period (hour, half hour, etc.)

B. Supplementary information

1. observer location
2. wind direction and speed
3. cloud cover and weather conditions
4. date and time of observation
5. name and address of violator
6. type of air pollutant
7. description of source
8. inspector's signature

C. Photographs

1. good idea for presentation in court
2. do not take them at same time as the visual observation
   a. the shade on the photo may not match the observation
   b. processing may change the photo
3. have complete record of who handled and processed the film
   a. can be done by commercial firm

LESSON OUTLINE	Aids & Cues
III. Summary The air pollution inspector should know the regulations he is enforcing and be able to relate the items on his report forms to their specific uses in making a record of his observations that will stand in court whether he gave the testimony or someone else gives it using his report. Sometimes a case may not come up until after the inspector has changed jobs. However, his report and his qualifications as an inspector can still be used by someone else in presenting the case.	

Subject: EMISSION GENERATOR

Objective: The student should be able to list the important components of the emission generator and describe how black and white smoke are produced and measured by the emission generator.

Suggested Time: 30 minutes

Required Equipment: 35 mm Slide Projector

LESSON OUTLINE	Aids & Ques
Introduction: To qualify you as an expert visible emission reader we use a device that produces different shades of black or white emission. Before you are exposed to this smoke generator I want to explain how it operates and tell you how the field testing portion of this course will be conducted. Visible emission generating equipment, for use in courses like this one, can be built by air pollution control agencies or can be purchased commercially. At present, the most widely used smoke generators are made by Environmental Industries, P. O. Box 441, Cary, N. C. 27511. It is mounted on a boat trailer for easy portability. The unit is custom made to the pruchaser's specifications, but the principal features of it are present on all units. It costs from $8,500 to $10,500. In this lecture I will discuss the operation of the Mark II model of this visible emission generator. The Mark II model is no longer manufactured but is typical of the currently manufactured models. To begin with, it looks like a smokestack on wheels and basically that is correct. Black or white plumes can be produced and their opacity measured. But you will be primarily interested in what comes out the stack.	

LESSON OUTLINE 15	Aids & Cues
I. Describe the equipment and method for producing black and white emissions and for measuring the opacity of the emissions	
A. Black plume production	15-1
1. Black plume is produced by burning a fuel with insufficient air.	
2. Generating black plume	
a. fuel: Toluene	
1) flow regulated by valve	
2) fuel burned on the floor of combustion chamber	
b. furnace: steel combustion chamber lined with refractory brick or a double-walled steel chamber	
c. density of black plume controlled by varying the fuel flow rate.	
B. White plume production	15-2
1. Number two fuel oil is heated in absence of oxygen until it vaporizes. It cools and condenses into a white cloud of liquid aerosol droplets	
2. Vaporization	
a. heat for vaporization produced by exhaust gases from gasoline engine	
b. fuel oil injected into manifold carrying the exhaust from the engine	
c. vapor is cooled in the end of the manifold leading to the breeching and the stack.	
C. Exhaust to the stack	
1. Generated plumes, whether black or white, are pulled into stack by an induced-draft fan.	
2. Smoke is diluted by ambient air as it enters the stack.	

LESSON OUTLINE 15	Aids & Cues
D. Transmissometer 1. Components a. light source b. photocell 2. Housing a. four-foot length of pipe perpendicular to stack b. six feet below top of stack 3. Flushing to prevent smoke buildup a. one foot of beam length is through the stack b. other three feet 1) prevent smoke entrance by using smoke stops 2) flush air with fans at each end of the horizontal pipe 4. Indication or recording of transmission a. percent transmission of the light between source and photocell is relayed to micro-ammeter b. system calibrated to read 0-5 Ringelmann or 0-100% opacity. Calibrated in 5% opacity steps. c. adjustments 1) zero reading photocell reading with both the white and black plumes generating systems turned off 2) No. 5 Ringelmann or 100% opacity— photo-cell reading with bulb in transmissometer system turned off. III. Other smoke generating equipment A. Los Angeles (1962) 1. Black smoke	15-3

LESSON OUTLINE 15	Aids & Cues
a. atomizing-type fuel oil burner b. larger combustion chamber c. cooling chamber — prevents secondary combustion d. forced draft fan = helps to prevent distortion of plume by wind as the smoke exits from the stack 2. White plumes a. vaporization of distillate oil is caused by heat from an adjacent combustion chamber 3. Opacity and density detection system a. similar to Mark II B. Any available information on other smoke generators III. Explain how the training and testing of the student inspectors will be conducted during the field portion of this course. A. Training plumes are produced by a smoke generator and officially measured by a transmissometer in the stack. B. Runs of 25 shades of black and 25 shades of white plumes are used. C. Training begins with familiarization runs of black shades and of white shades. D. Readings are made at sound of the horn 1. Smoke passing photocell when horn sounds will reach top of stack at same time as student shifts his view to top of stack in response to the horn. 2. Generator operator will attempt to keep smoke output steady for a few seconds after sounding the horn a. wind gusts may cause variation in smoke density at top of stack. E. Student records his observations.	

