This manual covers a four and one half day laboratory course in source sampling for particulates. The course presents principles and techniques necessary for performing isokinetic source sampling procedures. Lectures cover formulas dealing with basic fluid mechanics appropriate to the techniques employed. Laboratory exercises are intended to familiarize students with the proper use and calibration of source sampling equipment. The course is designed for students of science and engineering backgrounds. (Author/RE)
APTI
Course 450
Source Sampling for Particulate Pollutants

Instructor's Guide

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Office of Air, Noise, and Radiation
Office of Air Quality Planning and Standards
Research Triangle Park, NC 27711
Notice

This is not an official policy and standards document. The opinions, findings, and conclusions are those of the authors and not necessarily those of the Environmental Protection Agency. Every attempt has been made to represent the present state of the art as well as subject areas still under evaluation. Any mention of products or organizations does not constitute endorsement by the United States Environmental Protection Agency.

Availability of Copies of This Document

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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.

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Northrop Services, Inc

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Technical Director
Northrop Services, Inc

Jean J. Schueneman
Chief, Manpower & Technical Information Branch
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## LABORATORY INSTRUCTIONS

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<tr>
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<th>Page</th>
</tr>
</thead>
</table>

iv
INTRODUCTORY MATERIALS FOR
COURSE 450 - SOURCE SAMPLING FOR PARTICULATE POLLUTANTS

This Instructor's Guide is to provide you as Course Moderator with assistance in the preparation and presentation of Course #450 - Source Sampling for Particulate Pollutants. It will provide you with guidelines, instructions and some general information that should facilitate your efforts in staging this course.

I. Course Description

Course 450 - Source Sampling for Particulate Pollutants is designed as a four and one half day laboratory course for students of science and engineering background. The course presents the principles and techniques necessary for performing isokinetic source sampling procedures for particulate matter given in the EPA Reference Method 5 of the Federal New Source Performance Standards. It should prepare engineers and technicians to perform and/or evaluate a particulate source test. Lectures cover formulas describing basic fluid dynamics involved in isokinetic sampling and students are given experience in problem solving and application using EPA Reference Methods 1, 2, 3, 4, and 5. Laboratory exercises are designed to familiarize students with the proper use and calibration of source sampling equipment. Students perform a source test, make all calculations, and report results. Major topics include:

- Basic Theories
- Description and Analysis of Source Sampling Equipment
- Explanation of EPA Method 1-5
- Source Sampling Calculations
- IsoKinetic Source Sampling Principles
- Gas Velocity, Molecular Weight, and Volumetric Flow Rate Measurement
- Laboratory Particulate Source Test
- Introduction to Alternate Methods of Particulate Analysis

II. Background, Origin, and Philosophy

The Environmental Protection Agency Air Pollution Training Institute (APTI) provides courses in air pollution control technology, ambient and source monitoring, and air quality management. In July, 1976 Northrop Services, Inc. was contracted to both present Training Institute courses and to provide support and technical services for the Institute as a whole. Source sampling and other laboratory courses of particular importance to governmental and industrial personnel concerned with air pollution problems received early efforts of instructional development to design the best possible training experiences for the students. This required thorough examination of both the materials for instruction and an examination of the characteristics of the student audience. From such studies, the courses have been revised and developed to provide training that enables every student to achieve the specific course objectives.
The demographic characterization of students attending source sampling classes has shown the following:

<table>
<thead>
<tr>
<th>Employer</th>
<th>Course 450</th>
</tr>
</thead>
<tbody>
<tr>
<td>Federal EPA</td>
<td>16%</td>
</tr>
<tr>
<td>Other Federal</td>
<td>5</td>
</tr>
<tr>
<td>State Government</td>
<td>12</td>
</tr>
<tr>
<td>Local Government</td>
<td>14</td>
</tr>
<tr>
<td>Industry</td>
<td>45</td>
</tr>
<tr>
<td>Consultant</td>
<td>6</td>
</tr>
<tr>
<td>Other</td>
<td>2</td>
</tr>
</tbody>
</table>

**TABLE I**

<table>
<thead>
<tr>
<th>Occupation</th>
<th>Course 450</th>
</tr>
</thead>
<tbody>
<tr>
<td>Administrator</td>
<td>3%</td>
</tr>
<tr>
<td>Chemist</td>
<td>14</td>
</tr>
<tr>
<td>Engineer</td>
<td>44</td>
</tr>
<tr>
<td>Ind. Hygenist</td>
<td>1</td>
</tr>
<tr>
<td>Phys. Scientist</td>
<td>3</td>
</tr>
<tr>
<td>Sanitarian</td>
<td>3</td>
</tr>
<tr>
<td>Technician</td>
<td>28</td>
</tr>
<tr>
<td>Other</td>
<td>4</td>
</tr>
</tbody>
</table>

**TABLE II**

<table>
<thead>
<tr>
<th>Educational Background</th>
<th>Course 450</th>
</tr>
</thead>
<tbody>
<tr>
<td>High School</td>
<td>24%</td>
</tr>
<tr>
<td>Bachelor</td>
<td>56</td>
</tr>
<tr>
<td>Master</td>
<td>18</td>
</tr>
<tr>
<td>PhD</td>
<td>2</td>
</tr>
</tbody>
</table>

**TABLE III**

<table>
<thead>
<tr>
<th>Years Experience</th>
<th>Course 450</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 - 1 years</td>
<td>48%</td>
</tr>
<tr>
<td>2 - 4</td>
<td>31</td>
</tr>
<tr>
<td>5 - 7</td>
<td>15</td>
</tr>
<tr>
<td>8 - 10</td>
<td>3</td>
</tr>
<tr>
<td>&gt; 10</td>
<td>3</td>
</tr>
</tbody>
</table>

Student intellectual characteristics were determined early in the initial contract year through standardized ability testing given to a total of 186 individuals in 10 different courses offered by the Institute. The Course #450 sample produced the following percentile rank scores:

<table>
<thead>
<tr>
<th>Percentile Rank</th>
</tr>
</thead>
<tbody>
<tr>
<td>Verbal ability</td>
</tr>
<tr>
<td>Numerical</td>
</tr>
<tr>
<td>Spatial</td>
</tr>
<tr>
<td>Reasoning</td>
</tr>
<tr>
<td>Memory</td>
</tr>
</tbody>
</table>
The characterization studies mentioned above have indicated that for APTI source sampling courses, the course content and instructional methods should be explicit rather than implicit. Although formal educational level tends to be generally high, the ability testing has indicated the need for the course content to be presented in a careful and logical order with the underlying principles and relationships of given concepts being taught directly. At critical junctures where students are required to visualize a concept, infer a relationship, or visualize an added dimension, instruction is mediated with the use of:

- Graphic illustrations usually in the form of 35 mm slides,
- Lecture demonstrations,
- Inclass problem-solving,
- Hands-on laboratory experience
- Constant repetition and review of fundamental concepts.

Course #450 is designed to teach the principles of isokinetic sampling to the engineer who finds it necessary to either conduct or to observe a stack test.

A stack tester normally stays in this type of work for 2 or 3 years before moving on to another position. This creates a continual need to train new people entering this field of work. Students attending #450 have ranged from high school graduates to Ph.D.'s involved in research work. The average student (see Tables II and III) has a bachelor's degree and is employed as a technician or an engineer. In this course, 50% of the students come from industry and 50% come from governmental agencies (this creates a forum for interesting discussions within the course presentations). Most of the students are also just entering the field of air pollution, 48% having less than one year of experience. The approach taken in instructing Course #450, is to direct the level of instruction towards the engineer with four years of college, newly entering the field of air pollution. Through the use of discussion sessions, those less prepared and those with more experience are provided the opportunity to supplement their learning in the course. This approach has succeeded, with most students gaining the knowledge they desired upon entry into the course.

The variety of activities that the student experiences in Course #450 aides in the assimilation of a great deal of knowledge in a short time. The first 3 days of the course are very rapidly paced and produce some stress in the students. The fourth and fifth day are conducted at a slower pace, still with a variety of activities, but with more opportunity for questioning and discussion. Here, the content of the first 3 days is reinforced and refined. Every effort is made to answer any question asked by a student, even at the expense of some of the more advanced members of the class. In fact, it has often occurred that the simpler questions lead into details that the class as a whole finds valuable. At the opposite end, the more complex questions, give the beginning stack sampler an opportunity to realize the complexities that can arise in performing the sampling method.
III. Instruction for Preparation and Presentation of Course

A. Responsibilities of Course Moderator

This course generally requires 4½ days for a complete presentation. It can also be expected that anywhere from 35 to 60 hours of additional preparation will be required by the individual designated Course Moderator. Preparation and continuity are the principle responsibilities of the Course Moderator who will coordinate all on-site activities both before and during the course presentation. The following lists the actual tasks that are considered the direct responsibility of the Course Moderator:

1. Scheduling the course presentation.
2. Recruiting (hiring) and briefing instructors.
3. Preparation of classroom and teaching facilities.
4. Preparation of and distribution of course materials.
5. Presentation of introduction and other appropriate lectures.
6. Maintaining continuity throughout the course.

B. Scheduling

The course itself is designed around a format using 18 lectures and 3 laboratory sessions, all of which are designed to fit into a 4½ day time frame of morning and afternoon sessions. Because the course contains a concentrated level of involvement with rather technical material, it is recommended that no more than seven (7) hours of class instruction be presented in one day.

The course materials contain 21 segments each listed below with its recommended time and schedule placement.

<table>
<thead>
<tr>
<th>Proposed Sequence</th>
<th>Lesson Title</th>
<th>Expected Time Required</th>
</tr>
</thead>
<tbody>
<tr>
<td>Day #1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lesson #1</td>
<td>Welcome and Registration</td>
<td>30 minutes</td>
</tr>
<tr>
<td>Lesson #2</td>
<td>Introduction to Source Sampling</td>
<td>1 hr 15 min</td>
</tr>
<tr>
<td>Lesson #3</td>
<td>EPA Method 5 Sampling Train</td>
<td>1 hour</td>
</tr>
<tr>
<td>Lesson #4</td>
<td>Discussion of Laboratory Exercises</td>
<td>1 hour 30 min</td>
</tr>
<tr>
<td>Laboratory #1</td>
<td>Lab Exercises</td>
<td>2 hours 30 min</td>
</tr>
<tr>
<td>Day #2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lesson #5</td>
<td>Isokinetic Source Sampling</td>
<td>1 hour 15 min</td>
</tr>
<tr>
<td>Lesson #6</td>
<td>Setting the Isokinetic Sampling Rate</td>
<td>1 hour 15 min</td>
</tr>
<tr>
<td>Lesson #7</td>
<td>Discussion of Laboratory Exercises</td>
<td>2 hours 45 min</td>
</tr>
<tr>
<td>Laboratory #2</td>
<td>Orsat Laboratory</td>
<td>1 hour 30 min</td>
</tr>
</tbody>
</table>
### Day #3

<table>
<thead>
<tr>
<th>Lesson #8</th>
<th>Calculations and Interpretation of % Isokinetic</th>
<th>1 hour 45 min</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lesson #9</td>
<td>Definition of a Particulate</td>
<td>15 min</td>
</tr>
<tr>
<td>Lesson #10</td>
<td>Discussion of Source Sampling Exercise</td>
<td>1 hr 15 min</td>
</tr>
<tr>
<td>Laboratory #3</td>
<td>RM5 Testing</td>
<td>3 hours</td>
</tr>
</tbody>
</table>

### Day #4

| Lesson #11      | Concentration Corrections                                        | 1 hour 15 min |
| Lesson #12      | Literature Sources                                              | 30 min        |
| Lesson #13      | F-Factor Method                                                  | 1 hour        |
| Lesson #14      | Calculation Review                                               | 1 hour 45 min |
| Lesson #15      | Error Analysis                                                   | 30 min        |
| Lesson #16      | Source Sampling Quality Assurance and Safety on Site             | 1 hour 20 min |

### Day #5

| Lesson #17      | Particulate Sizing Using Cascade Impactor                        | 1 hour        |
| Lesson #18      | Transmissometers                                                 | 1 hour 15 min |
C. **Instructors**

The **four** most important criteria in the selection of faculty for this course are:

1. A knowledge of the methods and procedure in particulate sampling.
2. Practical experience with a facility providing stack sampling.
3. Experience (and ability) to instruct adults using traditional and non-traditional methods, materials and techniques.
4. A positive attitude toward air quality management.

Before instructors are actually involved with instruction in the classroom the course moderator should conduct thorough briefing and preparation sessions in which an overview of the entire course presentation is given. Specific discussion of course and lesson objectives should result in an assurance that the instructor is well prepared and familiar with the materials, procedures, and techniques that they will be using.

The course moderator should stress the difference in the role that the instructor plays as compared to traditional university instruction situations. All instructors should fully understand the function of course and lesson objectives and the relationship of each objective to their particular materials and to the pre and post testing.

It may be particularly helpful to the instructors if they are able to sit in on early sessions of the course presentation, so that they get a feel for the way the students are oriented to the material and be able to incorporate the strengths and background experiences of the students into the various instructional sessions.

Preparation must be stressed to all prospective instructors. Thorough familiarization with all the prepared materials is essential for even "expert" instructors. Laboratory sessions require additional preparation and should include a complete run-through to check out the methods and equipment before ever presenting them to the students. Remember that Murphy's law will always hold true in a student laboratory exercise: "What ever can go wrong, will!"

D. **Physical Setting**

Room size: 1300 square ft/24 students
Seating arrangement: Double tables, 6-8 student/table
Audio visual requirements: 35 mm slide projector, overhead projectors, large screen
Lecture paraphernalia: Lighted lectern, blackboard, chalk
Laboratory room requirements: 700 sq ft, electricity, analytical balances.
E. Course Materials

In addition to the lesson outlines and audio-visual materials, the Instructional Resource Materials for Course 450 include copies of the following items needed for distribution to the student:

1. APTI Student Manual: "Source Sampling for Particulate Pollutants", EPA 450/2-79-006

2. APTI Student Workbook, EPA 450/2-79-007

3. Pre-test

4. Post-test

5. EPA Pamphlet - "Need Air Pollution Information", June 1979


9. Handout - Calculation Form for Method 5 Particulate Test


F. Lesson Plan Use

Each lesson plan module is designed to serve as:

A. Source of lesson objectives
B. Content guide for instructor
C. Lecture outline
D. Directions for use of visual aids
E. Guidelines for approach to the lesson.

Each lecture plan outline is carefully timed. Instructors should give attention to observing time schedules, and to becoming familiar with the "pace" of the lessons to be given.

Instructors must be familiar with the visual aids and handout materials before attempting to present any lesson.

Instructors may wish to vary slightly from the format or content for a given lesson but should be cautioned that schedules and lesson objectives must be maintained. Variations should be in the direction of greater student participation. Instructors should remember that the final exam reflects the lesson objectives as presented through these lesson outlines.

G. Audio-Visual Materials

The visuals for course 450 include 153 35mm slides. The slides are keyed using number references that are also found on the slide. The number identifies the lecture and sequence of the slide. Thus L2-16 identifies a slide in lecture 2 that comes before L2-17 and after L2-15. Some slides that are part of sequences are followed by a letter, thus L2-2a, L2-2b, and L2-2c are all members of a particular sequence.

The specific lessons are as follows:

<table>
<thead>
<tr>
<th>Lesson</th>
<th>No. of Slides</th>
<th>Slides/Sequence</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>no slides</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>20 slides</td>
<td>L2-1a through 2-14</td>
</tr>
<tr>
<td>3</td>
<td>no slides</td>
<td>Use L7-4, L7-5</td>
</tr>
<tr>
<td>4</td>
<td>no slides</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>4 slides</td>
<td>L5-1 through L5-4</td>
</tr>
<tr>
<td>6</td>
<td>21 slides</td>
<td>L6-1 through L6-21</td>
</tr>
<tr>
<td>7</td>
<td>35 slides</td>
<td>L7-1 through L7-35</td>
</tr>
<tr>
<td>8</td>
<td>12 slides</td>
<td>L8-1 through L8-12</td>
</tr>
<tr>
<td>9</td>
<td>no slides</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>no slides</td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>7 slides</td>
<td>L11-1 through L11-7</td>
</tr>
<tr>
<td>12</td>
<td>6 slides</td>
<td>L12-1 through L12-6</td>
</tr>
<tr>
<td>13</td>
<td>10 slides</td>
<td>L13-1 through L13-10</td>
</tr>
<tr>
<td>14</td>
<td>no slides</td>
<td></td>
</tr>
<tr>
<td>15</td>
<td>3 slides</td>
<td>L15-1 through L15-3</td>
</tr>
<tr>
<td>16</td>
<td>1 slide</td>
<td>L16-1</td>
</tr>
<tr>
<td>17</td>
<td>6 slides</td>
<td>L17-1 through L17-6</td>
</tr>
<tr>
<td>18</td>
<td>28 slides</td>
<td>L18-1 through L18-27</td>
</tr>
</tbody>
</table>
H. Grading Philosophy

The APTI guidelines for grading student's performance in "Source Sampling for Particulate Material" and granting Continuing Education Units (CEU's) are as follows:

The student must:

- attend a minimum of 95% of all scheduled class and laboratory sessions;
- complete and hand in copies of all laboratory data derived in the laboratories; and
- achieve an average course grade of 70% or better derived as follows:

1) 90% from final examination
2) 10% from laboratory performance

I. Other Logistics

Since the Course Moderator will need to consider a great variety of logistic and instructional concerns, the following checklist is provided to serve as a guide to meeting these responsibilities.

The course developers have tried to provide you with as much information and materials as possible to enable you to present a unique and exciting educational venture.

GOOD LUCK.
CHECKLIST
of Activities
For Presenting the Course

A. Pre-Course Responsibilities:

1. Reserve and confirm classroom(s), including size, "set-up," location and costs (if any).

2. Contact and confirm all faculty (speakers) for the course(s), including their A-V requirements. Send material to them.

3. Reserve hotel accommodations for faculty.

4. Arrange for and confirm food service needs (i.e., meals, coffee breaks, water, etc).

5. Prepare and reproduce final ("revised" if appropriate) copy of the detailed program schedule.

6. Reproduce final registration/attendance roster, including observers (if any).

7. Prepare name badges and name "tents" for students and faculty.

8. Identify, order, and confirm all A-V equipment needs.

9. Prepare two or three 12 in. x 15 in. signs on posterboard for posting at meeting area.

10. Arrange for and confirm any special administrative assistance needs on-site for course, including "local" Address of Welcome, etc.


12. Pack and ship box of supplies and materials one week prior to beginning of course (if appropriate).

13. Arrange and confirm the availability of satisfactory laboratory equipment and facilities. (See list following descriptions in rear of this manual)

14. Set up needed equipment in the laboratory setting and make sure all equipment and instruments are operating correctly.

15. Have run-through of lab exercise with instructors.
B. On-Site Course Responsibilities

1. Check on and determine final room arrangements (i.e., tables, chairs, lectern, water, cups, etc.)

2. Set up A-V equipment required each day and brief operator (if supplied).

3. Post signs where needed.

4. Alert receptionist, phone operator(s), watchmen, etc. of name, location, and schedule of program.

5. Conduct a net speaker(s) (i.e., instructor) briefing session on a daily basis.

6. Verify and make final food services/coffee arrangements (where appropriate).

7. Identify and arrange for other physical needs as required (i.e., coat racks, ashtrays, etc).

8. Make a final check on arrival of guest speakers (instructors) for the day.

9. If there is lab work on a real stack, find out how to call the local life squad or similar service, in case an accident occurs.

C. Post-Course Responsibilities

1. Return the following to APTI: (If APTI course):
   - Student Registration Cards
   - Pre-Test Answer Sheets - Graded
   - Post-Test Answer Sheets - Graded
   - Laboratory Data Summary Sheets from each student
   - Student Course Critiques

2. Prepare Course Director Report including pertinent comments on the presentation. (If APTI course)

3. Request honorarium and expense statements from faculty; order and process checks.

4. Write thank-you letters and send checks to paid faculty.

5. Write thank-you letters to non-paid guest speakers.

6. Prepare evaluation on each course (including instructions, content, facilities, etc).

7. Make sure A-V equipment is returned.

8. Return unused materials to your office.
COURSE #450
SOURCE TESTING FOR PARTICULATE POLLUTANTS

COURSE GOAL

The major goal of Course #450, "Source Sampling for Particulate Pollutants", is to provide the student with a basic understanding of the theory and experimental methods involved in isokinetic sampling, the foundation of EPA Method 5.

Knowledge of isokinetic sampling, serving as the core of the course material, will then be amplified with lectures, problem sessions and lecture-demonstrations in order to present the many facets of particulate sampling. Upon completion of the course, the student should be able to design and plan a source test, perform all of the calculations involved in reporting a mass emission rate, and understand problems of error and quality assurance. The student should also become conversant with the methods of particle sizing and transmissometry. He should attain an awareness of the problems involved in source sampling and be able to recognize what constitutes difficult experimental situations, a good test, good data, and a good final report.