LESSON OUTLINE 15	Aids & Cues
F. For testing, runs of 25 black and 25 white shades are used.	
1. Student must get a satisfactory score on a single run of 50 shades to qualify.	
2. Requirements	
a. average deviation on black and white smoke of not more than 7.5% in each category;	
b. no reading of the 50 may vary from the actual value of one Ringelmann or more or by 20% opacity or more — this is generally more stringent of the two requirements.	
G. Runs are repeated during the remainder of the field testing portion.	
H. Training and testing may be conducted under various conditions	
1. Different times of day	
a. testing at night may be included if inspector will be required to make night observations.	
2. Different atmospheric conditions	
a. varying cloud cover	
b. varying wind speeds	
c. varying sun angles	
I. Simulated field readings may be used during the testing period.	
IV. Summary	
You will be observing shades of black smoke and shades of white aerosol droplets from number two fuel oil both produced by our generating equipment. In the test portion you will read and record your observation of 25 shades of white plumes in percent opacity to the nearest 5% and 25 shades of black plumes (in Ringelmann number to the nearest 1/4) or (in opacity to the nearest 5%). (Use the one appropriate for your agency.)	

LESSON OUTLINE	Aids & Cues
There will be a long familiarization session before the testing begins and short familiarization sessions in between testing runs. By training your eye on these familiarization runs and by profiting from your mistakes during the early test runs you should be able to become proficient at glancing at the plume for a second and silently noting its opacity within the required limit of accuracy.	

ENVIRONMENTAL PROTECTION AGENCY
VISIBLE EMISSION TRAINING FORM

1. Name of Observer ____________
2. Affiliation ____________
3. Date ____________ Time ____________
4. Wind Speed ____________ Direction ____________ Sky Condition ____________
5. Observers Position ____________
6. Corrected By ____________

Record Black and/or White Smoke in Percent Opacity (for example: 5 percent smallest division)

RUN NO.									
Reading No.	Observer Reading	Transmissometer Reading	+ Deviation	− Deviation	Reading No.	Observer Reading	Transmissometer Reading	+ Deviation	− Deviation
1					13				
2					14				
3					15				
4					16				
5					17				
6					18				
7					19				
8					20				
9					21				
10					22				
11					23				
12					24				
					25				

RUN NO.									
Reading No.	Observer Reading	Transmissometer Reading	+ Deviation	− Deviation	Reading No.	Observer Reading	Transmissometer Reading	+ Deviation	− Deviation
1					13				
2					14				
3					15				
4					16				
5					17				
6					18				
7					19				
8					20				
9					21				
10					22				
11					23				
12					24				
					25				

7. Run Number
8. Number Correct
9. Number of Plus Deviations
10. Number of Minus Deviations
11. Average Plus Deviations = $\frac{\text{Sum of Plus Deviations}}{\text{No. of Plus Deviations}}$
12. Average Minus Deviations = $\frac{\text{Sum of Minus Deviations}}{\text{No. of Minus Deviations}}$
13. Average Deviation = $\frac{\text{(Sum of Plus Deviations) + (Sum of Minus Deviations)}}{\text{Total No. of Readings}}$
14. Number of Readings 20% Deviation and Over (or 1 Ringelmann and more)

7.		
8.		
9.		
10.		
11.		
12.		
13.		
14.		

QUIZ I

1. Which analysis would you need to find out how much ash is in a coal, proximate or ultimate?

2. Are kerosine, and fuel oil for home furnaces classified as distillate or residual?

3. What are the "3 T's" of combustion?

____

____

____

4. What other element is needed besides the "3 T's"?

5. In five words or less for each "T" give an example of the practical application of each "T" in the burning of fuel in either a furnace, kerosine lamp, or other combustion device.

T______________ --

T______________ --

T______________ --

QUIZ II

Exercise in Recording for Qualification*

Slide Number	Topic	Comment
10-1	Smoke School Training Form	
10-2	Steam electric plant St. Louis, Missouri (coal-fired)	35%
10-3	Steam electric power plant Columbus, Ohio (coal-fired)	85%
10-4	Pathological incinerator New Orleans, Louisiana	50%
10-5	Feed plant, Sharonville, Ohio	75%
10-6	Industrial boiler at a Cigarette manufacturer Durham, North Carolina (coal-fired)	45%
10-7	Fertilizer manufacture Columbus, Ohio	Read at end of water portion of plume, 25%
10-8	Portland cement plant Fairborn, Ohio	Read at top of stack 50%
10-9	Aluminum reduction plant Chalmette, Louisiana	Read at point where water evaporated, 80%
10-10	Sulfuric acid manufacture Columbus, Ohio	Read at top of tall stack 10%
10-11	University power plant Columbus, Ohio (coal fired)	Equivalent opacity of wet plume read at top of nearer stack 100% read at point where water evaporates 0%

* Student should be able to identify each source type. Other slides may be substituted at the discretion of the instructor.

Note: These are the same slides as those used in Lesson Plan 10

QUIZ III

1. Why will a temperature inversion frequently form on cloudless nights?

2. Will cool or warm air hold more water vapor?

3. Draw a weather system with the following parts in approximately proper orientation to each other:

   a) low pressure area
   b) cold front
   c) warm front
   d) high pressure area

4. Show the correct meteorological symbols for A through D in question 3.

5. Use arrows to show the correct wind flow direction around the low and high pressure areas.

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Instructor: Questions should be selected to reflect only that material covered by your course presentation. Whenever necessary, the questions should be revised to coincide with local or state regulations.

Visible Emissions Examination

Fill in the following for the time you are taking this test or for the last time you were outside:

Name____________________ Time________________

Date____________________

Wind Speed____________________

Wind Direction____________________

Sky Condition____________________

True or False

Place a T or F to the left of the question number.

1. Smoke is a visible effluent resulting from incomplete combustion.
2. All air pollutants are visible.
3. Solid or liquid particulates in the air can affect safe operation of aircraft and automobiles.
4. Dust settles faster than smoke.
5. A white plume of 60 percent opacity is equivalent to Ringelmann No. 2.
6. Fluoride dust is a product of poor combustion.
7. Black smoke can indicate that fuel is being wasted.
8. Distillate fuel oils are limited to less than 1 percent sulfur and 1 percent ash content.
9. The particulates coming from efficient combustion are chiefly ash.
10. Sulfuric acid mist is invisible.
11. A forced draft is created by pulling air out of the system with a fan.
12. Secondary air jets in a furnace tend to reduce emission of particulates.
13. Most tepee burners can be classified as multiple-chamber incinerators.
14. There is a higher percentage of hydrogen in natural gas than in oil.
15. Blue smoke indicates that an automobile engine needs repair.
16. Jet engines usually emit excessive visible smoke only on takeoff and landing.
17. Large power plants usually burn coal with low ash content.

18. The smoke reading proficiency test requires the inspector to observe 50 shades of black smoke and read each shade with no deviations greater than 25 percent.

19. Readings should be made at approximately right angles to the wind direction.

20. White plumes should be read against a contrasting background such as tree leaves, when practicable.

21. An inspector should wear dark glasses to avoid glare whenever he makes readings while looking toward the sun.

22. To make a legally valid observation, an observer must have a Ringelmann Chart to compare with the smoke shade.

23. The lapse rate refers to the difference of temperature with height.

24. The effective stack height is the distance from the ground to the top of the plume after the plume becomes horizontal.

25. When both are saturated, cool air can contain more water vapor than warm air.

26. Pure water plumes tend to be denser on hot days.

27. A pure water plume is wispy and disappears rapidly.

28. The Ringelmann and the equivalent opacity regulations are examples of common law, not statute law.

29. In court, volunteer any information related to the topic or question.

30. Always meet a plant operator before having telephone conversations with him.

31. The white plume from the emission generator is primarily water vapor.

32. Wind direction is defined as the direction toward which the wind is blowing.

Choose the correct item or items from the following statements and place the letter or letters to the left of the question number.

33. The principal cause of the blackness of a smoke plume is (a) fly ash, (b) water vapor, (c) soot, or (d) gases.

34. Fumes consist of (a) carbon, (b) condensed metal vapors, (c) soot, or (d) liquid particles.

35. A visible pollutant gas is (a) nitrogen dioxide, (b) carbon monoxide, (c) sulfur dioxide, or (d) nitric oxide.

36. The component of fuel that does not burn is (a) carbon, (b) sulfur, (c) hydrogen, or (d) ash.

37. Incinerator smoking may be reduced by (a) keeping the charging opening practically blocked by waste, (b) mixing slow burning material with flash burning material, (c) dumping wet garbage into the combustion chamber.