COURSE OBJECTIVES

On completion of this course the student should be able to:

- Define symbols and common source sampling terms used in source sampling for particulate pollutants.
- Recognize, interpret and apply sections of the Federal Register pertinent to source sampling for particulate pollutants.
- Understand the construction, operation and calibration of component parts of the Federal Register Method 5 sampling train.
- Recognize the advantages and disadvantages of the nomograph and its uses in the establishment of the isokinetic sampling rate.
- Understand the "working" isokinetic rate equation and its derivation.
- Define isokinetic sampling and illustrate why it is important in sample extraction.
- Apply Federal Register Methods 1 through 4 in preparation for a particulate sampling test.
- Understand the construction, evaluation, standardization, and orientation of the "S Type" pitot tube and its application to source sampling.
- Calculate the "Percent Isokinetic" value for a source test, and interpret the effect of over or under-isokinetic values on the source test results.
- Understand the quality assurance programs involved in source sampling dealing with nozzle sizing, orifice meter calibration, nomograph standardization and sample recovery.
- List the steps involved in conducting a source test, including completion of pre-test and post-test forms. The student should be able to recognize potential problem areas in preparing and conducting a source test.
COURSE OBJECTIVES - Continued

- Properly assemble, leak check, conduct and recover a Method 5 sample according to Federal Register, August 18, 1977.

- Apply Federal Register Method 3 gas analysis in formulating the stack gas molecular weight and % excess air.

- Explain the principles behind the operation of particle sizing devices for sources and name some of those devices being tested by EPA.

- Define the terms opacity, transmittance and transmissometer.

- Recognize the relationship between optical density and particulate concentration.
LABORATORY EQUIPMENT LIST FOR 24 STUDENTS

COURSE 450

SOURCE SAMPLING FOR PARTICULATE POLLUTANTS

GENERAL EQUIPMENT FOR SOURCE TEST

24 nomographs
4 meter boxes
4 sample boxes
4 umbilical cords
4 sets of glassware
4 probes
4 filter holders, frits
4 pre-weighed filters
4 containers of silica gel (200g each)
6 extension cords
4 t'olding wood rulers
2 calipers
1 ice chest
4 funnels
2 250ml graduated cylinders
8 stopwatches
2 boxes kaydry towels
4 tweezers
4 probe wrenches - 3/4" and 1" open end wrenches
1 spare filter set-up
2 sets of spare glassware
misc. tools
4 rolls duct tape
ice
flyash

TESTING FACILITY - see Laboratory 1 for diagrams.

2060 CFM Squirrel Cage blower with 3/4 HP motor
12" diameter galvanized duct work
6 5 foot sections
4 2 foot sections
3 elbows
2 adapters; 1 to reduce 14" diameter fan inlet to 12" diameter;
1 section to adapt rectangular fan outlet to 12" diameter.

PITOT TUBE EXPERIMENT

4 standard pitot tubes
4 inclined manometers, (oil, reading to at least 6" H2O)
4 sets of manometer lines w/connectors
8 ring stands each with 3 finger clamps
WET BULB-DRY BULB EXPERIMENT

?  beakers with water
4  thermometers (to 300°F)
2  wicks

M.W. EXPERIMENT

4  Orsats
SAMPLE AGENDA

Name and address of agency conducting course

(Dates of course)

450 SOURCE SAMPLING FOR PARTICULATE POLLUTANTS

Course location

DAY & TIME

SUBJECT

SPEAKER

MONDAY
8:30 Welcome and Registration
9:00 Pretest
9:45 Introduction to Source Sampling
1. Objectives
2. Definitions
3. Pollutant Mass Rate
4. Gas Physics
10:30 - EPA Method 5 Sampling Train
11:30 LUNCH
12:15 Discussion of Laboratory Exercises
1. Sample & Velocity Traverses for Stationary Sources
2. Determination of Stack Gas Velocity and Volumetric Flow Rate
3. Wet Bulb-Dry Bulb Moisture Estimation
4. Orifice Meter Calibration
1:45 Travel to Source Simulator

If course is not conducted by EPA, but EPA/APTI materials are used, it would be appreciated that an acknowledgement appear here.
MONDAY (Continued)
2:00 Laboratory Exercises
   Station #1. Traverse Point Determination
   Station #2. Pitot Tube Calibration
   Station #3. Moisture Estimate
   Station #4. Calibration of Orifice Meter

HOMEWORK:
1. Complete Laboratory Exercises Calculations
2. Read Example Problems - Workbook pp. 165-174
3. Work Problems 1, 2, and 3 - Additional Problem Section pp. 177-178

TUESDAY
8:30 Isokinetic Source Sampling
9:45 Setting the Isokinetic Sampling Rate
11:30 LUNCH
12:15 1. Review of Sample and Velocity Traverses
       2. Reference Method Determination of Moisture in Stack Gas
       3. Gas Analysis for Carbon Dioxide, Excess Air and Dry Molecular Weight
3:00 Orsat Laboratory

HOMEWORK:
1. Do Problems 1, 2, and 3 - Setting Isokinetic Sampling Rate p 57
2. Work Problems 4, 5, and 6 - Additional Problems Section pp 179-181

WEDNESDAY
8:30 Calculation and Interpretation of % Isokinetic
    1. Equations for % Isokinetic
    2. Evaluating Anisokinetic Source Test Results
10:15 Definition of a Particulate
10:30 BREAK
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<td><strong>WEDNESDAY (Continued)</strong></td>
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<td>10:45</td>
<td>Discussion of Source Sampling Exercise</td>
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<td>12:00</td>
<td><strong>LUNCH</strong></td>
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<td>Travel to Source Simulator</td>
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<td>1:00</td>
<td>Stack Test</td>
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<td><strong>HOMEWORK:</strong> Complete Stack Test Data Summary Form</td>
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<td><strong>THURSDAY</strong></td>
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<td>Concentration Corrections</td>
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<td>Class Problems</td>
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<td>Literature Sources</td>
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<td>F-Factor Method</td>
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<td>11:30</td>
<td><strong>LUNCH</strong></td>
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<td>12:15</td>
<td>1. Calculation Review - Hand in Stack Test Data Summary</td>
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<td>2. Discussion of Laboratory Results</td>
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<td>3. ERROR Analysis</td>
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<td>2:30</td>
<td>Source Sampling Quality Assurance and Safety on Site</td>
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<td><strong>HOMEWORK:</strong> Read Manual Selections</td>
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<td><strong>FRIDAY</strong></td>
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<td>8:30</td>
<td>Particle Sizing</td>
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<td>9:30</td>
<td>Transmissometers</td>
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<td>10:45</td>
<td>Post Test and Closing</td>
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The Course closes at 12:00 a.m. on Friday, please plan to remain until that time.

Three Continuing Education Units (CEU's) will be awarded to those students who attend a minimum of 95% of all scheduled class and laboratory sessions and who satisfactorily pass examinations based on studies and assignments.
SOURCE SAMPLING FOR PARTICULATE EMISSIONS
APTI COURSE NUMBER 450

PRETEST

DIRECTIONS: Circle the best answer (there is one and only one correct answer for each question). Mark answers both on your Exam Sheet and on the Answer Sheet. You will be asked to turn in only the Answer Sheet. (The August 18, 1977 Federal Register and a scientific calculator may be used during this test. You should take no more than 45 minutes.)

1. How would you correct the “C” factor of your nomograph if your pitot tube had a coefficient of $C_p = 0.79$?

   a. Take $C_{corr}^{nomog} = \frac{0.85}{0.79}C_{nomog}$

   b. Use $C_{corr}^{nomog} = \frac{0.79}{0.85}C_{nomog}$

   c. The nomograph can’t be corrected for a different $C_p$.

   d. Use $C_{corr}^{nomog} = \frac{(0.79)^2}{(0.85)^2}C_{nomog}$

2. The Type S pitot tube has demonstrated several characteristics that are important in understanding its proper function and application in measuring gas velocity. Those characteristics which can affect its performance are:

   a. Tube length and diameter

   b. Sensing area and tube length

   c. Sensitivity to turbulence and orientation

   d. Sensitivity to temperature variation and abusive environments

3. What assumptions does the nomograph make about the stack gas molecular weight?

   a. The molecular weight can be corrected for %CO$_2$ and %O$_2$.

   b. The dry stack gas molecular weight is measured to be 29.

   c. The molecular weight (wet) is assumed to be 29.

   d. The stack gas molecular weight is directly related to $v_g$, the stack gas velocity.

4. Correcting pollutant concentrations to 12% CO$_2$ is applicable to:

   a. Non-combustion processes

   b. All chemical processes except oil refineries

   c. Combustion processes

   d. Only those processes burning No. 2 diesel oil
5. If the particulate concentration is measured as 0.1 grains per dry standard cubic foot (DSCF), and the stack gas flow rate is 70,000 DSCF per minute, what is the particulate emission rate in pounds per hour (7000 grains = 1 pound)?
   a. 60 pounds/hour
   b. 1 pound/hour
   c. 10 pounds/hour
   d. Need more information

6. If the gas analysis is 6.2% O₂, 14.2% CO₂, 0% CO, 79.6% N₂ and the % H₂O is 7.0%, the wet molecular weight of this mixture is:
   a. 29.6
   b. 23.8
   c. 9.0
   d. 30.9

7. The greatest source of experimental error for a stack test arises out of the measurements for:
   a. Moisture content of the stack gas
   b. Molecular weight of the stack gas
   c. Velocity of the stack gas
   d. Sample point position within the duct

8. The most important aspect of a safety evaluation procedure designed to prevent accidents is a continuous:
   a. Reminder to personnel of previous accidents
   b. Accident analysis program
   c. Safety indoctrination program
   d. Stronger enforcement of safety rules

9. The on-site sampling team should follow
   a. Their developed safety methods
   b. Plant safety regulations and those guidelines given in the CRC safety handbook
   c. All plant safety guidelines in addition to those developed specifically for the sampling team
   d. Posted plant regulations

10. The Glass Fiber Filter used in Method 5 particulate sampling must:
    a. Exhibit at least 96.5% collection efficiency
    b. Be dessicated 24 hours and weighed to a constant weight
    c. Be dessicated 24 hours and weighed to the nearest 1.0 mg
    d. Be dessicated 6 hours and weighed
11. Turbulence is created by any accessory adjacent to the Type S pitot tube. The effect of turbulence upon the calibration of the Type S pitot tube is minimized when the accessory is separated from the pitot tube by a distance:

a. 7.62 mm
b. 3/4"
c. 2"
d. 3"

12. The term $\Delta H_{st}$ is defined as:

a. The sum of the stagnation pressure and static pressure in the duct.
b. The flow rate of dry air flowing through a flat, sharp-edged orifice
c. Sampling Meter Console calibration factor
d. The pressure differential across the sampling console orifice meter that creates a flow rate through the meter of 0.75 cfm dry air at 70°F and 29.92 in. Hg.

13. The Type S pitot tube must be properly oriented in the gas stream if it is to measure the correct gas velocity impact pressure. A serious drawback of sampling probe design in some equipment systems is:

a. The pitot tube is permanently welded to the sampling sheath
b. The pitot tube-probe sheath assembly can be accidently twisted into misalignment in the gas stream
c. The pitot tube is constructed of 316 stainless steel
d. The pitot tube-probe sheath assembly is out of round

14. Blowers are necessary on transmissometers to:

a. Prevent mirror lock-up
b. Provide a purge system through the instrument to eliminate the effects of corrosive gases
c. Air-condition the optical system
d. Keep the optical windows free of particulates

15. How is transmittance related to opacity?

a. $\%$ opacity - $\%$ transmittance - Ringelmann number
b. Transmittance $= (1 - \%$ opacity $) \times 100$
c. Transmittance/opacity = Ringelmann number
d. $\%$ opacity $= 100\% - \%$ transmittance
16. The cascade impactor particle sizer can give representative particle size data if:
   a. It is properly calibrated and operated
   b. A cyclone is used to knock out large particle in the gas stream
   c. Only if it is not at stack temperature when sampling
   d. Agglomeration and fracturing of particles takes place in the device

17. For tangential cyclonic flow in a stack, the best way to determine the velocity is:
   a. Orient the pitot tube until maximum reading is obtained. This is the true $\Delta p$.
   b. Orient the pitot tube parallel to the sides of the stack and the $\Delta p$ reading is the upward vector of the velocity.
   c. Measure the impact pressure and the static pressure separately and by difference obtain the velocity head ($\Delta p$).
   d. Install gas flow straightening vanes and sample in the usual manner.

18. "Isokinetic," in stack sampling, means:
   a. The volumetric flow rate at the tip of the probe nozzle is equal to the volumetric flow rate at the metering device.
   b. The velocity at the tip of the nozzle is equal to the velocity at the metering device.
   c. The velocity at the tip of the nozzle is equal to the velocity of the approaching stack gas stream.
   d. A term used by stack samplers to impress plant personnel.

19. Cascade impactor particle sizing devices are subject to errors produced when the sample gas flow rate through the device is too high. These errors are caused by:
   a. Poor leak test procedures
   b. Process fan fluctuations
   c. Scouring and reentrainment of particles deposited on stage plates
   d. Under isokinetic flow through the impactor

20. The Type S pitot tube is the most commonly used device for the EPA Method 5 sampling train gas sensor. It aids in the measurement of the stack gas velocity. The Type S pitot tube directly measures:
   a. The gas velocity impact pressure and static pressure
   b. Gas flow rate through the A and B legs of the tube
   c. Stack gas viscosity
   d. The difference between gas viscosity and gas density
21. Source sampling nozzles should be:

a. Tapered to ≤ 40°

b. Must not exceed 3/4" diameter

c. Calibrated regularly to the nearest (0.001 inch) 0.025 mm

d. Replaced at specific intervals

22. In the following equations:

\[ v_s = \text{stack gas velocity} \]
\[ A_s = \text{stack cross-sectional area} \]
\[ A_n = \text{nozzle cross-sectional area} \]
\[ \theta = \text{sampling time (minutes)} \]
\[ V_m = \text{standard volume metered at the dry gas meter} \]
\[ V_n = \text{volume at stack conditions passing through the nozzle} \]

The % isokinetic for a stack may be calculated using equation:

a. \[ \% \text{isokinetic} = \frac{A_n}{A_s} \times 100 \]

b. \[ \% \text{isokinetic} = \frac{V_n}{A_n v_s} \]

c. \[ \% \text{isokinetic} = \frac{V_m}{\theta A_n v_s} \times 100 \]

d. \[ \% \text{isokinetic} = \frac{V_n}{\theta A_s v_s} \]

23. The New Source Performance Standards for a Fossil Fuel Fired Steam Generator define a particulate as:

a. Any solid or liquid in the stack gas

b. Any solid in the stack gas

c. Any solid or liquid other than uncombined water in the stack gas as measured by Method 5.

d. Any solid or liquid other than uncombined water as measured by Method 5 sampling train maintained at ≤ 400°F
24. An Orsat analyzer is commonly used to determine the composition of a combustion effluent where N₂, O₂, CO, and CO₂ are the principal constituents of the gas stream. It directly measures:

a. O₂, N₂, CO, and CO₂
b. CO, CO₂, O₂
c. CO₂, O₂, N₂
d. N₂, O₂, CO

25. An Orsat analyzer yields results on a:

a. Wet basis because it essentially is a wet chemical analysis.
b. Wet basis because the effluent usually contains moisture.
c. Dry basis because the moisture condenses until the effluent is dry.
d. Dry basis because the vapor pressure of water remains the same.

26. The order in which we analyze the components is:

a. CO₂, O₂, CO
b. O₂, CO₂, CO, N₂
c. CO, O₂, CO₂
d. N₂, O₂, CO

27. The Type S pitot tube must be calibrated while assembled in the sampling configuration for which its use is intended. This is necessary because:

a. The Type S pitot tube is not an accepted standard for gas velocity measurements.
b. It may be Reynold's Number Dependent
c. It is not manufactured according to an established National Standard
d. All the preceding reasons in conjunction with the dictates of good experimental procedure for preparation and use of any scientific measuring device.
28. Select the equation that best describes the calibration of a pitot tube using a known standard pitot tube.

a. \( C_p = \frac{Q_s / A_s}{K_p \sqrt{\frac{T_s \Delta p}{P_s M_s}}} \)

   \( A_s \) = stack cross-sectional area

   \( C_p \) = pitot tube calibration coefficient

   \( C_p(\text{std}) \) = standard pitot-static tube calibration coefficient

   \( K_p \) = dimensional constant

   \( M_s \) = wet molecular weight of the gas

   \( P_s \) = absolute pressure of the gas

   \( \Delta p \) = pitot tube velocity pressure

   \( \Delta p(\text{test}) \) = test pitot tube velocity pressure

   \( \Delta p(\text{std}) \) = standard pitot-static tube velocity pressure

   \( Q_s \) = volumetric flow rate

   \( T_s \) = absolute temperature of the gas

b. \( C_p = \frac{Q_s / A_s}{K_p \sqrt{\frac{P_s \Delta p}{T_s M_s}}} \)

c. \( C_p = C_p(\text{std}) \sqrt{\frac{\Delta p(\text{test})}{\Delta p(\text{std})}} \)

d. \( C_p = C_p(\text{std}) \sqrt{\frac{\Delta p(\text{test})}{\Delta p(\text{std})}} \)

29. The \( D_{50} \) of a cascade impactor stage is defined as:

a. The particle diameter at which the stage is 50% efficient

b. The \( D_p \) of that stage

c. The particle diameter at which the stage is 50%

d. The \( D_{50} \) aerodynamic diameter of the particles on that stage

30. The photopic region is

a. The region of the electromagnetic spectrum covered by the spectral output of a tungsten filament.

b. The effective sensing area of the detector on a transmissometer.

c. The range of particle sizes which scatter visible light.

d. The visible region of the electromagnetic spectrum.
31. The moisture content of the stack gas enters into calculation of the wet molecular weight of the gas, in the expression:

a. \[ M_d = \sum M_x B_x \]

b. \[ M_s = M_d (1-B_{ws}) + 18 (B_{ws}) \]

c. \[ M_s = M_d (1-B_{ws}) + 0.025 \]

d. \[ M_s = M_d (1-B_{ws}) + B_{ws} \]

\[ B_{ws} = \text{mole fraction H}_2\text{O (}\%\text{ H}_2\text O) \]

\[ M_s = \text{weight molecular weight of the stack gas} \]

32. What must you do if you encounter effluents other than \( \text{CO}_2, \text{O}_2, \text{CO}, \text{or} \text{air} \) in order to determine the molecular weight?

a. Guess the molecular weight to be 29.

b. Use appropriate analytical procedures to determine the mole fraction of each constituent of the effluent gas.

c. Go ahead and use the Orsat anyway. The principle is “anything is better than nothing”.

d. Use a Fyrite.

33. If you sample over-isokinetically, your particle concentration will be

a. Less than the true concentration

b. Greater than the true concentration

c. The true concentration

d. Greater than the true concentration only if large particles make up a significant percentage of the particle size distribution

34. A quick approximation of stack gas velocity in a duct can be made using the equation:

a. \[ v_s = 2.46 \sqrt{T_s \Delta p} \]

b. \[ v_s = 85.48 \sqrt{(T_s \Delta p)} \]

c. \[ v_s = K_p C_p \left[ \frac{T_s P_m}{T_m P_s} \right] \]

d. \[ v_s = K_p C_p \sqrt{\frac{T_s \Delta p}{P_s B_w}} \]
35. The ideal gas law states that:

\[ PV = \frac{m}{M} \cdot RT \]

Select the statement that is false.

a. The universal gas constant, \( R \), is dimensionless.
b. The above relationship can be used to find the density of a gas at any conditions of \( P, T, \text{ and } M \).
c. Molecular weight is determined by knowing the composition of gas stream.
d. \( T \) must be in absolute units.

36. Why is the determination of moisture content of the effluent gas important in isokinetic sampling?

a. Because moisture tends to corrode the nozzle.
b. Because it enters as a variable in the isokinetic sampling equation and must be considered in setting the isokinetic flow rate.
c. It can dissolve particulates and yield low results.
d. It is not important in isokinetic sampling.

37. One of the important hydrodynamic principles used in isokinetic considerations, is

a. Large particles tend to move in their same initial direction.
b. Barriers to flow develop vortices.
c. Pressure is inversely related to volume.
d. A flowing gas stream will decrease the pressure in a tube normal to the flow direction.