38. Blue smoke from an automobile is caused by (a) excessive fuel pump pressure, (b) oil entering combustion chamber, (c) clogged air cleaner, (d) faulty spark plugs.

39. Clues to the origin of emissions come from (a) color and odor of plume, (b) files of permits for construction and operation, (c) shape of building, (d) surroundings of source.

40. To determine if white plumes have particulates as well as water, the inspector should (a) read the plume at its densest point, (b) observe the plume where water vapor has evaporated, (c) read the area between the top of the stack and the plume when the plume is a "detached plume."

41. The dispersion of a plume is influenced by (a) wind speed, (b) temperature lapse rate, (c) dew point, (d) depth of snow on the ground, (e) visibility.

Answer each of the following questions as directed by placing the answer to the left of the number.

42. Designate (by C for combustion and P for process) which of the following plumes you would expect to have originated from combustion of material containing carbon and which from the exhaust from an industrial process:

(a) Black plume from a tall stack

(b) Brown plume from the end of a long rotating cylinder

(c) White plume from a tall stack at a fertilizer plant

(d) Plume from a piece of equipment that looks like an Indian wigwam with a cap on it

(e) White plume from a very thin, tall stack

(f) Black plume from the top of a tall tower near an oil refinery

(g) Reddish plumes from several tall stacks on a long building

(h) White plume from a tall stack, accompanied by a strong odor

(i) White plume from a tall, tapered stack on a large, box-like building; plume generally seen only in cold weather.

43. If the emission generator had only the following equipment operating:

(a) Combustion chamber

(b) Auxiliary blower

(c) Transmissometer

(d) Recorder

— would it produce and measure white or black smoke?

44. Are the following conditions typical of a high- or low-pressure area? Write H or L.

(a) Winds blowing in a clockwise direction around the center

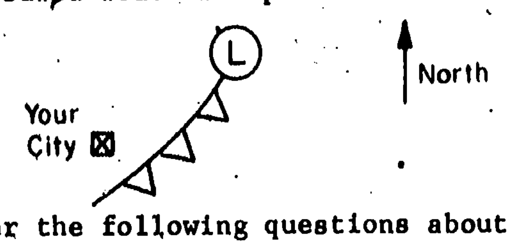
(b) Low relative humidity

(c) Few clouds, sunny skies

(d) Low wind speeds

(e) Inversion development likely.

45. If in December you saw a weather map with the following symbols located around your city,



how would you answer the following questions about your smoke-plume observing activities for the day of the map? (Answer each question to the left of the question number.)

(a) Are the clouds going to decrease?

(b) Is the wind going to be more from the south or from the north?

(c) Are the chances of rain going to increase or decrease?

(d) If the cloud cover disappears, will there probably be an inversion that night?

(e) Had one better wear a coat or jacket?

(f) If rain occurred when the front passed, do you expect better visibility today than before the rain?

46. List the letters of the following devices or techniques that can be used for making eye measurements of emissions:

(a) Umbrascope

(b) Smoke tintometer

(c) Lidar

(d) Sight reading

(e) Stack sampling

(f) Smokescope

47. State which of the four requirements for good combustion—time, temperature, turbulence, sufficient oxygen—is improved by the following:

(a) Heating the chimney of a kerosene lamp

(b) Building a higher chimney by putting a tin can on the top of the kerosene lamp chimney

(c) Raising the kerosene lamp chimney above its base

(d) Using the tuyere (pronounced tweer) on the kerosene lamp

(e) Placing the chimney over the kerosene lamp flame

(f) Putting baffles in the combustion chamber

(g) Using refractory brick in a combustion chamber

(h) Building a larger combustion chamber

(i) Introducing jets of steam into the flame at the top of a flare tower

(j) Heating the air before it enters the furnace

(k) Injecting overfire air above a fuel bed

(l) Reducing the amount of fuel injected into a diesel engine cylinder

48. Some requirements for a good air pollution law are

(a) It must have the authority to reduce contamination

(b) It must be enforceable

(c) It must be reasonable

(d) It must be clear and precise

(e) It must require proof that the owner of a stack had criminal intent in violating the ordinance.

49. A proximate analysis of coal gives the percentage by weight of

(a) Nitrogen

(b) Fixed carbon

(c) Ash

(d) Hydrogen

(e) Moisture content

(f) Volatile matter

(g) Pieces which will pass through a 3/4" screen

(h) Distillate fraction

(i) Sulfur oxides

50. State the elements of your city's, State's, or county's visible emission code or for a typical city:

(a) Ringelmann Number __________ not to be exceeded for longer than __________ minutes in any period of __________ minutes.