38. Which one of the following relates pressure differential across a system to the flow rate of the gases in the system:

a. Stokes Law
b. Reynolds’ Number
c. Bernoulli’s Theorem
d. Avagadro’s Number
39. Reference Method 4 in the Federal Register outlines the procedures for determination of the moisture content of a stack gas. Moisture content is best determined from the equation: (Note \( B_{wo} \) is the same as \( B_{ws} \))

\[
\begin{align*}
\text{a.} & \quad B_{ws} = \frac{V_{wc}}{V_{wc} + V_m} + 0.02 \\
\text{b.} & \quad B_{ws} = \frac{V_{wc(\text{std})} + V_{wsg(\text{std})}}{V_{wc(\text{std})} + V_{sg(\text{std})} + V_m(\text{std})} \\
\text{c.} & \quad B_{ws} = -\frac{1}{V_{wc} + V_m} \\
\text{d.} & \quad B_{ws} = 1 - \left[ -\frac{V_{wc}}{V_m} \right]
\end{align*}
\]

40. The % isokinetic calculated at the end of a Method 5 test is a measure of:

\[
\begin{align*}
\text{a.} & \quad \text{The precision with which sampling rates were set based on test velocity and volumetric flow rate data} \\
\text{b.} & \quad \text{Experimental discrepancies} \\
\text{c.} & \quad \text{Experimental error} \\
\text{d.} & \quad \text{Accurate pollutant mass emissions}
\end{align*}
\]

TRUE – FALSE

41. The static pressure of a duct is that pressure which would be indicated by a gage moving along with the gas stream in the duct.

42. The nomograph supplied with most commercial EPA trains is the most accurate method for setting isokinetic flow rate.

43. When any fuel is burned at 50% excess air, the flue gas will contain the same \( \%O_2 \) and \( \%CO_2 \).

44. An inclined manometer must always be leveled and properly zeroed if good \( \Delta p \) readings are expected.

45. Gas straightening vanes will assist in reducing gas turbulence within a duct.

46. The standard pitot tube has standard design criteria accepted by the National Bureau of Standards.

47. The analytical technique and properties of the pollutant and other constituents are of prime importance when designing sampling trains and experiments.

48. Sampling for the average pollutant concentration at the point of average velocity is common practice for isokinetic sampling.
49. The optical density measured across a stack can be correlated to mass emission concentration.

50. The relationship used to find the proper isokinetic sampling rate when the $\Delta p$ is known, is:

$$\Delta H = K \Delta p.$$
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ANSWER SHEET #450

Name

KEY -- PRE-TEST

Date

1. a b c
2. a b
3. a b c d
4. a b d
5. a b c d
6. b c d
7. a b d
8. a b c d
9. a b c d
10. a c d
11. a c d
12. a b c
da
13. a b c d
14. a b c
da
15. a b c
da
16. b c d
17. a b c
da
18. a b d
da
19. a b d
da
20. b c d
21. a b d
da
22. a b d
da
23. a b d
da
24. a b c
da
25. a b c

26. b c d
27. a b c d
28. a b d
29. b c d
30. a b c
31. a c d
32. a c d
33. b c d
34. b c d
35. b c d
36. a c d
37. b c d
38. a b c d
39. a c d
40. b c d
41. F
42. T
43. T
44. F
45. F
46. F
47. F
48. T
49. F
50. F

31 30
SOURCE SAMPLING FOR PARTICULATE EMISSIONS
APTI COURSE NUMBER 450

POST TEST

DIRECTIONS: Circle the best answer (there is one and only one correct answer for each question). Mark answers both on your Exam Sheet and on the Answer Sheet. You will be asked to turn in only the Answer Sheet. The August 18, 1977 Federal Register and a scientific calculator may be used during this test. You will have 45 minutes to complete this test.

1. If the particulate concentration is measured as 0.1 grains per dry standard cubic foot (DSCF), and the stack gas flow rate is 70,000 DSCF per minute, what is the particulate emission rate in pounds per hour (7000 grains = 1 pound)?
   a. 60 pounds/hour
   b. 1 pound/hour
   c. 10 pounds/hour
   d. need more information

2. A Stack Tester needs an estimated stack gas velocity for pre-survey information. He is told that the stack gas is exiting from a combustion source and that the average stack gas temperature is 440°F. A velocity traverse with an "S" type pitot tube ($C_p = 0.85$) gave the average $\Delta p = 1.0$ in H$_2$O. Estimate the gas velocity in the duct.
   a. 69 ft./sec.
   b. 74 ft./sec.
   c. 60 ft./sec.
   d. 78 ft./sec.

3. A Type S pitot tube was calibrated against a standard pitot-static tube assigned a $C_p = 0.998$ by NBS. The Type S tube measured $a' \Delta p = 0.500$. The standard tube measured $a'' \Delta p = 0.350$. What is the $C_p$ of the Type S tube based on this data?
   a. $0.98 (0.7)^2$
   b. $0.998/\sqrt{0.7}$
   c. $0.998 \sqrt{0.7}$
   d. $0.998(0.7)^2$

February 14, 1980
4. A Stack Test was performed at a wood fired boiler. The stack gas contained 10% H₂O and traveled up the stack at 30 ft./sec. The stack had a cross-sectional area of 20 ft.², average temperature of 335°F, and absolute pressure of 29.92 in. Hg. What was the volumetric flow rate in dry standard cubic feet per hour?

a. 144,000  
b. 1,300,000  
c. 130,000  
d. 1,960,000

5. Method 1 presents guidelines for the selection of a sampling site and minimum number of sampling points for a particulate traverse for a stack diameter greater than 24 inches. The criterion for using 12 sampling points in the duct states that the sampling site is at least:

a. 8 duct diameters downstream and 2 duct diameters upstream of a flow disturbance.  
b. 2 duct diameters downstream and 8 duct diameters upstream of a flow disturbance.  
c. 4 duct diameters downstream and 8 duct diameters upstream of a flow disturbance.  
d. 6 duct diameters downstream and 2 duct diameters upstream of a flow disturbance.

6. The Code of Federal Regulations outlines the procedures for Method 3. The method gives details on how to analyze the stack gas for its constituent components using the Orsat. Orsat analysis makes possible the calculation of:

a. Mole fraction of CO₂, O₂, and CO, dry gas molecular weight and percent excess air in the duct  
b. Percent excess air, CO₂, and volumetric flow rate (dry)  
c. Percent CO₂, O₂, and CO, and moisture content  
d. Only the percent oxygen present in the dry gas.

7. Method 1 guidelines suggest that all sampling points in a rectangular duct be located at the centroid of an equal area so that:

a. There is a length to width ratio of 1:4  
b. There is a length to width ratio of 2:1  
c. Two and five are concentric equal areas  
d. There is a balanced matrix.
8. Using Method 1 guidelines it is necessary to calculate an equivalent diameter 
\( (D_e) \) for rectangular stacks to be sampled. This is done using:

- a. \( D_e = \frac{L(W)}{(L)^2} \)
- b. \( D_e = \frac{L(W)}{(W)^2} \)
- c. \( D_e = \frac{2(L)(W)}{L + W} \)
- d. \( D_e = \frac{4(L)(W)}{W + L} \)

9. If fibers from a filter adhere to the gasket part of the filter assembly a proper procedure to follow would be to:
   a. Wash the gasket in an acetone/water rinse.
   b. Retain the fibers on the gasket for the next run.
   c. Scrape off the fibers into the filter recovery dish.
   d. Wipe the fibers off with a Kimwipe.

10. The mole fraction of \( \text{H}_2\text{O} \) in a stack gas as calculated by the 
    Reference Method, is determined using the equation

- a. \( B_{ws} = \frac{V_{wc}}{V_{wc} + V_m} + 0.02 \)
- b. \( B_{ws} = \frac{V_{wc(\text{std})} + V_{wsg(\text{std})}}{V_{wc(\text{std})} + V_{wsg(\text{std})} + V_m(\text{std})} \)
- c. \( B_{ws} = \frac{V_{wc}}{V_{wc} + V_m} \)
- d. \( B_{ws} = \frac{1}{V_{wc} + V_m} \)
11. The following statements give some of the advantages gained by using a Type S pitot tube. Which statement is not always true?

a. The Type S pitot tube is easy to use in small sampling ports.
b. The Type S pitot tube resists abusive environments and holds its calibration.
c. The Type S pitot tube consistently calibrates to a known \( C_p \) value of 0.84, therefore, individual calibration is not necessary.
d. The large gas sensing orifices of the Type S pitot tube help prevent clogging in heavily loaded particulate gas streams.

12. The standard pitot-static tube has small openings surrounding the tube for measuring:

a. Standard pressure
b. Static pressure
c. Rotational gas velocity vector
d. Parallel gas axis angle

13. The small opening surrounding the standard pitot-static tube may clog with particulate in a heavily loaded gas stream. For this reason the standard pitot-static tube should:

a. Never be used for this type situation
b. Used only to calibrate a Type S pitot tube
c. Be a second choice to a well calibrated Type S tube in this situation
d. Protected from clogging by stuffing glass wool into the small opening

14. The Type S pitot tube is the most commonly used device for the EPA Method 5 Sampling Train gas sensor. It aids in the measurement of the stack velocity. The Type S pitot tube directly measures:

a. The difference between total pressure and static pressure
b. Gas flow rate through the A and B legs of the tube
c. Stack gas viscosity
d. Difference between gas viscosity and gas density

15. The requirements concerning minimum distances for separation of the Type S pitot tube and any accessory on the sampling probe are established because:

a. The Type S pitot tube has a slow response time when gas turbulence exists about the sensor.
b. The Type S pitot tube has exhibited a sensitivity to gas turbulence that can effect its calibration coefficient.
c. The Type S pitot tube must be isolated from the sampling nozzle to ensure that the volume at the nozzle equals the velocity of the approaching gas stream.
d. Manufacture calibration guarantees are void if the pitot tube is too close to other train components.
16. In the isokinetic rate equation $\Delta H = K \Delta p$, $K$ is:
   a. Always equal to 1.84
   b. Only a function of the stack temperature
   c. A function of many variables
   d. Independent of the $C_p$ value

17. Isokinetic sampling is:
   a. Used only for gas sampling from stationary sources
   b. Is necessary when sampling for gases as well as for particulates to obtain the proper influx of pollutant
   c. The same as proportional sampling
   d. Is necessary to obtain a particulate sample having the same size distribution as that occurring in the stack

18. What is the purpose of the Method 5 nomograph?
   a. It is a type of slide rule used to determine the $\Delta p$ for the chosen sampling train.
   b. It is a type of slide rule used to correct the nozzle velocity to standard conditions.
   c. It is a type of slide rule used to determine a $\Delta H$ from the observed $\Delta p$.
   d. It is a type of slide rule used to determine a $\Delta p$ from the observed $\Delta H$.

19. In the expression $\Delta H = K \Delta p$, $K$ represents the reduction of several variables into a constant term that may be calculated for the existing conditions at the source. Which of the following variables is assumed to be zero in the reduction of terms to $K$?
   a. $\Delta H_a = 0$
   b. $B_{wm} = 0$
   c. $B_{ws} = 0$
   d. $(1-B_{ws}) = 0$

20. A Source Test was performed at an isokinetic rate of 86%. The emissions calculated from this test are biased:
   a. By large particulates and a higher emission rate than true
   b. By large particulates and a lower emission rate than true
   c. Small particulates and a higher emission rate than true
   d. Small particulates and a lower emission rate than true
21. A transmissometer measures the opacity of an effluent stream using light with wavelengths between 500-600 nm. These wavelengths are chosen for which of the following reasons?

a. These wavelengths are specific to fly ash particles
b. Transmissometer opacity readings in this area of the electromagnetic spectrum are free from H₂O and CO₂
c. Present technology does not allow economical construction of instruments employing other wave lengths
d. Combustion sources emit light in this region of the spectrum

22. The percent isokinetic should be 100%, and if it is:

a. It ensures sampling accuracy.
b. It means only that, based on the volumetric and velocity data, the proper sampling rates were used.
c. It means that the source is in compliance with regulations.
d. It means that only the pollutant mass rate will be accurate.

23. In the clean-up procedures of an EPA particulate train, acetone is used to wash all internal surfaces of:

a. Nozzle, probe, and front half of filter holder
b. Answer "a," except the probe is rinsed only if the liner is glass
c. Probe and filter holder only
d. Acetone is not used because it is highly volatile

24. A sampling team performed reference method 5 particulate test at a municipal incinerator. Test results showed an emission rate of 0.01 lb./dscf with 8% CO₂ in the stack gas. What is the emission rate connected to 12% CO₂?

a. 0.010 lb./dscf
b. 0.015 lb./dscf
c. 0.020 lb./dscf
d. 0.025 lb./dscf
25. Error analysis of the Method 5 sampling system suggests that the greatest errors occur in
determination of:

a. Stack gas velocity and dry molecular weight  
b. Stack gas velocity and sampling site selection  
c. Stack gas velocity and wet molecular weight  
d. Stack gas velocity and moisture content

26. If entrained water is observed in the stack, which of the following methods
would give the best estimate for B_{ws}?

a. Just use the saturated moisture value at the stack temperature  
b. Use the wet bulb-dry bulb method  
c. Use Method 4  
d. Just use the saturated moisture value at the ambient temperature

27. The moisture content of the stack gas enters into the calculation of the wet molecular weight
of the gas, in the expression:

a. \[ M_d = \sum x M_x \]  
b. \[ M_s = M_d(1-B_{ws}) + 18(B_{ws}) \]  
c. \[ M_s = M_d(1-B_{ws}) + 0.025 \]  
d. \[ M_s = M_d(1-B_{ws}) + B_{ws} \]

28. For tangential cyclonic flow in a stack, the best way to determine the velocity is:

a. Orient the pitot tube until maximum reading is obtained. This is the true \( \Delta p \)  
b. Orient the pitot tube parallel to the sides of the stack. The \( \Delta p \) reading is the upward
   vector of the velocity  
c. Measure the impact pressure and the static pressure separately and by difference obtain
   velocity head (\( \Delta p \))  
d. Pull gas flow straightening vanes and sample in the usual manner
29. Best Tester sampling team had just completed a Method 5 test at a cost of $2000 to the source. The value obtained for the emissions, E, in \( \text{lbs/10}^6 \text{ Btu} \), was below the standard, indicating that the source was in compliance. The test itself, however, was only 80% isokinetic. This test data:

a. Would be rejected by EPA since it is not within \( \pm 10\% \) of 100% isokinetic.

b. Could be easily corrected to give the value of E at 100% isokinetic conditions.

c. Could be accepted by EPA since the value of E would be even lower at 100% isokinetic conditions.

d. Could be accepted by EPA since the value of E would be even higher at 100% isokinetic conditions.

30. Correcting pollutant concentrations to 12% CO\(_2\) is applicable to:

a. All processes

b. Incineration processes and other combustion sources

c. Sources in operation prior to April 1, 1970

d. Sources covered by State Implementation Plans

31. The ideal gas law states that:

\[
PV = \frac{m}{M} RT
\]

Select the statement that is false.

a. The universal gas constant, R, is dimensionless.

b. The above relationship can be used to find the density of a gas at any conditions of \( P, T, \) and \( M \).

c. Molecular weight is determined by knowing the composition of gas stream.

d. \( T \) must be in absolute units.

32. The \( D_{50} \) of a cascade impactor stage is defined as:

a. The average aerodynamic diameter of the particles on that stage

b. The physical diameter of the particles on that stage

c. The particle diameter at which the stage is 50% efficient

d. Calibration coefficient of that stage
33. Cascade Impactor particle sizing devices are subject to errors produced when the sample gas flow rate through the device is too high. These errors are caused by:

a. Anisokinetic flow through the impactor
b. Over isokinetic flow through the impactor
c. Under isokinetic flow through the impactor
d. Scouring and reentrainment of particles deposited on stage plates

34. The maximum total angle of radiation that can be projected by the lamp assembly of the transmissometer is known as:

a. The angle of trajectory
b. The angle of declination
c. The light scattering angle
d. The angle of projection

35. How is transmittance related to opacity?

a. transmittance = \log_{10} \left( \frac{1}{1 - \text{opacity}} \right)
b. transmittance/opacity = naq\]
c. % opacity = 100\% - % transmittance
d. % opacity = % transmittance - naq]\n
36. A transmissometer will provide information on mass emissions from a pollutant source for a given time period if:

a. The neutral density filters are calibrated to 3% and the particle characteristics do not change.
b. A reference light source is used and the particle characteristics do not change.
c. The manufacturer supplies a calibration chart.
d. The optical density can be correlated to grain loading and the particle characteristics remain unchanged.

37. If a post-leak check of a Method 5 train gives a value of 0.032 cfm, the test should be:

a. Rejected without question.
b. Accepted without question.
c. Accepted, if \( V_m \) is corrected, using the leak rate value
d. Accepted, if \( V_m \) is modified by averaging the pre-test and post-test leak rates.
The following questions are related to the diagram of the Method 5 Sampling Train. Questions vary in complexity from simple identification of equipment to others that test understanding and comprehension of equipment use.

38. When performing an EPA Method 5 test, in order to draw a sample through the sampling train at a controlled rate, the by-pass valve is:

a. Turned all the way off
b. Turned clockwise from a fully open position
c. Turned counter-clockwise from an off position
d. Turned to a fully open position
39. What is the function of the orifice meter in a Method 5 test?

a. It is used to eliminate correcting the sample volume to standard conditions
b. It is used to determine the value of K of the isokinetic rate equation during the test
c. It is used to determine the flow rate of the gas through the sampling train
d. It is used to determine the flow rate of the gas in the stack

40. In the EPA Method 5 Sampling Train, what are each of the impingers filled with and what is the correct order?

a. 1 - 100cc H₂O, 2 - Dry, 3 - 100cc H₂O, 4 - Silica Gel (100g)
b. 1 - 100cc H₂O, 2 - 200cc H₂O, 3 - Dry, 4 - Silica Gel (200g)
c. 1 - 100cc H₂O, 2 - 100cc H₂O, 3 - Dry, 4 - Silica Gel (200g)
d. 1 - 200cc H₂O, 2 - 200cc H₂O, 3 - Dry, 4 - Silica Gel (100g)

41. All leak checks for the sample train should be conducted:

a. From the nozzle inlet with all train components at operating temperature
b. From the filter inlet at room temperature
c. From the probe inlet at ambient temperature
d. From the nozzle inlet at ambient temperature

42. The post-test leak check at the highest vacuum recorded during the stack test is:

a. An unnecessary and useless procedure because it is not required by present regulations
b. A possible source of error creating particulate penetration through the glass mat filter
c. Required in the August 18, 1977 Federal Register revisions to Method 5
d. The work of a novice tester unaware of the possible problems

43. The August 18, 1977 Federal Register gives guidelines on the type of sampling probe liner that may be used in the Method 5 sampling system. It recommends that probe liners be:

a. Borosilicate glass
b. Borosilicate glass or stainless steel
c. Quartz glass or stainless steel
d. Borosilicate or quartz glass; stainless steel with the approval of the administrator
44. The Federal Register guidelines for Method 5 suggest a pre-test leak check of the sampling train. The test recommendations are:

a. A leak check of the entire system at operating temperature and a vacuum gage reading of 15 in. Hg
b. A leak check of the entire system at a vacuum gage reading of 14 in. Hg
c. A leak check at the filter inlet at a vacuum gage reading of 14 in. Hg and maximum leak rate of 0.02 cfm
d. A leak check at the filter inlet at a vacuum gage reading of 15 in. Hg and maximum leak rate of 0.25 cfm

45. The F-Factor is:

a. Used to determine the concentration of the stack gas.
b. Permitted by the Federal Register to convert emissions data for FFSG into the units lb/10^6 Btu.
c. Used to calculate the stack gas volumetric flow rate
d. Used to determine the (pmr) pollutant mass rate.

46. The EPA Method 5 Sampling procedure specifies that the out-of-stack filter temperature (unless stated otherwise in the subparts) be maintained at

a. \( \leq 250^\circ F \)
b. \( \geq 250^\circ F \)
c. No greater than 248°F + 25°F
d. 250°F

47. Maintaining the filter at this temperature is:

a. Part of the definition of "particulate" as the method is written
b. Necessary to prevent sulfate formation on the glass mat
c. The best temperature to assure a leak-tight filter holder
d. Easier than setting it at any other temperature

48. The desired flow rate through the Method 5 Sampling Train is 0.75 cfm dry air at 68°F and 29.92 in. Hg. These conditions are designated by a single term \( \Delta H_{\theta} \). Solving the orifice meter flow rate equation for \( \Delta H_{\theta} \) that meets the stated conditions we find:

\[
\begin{align*}
a. \quad \Delta H_{\theta} &= \frac{Q_m^2}{K_m^2} \\
 b. \quad \Delta H_{\theta} &= \frac{1}{K_m^2} \\
 c. \quad \Delta H_{\theta} &= \frac{0.9244}{K_m^2} \\
 d. \quad \Delta H_{\theta} &= \frac{Q_m}{K_m} \left[ \frac{P_m}{T_m} \right]^{\frac{2}{2}} \\
\end{align*}
\]
ANSWER SHEET

KEY -- POST TEST

1. b c d
2. a b c d
3. a b c d
4. a b c d
5. b c d
6. b c d
7. a b c
8. a b c
9. a b c
10. a b c
11. a b c
12. a b c
13. a b c
14. a b c
15. a b c
16. a b c
17. a b c
18. b c d
19. a b c d
20. b c d
21. a b c d
22. a b c d
23. b c d
24. a b c d
25. a b c

3 pts each
all others
2 pts

Date

26. b c d
27. a b c d
28. a b c
29. a b c d
30. a b c d
31. b c d
32. a b c d
33. a b c
34. a b c
35. a b c d
36. a b c
37. a b c d
38. a b c d
39. a b c d
40. a b c d
41. b c d
42. a b c d
43. a b c
44. b c d
45. a c d
46. a b c d
47. b c d
48. a b c d
ANSWERS TO ADDITIONAL PROBLEMS
Given as Homework
(See Workbook pages 175-181)

PROBLEM #1

Stack diameter: 16"
Upstream to nearest disturbance: 54"
Downstream to nearest disturbance: 125"

Diameter: Upstream: \( \frac{54''}{16''} = 3.37 \) eq. Dia = 8 pts

Diameter: Downstream: \( \frac{125''}{16''} = 7.81 \) eq. Dia = 10 pts

From Figure #1-1 of Federal Register, calculate 10 traverse pts.

```
1st Traverse

Sample Point  Circular Stack  Distance from
Number       % Diameter       Sample Port

1. 1A  0.044          0.70"
2. 2A  0.146          2.33"
3. 3A  0.296          4.73"
4. 4A  0.704         11.26"
5. 5A  0.854         13.66"
6. 6A  0.956         15.29"
7. 1B  0.044          0.70"
8. 2B  0.146          2.33"
9. 3B  0.296          4.73"
10. 4B  0.704        11.26"
11. 5B  0.854        13.66"
12. 6B  0.956        15.29"
```

2nd Traverse

Diameter

Because the number has to be a multiple of 4.
**PROBLEM #2**

\[ v_s = \frac{K_p C_p \sqrt{T_s \Delta p}}{P_s M_s} \]

\[ K_p = 85.49 \]
\[ C_p = 0.845 \]
\[ T_s = 303 + 460 = 763 \, ^oR \]
\[ \Delta p = 0.15 \]
\[ P_s = 30.3'' \, \text{Hg} \]

\[ M_d = 0.44 \, (\% \text{CO}_2) + 0.32 \, (\% \text{O}_2) + 0.28 \, (\% \text{N}_2 + \% \text{CO}) \]
\[ M_d = 0.44 \, (14.2) + 0.32 \, (5.0) + 0.28 \, (80.8) \]
\[ \gamma_d = 6.248 + 1.6 + 22.62 \]
\[ M_d = 30.47 \]

\[ M_s = M_d \, (1 - B_{ws}) + 18 \, B_{ws} \]
\[ M_s = (30.47) \, (1 - 0.07) + 18 \, (0.07) \]
\[ = 28.34 + 1.26 \]
\[ = 29.59 \]

\[ v_s = (85.49)(0.845) \sqrt{\frac{(763)(0.15)}{(30.3)(29.59)}} \]
\[ = 72.24 \sqrt{\frac{114.45}{896.79}} \]
\[ = 72.24 \frac{\sqrt{0.128}}{25.81 \, \text{ft/sec.}} \]

\[ Q_s = 3600 \, (1 - B_{ws}) \, v_s \, A \left( \frac{T_{std}}{T_{s(avg)}} \right) \left( \frac{P_s}{P_{std}} \right) \]
\[ = 3600 \, (1 - 0.07)(25.81)(A) \left( \frac{528}{763} \right) \left( \frac{30.3}{29.92} \right) \]

\[ \text{Diameter} = \frac{16''}{2} = 8'' \, \text{radius} \]

\[ \text{Area} = \pi r^2 \]
\[ = (3.14)(8)^2 = \frac{201 \, \text{sq. in.}}{144 \, \text{sq. in./sq. ft}} = 1.40 \, \text{ft}^2 \]
\[ = 3600 \, (1 - 0.07)(25.81)(1.40) \left( \frac{528}{763} \right) \left( \frac{30.3}{29.92} \right) \]
\[ = 8.48 \times 10^4 \, \text{ft}^3/\text{hr.} \]

\[ Q_A = (v_s)(A) = (25.65 \, \text{ft/sec})(1.40 \, \text{ft}^2) \]
\[ = 35.91 \, \text{ft}^3/\text{sec.} \]
\[ (35.91 \, \text{ft}^3/\text{sec})(3600 \, \text{sec/hr.}) = 1.29 \times 10^5 \, \text{ft}^3/\text{hr.} \]
PROBLEM #3

\[ v_s = \frac{K_p C_p}{P_s M_s} \sqrt{\frac{T_s \Delta p}{P_s M_s}} \]

\[ K_p = 85.49 \]
\[ C_p = 0.842 \]
\[ T_s = 300 + 460 = 760 \, ^\circ R \]
\[ \Delta p = 2.5'' \, H_2O \]
\[ P_s = 30.1 + \left( \frac{-15.0}{13.6} \right) \]
\[ = 28.99 \]

\[ M_d = 0.44 \, (%CO_2) + 0.32 \, (%O_2) + 0.28 \, (%N_2 + %CO) \]
\[ %CO_2 = 17 \]
\[ %O_2 = 2 \]
\[ %N_2 = 100 - 17 - 2 = 81 \]
\[ = 0.44 \times 17 + 0.32 \times 2 + 0.28 \times 81 \]
\[ = 7.48 + 0.64 + 22.68 \]
\[ = 30.8 \]

\[ M_s = M_d (1 - B_{ws}) + 18 (B_{ws}) \]
\[ = (30.8) \times (1 - 0.12) + 18 \times (0.12) \]
\[ = 27.10 + 2.16 \]
\[ = 29.26 \]

\[ v_s = (85.49)(0.842) \sqrt{\frac{(760)(2.5)}{(28.99)(29.26)}} \]
\[ = (71.9826) \sqrt{\frac{1900}{848.36}} \]
\[ = (71.9826)(1.4965) = 107.7 \, ft/sec. \]
PROBLEM #4

H₂O collected in impingers: 75 ml
H₂O collected in the silica gel: 25 g
Volume = 40.20 ft³
Pₘ = 30.0″ Hg
Tₘ = 100 °F + 460 = 560 °R

(a) \( V_m(\text{std}) = K_3 Y \frac{V_{mP_m}}{T_m} = (17.64)(1) \frac{(40.20)(30.0″ \text{ Hg})}{560} = 37.991 \text{ SCF} \)

(b) \( V_{wc}(\text{std}) = K_1 (V_f - V_i) = (0.04707 \text{ ft}^3/\text{ml})(75\text{ml}) = 3.53 \text{ ft}^3 \)

(c) \( V_{wsg}(\text{std}) = K_2 (W_f - W_i) = (0.04715 \text{ ft}^3/\text{g})(25 \text{ g}) = 1.18 \text{ ft}^3 \)

(d) \( B_{ws} = \frac{V_{wc}(\text{std}) + V_{wsg}(\text{std})}{V_{wc}(\text{std}) + V_{wsg}(\text{std}) + V_m(\text{std})} = \frac{3.53 + 1.18}{3.53 + 1.18 + 37.99} = 0.0471 = 0.1103 \)

\( 0.1103 \times 100% = 11.03% \)
PROBLEM #5

(a) \[ C_p(s) = C_p(\text{std}) \sqrt{\frac{\Delta p(\text{std})}{\Delta p(s)}} \]
\[ = 0.99 \sqrt{\frac{0.31}{0.42}} = 0.851 \]

(b) \[ M_d = 0.44(\%CO_2) + 0.32(\%O_2) + 0.28 (\%N + \%CO) \]
\[ = 0.44 (13) + 0.32(6) + 0.28 (80) \]
\[ = 5.72 + 1.92 + 22.4 \]
\[ = 30.04 \text{ lb/lb-mole} \]

(c) \[ M_s = (1 - B_{ws}) M_d + 18 B_{ws} \]
\[ = (1 - 0.1) 30.04 + 18(0.10) \]
\[ = 27.036 + 1.8 \]
\[ = 28.84 \text{ lb/lb-mole} \]

(d) \[ \bar{v}_s = K C_p \frac{T_s(\text{avg})}{P_s M_s} \sqrt{\Delta p} \]
\[ = (85.49)(0.851) \sqrt{\frac{810}{(29.00)(28.84)}} \sqrt{0.59} \]
\[ = (72.75) \left( \sqrt{\frac{810}{836.36}} \right) \left( \sqrt{0.59} \right) \]
\[ = (72.75) (0.984)(0.768) \]
\[ = 54.98 \text{ ft/sec} \]

(e) \[ Q_s = 3600 (1 - B_{ws}) \bar{v}_s A \left( \frac{T_{\text{std}}}{T_s(\text{avg})} \right) \left( \frac{P_s}{P_{\text{std}}} \right) \]
\[ = 3600 (.9)(54.98)(1200) \left( \frac{528}{810} \right) \left( \frac{29.00}{29.92} \right) \]
\[ = 3600 (.9)(54.98)(1200)(.652)(0.969) \]
\[ = 1.35 \times 10^8 \text{ SCFH} \]
PROBLEM #6

(a) \[ V_{m\text{(std)}} = K_Y V_m \frac{P_{\text{Bar}} + \Delta H}{T_m} = \frac{(17.64)(1)(50)}{13.6} \]

\[ = 46.64 \text{ DSCF} \]

\[ V_{ws} = K_1 (V_f - V_i) \]

\[ = 0.04707 \times 100 = 4.707 \text{ SCF} \]

(b) \[ \frac{R_{ws}}{560} = \frac{4.707}{4.707 + 46.64} = \frac{4.707}{51.343} = 0.0919 \]

\[ 0.0919 \times 100 = 9.19\% \]

(c) \[ C_s = \frac{100 \text{ mg}}{46.46 \text{ ft}^3} = \frac{0.00215 \text{ g/ft}^3}{46.46 \text{ ft}^3} = 0.0215 \text{ g/ft}^3 \]

\[ (0.0215 \text{ g/ft}^3)(15.43) = 0.33 \text{ gr/DSCF} \]

(d) \[ \%I = 100 \times \frac{T_{sV_{m\text{(std)}}}}{T_{\text{std}} V_{s\text{std}}} \frac{P_{\text{std}}}{\theta \text{ min. (60 sec/min) A}_{n}(1-B_{ws})} \]

\[ = 100 \times \frac{(760)(46.64)(29.92)}{(528)(48)(29)(60)(60)(0.0034)(1-0.0919)} \]

\[ = 1.06 \times 10^8 = 0.1297 \times 10^3 \]

\[ 8.17 \times 10^5 \]

\[ = 129.7 \%I \]
Lesson Goal:

Allow students to introduce themselves to the class; determine the actual level of job experience in the class - the number of stack tests in which each student has participated.

Lesson Objectives:

Each student should know:

1. The following information:
   a. Organization presenting the course
   b. Organization providing the funds for the course (e.g. - EPA Manpower and Technical Information Branch)
   c. Organization providing the course materials (e.g. Northrop Services, Inc. under contract to EPA)

2. The name of all instructors and their affiliation

3. The name and employer of each student in the class

4. Phone number where a student may receive messages

5. Requirements for passing the course
   a. Completed registration card
   b. Pre-test
   c. 95% attendance - minimum
   d. All laboratory work completed and turned in
   e. Post-test - 70% minimum passing grade
   f. Critique

6. Teaching method in the course - problem solving using the basics learned in these lectures.

7. All class materials
   a. Workbook
   b. Manual
c. Quality assurance document

d. Agenda

e. Selected handouts

f. Note paper

g. Federal Registers; 8/18/77; 2/23/78

h. Registration card

i. APTI chronological course schedule

j. EPA Traineeship Program Brochure

7. Location of

   a. Restrooms

   b. Refreshments

8. Address and phone number (919-541-2766) of EPA - APTI MD-20, Research Triangle Park, N. C. 27711 as the place to contact concerning course materials and the EPA air pollution training program.

Support Materials:

1. Student materials package

2. Blackboard and chalk
I. Introduce instructors
   A. Names and affiliation
   B. Experience
   C. Areas of expertise

II. Explain relationship between the organization presenting the course and EPA-APTI-MTIB

III. Logistics of the course location
   A. Message phone number
   B. Restrooms
   C. Refreshments and restaurants

IV. Introductions - have each student stand
   A. Let student give name and employer
   B. Have the student describe stack test experience
      1. Number of tests or years in stack testing
      2. Level of participation
         a. Observer
         b. Engineer in the field
         c. Report writing
   C. Have the student describe what he hopes to get from the course

V. Description of teaching methods
   A. Training
      1. Course directed at training students to perform a specific skill
      2. Methods used in the course will be explicit not implicit
B. Instructors
   1. Will be there to help student become trained
   2. Will add their experience and expertise to the training
   3. Encourage questions

C. Approach
   1. Teach the basic math and sampling techniques
   2. Solve new problems by applying these fundamentals

VI. Course requirements
   A. Completed registration card
   B. Pre-test
   C. 95% attendance - minimum
   D. All laboratory work completed and turned in
   E. Post-test - 70% minimum passing grade
   F. Course critique completed and turned in

VII. Materials - have students check that they have
   A. Manual
   B. Workbook
   C. Agenda
   D. Quality assurance document
   E. Federal Registers; 8/18/77; 2/23/78
   F. Note paper
   G. Registration card
   H. Selected handouts
   I. APTI Chronological Course Schedule
   J. EPA Fellowship Program Brochure

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VIII. Pre-test and registration

A. Explain that the pre-test
   1. Tests what they know as they enter the course
   2. Does not count in the final course grade
   3. Will be correlated to post-test grades to measure actual learning in the course
   4. Students should not guess at answers

B. Registration card - completely filled out

C. Begin the pre-test and tell students to take a break after the test

D. Collect all tests and registration cards - grade tests promptly and report low, high, and average grades
Lesson Goal:

To introduce the student to the symbols and common source sampling terms to be used in the course. To introduce the student to the basic EPA Method 5 Train and the basic concepts of gas physics needed for the comprehension of the course material.

Lesson Objectives:

The student will be able to:

1. Locate the goals and objectives of the course in the course manual.
2. Describe the symbols and common source sampling terms used in the course.
3. Recognize the basic features of the EPA Method 5 sampling train.
4. Write the expressions for pollutant mass rate and emission rate, using symbols for stack gas concentration, stack gas volumetric flow rate, and heat input rate.
5. Recognize the pitot tube equation on sight and understand the relative importance of the parameters in the equation.
6. Write the ideal gas law equation and be able to describe the effects of changing pressure and temperature on a gas volume.
7. Recognize the form of an ideal gas law correction equation.
8. Recognize the importance of Bernoulli's principle, gas viscosity and gas Reynold's number in source sampling.

Student Prerequisite Skills:

Basic mathematics.

Level of Instruction:

College Undergraduate Science
Intended Student Professional Background:

High school math and high school or college general science.

Support Materials and Equipment:

1. Course workbook
2. Course manual
3. Projector

Special Instructions:

This lecture lays the foundation for the rest of the course. Stress on the ideal gas law equation is important. It has been found necessary to review the Method 5 Sampling Train before Lesson 3, since some students may not be familiar with the terminology in the lecture. The detailed explanation of the sampling train in Lesson 3 supplements this earlier introduction.

References:

None.
The purpose of this lecture is to introduce the students to the EPA Method 5 train, source sampling terminology, the reasons for obtaining Method 5 data, and to review the ideal gas law equation.

I. Review of course objectives
   A. Symbols and terms - objectives
   R. Calculations
   G. Equipment familiarity
   D. Isokinetic sampling
   E. Doing the source test
   F. New methods

II. Methods of source sampling
   A. Methods of monitoring source emissions
      1. Manual
      2. Extractive-continuous
      3. In-situ-continuous
      4. Remote sensing
      5. Long path
      6. Visible emissions observations

III. B. The manual method for particulates - EPA methods
       1. Review Method 5 Train - show flow
       2. Define each of terms used - pitot tube, orifice meter, etc.
       3. Define isokinetic sampling -
          iso - same as, kinetic - pertaining to motion. State that purpose of M5 train
          is that \( v_n = v_s \)
       4. Show slides of train
          Point out significant features - orifice meter, fine control knob, filter holder

students to turn to page 3 workbook

slide L2-1a-f

Turn to page 14 of workbook

1.2-2

Diagram on page 18
III. Nomenclature

A. Symbols and subscripts

1. Review symbols and subscripts - defining important terms such as Δp, ΔH, ΔH₀, etc.

2. Stress that they are using English units since equipment is designed that way - not a course in metric conversion.

3. Define standard temperature = 68°F and pressure = 29.92 "Hg - define absolute T in °R and absolute pressure.

B. Pollutant mass rate and emission rate

1. Reason for doing Method 5 test - to obtain concentration, pollutant mass rate, emission rate.
   
a) Concentration \( c_s \)

\[ c_s = \text{quantity of pollutant (mass)} / \text{quantity of effluent gas (volume)} \]

units: \( \text{grains/ft}^3, \text{lbs/ft}^3, \text{grains/ft}^3 \cdot \text{M}^{-3} \)

note: 7000 grains = 1 lb

b) Stack gas volumetric flow rate \( \bar{Q}_s \)

\[ \bar{Q}_s = \text{quantity of effluent gas passing up stack (volume)} / \text{time} \]

\( \text{ft}^3 \text{/hr}, \text{etc.} \)

\[ Q_s = A_s V_s = \text{ft}^2 \times \text{ft} = \text{ft}^3 \text{/hr} \]

area of stack stack gas velocity
c) Pollutant mass rate \( \text{pmr}_S \)

\[
\text{pmr}_S = \frac{\text{quantity of pollutant (mass)}}{\text{time}}
\]

\[
\text{pmr}_S = \frac{\text{lbs}}{\text{hr}}, \frac{\text{grains}}{\text{hr}}, \frac{\text{grams}}{\text{hr}}
\]

d) Relationship of the three units

\[
\frac{\text{pmr}_S}{\text{Q}} = \frac{c}{\text{s}} \frac{Q S}{S}
\]

\[
\frac{\text{lbs}}{\text{hr}} = \frac{\text{lbs}}{\text{hr}}
\]

Stress units and unit cancellation

e) Emission rate - NSPS units are given in terms of the weight of emissions/10^6 Btu heat input

\[
E = \frac{\text{pmr}_S}{Q_H} = \frac{c}{\text{s}} \frac{Q S}{Q_H}
\]

\[
Q_H = \text{heat input rate} = \frac{10^6 \text{Btu}}{\text{hr}}
\]

See course manual Page 9-5

\[
E = \frac{\text{lbs}}{10^6 \text{Btu}} = \frac{10^6 \text{Btu}}{\text{hr}}
\]
Lecture Title: INTRODUCTION TO SOURCE SAMPLING

f) Review of pollutant mass rate

1. Refer to slide - pointing out the large number of variables in the test

2. Point out necessity for isokinetic sampling

3. Point out pitot tube equation - make no attempt to derive - point out variables

[Memorize]

Comes from Bernoulli's principle

\[ v_s = K C P \left( \frac{T_s \Delta p}{P_s M_s} \right) \]

EPA M2 M2 M3 M4

Will do these in the laboratory

4. Re-emphasize importance of emission rate calculation - This is the END RESULT

\[ E = \frac{c_s Q_s}{Q_H} \]

IV. Gas physics - review of concepts

A. Ideal gas law

1. Important in course

\[ PV = \frac{m}{M} \cdot RT \quad PV = nRT \]

review terms \( R = 21.83 \) \( \text{(in. Hg)(ft}^2) \)

\[ \text{lb-mole} \]

review mole concept

mole = molecular weight in grams or pounds

2. A trick

\[ p = \frac{m}{V} \frac{RT}{M} = \frac{c}{M} \quad \frac{RT}{M} \quad c \quad \text{concentration} \]

By now, students are somewhat tired and almost saturated - but this is Berlitz and the instructor must press on

Write on board

Few students understand the concept of the mole - stress its importance in chemistry

Ask students what c is
B. Correcting pressure or volume to standard conditions — very important

1. Do this derivation

\[ V_{\text{corr}} = nR \frac{T_{\text{std}}}{P_{\text{std}}} \]
\[ V_{\text{stack}} = nR \frac{T_{\text{corr}}}{P_{\text{corr}}} \]

to

for the same number of moles (molecules) of gas, what volume would these molecules occupy at standard conditions, rather than stack conditions?

\[ \frac{nRT_{\text{std}}}{P_{\text{std}}} = \frac{VT_{\text{corr}}}{P_{\text{corr}}} = \frac{VT_{\text{std}}}{P_{\text{std}}} \]

Very important to understand this — essential for understanding operation of Method 5 trick.