(b) Exception for incinerators? Yes _____ No ________.

(c) Exception for startup or building a fire? Yes _______ No ________.

Answers to Visible Emissions Examination

Name, Date, Wind Speed, Wind Direction, Sky Condition, and Time are to be filled out by student using the proper terminology or symbols. Entries do not have to be checked.

True or False

1. T
2. F
3. T
4. T Dust particles are larger and heavier than smoke particles.
5. F
6. F
7. T
8. T
9. T
10. F
11. F
12. T
13. F
14. T
15. T So does black smoke
16. T
17. F Typical coals used in large plants range from 8 to 20% ash.
18. F 25 shades of white, 25 shades of black; no deviation greater than 15%
19. T
20. T
21. F Inspector should not make readings while looking in the direction of the sun. He should not wear dark glasses while making field observations unless he wore them during his certification test.
22. F
23. T
24. F It is the distance to the center of the plume.
25. F
26. F Water vapor will evaporate more quickly on hot days.
27. T
28. F
29. F
30. T An inspector should have met a person and be able to identify his voice before talking to him on the telephone. This identification would be necessary if the inspector should have to testify concerning a telephone conversation.
31. F It is condensed vapor from #2 fuel oil
32. F Wind direction is the direction from which the wind blows

Complete the Statement

33. c
34. b
35. a
36. d
37. a and b
38. b The other answers would cause black smoke

39. a, b, c, d
40. b and c

41. a and b

Other Questions

42. (a) C example, coal-burning heating plant
    (b) P dust from a rotary drier
    (c) P plume from drying operations
    (d) C tepee burner used for incineration
    (e) P example, sulfuric or phosphoric acid plant
    (f) P or C flare tower
    (g) P open hearth steel furnaces
    (h) P kraft pulp mill, rendering plant, or brewery
    (i) C natural-gas-fired boiler used for heating

43. black
44. high pressure area
45. (a) yes
    (b) north
    (c) decrease
    (d) yes, if the skies clear
    (e) yes
    (f) yes, the rain cleanses the air and the stronger winds behind the cold front give better dilution
46. a, b, d, f
47. (a) temperature
    (b) oxygen
    (c) oxygen; however it may cool the fire
    (d) turbulence
    (e) time, turbulence, and temperature
    (f) time and turbulence
    (g) temperature
    (h) time; however it may cool the fire if chamber is too large
    (i) turbulence and oxygen
    (j) temperature
    (k) oxygen
    (l) oxygen; the fuel to air ratio is reduced

48. a, b, c, d
49. b, c, e, f
50. To be filled out in accordance with local regulations.

SPECIFICATIONS FOR A SMOKE GENERATOR

Generator -	Dayton Electric Co. 2000 watt
Furnace -	14 ga. steel lined with GR-2000 insulating brick
Blower -	Dayton Electric Co. #7C 554
Hydraulic Cylinder -	1" piston, 36" reach
Smokestack -	14 ga.; 12" diameter
Trailer -	Neptune Trailer - 1000 lb capacity
Hitch -	requires 1-7/8" ball
Fuel Tanks -	6 gal.; Outboard Marine
Fuel Pumps -	AC Type EP-1 12 volt DC
Fuels -	#2 Fuel Oil (White smoke) Industrial Grade Toluene
Trailer Running Lights -	12 volts
Fuel Control Valve -	Whitey #OR F2-A
Flue Effluent Velocity -	1200 ft/min
Flue Diameter -	12 inches
Weight -	900 lb.
Height -	Travel Configuration: 7 ft. Erect Configuration: 15-1/2 ft.
Transmissometer Readout -	0-200 microamp DC Triplett Model 320-M or, 0-10 millivolt Recorder; Yeiser Model 28
Photocell -	International Rectifier 15 N
Bulb -	PR-16
Exhaust Fans -	Dayton Electric Co. 2C 782

STUDENT COURSE CRITIQUE

I. For each statement circle the one response that is the closest to your opinion.

1. The course objectives were:
   1. clearly stated or written
   2. stated or written; but not all of them were clear to me
   3. stated or written; but most of them were not clear to me
   4. neither stated or written

2. The course content was geared to a level that was generally:
   1. appropriate for my background
   2. too elementary
   3. too difficult
   4. inappropriate for my background

3. I think the organization of the course material was:
   1. completely clear and useful; excellent
   2. for the most part, clear and useful; good
   3. some topics were organized in a clear and useful manner, while others were not; fair
   4. there was little apparent organization in this course; poor