C. Other terminology of gas physics

1. Bernoulli's principle

\[ \frac{1}{2} m\dot{V}^2 + mg \Delta h + V\Delta p = 0 \]

Pitot tube equation derived from this expression

2. Viscosity — \( \eta \)

3. Reynolds' number — \( Re \)

Refer students to Course Manual — Chapter 2
page 2-10
They are now too saturated to absorb any more mathematics — take a break-next lecture to be show and tell casing off

Note: Students who have had no previous experience in source sampling will forget what per.

E mean, by Tuesday afternoon.
Review the definitions on occasion throughout the course.
Lesson Goal:

To familiarize the students with the equipment used for EPA Method 5 Particulate sampling; point out construction details required in the August 18, 1978 Federal Register; illustrate equipment design factors influencing sampling accuracy and convenience.

Lesson Objectives:

The student will be able to:

1. List the construction and calibration requirements for the Method 5 sampling nozzle

2. List the nozzle, probe, pitot tube, and thermocouple placement requirements to minimize aerodynamic interferences

3. List the approved construction materials for the nozzle probe, pitot tube, and probe liner

4. Describe the probe locking system for preventing misalignment in the gas stream

5. Describe the advantages and disadvantages of various types of sample cases and glassware

6. List the advantages and disadvantages of various materials used in constructing umbilical lines

7. Describe the advantages of magnehelic gages for pressure measurements and list the requirements for using these gages in an EPA Method 5 Sampling System

8. Compare the cost effectiveness of the omnograph and calculator

Student Prerequisite Skills:

None
Support Materials and Equipment:

1. Course Workbook
2. 8/18/77 Federal Register
3. Slide Projector
4. EPA Method 5 Sampling Train - Nutech

Special Instructions:

None

References:


The purpose of this lecture is to familiarize you with EPA Method 5 sampling equipment and its construction requirements given in the 8/18/77 Federal Register. The descriptions will start with the sampling nozzle and proceed through the sampling system to the Meter Console.

At the end of this lecture you should be able to:

1. List the construction and calibration requirements for the Method 5 sampling nozzle
2. List the nozzle, probe, pitot tube, and thermocouple placement requirements to minimize aerodynamic interferences
3. List the approved construction materials for the nozzle probe, pitot tube, and probe liner
4. Describe the probe locking system for preventing misalignment in the gas stream
5. Describe the advantages and disadvantages of various types of sample cases and glassware
6. List the advantages and disadvantages of various materials used in constructing umbilical lines
7. Describe the advantages of magnetoelastic gages for pressure measurements and list the requirements for using these gages in an EPA Method 5 Sampling System
8. Compare the cost effectiveness of the microcomputer and calculator
I. The Sampling Nozzle

A. Must be made of 316 SS or glass
   1. Seamless tubing
   2. Other materials must be approved by the Administrator

B. Must be button-hook on elbow design – unless Administrator approves otherwise
   1. Must have sharp, tapered leading edge
   2. Taper must be on the outside with $\leq 30^\circ$ taper angle
   3. Constant internal diameter should be preserved

C. Range of nozzle sizes should be on hand – 0.32 – 1.27 cm ID suggested

D. Calibration – Record results in laboratory logbook
   1. Calibrated before initial use in the field
   2. Using micrometer measure ID to nearest 0.025 mm (0.001 in)
      a. Measure 3 separate diameters
      b. Average the readings
      c. The difference between the low and high numbers shall not exceed 0.1 mm (0.004 in) or nozzle must be reshaped
   3. Nozzles that have been nicked, dented or corroded must be reshaped and recalibrated
   4. Each nozzle must have a permanent identification

II. The Pitot Tube – "S" Type is recommended; others may be used with Administrator approval

A. Construction details and calibration procedures are covered in the lecture on Reference Method 2

B. Position in relation to the sampling nozzle is of interest here (page 41784 FR 8/18/77)
   1. The nozzle entry plane must be even with or below pitot orifice
   2. Centerline of orifice and nozzle must agree
   3. Minimum separation for 1.3 cm diameter nozzle and pitot tube is 1.90 cm
III. The Sampling Probe

A. 2.54 cm in diameter is most useful and prevents probe from becoming a flow obstruction in the duct. This is covered in more detail in RM 2 lecture.

B. Should be 316 SS or equivalent

C. Pitot tube should be firmly welded to the probe. This helps prevent pitot misalignment

D. The probe should be designed to prevent accidental misalignment in the gas stream

1. During use it is common to handle the sample train and probe

2. Very easy to misalign some sampling systems

3. A good probe will not allow itself to be twisted into misalignment

4. Misalignment causes errors in velocity measurement

5. Full evaluation of possible errors owing to misalignment covered in RM 2 lecture

E. Probe should be designed to protect the liner and prevent accidental breakage

1. Nutech System - glass liner is not exposed to stress and easy breakage

2. Other systems - glass liner is more exposed to breakage

IV. The Probe Liner

A. Must be borosilicate or quartz glass tubing

1. Must have heating system capable of maintaining exit gas temperature of $120^\circ C \pm 14^\circ C$ ($248^\circ F \pm 25^\circ F$).

   a. Exit temperature calibrated as shown in APTD-0576

   b. Administrator may specify other temperature requirements

NOTES

C. Position of pitot tube in relation to the sampling probe sheath and thermocouple is also important.

1. The probe sheath end and pitot orifice opening must be separated by a distance of 7.62 cm.

2. The Thermocouple must either be offset 1.90 cm at the pitot tip or be no closer than 5.08 cm to pitot orifice.

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1. Must have heating system capable of maintaining exit gas temperature of $120^\circ C \pm 14^\circ C$ ($248^\circ F \pm 25^\circ F$).

   a. Exit temperature calibrated as shown in APTD-0576

   b. Administrator may specify other temperature requirements
2. Borosilicate glass liners used up to 480°C (900°F)

3. Quartz glass liners used from 480°C - 900°C (900 - 1650°F)

B. Stainless steel liners (316SS) may be used with the approval of the Administrator

V. The Sample Case

A. Federal Register requirements

1. Filter heating system capable of maintaining a temperature around the filter holder of 120° ± 14°C (248° ± 25°F)

2. Temperature gage capable of + 3°C (5.4°F) accuracy

B. Desirable features

1. Light weight

2. Good insulation - hot and cold areas

3. Positive probe alignment locking system

4. Easy accessibility to all parts

5. Good glassware protection

6. Good electrical system

7. Reasonably accurate thermostat for filter chamber and probe heater

8. Single point monorail attachment

9. Durability

10. Flexibility for vertical or horizontal stack traverses

11. Sometimes two piece construction is added convenience - able to separate heated filter and cold impingers

C. Glassware - 2 types; decision on use is personal preference

1. Ball joint

   a. Standard type

   b. Works well

   c. Must use non-volatile silicone grease

   d. Grease is inconvenient, messy, and can contaminate sample or catch particulate
2. Compression Fittings (screw type)
   a. More convenient
   b. Reduced contamination probability
   c. Easier to clean
   d. Can, however, increase breakage

VI. The Umbilical Cord
   A. The umbilical cord is simply a bundle of lines for:
      1. Vacuum tube
      2. Pitot tubes
      3. Electrical connections
   B. It is recommended that:
      1. Keep it simple - don't add too many lines
         a. Makes it heavy
         b. Hard to repair a broken line when so many are wrapped together
      2. Use heavy rubber vacuum tubing for the pump-impinger connection
         a. Not cut easily
         b. Not easily melted or burned
      3. Use Tygon for the pitot tube lines for the same reasons as B2

VII. The Meter Console
   A. Meter console encloses the gas metering system illustrated on page 41777 FR 8/18/77 Figure 5.1
      1. An enclosed system is not required but is usually easiest to use
      2. It is recommended that the meter console be a simple system containing
         a. Flow control valves
         b. Pump
         c. Dry gas meter with dialface calibration of 0.1 CFM/Revolution
d. Pitot tube differential pressure gage

3. Communication systems and thermo-couples are cheaper and more useful as separate components
   a. Lower initial cost
   b. Easier to repair and check
   c. Can be used for other applications without the full sample train

B. Desirable features
   1. Light weight
   2. Reliable leak free pump preferably oil lubricated fiber vane
   3. Easy readability
   4. Good temperature controls
   5. Averaging dry gas meter thermometer (must be accurate to ± 3°C (5.4°F))
   6. Rugged construction
   7. Good carrying handles
   8. Magnehelic differential pressure gages
      a. FR 8/18/77 allows magnehelic gages when they agree with 3 oil manometer Δp readings in the duct within 5%
      b. Very reliable when properly calibrated
      c. Easier to read
      d. Less sensitive to vibrations
      e. No need to continuously recheck zero setting

VIII. The Nomograph
   A. This course covers the derivation of the isokinetic rate equation
      1. Nomograph is used to solve the equation for ΔH based on the stack gas variables
      2. A calculator can solve the equation more accurately
   B. Nomographs must be calibrated
1. Check scale alignment

2. Check accuracy

C. Nomograph is an expensive specialized slide rule
   1. Calculator is more accurate and more easily reset
   2. Calculators can be used to work up other data. Nomograph does only one calculation

This lecture has covered an overview of the EPA Method 5 Sampling Train. We have

1. Identified individual components

2. Listed FR requirements

3. Pointed out some advantages and disadvantages of different equipment designs
Lesson Goal:

Provide the students with explanations of the laboratory procedures to be performed in the Monday afternoon Laboratory.

Lesson Objectives:

The student will be able to

1. List the procedures for applying reference Method 1 at circular and rectangular stacks
2. List the steps involved in performing an "S" type pitot tube calibration
3. Describe the procedures for wet bulb-dry bulb moisture estimation
4. Calibrate the meter console orifice meter when the dry gas meter has been calibrated against a reference volume standard.

Prerequisite Skills:

None

Support Materials and Equipment:

1. August 18, 1977 Federal Register 3. slide projector
2. Blackboard and chalk 4. 450 workbook
Special Instructions:

Refer students to FR during the lecture so they may mark important items.

References:


The success of the afternoon laboratory sessions depends upon a thorough understanding of the methods and procedures used. The experience gained in this laboratory will be very useful when actually performing an EPA Method 5 test or any other type of sampling. You (students) will calibrate an "S" type pitot tube, calibrate the meter console orifice meter, perform wet bulb - dry bulb moisture estimates, and apply Method 1 guidelines for sample and velocity traverses. After completing the lab you should be able to:

1. Select a sample site and sampling traverse points following Reference Method 1 Criteria
2. Describe and perform the calibration of a Type S pitot tube
3. Calibrate an orifice meter
4. Estimate the percent moisture in a stack gas
I. Reference Method 1

A. Principle

1. Aid in making representative measurements from a stationary source
   a. Pollutant emissions
   b. Total volumetric flow rate

2. Stack cross-section is divided into equal areas

3. A traverse point is located in each equal area

B. Applicability - The method may be applied to flowing gas streams in any duct, stack, or flue except under any of the following circumstances:

1. Cyclonic or swirling gas flow (defined on page 41758 paragraph 2.4) exists in the duct

2. The stack is smaller than 0.30 m (12 in.) in diameter or the cross-sectional area is less than 0.71 m² (113 in.²)

3. The measurement site is less than 2 duct diameters downstream or less than 0.5 diameters upstream from a flow disturbance

C. Description of Laminar Gas Flow

1. Laminar gas flow is a theoretical concept - it may never exist in actual practice

2. Laminar flow in a duct is described in this drawing:

   ![Drawing of laminar flow]

3. The "Bullet" shape of the gas is caused by friction
   a. Gas layer closest to the stack wall dissipates some energy as friction and slows down
   b. The layer of gas above the boundary layer proceeds to give up some energy contacting the slower more viscous boundary layer

Lab exercise covered on page 21 in the workbook

Note paragraph 1.2 page 41755, 8/18/77 FR

A description is covered in the procedures section of this lecture (El).

A hand drawing on the board is more effective, here, than a slide

This should remain simple - try not to get bogged down in fluid dynamics.
c. This action proceeds— theoretically— in a symmetrical manner across the gas velocity head.

4. It is easiest to measure the velocity pressure of a gas when it is in a flow pattern approximating laminar flow.

D. Flow Disturbance

1. A flow disturbance is a
   a. Bend in the duct
   b. Expansion or contraction of the duct
   c. Visible flame

2. At 8 duct diameters downstream and 2 diameters upstream of a flow disturbance
   a. Velocity head profile is assumed to resemble laminar conditions
   b. The minimum number of sample points may be used

3. Draw flow disturbance at $8\phi$ and $2\phi$

\[ \phi = \text{diameter} \]

When sampling at this point the minimum $\phi$ of pts may be used — 12 pts.
4. When sampling at a site other than 8\(^\circ\) and 2\(^\circ\)
   a. You will have to use the chart on page 41756 to determine the number of traverse pts.
      required
   b. You may not sample at a site that does not have at least 2\(^\circ\) downstream and 0.5\(^\circ\) upstream
      of a disturbance

E. Procedures - Circular stacks

1. Determine the following
   a. Duct internal diameter - is it larger than 0.3 meter?
   b. Cyclonic flow condition using the Type S pitot tube
      1) Prepare differential pressure gage
      2) Connect pitot tube to the gage
      3) Position pitot tube orifice openings perpendicular to the plane of the stack, cross-sectional
         area-orifice is parallel to the gas flow
      4) At this point the "S" tube should show "0" reading on the gage. (Equal forces will act on both
         orifice openings)
      5) If the gage does not show "0" rotate the pitot until a "0" reading is shown
      6) Record the rotation angle from the original position
      7) Repeat the procedure for all traverse pts.
      8) Assign traverse pts which require no rotation to reach "0" gage reading a value 0.
      9) Average all readings. If the average of all rotation angles is greater than 10\(^\circ\) the duct has an unacceptable flow condition

   c. Duct diameters of "straight run" from all disturbances

2. Based on duct diameters straight run locate the sampling site 77
Course: 450 Lecture 4
Lecture Title: Discussion on Laboratory Exercises

1. Choose the most convenient site

2. 8" and 2" not always possible

3. Choose a site that will allow the least number of traverse pts.

3. Use the graph on page 41756 to determine the number of traverse pts. for sampling. Use the graph given for the appropriate duct internal diameter
   a. Remember when reading the graph that both upstream and downstream diameters from a disturbance are important
   b. You can always sample more traverse pts but never are you allowed to sample less than the minimum shown on the graph
   c. The number of pts. must be a multiple of 4
   d. This number is the total traverse pts. Half of these are on each traverse diameter

4. Calculate the percent diameter into the duct from the stack wall for each traverse point.
   a. Use the table 1.2 on page 41758
   b. \( \frac{\text{total traverse pts}}{2} = \text{pts/diameter} \)
   c. Find the pts./diameter in the table and multiply actual duct \( \phi \) by the decimal % shown

Example:
   duct \( \phi = 100 \text{ cm} \)
   total traverse pts. = 12
   traverse pts/diameter = 6
   1st pt = 100 cm \( \times 0.044 = 4.4 \) cm from stack wall into the duct
   2nd pt = 100 cm \( \times 0.146 = 14.6 \) cm into the duct

5. Locate the traverse pts on 2 perpendicular diameters one of which is in the plane of highest anticipated dust concentration

6. Locate the traverse pts on 2 perpendicular diameters one of which is in the plane of highest anticipated dust concentration

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Note guides for location of traverse pts. within 2.5 cm of the stack wall in paragraphs 2.3.1 and 2.3.1.1.
F. Procedures - Rectangular Ducts
   1. Check for cyclonic flow
   2. Calculate duct equivalent diameter
      \[ D_e = \frac{2\text{ LW}}{\text{LW}} \]
   3. Determine the duct diameters of straight run
   4. Use the appropriate graph on page 41756 to determine No. cf traverse pts.
   5. Refer to Table 1-1 for the required Balanced Matrix

II. Calibration of the "S" type pitot tube
   A. The complete details of the reference method 2 will be covered in lecture seven.
      1. All Federal Register requirements will be highlighted.
      2. Today we want to give the procedures for calibration of the "S" tube in the laboratory
   B. Equipment
      1. Standard pitot-static tube or "andtl Tube.
      2. Inclined oil manometer (use only one)
      3. Calibration duct
         a. Must have at least 8φ and 2φ straight run from disturbances
         b. Capable of steady gas velocity of 15 -/sec (30-40 ft/sec)
         c. Ports must be arranged so Prandtl Tube and "S" Tube would be at the same point in the gas stream
      4. Type S pitot tube attached to the sampling probe tube used in Wednesday's source sampling lab, including the sampling nozzle.
      5. Laboratory data sheet
   C. Procedures
      1. Record identification numbers of all equipment used
      2. Level and zero the manometer
      79
      J. Check Probe-Nozzle-Pitot tube separations and record
4. Leak check the system
   a. Prandtl tube and tubing to manometer
   b. Pitot tube and tubing to manometer
   c. Recommended leak check is positive pressure at impact opening and negative pressure at static opening to 7.6 cm (3 in) H₂O.
   d. Leak check should be stable for 15 seconds

5. Check the calibration duct for cyclonic flow

6. Mark Prandtl and "S" tube so they will be at the same point in the duct

7. Mark legs A and B of the "S" tube

8. Insert Prandtl tube
   a. Record Δp (when reasonably steady)
   b. Remove the tube

9. Insert leg A of the "S" tube
   a. Record Δp
   b. Remove

10. Insert Prandtl tube

11. Insert leg B of the "S" tube

12. Repeat 8-11 until 3 pairs of readings are completed

13. Measure duct static pressure

14. Record
   a. All Δp readings
   b. Duct static pressure
   c. Duct gas temperature
   d. Actual barometric pressure at the site

Make sure students keep all pitots properly level and aligned in the duct.
15. Calculate
   a. \( C_p \) for the "S" tube for each reading
   \[
   C_p(s) = C_p(std) \sqrt{\frac{\Delta P(s)}{\Delta P(std)}}
   \]

   b. Calculate average \( C_p \) for leg A and leg B

   c. Average deviation for leg A and B
   \[
   \sigma_A = \frac{1}{3} \left| \frac{C_p(s)^A - C_p(s)^B}{C_p(s)^B} \right| \leq 0.01
   \]

   d. Deviation between leg A and B
   \[
   \sigma = \left| C_p(s)^A - C_p(s)^B \right| \leq 0.01
   \]

16. Calculate
   a. Velocity (m/sec)
   \[
   v_s = \frac{K_p C_p}{P_s} \sqrt{\frac{T_s}{\Delta P_{avg}}}
   \]

   b. Volumetric flow rate (m^3/ Hour)
   \[
   Q_s = 3600 \left( v_s \right) A \left( 1 - B \right) \left( \frac{P_s}{P_{std}} \right) \left( \frac{T_s}{T_{std}} \right)
   \]

III. Wet Bulb - Dry Bulb Moisture Estimate

A. The Wet Bulb-Dry Bulb Technique for moisture estimation is used in this laboratory

1. Reference Method 4 will be discussed later

2. Wet Bulb-Dry Bulb is easy and can give a good estimate of the \( \text{H}_2\text{O} \) content of the stack gas

B. The \( \text{H}_2\text{O} \) in the stack is by Dalton's Law of Partial Pressure
   \[
   \frac{V p_{\text{H}_2\text{O}}}{p_{\text{H}_2\text{O}}} = \frac{\text{H}_2\text{O}}{p_{\text{total}}}
   \]

1. \( B_{\text{H}_2\text{O}} = \frac{V p_{\text{H}_2\text{O}}}{p_{\text{total}}} \) ratio of component partial pressure to total system pressure

2. The workbook shows the calculations for the actual \( V p_{\text{H}_2\text{O}} \) using knowledge of...
a. The saturated V.P. $H_2O$ at constant temperature and pressure

b. Latent heat of vaporization for $H_2O$

3. The $\% H_2O$ can be found using
   a. The calculation $B_{ws} = \frac{V.P.}{P_{abs}}$, page 30 of Workbook
   b. Psychometric chart page, page C-22 of Course Manual
   c. Nomograph page 32 of Workbook

C. Procedure

1. Take dry bulb temperature

2. Take wet bulb temperature
   a. Preferably using the same thermometer or one very similar
   b. Cover entire area inserted into the duct with a cotton wick, tightly wrapped around the thermometer
   c. Saturate wick in $H_2O$ before inserting into the duct
   d. Watch temperature rise carefully
   e. When temperature rise stops record the temperature
   f. Temperature will continue to rise after the momentary pause

3. Use any procedure given in IV. Cross check procedures for agreement if interested

IV. Orifice Meter Calibration

A. APTD-0370 calibration procedures give reference calibration for
   1. Orifice meter
   2. Dry gas meter

Laboratory exercise will differ only slightly

1. Wet test meter will not be used
2. Dry gas meter correction factors will be set determined against a spinometer

Note: The wet bulb-dry bulb procedure does not work in acid gas streams
3. We will calibrate orifice meter for the desired flow rate

C. Orifice meter $\Delta H_o$ is a calibration factor. It is the pressure differential across the meter which allows 0.75 CFM flow rate at 29.92 in. Hg Barometric pressure and 68°F.