4. After reading the course manual, I think it is:
   1. both a well written and useful document
   2. a fairly well written document, but nevertheless useful
   3. a poorly written document that is of limited utility
   4. neither a well written nor useful document
   5. there is no course manual

5. The time required to complete the homework assignments was:
   1. reasonable
   2. unreasonable
   3. wasted; these assignments were "busy work"
   4. other ______________________

NAME ______________________ COURSE ____________ DATE ____________

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6. The amount of time allotted for this course was:
   1. sufficient
   2. too long
   3. too short
   4. this course should last ____________ number of days

7. Overall, I think this course was:
   1. excellent
   2. good
   3. fair
   4. poor

8. Given the objectives of the course and the skills required for a meaningful understanding of the material, I would:
   1. recommend this course to a friend without reservation
   2. recommend this course with some possible changes
   3. not recommend this course unless there were definite improvements
   4. not recommend this course under any circumstances

9. For future courses, there should be:
   1. no substantive changes
   2. more practical application of the course material
   3. more theory presented as a basis for the material taught
   4. more of a "balance" provided between theory and practical application

10. How did you hear about this course?
   1. employer
   2. friend
   3. schedule
   4. conference
   5. other ____________________

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II. Please circle the one number that represents the extent of your agreement with each of the following statements. READ EACH ITEM CAREFULLY.

	STRONGLY AGREE	AGREE	DISAGREE	STRONGLY DISAGREE	NO OPINION
11. The course content was useful for my professional growth.	5.	4.	3.	2.	1.
12. The course content was what I had expected.	5.	4.	3.	2.	1.
13. The course content was too complex.	5.	4.	3.	2.	1.
14. The course content was too simple.	5.	4.	3.	2.	1.
15. The course content was up to date.	5.	4.	3.	2.	1.
16. During the course I felt challenged to learn.	5.	4.	3.	2.	1.
17. Generally, the course materials were presented in an interesting manner.	5.	4.	3.	2.	1.
18. The course content was well coordinated among the instructors.	5.	4.	3.	2.	1.
19. The instructors were well prepared for most class sessions.	5.	4.	3.	2.	1.
20. The instructors were quite knowledgeable about their subject areas.	5.	4.	3.	2.	1.
21. Generally, I understood what I was expected to learn in this course.	5.	4.	3.	2.	1.
22. Throughout the course I received sufficient information on anything I did not understand.	5.	4.	3.	2.	1.
23. The questions raised during the lectures were usually answered to my satisfaction.	5.	4.	3.	2.	1.
24. My background was adequate for success in this course.	5.	4.	3.	2.	1.
25. The teaching methods used in this course were effective for my learning.	5.	4.	3.	2.	1.
26. This course contained a sufficient amount of practice exercises.	5.	4.	3.	2.	1.
27. The course assignments were useful for my learning.	5.	4.	3.	2.	1.
28. The production quality of the audio-visual materials was technically adequate.	5.	4.	3.	2.	1.
29. The audio-visual materials aided my understanding of the topics presented.	5.	4.	3.	2.	1.
30. The final exam accurately represented the material covered in this course.	5.	4.	3.	2.	1.
31. Overall, I was pleased with this course.	5.	4.	3.	2.	1.
32. I think my technical skills and/or knowledge have been strengthened as a result of this course.	5.	4.	3.	2.	1.
33. I think I will be able to use what I have learned from this course in my current position.	5.	4.	3.	2.	1.

I consider the most needed improvement in this course to be: ____________

The "best" part of this course was: ____________

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III. Please circle the one number that represents the extent of your agreement with each of the following statements. READ EACH ITEM CAREFULLY.