D. Workbook shows equations used
   1. $Q_m = K_m \left[ T_m \sqrt{\frac{\text{OR} \Delta H}{P_m \text{M} \text{m}}} \right]^{1/2}$
   2. Solving for $\Delta H$ at given conditions
      $\Delta H_o = \left( \frac{0.75 \text{ CFM}}{K_m} \right)^2 \left( \frac{29.92}{528} \right) \frac{(29)}{0.9244} = \frac{0.9244}{K_m^{1/2}}$

E. Procedure
   1. Follow lab instructions
   2. Use form on page 36 of workbook
   3. Solve equations $\Delta H$ should fall within 1.5 - 2.1 in. H$_2$O or there is probably a mistake

V. Closing Comments
   A. A large amount of information has been presented very quickly
      1. A great many things to cover, however, if confusion exists it will all come together by Wednesday
      2. DO NOT become discouraged
   B. Laboratory will be
      1. Electric
      2. Solar
     Instructors will help with all problems
   C. You will get as much out of the lab as you put in so apply yourself
   D. Be sure to read the workbook carefully. You will be doing
      1. Write pre-experiment report notes
      2. Redo any work on problems you find difficult

Experience has shown this is very true
3. Pitot tube calibration
4. Moisture estimation
5. Orifice calibration
6. Volumetric flow rate

Sheet on page 41 to be turned in on Wednesday morning.
Lesson Goal:

To present the concept of isokinetic sampling, providing the rationale of why it is necessary to sample isokinetically for particulate matter.

Lesson Objectives:

The student will be able to:

1. Define isokinetic sampling
2. Illustrate why isokinetic sampling is necessary when sampling for particulate emissions
3. State how the particulate concentration given by the Method 5 train will change when the sampling is performed over isokinetically
4. State how the particulate concentration given by the Method 5 train will change when the sampling is performed under isokinetically.

Student Prerequisite Skills:

Ability to multiply and divide

Support Materials and Equipment:

1. Course workbook
2. Slide projector
Special Instructions:

This lecture is the first of a sequence of three lectures given on isokinetic sampling, Tuesday morning. The three lectures work extremely well together, if presented with a proper appreciation of how fast the students can grasp the concepts.

References:

None
I. Review of previous day's material

A. Ask following questions concerning M5 sampling train.
   1. Where is the orifice meter?
   2. Where does one read Δp, ΔH?
   3. What is Δp related to?
   4. What is ΔH related to?
   5. What is ΔHr? — students did this Monday laboratory, but were not formally presented with it in lecture.

\[
Q_m = K_m \sqrt{\frac{T_m \Delta H}{P_m N_m}}
\]

\[
\Delta H_r = \frac{K_m^2}{P_m N_m} \frac{(29.92)(29.0)}{(460 + 68)}
\]

6. What is the isokinetic sampling condition?
   \(v_n = v_s\) stress this!

7. What happens in the impingers?

8. Does the same amount of gas (volume) go through the nozzle as goes through the orifice meter, per unit time?

9. How does the pressure and temperature change from the nozzle to the orifice meter?

10. What is pmr, E?

11. Write the pitot tube equation

12. What is the expression for a volume correction?

II. Isokinetic sampling

A. Definitions and principles

1. Isokinetic
   a. "iso" - denotes equality, similarity, uniformity
   b. "kinetic" - pertains to motion

To warm up the class it has been found necessary to first review some of the previous day's material. Conduct this part as a question and answer session.

Note: These questions are slanted so that the student may be better able to comprehend the Tuesday morning lectures.

Turn to page 45 of workbook.
c. Isokinetic sampling is where velocity of gas through probe nozzle is equal to stack gas velocity.

2. Principles

a. Large particles tend to move in same initial direction - have enough inertia to deviate from streamline pattern.

b. Small particles tend to follow streamlines.

c. Intermediate size particles are somewhat deflected.

d. This is watered down aerodynamics for purpose of this lecture - a large particle \( \geq 5 \mu m \) in diameter - small particle \( \leq 1 \mu m \) in diameter. (This corresponds with EPA's feelings for large and small particle definitions - but you may get some argument).

B. The Example

1. 100% Isokinetic sampling - what would be the concentration collected?

Note: Assume a large particle weighs 6 mass units and that we have a small particle weighing .01

\[ v_n = v_s \]

Mass rate = \( M_n = (4 \times 6) + (4 \times .01) \) mass units/minute

Flow rate = \( Q_n = 1 \text{ ft}^3/\text{minute} \)

\[ \text{Concentration} = \frac{\text{mass rate through nozzle}}{\text{volumetric flow rate through nozzle}} \]

\[ = \frac{24.01 \text{ mass units/minute}}{1 \text{ ft}^3/\text{minute}} \]

\[ = 24.01 \text{ mass units/ft}^3 \]
2. 200% Isokinetic
Larger volume collected per unit time - large particles not sliced out by nozzle, are lost. All smaller particles in volume are collected.

\[ v_n = 2v_s \]

\[ Q_n = 2 \text{ ft}^3/\text{min} \]

\[ C_n = \frac{(4x6) + (8x.03)}{2} \]

\[ = \frac{24.2}{2} = 12.1 \text{ mass units/ft}^3 \]

Over isokinetic sampling gives concentration lower than true.

3. 50% Isokinetic
Smaller volume collected per unit time - large particles don't follow streamlines, but punch into nozzle.

\[ v_n = \frac{1}{2} v_s \]

\[ Q_n = .5 \text{ ft}^3/\text{min} \]

\[ C_n = \frac{4x6 + (4x.03)}{.5} \]

\[ = 48.2 \text{ mass minutes/ft}^3 \]

Under isokinetic sampling gives higher concentration than true.

4. Generalizations:
   a. 100% Isokinetic - gets representative particulate distribution on filter
   b. Over isokinetic - get lower weight of particles per amount of volume due to loss of large particles through inertia effects.
c. Under isokinetic - get more weight of particles per amount of volume due to addition of large particles punching through streamlines.

d. These are generalizations - may have exceptions in special cases - refer to references given on page 47 of course workbook.

C. The Question - Problem is, how does one sample isokinetically?
   - Given the EPA Method 5 train, how is it set up so that \( v_n = v_s \)?
Lesson Goal:

To derive the isokinetic rate equation for the EPA Method 5 train, from basic principles of the ideal gas law, and to present methods for its solution.

Lesson Objectives:

The student will be able to

1. Recall the basic equation for establishing the isokinetic rate, \( \Delta H = K \Delta p \).

2. Explain that gas passing through the sampling train undergoes changes of moisture content, temperature, and pressure.

3. Explain that the isokinetic rate equation is derived from the requirement that \( v \) must equal \( v_n \), and that one obtains the final expression by substituting the Pitot tube equation and orifice meter equation and by making proper corrections for pressure, temperature, and moisture content.

4. Recognize the fact that a separate equation exists for the determination of the nozzle diameter

5. Calculate the value of \( D_n \), the nozzle diameter, given the appropriate input data, using a calculator or a slide rule

6. Calculate the value of \( K \) and \( \Delta H \), given the appropriate input data, using a calculator or a slide rule

7. Calculate values of \( D_n \), \( K \), and \( \Delta H \) using a source sampling nomograph

8. State the assumptions of the source sampling nomograph

9. Check the accuracy of the source sampling nomograph and recognize the effect of errors in computed \( \Delta H \) values on test results.
Intended Student Background:

High school math and high school or college general science. Attendance at 1st day laboratory mandatory for comprehension of this lecture.

Support Materials and Equipment:

1. Course workbook
2. Slide projector
3. Pocket calculator with square root function, for each student — or slide rule to do extended calculations
4. One source sampling nomograph for each student

Special Instructions:

Some students may "turn off" when they realize you are going to derive an equation. Never tell them that you are doing a derivation — just do it as if it proceeds logically out of the last lecture — don't make a big deal out of it. Approximately ½ of the class will be lost or won't care about the equation after the derivation is finished (depending upon your presentation abilities). Immediately after the derivation, the students are to calculate the problem given on page 59 of the workbook. The students that didn't care, will now care very much, especially if you go around from student to student to see how they are doing.

References:

Yergovitch, T. W., "Development of a Practical Source Sampling Slide Rule", JAPCA 26 #6 June 1976, pp 590-592
Derivation of the Isokinetic Rate Equation

A. \( \Delta H = K \Delta p \) — The relationship between \( v_n \) and \( v_s \). Note that get \( \Delta p \) from pitot tube — Set the \( \Delta H \) calculated from this equation with the orifice meter. This makes \( v_n = v_s \)

Ask following questions:

1. On what oil manometer do we read \( \Delta p \)?
   Ans. - red

2. On what oil manometer do we read \( \Delta H \)?
   Ans. - Yellow oil manometer

3. How is the \( \Delta H \) set? Ans. - with fine control knob. (students should know this from lab, but \(\frac{1}{2}\) the class will not understand it)

B. \( Q_n = \frac{n}{n} v_n = A_n v_s \) under isokinetic conditions

   What is the area of the nozzle?
   \( A_n = \pi \left( \frac{D_n}{2} \right)^2 \)

   Therefore
   \( \frac{n}{4} \pi D_n^2 \)

   \( Q_n = \frac{n}{4} v_s \) is the volumetric flow rate through the nozzle

C. What is the volumetric flow rate through the orifice meter?
   \( Q_m = k_m \sqrt{\frac{T_m \Delta H}{P_m m}} \)

D. If the stack gas contained no moisture, how would \( Q_n \) be related to \( Q_m \)? Would it be the same? No — because have change of temperature and pressure through the train.

   \( Q_n = \frac{P_m}{P_s} \frac{T_s}{T_m} Q_m \)
For lecturer's information don't give in class unless asked

Since

\[
PV = nRT \\
\frac{P}{s}V = nRT \\
\frac{P}{m}V = nRT
\]

\[
n_s = n_m \quad (\text{since have no } H_2O)
\]

\[
\frac{P}{s}V = \frac{P}{T} \frac{T}{s}V \quad \text{or} \quad Q_n = \frac{P}{T} \frac{T}{s} Q_m
\]

E. Now, if stack contains moisture

\[
n_s (1 - B_{ws}) = n_m (1 - B_{wm})
\]

\[
n_s (1 - B_{ws}) = n_m \quad \text{if use silica gel i.e. the number of moles of gas at stack conditions is made up of combustion gases and water. The fraction of combustion gases} \quad (1 - B_{ws}) \times n_s \quad \text{gives} \quad n_m.
\]

F. Flow rate corrected for T, P, and moisture, is now

\[
Q_n = \left( \frac{1 - B_{wm}}{1 - B_{ws}} \right) \frac{T_s}{T_m} \frac{P_m}{P_s} Q_m
\]

Since

\[
P \frac{V}{s} = n_s RT \\
P \frac{V}{m} = n_m RT
\]

\[
\left(1 - B_{wm}\right) \quad n_s = \left(1 - B_{ws}\right) \quad n_m
\]

\[
P \frac{V}{s} = \left(1 - B_{wm}\right) \quad n_m RT \\
(1 - B_{ws}) \quad n_s
\]

but \( n_m = \frac{P_{s}V_{m}}{RT_{m}} \)

Do not give this derivation in lecture unless asked. It is too involved and you will lose most of the class if you give it -- it would also waste too much time.
therefore
\[ \begin{align*}
P_{sn} & = \frac{(1 - B_{wm})}{(1 - B_{ws})} P_{m} T_{m} X_{Tm} X_{Ts} \\
V_{n} & = \frac{(1 - B_{wm})}{(1 - B_{ws})} P_{m} T_{s} P_{m} s V_{m} \\
Q_{n} & = \frac{(1 - B_{wm})}{(1 - B_{ws})} T_{s} P_{m} s Q_{m}
\end{align*} \]

G. Solution is then:
\[ Q_{n} = \frac{(1 - B_{wm})}{(1 - B_{ws})} T_{m} P_{m} s K_{m} \sqrt{\frac{T_{m} \Delta H}{P_{m} m}} \]
substituting for \( Q_{m} \)

H. Now substitute for \( Q_{n} \)
\[ \frac{\pi D_{n}^2}{4} v_{s} = \frac{(1 - B_{wm})}{(1 - B_{ws})} T_{m} P_{m} s K_{m} \sqrt{\frac{T_{m} \Delta H}{P_{m} m}} \]

I. What is the pitot tube equation?
\[ v_{s} = K_{C} C \frac{\sqrt{T_{s} \Delta p}}{P_{m} m} \]

J. Substitute
\[ \frac{\pi D_{n}^2}{4} K_{C} C \frac{\sqrt{T_{s} \Delta p}}{P_{m} m} = \frac{(1 - B_{wm})}{(1 - B_{ws})} T_{m} P_{m} s K_{m} \sqrt{\frac{T_{m} \Delta H}{P_{m} m}} \]
K. Simplifying

$$\Delta H = \left( \frac{D^4}{n} \left( \frac{\pi K C_p}{4K_m} \right) \frac{(1-B_{ws})^2}{(1-B_{wm})^2} \right) \frac{M_m T_p s}{M_a T_s m} \Delta p$$

L. Note moisture relationships for molecular weight

$$M_m = M_d (1 - B_{wm}) + 18 B_{wm}$$

$$M_s = M_d (1 - B_{ws}) + 18 B_{ws}$$

M. Substitute to obtain Isokinetic rate equation

$$\Delta H = \left( \frac{D^4}{n} \left( \frac{\pi K C_p}{4K_m} \right) \frac{(1-B_{ws})^2}{(1-B_{wm})^2} \right) \frac{M_d (1-B_{wm}) + 18 B_{wm}}{M_d (1-B_{ws}) + 18 B_{ws}} \frac{T_p m s}{T_s m} \Delta p$$

N. Now want to get above equation into a working form using all of our constants and variables

Define $$\Delta H_0$$ as the orifice pressure differential that gives $$0.75 \text{ cfm}$$ of air at $$68^\circ \text{F}$$ and $$29.92'' \text{Hg}$$

O. Substitute values into orifice meter equation

$$\Delta H = \left( \frac{C_m}{K_m} \right)^2 \frac{P_m}{T_m} M_m$$

$$\Delta H_0 = \left( \frac{.75 \text{ cfm}}{2} \right)^2 \frac{(29.92 \text{ in. Hg})(29.0)}{(460 + 68^\circ \text{F}) K_m^2}$$

$$\Delta H_0 = \frac{.9244}{K_m^2}$$
P. Assume the following

\[ B_{wm} = 0 \]
\[ \Delta H_0 = \frac{9244}{K_m^2} \]
\[ K_m^2 = 85.49 \]

Q. Isokinetic rate equation working form

\[ \Delta H = \left\{ 846.72 \frac{D_{n}^{4}}{\Delta H_{C_{p}}} \left(1 - B_{ws}\right)^{2} \frac{M_{d}}{\Delta P} \frac{M_{m}}{\Delta H_{C_{p}}} \frac{T_{m}}{P_{s}} \right\} \Delta P \]

R. Similarly, one can derive an expression for the nozzle diameter

\[ D_{n} = \sqrt{\left(\frac{0.035 Q_{m m}}{T_{m} C_{p}}\right) \left(\frac{1}{(1 - B_{ws})^{2}} \frac{M_{d}}{P_{s} \Delta P} \frac{T_{m}}{P_{s}} \frac{M_{s}}{P_{s}} \frac{T_{C_{p}}}{P_{s}} \right)} \]

S. Immediately turn to page 53 of the course workbook and have the students do the lecture problem.

Ans:

\[ M_{s} = M_{d} \left(1 - B_{ws}\right) + 18 B_{ws} \]
\[ M_{s} = 29 \left(1 - .12\right) + 18 \left(.12\right) = 27.7 \]

\[ D_{n} = \sqrt{\left(\frac{0.0357 Q_{m m}}{T_{m} C_{p}}\right) \left(\frac{1}{(1 - B_{ws})^{2}} \frac{T_{m}}{P_{s} \Delta P} \frac{M_{s}}{P_{s}} \frac{T_{C_{p}}}{P_{s}} \right)} \]
\[ = \sqrt{\left(\frac{0.0357 \times .75}{546 \times .85}\right) \left(\frac{1}{(27.7)^{2}} \frac{740}{29.6 \times .80}\right)} \]
\[ = .241 \]
Tell the class to choose a .25" nozzle after they have completed the first part of this calculation.

\[
\Delta H = \left[ 846.72 \frac{D^4}{n} \Delta H \frac{C}{\rho} 2 \left(1 - \frac{B}{\text{ws}}\right) 2 \frac{M_d}{M_s} \frac{T_m}{T_s} \frac{P}{P_m} \right] \Delta p
\]

\[
= \left\{ 846.72 \left(0.25\right)^4 1.85 \left(0.85\right)^2 \left(0.88\right)^2 \frac{29}{27.7} \left(\frac{540}{740}\right) \left(\frac{29.6}{30.0}\right) \right\} \Delta p
\]

\[
= 2.59 \Delta p
\]

\[
\Delta H = 2.59 \Delta p
\]

T. Ask questions:

What do you do if \( \Delta p = 1.0 \)

.80

.60

Say if moving probe from traverse point to traverse point - get new \( \Delta p \)'s at each point, calculate and set new \( \Delta H \)'s at each point.

How do you set the \( \Delta H \)?

II. Using the nomograph to solve the isokinetic rate equation

A. The nomograph - A type of slide rule to do the calculations given in I. Show several types of nomographs. Show several types of other slide rule calculators. Mention prices - Nomograph $140, Slide rule $40 + $140

B. Assumptions of the nomograph

1. Assume

\[
\rho = 0.85
\]

\[
T_m = 530^\circ R
\]

\[
\Delta H = 1.84" \text{ H}_2\text{O} 100
\]
Ps = Pn = 29.92"Hg
Md = 29.0
Bws = .05

Substitute into
\[ \Delta H = \left[ 846.72 \ D_n^4 \Delta H @ \ C_p^2 (1 - B_{ws})^2 \ \frac{M_d}{M_s} \ \frac{T_m}{T_s} \ \frac{P_{s}}{P_m} \right] \Delta p \]

get
\[ \Delta H = K \ C \ \frac{D_n^4}{T_s} \ \Delta p \]

K = 5.507 \times 10^5

C is a correction factor

2. C Factor
   a. C factor corrects for \( \Delta H \), \( T_m \), \( T_{\text{c}} \), \( H_2O \), \( P_s \), and \( P_m \)
   b. C does not correct for \( C_p \) or \( M_d \)

C. Using the nomograph

1. Compute C factor using data for previous lecture problem
   C should = .91 or .32

2. Turn nomograph over - compute nozzle diameter
   \( D_n = .241 \)

3. Compute K and \( \Delta H \) using nomograph and choosing nozzle diameter of .25"
   K = 2.59 when \( \Delta p \) is set = 1
   Show use of nomograph to obtain \( \Delta H \) from \( \Delta p \)'s

4. Nomograph check for scale alignment. Fill in table given in slide 101
D. Errors in calculating $\Delta H$

1. Calculator and equation, the best way
   a. Problems with battery discharging
   b. Punching numbers or operations incorrectly (Magnetic and programs minimize this)
   c. Soiling with fly ash (put calculator in plastic bag)

2. Nomograph
   a. Can get errors up to 10% of true for $\Delta H$ values - this will contribute approximately a 5% error to the % isokinetic.
   b. Check out nomographs at pretest meeting.
   c. Many stack samplers are used to nomographs and find them to be more convenient than calculators.

3. Slide rule calculators
   a. More accurate than nomograph, less accurate than calculator.
   b. Smaller, convenient
   c. Problem with scales moving.

4. Microprocessors
   b. Expensive.
   c. Save some work, but stack sampler not doing much during this period of test anyway.

5. Choice of $\Delta H$ calculation method is that of individual - just be sure that method is done correctly.

III. Assign homework problem - page 57 of Workbook. Ask to hand in page 59, with answers, Wednesday.

NOTE: It is sufficient to do problems 1 & 3.
Lesson Goal:

Illustrate to the students the proper methods for completing RM1 and RM2. Explain the RM4 method for moisture determination. Explain the RM3 procedures for gas analysis.

Lesson Objectives:

The student should be able to:

1. Fully describe and perform RM1 procedures
2. List all Federal Register requirements for pitot tube calibration, construction, and use
3. Describe RM4 procedures for moisture determination
4. Use RM4 equations for calculation of $B_{ws}$
5. List the procedures for RM3 gas analysis
6. Calculate and mathematically define
   a. $M_d$
   b. $M_s$
   c. % Excess air

Prerequisite skills:

None

Level of Instruction:

College undergraduate science
Intended Student Professional Background:

General Science

Support Materials and Equipment

1. FR 8/18/77
2. Blackboard and chalk
3. Slide projector
4. 450 Workbook
5. Standard pitot
6. S-type pitot tube
7. Orsat apparatus

Special Instruction:

Point out the important sections to the students in FR 8/18/78. This lecture has a great deal of latitude. Students generally show interest in all sections. Concentrate on areas of greatest student interest as indicated during the lecture.

References:


This lecture is divided into several discrete sections:

I. Review of the Sample and Velocity Traverse Procedures for RM1

II. Detailed Evaluation of "S" Type Pitot Tube Calibration and RM2

III. Discussion of RM4 - Determination of Moisture in Stack Gas
   A. Procedures
   B. Calculations

IV. Discussion of RM3 - Gas Analysis for CO₂, Excess Air and Dry Molecular Weight
   A. Procedures
   B. Calculations

After the RM3 discussion we will proceed to the laboratory for practice in using the Orsat apparatus for gas analysis.
I. Review of RMI procedures

(The review should be done with the instructor drawing the schematic diagrams necessary for RMI procedures from FR 8/18/77. Class input should be requested to assist in making the drawings).

II. Reference Method 2 - Determination of Stack Gas Velocity and Volumetric Flowrate

A. Principle

1. Average stack gas velocity is determined from the gas density and average velocity pressure head

$$\bar{v}_s = K_1 C_{Pp} \sqrt{\frac{T_s}{P_s M_s}} \cdot \frac{[\Delta p]}{\text{Average}}$$

2. The gas velocity and stack cross-sectional area are used in calculating the average standard dry gas volumetric flow rate

$$\bar{Q}_s = 3600 \left( \bar{v}_s \right) (A_s) (1 - B_{ws}) \left( \frac{T_{std}}{P_{std}} \right) \left( \frac{P_s}{T_s} \right)$$

B. Applicability

1. Not applicable to sampling sites that do not meet RMI criteria

2. If cyclonic flow exists

   a. Install gas straightening vanes

   b. Calculate the total volumetric flowrate stoichiometrically

   c. Move to another sampling site
C. Standard or Prandtl Pitot tube design specifications

1. The Standard or Prandtl pitot tube has specific design criteria accepted by the National Bureau of Standards.

2. (Point out construction details shown on the L7-1 slide)

3. The construction of this tube following these criteria has shown:
   a. Turbulence around the measuring orifices does not occur to any significant amount that could affect readings.
   b. Gas stream orientation sensitivity is greatly reduced.
   c. The calibration coefficient \( C_p \) is generally 0.99 ± 0.01.

4. The \( C_p \) of the standard pitot tube may be determined by NBS, however, the FR allows the user to assume \( C_p = 0.99 ± 0.01 \).

5. An "S" type tube must be calibrated against a Prandtl or standard tube.

6. The Prandtl tube is not generally used for source sampling:
   a. Static pressure taps may be plugged in a heavy particulate gas stream.
   b. The long impact opening section is difficult to get into standard diameter ports.

D. The "S" type (Stausscheibe) pitot tube

1. The Federal Register now includes construction details for the "S" type tube.

2. The Federal Register describes:
   a. Proper tube alignment.
   b. Appropriate sizes of tubing for construction.
   c. Preferred plane of orifice openings.
   d. Proper configuration with the probe and sampling nozzle to minimize aerodynamic interferences.

Note: It is more convenient and clearer to students to refer to \( C_p \) as the calibration coefficient.
3. When all construction and placement requirements are met the baseline coefficient $C$ for the "S" type may be assumed to be 0.84. (Refer to FR page 41764, paragraph 4.1 and 4.1.1)

Ask class laboratory groups:

1. How many calculated a $C_p$ different than 0.84?
2. How much different?
3. What conclusion would they draw?

E. Calibration of the "S" type tube

1. Equipment
   a. Calibration duct
      1) Proper port openings
      2) 8 and 2 diameters minimum
      3) Capable of steady gas flow
         a) Single pt. calibration 700 m/min (2000 ft/min) or about 30-40 ft/sec
         b) 4 pt. calibration - variable from 180-1525 m/min (600-5000 ft/min) at regular intervals
   
   b. Pitot tubes
      Inclined manometer - sensitivity is stated in paragraph 2.8 FR page 41762

   d. A mock-up port surrounded by circular graph paper is shown in these slides so we may discuss misalignment errors of the "S" type tube.
2. Procedures
   
a. Check for duct blockage

\[
2\% = \frac{\text{length of Probe}}{\text{in duct}} \times \frac{\text{Probe diameter}}{\text{Duct area}} \times 100
\]

b. Check for cyclonic flow - pitot tube may be used as in IR or streamers can be effective

L7-13; L7-14

c. Remember if the pitot tube is oriented as shown a proper flow condition is indicated by a zero reading on the manometer

L7-15

d. The velocity profile across the duct may resemble these readings

L7-16, 17, 18, 19

e. Mark the standard pitot tube and "S" type so they will be at the same place in the gas stream

L7-20

f. Insert the standard tube with the "S" type tube removed and record the \( \Delta p \)

L7-21

g. Insert leg A of the "S" tube and record \( \Delta P \)

L7-22

h. Repeat this procedure for leg B

L7-23, 24, 25

i. Collect 3 sets of readings for leg A and B at each velocity used for the calibration

L7-26

j. Plot the data for the readings

a. This is actual NBS data for an "S" type tube calibration

\[
C_p = \sqrt{\frac{1}{K}}
\]

b. \( K \) plotted against Reynolds's Number gives a very detailed description of all gas parameters

L7-27

c. It is sufficient for source sampling purposes to plot \( K \) versus gas velocity
3. Misalignment errors
   
a. During the course to this point we have mentioned misalignment errors
   1) The "S" type pitot tube does not measure the correct gas velocity vector unless it is aligned parallel with the stack wall - perpendicular to the gas flow
   2) Turning the pitot tube out of perpendicular giving it a yaw angle - produces velocity measurement errors
   3) We will evaluate yaw alignment errors. Pitch errors are much less critical and do not become evident unless gross pitch error is made

b. Examining the theoretical pressure distribution in a duct and the AP readings we would get using an "S" type tube and rotating it through 90° of yaw angle we can plot the data

Stop on slide L7-33 and point out % error in velocity readings versus degree yaw misalignment. Cyclonic gas flow creates the same problems.

Ask if there are questions on the method

III. Discussion of Reference Method 4 - Determination of Moisture Content in Stack Gas

It is necessary to determine stack gas moisture content so measured volumes can be corrected to dry standard conditions and the volumetric flow rate of the stack gas can be calculated on a dry basis.

A. Principle - Reference method only

1. A gas sample is extracted
2. The moisture in the gas is removed by passing through the cooled impingers (as in Method 5 train)
3. The volume of H₂O removed is measured volumetrically or gravimetrically
B. Applicability

1. The reference method using the Method 5 sampling train is designed for accurate moisture determination in the stack gas.

2. The reference method is often conducted simultaneously with pollutant emissions measurement.
   a. Method 4 is actually combined with Method 5 during a particulate run.
   b. Only the H₂O trapped in the combined run is used for reference method moisture determination.
   c. This means that even if RM4 is run along with Method 5 only the H₂O in the Method 5 train is considered reference method moisture.

3. The reference method can yield questionable results in saturated gas streams or streams that contain H₂O droplets.
   a. Under these conditions a second H₂O determination is made.
   b. The second H₂O determination may be done using stack temperature and a psychrometric chart or vapor pressure tables or by alternate method approved by the administrator.
   c. We used wet bulb - dry bulb:
      1) Makes a good estimate of H₂O in the gas.
      2) Quick.
      3) Only H₂O in Method 5 is actual RM H₂O so wet bulb-dry bulb is a good way to
         a) Save time.
         b) Get H₂O estimate for nomograph calculations.
         c) Could be used as 2nd method for H₂O in saturated gas streams.

C. Procedures

1. RM4 procedures use the RM5 sampling train

2. The RM4 system requires RM5 operation with the following variations
   a. Sample at a constant rate ± 10%
   b. Traverse at least 8 pts in the duct
   c. Sample rate maximum = 0.02l m³/min (0.75cfm)
   d. Minimum sample volume = 0.6 scm (21 scf)
   e. Run time shall = RM5 run time

3. Since we will be operating RM5 this discussion will be all that we allot to RM4

D. Calculations

1. The Ideal gas law

   \[ PV = \frac{m}{M} RT \]

2. Solving for volume

   \[ V = \frac{mRT}{PM} \]

3. Substituting \( \rho_{H_2O}V_{liq} = m \)

   \[ V_{wc} = \frac{\rho_{H_2O}V_{liq} RT}{PM} \]

4. Then at standard conditions the \( H_2O \) collected in the impingers can be converted to standard cubic volume by:

   a. \( V_{wc}^{(std)} = \frac{(V_f - V_i) \rho_{H_2O} RT}{P_{std} M_{H_2O}} \)
b. Replacing known terms and solving

\[ V_{wc_{(std)}} = K_1 (V_f - V_i) \]
\[ K_1 = 0.04707 \text{ ft}^3/\text{ml} \]
\[ K_1 = 0.001335 \text{ m}^3/\text{ml} \]

5. The same equation is solved to convert grams of \( \text{H}_2\text{O} \) caught in the silica gel to vapor with the simplified equation written:

\[ V_{wsg_{(std)}} = K_2 (W_f - W_i) \]
\[ K_2 = 0.04715 \text{ ft}^3/\text{ml} \]
\[ K_2 = 0.001335 \text{ m}^3/\text{ml} \]

6. The dry gas volume metered at standard conditions is

\[ V_{m_{(std)}} = V_m \left( \frac{P_{bar} + \Delta H}{13.6} \right) \left( \frac{T_{std}}{P_{(std)} T_{m}} \right) \]

7. The mole fraction of \( \text{H}_2\text{O} \) is then

\[ B_{ws} = \frac{V_{wc_{(std)}} + V_{wsg_{(std)}}}{V_{m_{(std)}}} \]

IV. Reference Method 3 - Gas Analysis for Carbon Dioxide, Oxygen, Excess Air, and Dry Molecular Weight

RM3 gas analysis yields data used in calculating the percent excess air in a duct; stack gas molecular weight; and process emission rate using the F-Factor.

A. Principle

1. A gas sample is extracted from the stack
   a. Single pt. grab sample
   b. Single pt. integrated sample
   c. Multi pt. integrated sample
   d. Multi pt. grab sample

Note: Tell the class that we will cover the sample procedure and calculations then go to the lab to practice the Orsat
2. The sample is analyzed for CO₂, O₂, CO using an Orsat analyzer or Fyrite.
   a. The Orsat must be used for
      1) Excess air calculations
      2) Emission rate calculations based on the F-Factor
   b. Fyrite may be used when only the dry molecular weight of the gas is needed

B. Applicability

1. Applicable for CO₂, O₂, CO, excess air, and dry molecular weight determinations from fossil-fuel combustion processes

2. May be used at other processes where other compounds are present in the stack gas if these compounds are not in high enough concentration to effect the results

3. Other methods and modifications may be used with administrator approval

C. Procedures - Emission Rate and Excess Air

1. Check the FR subparts for appropriate procedure
   a. Single pt. grab sample
   b. Multi pt. integrated sample
   c. Multi pt. grab sample

2. The procedures given here are for emission rate and excess air determinations
   a. The data for these procedures is the most critical
   b. It is good practice to use these procedures for all determinations
   c. These collect the greatest amount of data

F-Factor:

\[
E = \frac{20.9 - X_{O_2}}{s_d}
\]
3. Sample train - draw train shown on page 41769 FR 8/18/77

4. Train operation - general for all procedures
   a. Leak check the train at 250 mm Hg (10 in Hg) following paragraph 3.2.2 page 41770
   b. Position the probe at the traverse point
   c. Purge sampling lines
   d. Sample at a constant rate and equal length of time at each traverse point
   e. Sample for the same period and simultaneously as the Method 5 sample
   f. Collect at least 30 liters (1CF) of stack gas
   g. Analyze using the Orsat

5. Orsat Analysis
   a. Analyze sample within 4 hrs after extraction
   b. Leak check the Orsat
      1) Bring bubbler solutions to reference marks
      2) Bring burette solution to mid scale and record reading
      3) Let apparatus sit for 4 minutes
      4) If all solutions still at reference marks leak check is OK. Find any leaks noted
   c. Analyze the stack gas
      1) CO₂ read directly as %CO₂
      2) O₂ is cumulative so
         \[ %O₂ = (CO₂ + O₂) - %CO₂ \]
      3) CO is also cumulative so
         \[ %CO = (CO₂ + O₂ + CO) - (%O₂ + %CO₂) \]
      4) N₂ is determined by difference
         \[ 100 - (CO₂ + O₂ + CO) = %N₂ \]
d. Calculations

1. Dry molecular weight ($M_d$)

$$M_d = 0.44(\%CO_2) + 0.32 (\%O_2) + 0.28 (\%N_2) + 0.28(\%CO)$$

2. Apparent wet molecular weight ($M_s$)

$$M_s = M_d(1-B_{w_s}) + 18(B_{w_s})$$

3. % Excess Air

$$\%EA = \frac{\%O_2 - 0.5 (\%CO)}{0.264(\%N_2) - \%O_2 + 0.5(\%CO)} \times 100$$

Proceed to Orsat Laboratory - The Orsat Lab is designed for practice only. Students will need instructor demonstration of Orsat procedures and careful attention during the practice session.

This is the correct equation FR 8/18/77, page 41771 Equation 3-1 is wrong.
Lesson Goal:

To present the concept of % isokinetic, derive the expression given for % I in the Federal Register, and present the method used for evaluating the adequacy of source tests which are not 100% isokinetic.

Lesson Objectives:

The student will be able to:

1. Locate the equations for %I in the Federal Register and in the course workbook.

2. Explain how the %I expression is derived.

3. Explain the relative importance of the variables in the %I expression and point out which ones should be closely checked on the source test report.

4. Illustrate the effect of underisokinetic sampling on the measured pmr, relative to the true pmr.

5. Illustrate the effect of overisokinetic sampling on the measured pmr, relative to the true pmr.

6. Evaluate whether a source test should be rejected or accepted, based upon the value of the % isokinetic and whether the emission rate value is above or below the standard.

Student Prerequisite Skills:

Ability to multiply and divide and to have deductive reasoning ability.

Level of Instruction:

College undergraduate science
Intended Student Professional Background:

High school math and general science. Understanding of previous day's material is important for this lecture.

Support Materials and Equipment:

1. Course workbook
4. Slide projector

Special Instructions:

This is an important lecture for agency people. The latter part of the lecture, however, is difficult for some people. One should proceed carefully and slowly in this presentation. Hand out the monograph by R. Shigehara at the end of the lecture - not before, or everyone will immediately turn off. For those who don't understand the lecture, the monograph will serve as a "cookbook" procedure for them.

References:
I. Derivation of the % Isokinetic Equation

A. Expression given in Federal Register
   Refer to 42 FR 41782 August 18, 1977
   Equations 5-7 and 5-8

B. %I indicates how well the source tester was able to
   achieve the AHI's required for isokinetic sampling.

C. %I is not an indication of the accuracy of the test.
   Stress Point C.
   Ex. - If one drops the filter paper and loses particulate
   matter, this does not show up in the %I calculation

D. %I value is important to source tester and agency operator
   since it provides one of the bases for accepting or
   rejecting a test, as given in paragraph 6.12.
   1. If 90 ≤ %I ≤ 110 tests are acceptable
   2. If E < standard and %I < 90, test can be accepted.
      (on approval by Administrator)
   3. If E > standard and %I > 110, test can be accepted
      (on approval by Administrator)

E. Derivation
   1. %I = \( \frac{v_n}{v_s} \times 100 \) "definition"
   2. From the equation of continuity
      \( v_n = \frac{Q_n}{A_n} \)
   3. \( Q_n \) from collected data
      \( Q_n = \frac{V_{sw} + V_{meter corrected}}{\theta} \)
      where \( \theta \) = sampling time period
4. Correction of volume metered at orifice, to stack conditions

\[ V_{\text{orifice corrected to stack conditions}} = \left( \frac{T_s}{p_s} \left( \frac{P_b + \Delta H}{T_m} \right) \right) V_{\text{meter}} \]

5. Correction for water collected in impingers

\[ V_{\text{lc}} = \rho_{H_2O} = M_{H_2O} \]

\[ p_v \frac{V_s}{sw} = \frac{m}{M} \frac{RT_s}{p_s} \]

and

\[ V_{sw} = \frac{m_{H_2O}}{M_{H_2O} p_s} \frac{RT_s}{p_s} \]

\[ V_{sw} = V_{\text{lc}} \rho_{H_2O} \frac{RT_s}{M_{H_2O} p_s} \]

= the volume of water vapor at stack conditions.

6. Substituting T & P correction into \( Q_n \)

\[ Q_n = \frac{T_s}{p_s} \left[ \frac{V_{\text{lc}} K_3}{V_s} + \frac{V_{\text{m}}}{T_m} \left( \frac{p_b + \Delta H}{13.6} \right) \right] \]

where \( K_3 = \frac{\rho_{H_2O}}{M_{H_2O}} = 0.00267 \) in Hg ft \(^3\)/ml \( \rho_n \)

stress that all are really doing is relating the volume of gas going through the orifice meter to that going through the nozzle.

Note:
\( V_{\text{lc}} \) = volume of liquid collected in impingers and silica gel. Silica gel volume obtained from weight difference using Fig. 5-42 FR 41780 Aug. 18, 1977.

L8-5

L8-6

L8-7

point out value of \( K_3 \) in paragraph 6.12 so they will believe you.
7. Substituting into \( \% I \) expression

\[
\% I = \frac{\frac{v}{n}}{\frac{1}{s}} = \frac{\frac{Q}{n}}{\frac{v}{s}A_n} = 100
\]

\[
\% I = \frac{T_s}{P_s} \left[ \frac{K_3 V_{1c} + \frac{V_m}{T_m} \left( \frac{P_b + \frac{\Delta H}{13.6}}{A_n \theta V_s} \right)}{100} \right]
\]

8. \( \% I \) - Federal Register Expression

\[
\frac{100 \frac{T_s}{P_s} \left[ V_{1c} K_3 + \frac{V_m}{T_m} \left( \frac{P_b + \frac{\Delta H}{13.6}}{A_n \theta V_s} \right) \right]}{60 \frac{s}{P} \frac{A_n}{s}}
\]

9. \( \% I \) FR expression from intermediate data

\[
\% I = K_4 \frac{T_s \frac{V}{s} \frac{m}{s}}{P \frac{v}{s} A_n \theta (1-B_{ws})}
\]

\[
K_4 = 0.09450 \text{ for English units}
\]

10. Special features of the expression

a. \( A_n \) is in \( ft^2 \) or \( m^2 \)

\[(42 \text{ FR 41781 paragraph 6.1 nomenclature)}\]

b. Values for \( A_n \) should be extended to 4 or 5 decimal places - be wary of rounding off.

c. A source test observer should check the values of \( A_n, B_{ws} \) and \( V_{1c} \) since small changes in these values can have a great effect on the value of \( \% I \). A source tester may attempt to alter the value of \( \% I \) by modifying these input values, so that the test will be approved without question. The student should be warned about this.
F. Acceptable results

1. Review of pmr

\[ \text{pmr} = \frac{m}{V_n} \left( \frac{A}{v} \right) \]

\[ Q_s \]

pmr is an older terminology. For pmr calculate by the concentration method. pmr is calculated by the ratio of areas method.

2. Effect of non-isokinetic conditions on the pmr measured value

a. First consider small particles < 1 \( \mu m \) under or over isokinetic sampling will not matter, since particles will follow streamlines and \( m \) will not vary \( v \).

b. Second, consider large particles > 5 \( \mu m \) under isokinetic sampling + get too high a concentration because large particles punch into probe and collect too much mass for a smaller volume. This varies as \( 1/v \).

Over isokinetic sampling ÷ get too low of a concentration because get too few large particles for the larger volume collected. This varies as \( 1/v \).

c. If plot pmr measured vs the % isokinetic, obtain the plot of given on page 76 of Workbook.

d. An actual particle distribution will lie somewhere in between.

e. Question:

If a test is done at 80% I and the value of the emission rate is below the standard, should the test be accepted or rejected?

Answer:

Accepted, since if the test was conducted at 100% I, the value of the emission rate would be even lower. This is obvious from the graph.

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f. Question:

If a test is done at 120% I and the value of the emission rate is above the standard, should the test be accepted or rejected?