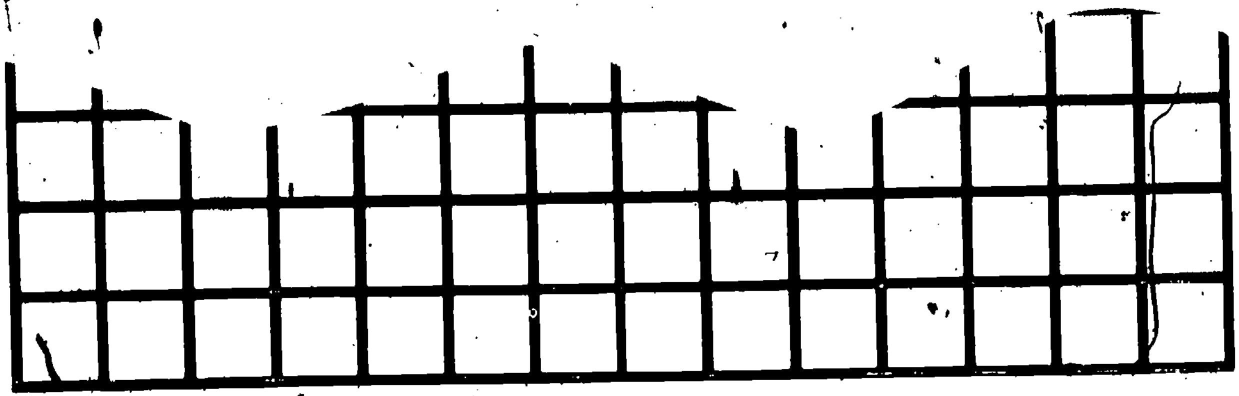
LABORATORY CRITIQUE

		STRONGLY AGREE	AGREE	DISAGREE	STRONGLY DISAGREE	NO OPINION
34.	The lab procedures were clearly explained.	5.	4.	3.	2.	1.
35.	Assistance was available to me during the laboratory sessions.	5.	4.	3.	2.	1.
36.	The lab sessions were well organized.	5.	4.	3.	2.	1.
37.	The content of the lab was an essential part of this course.	5.	4.	3.	2.	1.
38.	The lab assignments were of a reasonable length.	5.	4.	3.	2.	1.
39.	The time allotted for the laboratory sessions was sufficient.	5.	4.	3.	2.	1.
40.	The laboratory instructors were helpful.	5.	4.	3.	2.	1.
41.	The laboratory had an adequate amount of equipment.	5.	4.	3.	2.	1.

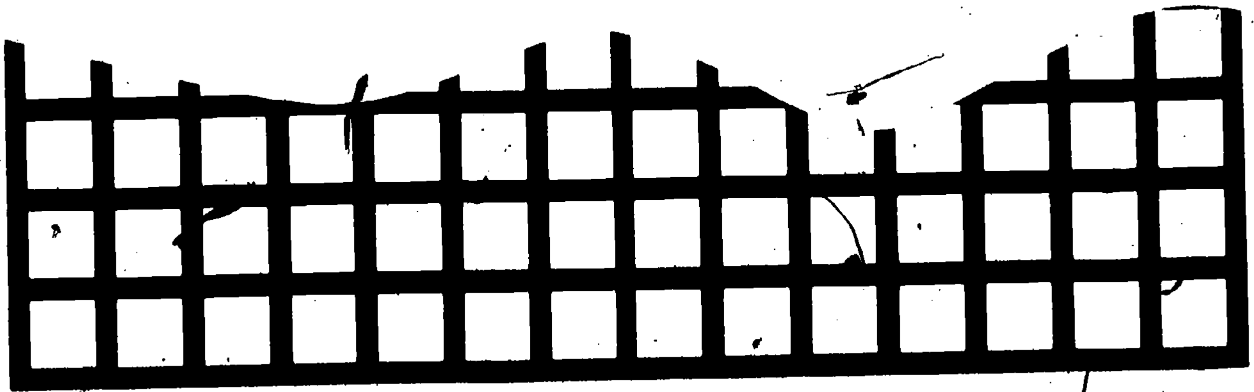
I consider the most needed improvement of the laboratory sessions to be:

The "best of the laboratory sessions was:

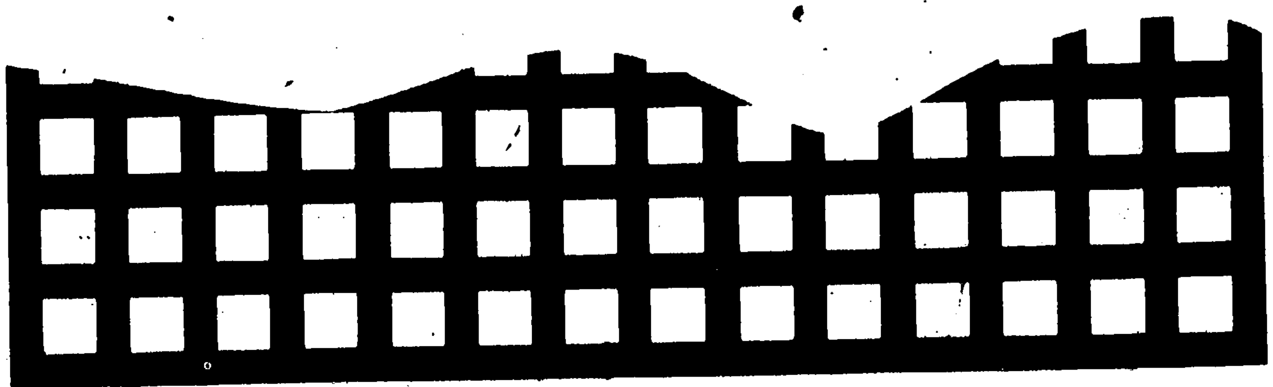
IV. ADDITIONAL COMMENTS



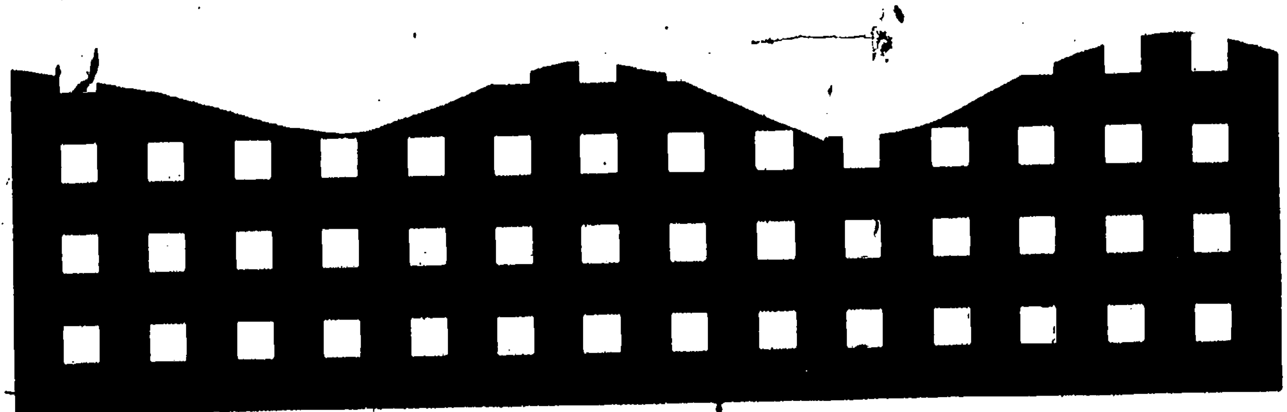
1. Equivalent to 20 percent black.



2. Equivalent to 40 percent black.



3. Equivalent to 60 percent black.



4. Equivalent to 80 percent black.

ACTUAL HEIGHT OF EACH CHART — 8½ inches

RINGELMANN'S SCALE FOR GRADING THE DENSITY OF SMOKE
(see page 46 for availability of charts)

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

1. REPORT NO. EPA-450/3-78-105	2.	3. RECIPIENT'S ACCESSION NO.
4. TITLE AND SUBTITLE VISIBLE EMISSIONS EVALUATION - AIR POLLUTION TRAINING COURSE 439 - Instructor Manual		5. REPORT DATE September 1978
		6. PERFORMING ORGANIZATION CODE
7. AUTHOR(S)		8. PERFORMING ORGANIZATION REPORT NO.
9. PERFORMING ORGANIZATION NAME AND ADDRESS Northrop Services, Inc. Air Pollution Training Institute c/o U.S. Environmental Protection Agency (MD-20) Research Triangle Park, NC 27711		10. PROGRAM ELEMENT NO.
		11. CONTRACT/GRANT NO. 68-02-2374
12. SPONSORING AGENCY NAME AND ADDRESS U.S. Environmental Protection Agency Office of Air Quality Planning and Standards Control Programs Development Division Research Triangle Park, NC 27711		13. TYPE OF REPORT AND PERIOD COVERED FINAL
		14. SPONSORING AGENCY CODE

15. SUPPLEMENTARY NOTES
There is an accompanying students manual to be used in conducting visible emissions training courses. See publication EPA-450/3-78-106.

16. ABSTRACT
This manual is to be used by instructors or teachers who are conducting classes on how to evaluate ("read") visible emissions to the atmosphere from air pollution sources. It includes everything the instructor needs when used with the student's manual (see block 15 on this form). Topics covered include course and lesson objectives; lesson plans; quizzes; instructions on operation of the "smoke" generator for black and white smoke; instructions on how to conduct the training course; and methods for evaluation of student performance. Sources of other needed items (films; slides; Ringelmann charts, etc.) are given.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group
EPA Method 9 Smoke Air Pollution Inspection Effluents Detection	training materials smoke inspection visible emissions	13 b 68 A

18. DISTRIBUTION STATEMENT Unlimited. Available from National Technical Information Service, 5285 Port Royal Road, Springfield, Va. 22161	19. SECURITY CLASS (This Report) unclassified	21. NO. OF PAGES 176
	20. SECURITY CLASS (This page) unclassified	22. PRICE

EPA Form 2220-1 (9-73)