Answer:

Accepted, since if the test was conducted at 100% I, the value of E would be even higher and still above the standard.

pmr measured at 100% < pmr measured at 120%.

same comment

g. Question:

In the previous question, if the results of the test meant that a $5,000,000 piece of control equipment would have to be installed, would you still accept the test?

Answer:

Debate

Note that if a test is not 100% Isokinetic, the value for C will be wrong. The above arguments are for an agency's use.

If a source operator needed the information to size a particulate control device, the above arguments are useless in giving him the right answer. Paragraph 6.12 is only a consideration to be used for agency test approval, and doesn't have too much to do with the value of the emission rate.

Note also that if a test is 100% isokinetic, in no way does this imply that the value of C, pmr, or E obtained, is the true value. Errors other than those due to not achieving the calculated emission rate may arise.

These may be the following:

1. Wrong input of variables into isokinetic rate equation will give wrong ΔH's. This however, will not appear in % I calculation.

2. Errors in nomograph will similarly not show up in % I calculation.
G. Causes of a test not being 100% isokinetic several reasons why a test may be out of isokinetic, are:

1. Moisture guessed wrong in setting isokinetic sampling rates.

2. Inability to follow rapid fluctuations in Δp and corresponding calculated ΔH's. Negative flow

3. Heavy grain loading -- plugging filter so can't achieve ΔH's at end of the test.

4. Large temperature variations not corrected in rate calculation

5. Leak in pitot or sampling lines (broken probe, lopsided filter, broken frit)


This is EPA policy and may be used as a guideline for administrative approval of tests < 90% or > 110% isokinetic.
Lesson Goal:

To point out to students the legal and scientific definitions of a particulate. Show students how sampling train is set-up and how physical operation can affect the particulate definition.

Lesson Objectives:

The student should be able to:

1. Write the Federal Register definition of a particulate given in the NSPS regulations.
2. Describe the sampling train parameters effecting the definition of a particulate.
3. Define "particulate" for the sampling train configurations given on page 78 of the workbook.

Prerequisite Skills:

None

Level of Instruction:

College undergraduate science

Intended Student Professional Background:

General Science

Support Materials and Equipment:

2. 450 Workbook
3. 450 Manual

*Originally given in FR 12/23/71. Has been updated several times in various FR's. Best example is FR 2/23/78 Part V, page 7584 Introduction.
The course up to this point has dealt with the reference method procedures for particulate source sampling. We have presented the bulk of the procedures required to get a sample from a stack gas. Now we want to direct more attention toward the type of sample we take and the various parameters which can effect the final emissions calculations. This lecture begins this phase of the course. We will define a particulate both legally and scientifically.
I. Legal Precedent – The Clean Air Act

A. New source performance standards
   1. The Clean Act gives EPA a mandate to protect our air resources
   2. The Act sets the policy for Standards of Performance
      a. The term "Standards of Performance" means a standard for emissions of air pollutants which reflects the degree of emission limitation achievable through the application of the best system of emission reduction which (taking into account the cost of achieving such reduction) the Administrator determines has been adequately demonstrated.
      b. This is important for it indicates political and economic realities which are reflected in the subparts pertaining to emission sources

   Refer to manual, page 9-1 for precise language

B. Legal definition of particulate -- FR 12/23/71 page 24878 Subpart D, § 60.41, (C)
   "Particulate matter means any finely divided liquid or solid material other than uncombined water as measured by Method 5."

C. The legal definition refers to the scientific definition for particulate
   1. The legal definition is stated in (B)
   2. The scientific definition is given by RM5
   3. Remember that the subparts give specific guides and requirements for sampling procedures at an affected facility
   4. These are all related to the Clean Air Act mandate
      a. The act does not state complete elimination of air pollution must be achieved
      b. NSPS requirements are written with control equipment technology and cost in mind
      c. The sampling methods can measure total emissions from a source
      d. The subparts specify the sampling methods used to test emissions
e. The point is that the sampling method may not measure all emissions from source - it tests emissions as required in the regulations.

f. The regulations may vary to give the source some economic relief.

D. Example

1. The nominal operating temperature of RM5 filter holder is 120 ± 14°C (248 ± 25°F).

2. However, the FR 10/6/75 page 46258 § 60.46, 5(b) states that RM at a fossil-fuel fired steam generator may have a filter holder and probe operating at 160°C (320°F).

Does this effect the particulate catch?

3. Yes.

Why?

4. At 320°F SO₂ and sulfuric acid mist will pass through the filter into the impingers.

   a. RM5 includes particulates caught in the nozzle, probe liner, and on the filter mat.

   b. SO₂ can form sulfates on the filter mat at temperatures below approximately 270°F.

   c. H₂SO₄ can be condensed on the filter mat and in the probe at temperatures below 250°F.

   d. 320°F assures neither SO₂ or H₂SO₄ is included in the particulate catch.

1) An ESP alone would have a tough time controlling these to meet NSPS.

2) An ESP and scrubber would surely handle this problem but can be expensive.

3) This strategy is now in line with the statement of reasonable cost factors.
5. These items illustrate all the points we have discussed
   a. There is a legal and scientific definition for a particulate
   b. The scientific definition is RM5
   c. Particulates caught in RM5 are determined partly by
      1) Operating temperature of the probe filter
      2) Portions of the train analyzed

II. Sampling Train Configurations

A. The sampling train set-up, operating temperature, and segments analyzed effect the definition of particulate

B. We want to examine several sampling train configurations to determine the effect on the definition of a particulate

1. This may be important in designing source sampling experiments

2. It is important to be sure a sampling train meets the requirements of state and federal agencies when doing compliance testing

3. It gives some background for possible modifications to a sampling system that may
   a. Make the job easier
   b. But not effect the particulate catch we would get using the straight RM5 system

C. Sample Trains (workbook page 78)

1. Reference Method 5 - Particulate defined
   a. Probe - filter temperature
   b. Analysis procedures

2. Configuration 1 - Particulate defined
   a. Condenser conditions
   b. Analysis procedure
### CONTENT OUTLINE

**Course:** 450  **Lecture 9**  
**Lecture Title:** SAMPLING TRAIN CONFIGURATIONS

### NOTES

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## Configuration 2

3. Configuration 2  
   a. Probe-filter temperature  
   b. Second filter may have particulate at condenser conditions  
   c. Analysis  

## Method 17 (Configuration 2)

4. Method 17 (Configuration 2)  
   a. Stack temperature  
   b. Analysis  
   c. May yield results significantly lower than RM5

This "definition of a particulate" discussion points out the important legal and scientific aspects of the particulate sampling method and its relationship to the Clean Air Act mandate. The discussion shows that careful preparation must go into planning stack tests to meet test goals, agency regulations, and allow reasonable sampling procedures. This leads us into the discussion on designing a stack test and performing our laboratory.

Hand out Feb 25, 1978  
FR on Kraft Pulp Mills at this point.
Lesson Goal:

To familiarize students with the procedures for designing, planning, and performing a stack test; the basic operation of the EPA Method 5 sampling train; and present a usable report writing format.

Lesson Objectives:

The student should be able to:

1. List the steps involved in designing a stack test
2. List the information necessary in a pre-survey of the stack test site
3. Recall the planning steps for a stack test
4. Recall a usable report writing format
5. Describe the basic procedures for performing an EPA Method 5 test including filling data forms and making calculations

Prerequisite Skills:

Knowledge of operating requirements for RM5 procedures and equipment (RM1, RM2, RM3, and RM4)

Level of Instruction:

College undergraduate science

Intended Student Professional Background:

General Science

Support Materials:

1. Manual page 7-1
2. Workbook pages 80-81, 79
3. Programmed calculation sheet
Special Instructions:

This lecture is an explanation of the manual and workbook flow charts, outlines and exercises for the EPA Method 5 test.

References:

None

This lecture will center on discussion of the flow chart on workbook page 80-81. This flow chart contains our thoughts and opinions on every aspect of planning and performing a source test. After we have discussed the items on page 80 we will go on to the workbook laboratory exercise on page 82. Writing a source test report will be covered last.
I. Designing a stack test

A. Determine stack test necessity

1. A stack test for compliance to regulations is obvious
2. Often stack tests yield valuable process operation data

B. Research the literature - Refer to flow chart section

1. This is extremely important
2. Provides information as given in flow chart

C. S tat. test objectives

1. With test necessity and research it is now possible to write complete test objectives
2. Objectives are extremely important
   a. Every experiment in science has objectives written prior to beginning the work
   b. Experiments are then designed to meet the objectives
   c. Experimental work then evaluated in terms of meeting, proving, or disproving the objectives
   d. Treat each stack test as an original scientific experiment - IT IS an original experiment

D. Design the experiment - follow the flow chart description

E. Do a pre-survey - follow the flow chart

1. A pre-survey is often overlooked
   a. To cut costs
   b. It is assumed there will be no problems
2. A pre-survey
   a. Can save time and money in the long run
   b. Makes the job easier
   c. Allows much better planning and experiment design

F. Finalize test plans - follow the flow chart

Use flowchart and these notes for the discussion

Stress this point - Take no part of the test for granted

NOTE:
This is not to imply that Method 5 is an experimental method. It has been well proven and documented over the past 10 yrs. The statements are given to instill an attitude which is held by the authors.
G. Prepare equipment - this is obvious and we have been
doing the type of preparation necessary in our laboratories

1. An important point to make is for the test team
to carry plenty of spare equipment

2. Test all equipment before leaving for the job site

H. Confirmations

1. Travel and accommodations are extremely important

2. Be sure the process is operating at desired level
before starting travel

I. Arrival at the site - follow flow chart

1. Inform plant contact of your arrival

2. Review the test plan with all persons involved in
the program

3. Confirm sampling site and process operation

This concludes the first part of our lesson concerning the design
and planning of the source test. Now we want to proceed to
the laboratory exercise on page 84. in the workbook to cover
items on performing the source test.

I. Equipment preparations

A. Check the nozzle

1. Round tip opening

2. Calibrate the nozzle using a micrometer as described
on Monday morning

B. The sampling probe

1. These items have been done by the laboratory staff
to save time for sampling

2. They should be checked routinely prior to use

C. Sample case - again this has been done by the staff
D. The impingers are filled by the staff and assembled. The procedure is straightforward and you will get some hands-on experience during the disassembly at the end of the test.

E. Check the umbilical line and meter console.

F. The sampling train leak test:
   1. The completely assembled sampling train is now ready for a leak test.
   2. For clarity we will go directly on with the leak test.
      a. At an actual test several tasks could be performed while waiting for the train to come up to operating temperature.
      b. A suggested sequence will be presented after we cover the leak test.
   3. Bring all train components to operating temp.
   4. Turn the fine adjust valve fully counter clockwise - open.
   5. Be sure coarse adjust valve is closed.
   6. Turn on the pump.
   7. Seal nozzle opening.
   8. Slowly open the coarse valve - fully open.
   9. Turn the fine adjust valve (by pass valve) slowly in a clockwise direction.
   10. Watch the vacuum gage as it proceeds toward 380 mm (15 in) Hg.
      a. Do not exceed 380 mm Hg.
      b. If you do exceed 380 mm Hg.
         1) Slowly release vacuum at the nozzle or
         2) Leak test at the vacuum reached.
      c. Do not turn the fine adjust valve counter clockwise at anytime during the leak test.
11. Time the leak rate using the dry gas meter and a stopwatch. The leak must be less than 0.00057 m³/min (0.02 cfm).

12. After timing the leak rate
   a. If it passes requirements record the leak rate and slowly release vacuum at the nozzle
   b. If the train has an unacceptable leak release vacuum at the nozzle then
      1) Track down the leak
      2) Re-test

II. Organization on the stack and in the lab
   A. Turn to the flow chart on page 80.
   B. We have covered to this point
      1. Equipment calibration
      2. Laboratory preparations before testing
      3. Train assembly
      4. Leak testing
   C. Several of these items can be going on simultaneously
      1. This will save time which is important on site
      2. Suggestions are
         a. 1 Technician assemble equipment for the test
         b. 1 Technician take measurements for RMI requirements
         c. Team leader prepare data forms and equations
      3. After taking RMI data
         a. Team leader makes RMI calculations
         b. Technicians assemble traversing system

This is the basic method in the FR. The procedure described therein is more elaborate and should be followed if wanting to meet the letter of regulations.
4. RM1 data completed
   a. Mark traverse points on probe
   b. Do velocity traverse - quick preliminary
   c. Do H₂O estimate

5. While the train is coming to operating temperature for leak test
   a. 1 Technician prepare RM3 equipment
   b. Team leader solve isokinetic equations and fill out data sheets
   c. 1 Technician prepare other sampling trains for runs 2 and 3

6. When ready perform leak test

7. After leak test
   a. Add ice to the impinger bath
   b. Record dry gas meter starting reading
   c. Inform plant of test about to start
   d. Position equipment at point 1 in the stack
   e. Record all data and calculate ΔH desired
   f. Start test and record time

8. The train remains on during the traverse in the port
   a. 15 seconds before time is up at a traverse point move train to next point - this allows Δp on the manometer to stabilize
   b. Record time interval readings
   c. Calculate new ΔH from Δp

9. When the port test time is over stop the train then move to next port

10. Repeat the procedures outlined for each port
11. Be constantly aware during the test of:
   a. Test times
   b. Dry gas meter revolutions
   c. Stack temperature
   d. Sample case temperature
   e. Pump vacuum
   f. Impinger temperature
   g. $\Delta H$ versus $\Delta p$ readings

D. At the end of the test
   1. Remove the sample case and probe from the stack with the pump off
   2. Record
      a. End time
      b. Dry gas meter final reading
   3. Let the train cool then seal the nozzle. Clean-up should be done in a laboratory or other clean area

III. Data sheet and calculations

A. Data averages
   1. Dry gas meter volume sampled - $V_m$ = final - initial dry gas meter reading
   2. Average $\Delta H$ - straight arithmetic average
   3. Average square root of the $\Delta p$ readings
   4. Average stack temperature

B. Calculations - use programmed sheet and explain to students


A. This is straightforward and can be done by following the manual sections.

B. If time is tight instruct students to read the section as homework

Clean-up is not done in lab except for measuring $H_2O$. Procedures are given in manual page 5-12.
Lesson Goal:
To introduce methods of correcting emissions data from combustion sources to different types of standard conditions.

Lesson Objectives:
The student will be able to:

1. Discuss the relationships that exist in fossil fuel-fired boilers between excess air, % O₂, and % CO₂
2. Define excess air
3. Correct a particulate concentration to standard temperature and pressure
4. Correct a particulate concentration to 50% excess air using two methods
5. Correct a particulate concentration to 12% CO₂
6. Correct a particulate concentration to 6% O₂

Student Prerequisite Skills:
Ability to multiply and divide

Intended Background:
General Science

Level of Instruction:
College undergraduate math
Materials:

1. Workbook
3. Slide Projector
4. Calculators

Special Instructions:

This is the first lecture Thursday morning. The pace of the course has been rather rapid and perhaps overwhelming to some students. Lectures on Thursday are intentionally slower paced so that the students may have an opportunity to digest the material and ask questions on points previously covered which may not be clear.

References:

Course Manual - Appendix
I. Correction of concentration to standard temperature and pressure

A. Did this in first lecture, using ideal gas law derivation is:

\[
V_{\text{corr}} = \frac{mRT_{\text{std}}}{MP_{\text{std}}} \\
V_{\text{std}} = \frac{cRT}{MP}
\]

\[
V_{\text{corr}} = \frac{T_{\text{std}}}{P_{\text{std}}} \\
V_{\text{std}} = \frac{T_{\text{std}}}{P_{\text{std}}}
\]

\[
V_{\text{corr}} = \frac{P_{\text{std}}}{T_{\text{std}}} \\
V_{\text{std}} = \frac{P_{\text{std}}}{T_{\text{std}}}
\]

\[
C_{\text{corr}} = \frac{M}{V_{\text{corr}}} = \frac{P_{\text{std}}}{T_{\text{std}}}
\]

\[
C_{\text{corr}} = \frac{P_{\text{std}}}{T_{\text{std}}}
\]

B. Need to first correct data to standard temperature and pressure before doing other corrections

C. In EPA reference methods:

Standard Temperature = 68°F

Standard Pressure = 29.92"Hg

II. Excess Air Corrections

A. Stoichiometric air vs. excess air

1. If you burn carbon stoichiometrically, what do you get? Gas, just CO₂ and N₂ left over.

2. Boiler operation - most combustion sources can't run stoichiometrically, need more air. Fuel in combustion zone of boiler will deplete immediate region of oxygen. New fuel entering region will lack enough oxygen to burn completely and will have incomplete combustion. Need to add excess air.
3. When adding excess air, get different percentages of CO\textsubscript{2} and O\textsubscript{2}, based upon type of fuel and amount of excess air.

B. Definition of Excess Air:

1. \( \% \text{EA} = \frac{\text{Volume Excess Air}}{\text{Theoretical Volume required for complete combustion}} \times 100 \)

2. \( \% \text{EA} = \frac{\% \text{O}_2 - 0.5 \times \% \text{CO}}{2.64(\% \text{N}_2) - \% \text{O}_2 - 0.5\times \% \text{CO}} \times 100 \)

C. Correcting a concentration to 50% excess air.

1. Between 1920-1940 many coal combustion sources operated at about 50% excess air. Today most sources operate at much lower excess air.

2. Excess air, \%CO\textsubscript{2}, \%O\textsubscript{2} corrections used to correct for dilution of the flue gas. Note that a concentration can be reduced by dilution and a source could pass a concentration standard by doing so. These corrections bring emissions to a common referent, accounting for such dilution.

3. 50% excess air correction

\[ \bar{C}_{50} = \frac{\bar{C}_s (100 + \% \text{EA})}{150} \]

4. 50% excess air correction from Orsat data

\[ \bar{C}_{50} = \frac{\bar{C}_s}{1 - \left[ \frac{1.5(\% \text{O}_2) - 0.133(\% \text{N}_2) - 0.75(\% \text{CO})}{21} \right]} \]

5. The equations are derived in Appendix of the manual. They are not equivalent expressions. In fact, both functions are not good functions and are not continuous. They will give different values for arbitrary values of \%O\textsubscript{2}, \%N\textsubscript{2}, and \%CO, but are almost identical combustion sources.
III. Correcting to 12% CO₂

A. Used in NSPS for municipal incinerators and by some states for some other sources.

B. \[ \frac{C_{s12}}{C_s} = \frac{12}{\% CO₂} \]

C. The correction may cause a significant error in the reported emission rate, due to errors in determining %CO₂ by Orsat. One collaborative test contracted by EPA had a between test team deviation of concentration value of ~15%. When corrections were made to 12%CO₂, deviation jumped to almost 25%.

IV. Correcting concentration to 6% oxygen

1. Some standards are written in terms of an oxygen correction instead of a CO₂ correction

2. \[ \frac{C_s}{C_{6\%O₂}} = \frac{[20.9 - 6.0]}{20.9 - \% O₂} \]

3. Some standards may be corrected to 3% O₂ instead of 6%. Change 6 to 3 in this case. 20.9 is the % O₂ in air.

V. Practice in performing concentration corrections.

A. Perform calculations page 100 of workbook - example given.

B. Answers - Problem I in workbook
C. Answers - Problem II in workbook

Fill in answers in table (on chalkboard or overhead) after most students have finished. Let the others work until they get the correct answers.

<table>
<thead>
<tr>
<th>Test Number</th>
<th>% EA</th>
<th>%CO₂</th>
<th>%O₂</th>
<th>%CO</th>
<th>%N₂</th>
<th>O₂ DSCF/min.</th>
<th>PMR gr./min.</th>
<th>C₁ gr./DSCF</th>
<th>C₁₂ %</th>
<th>C₁₄₁₂</th>
</tr>
</thead>
<tbody>
<tr>
<td>2A</td>
<td>48.6</td>
<td>12.1</td>
<td>7.1</td>
<td>0.3</td>
<td>80.5</td>
<td>18,000</td>
<td>13,000</td>
<td>.722</td>
<td>.712</td>
<td>.715</td>
</tr>
<tr>
<td>2B</td>
<td>100</td>
<td>9.1</td>
<td>10.6</td>
<td>0</td>
<td>80.3</td>
<td>24,000</td>
<td>13,000</td>
<td>.542</td>
<td>.714</td>
<td>.723</td>
</tr>
</tbody>
</table>

D. Note the differences in answers - for coal fired boiler, answers all close. Why? Not so for oil fired boiler.

Refer to Fig. 11-2. Coal combustion has the characteristics of 12% CO₂ corresponding to approximately 6% O₂ at 50% EA. Oil does not.
Lesson Goal:

To introduce the student to alternate sources of information on source sampling and environmental control.

Lesson Objectives:

The student will be able to:

1. Recall at least three types of sources from which information on source sampling methodology may be found (books, periodicals, newsletters, EPA publications).

2. List the most important periodicals and professional organizations that transmit source sampling information.

3. Tell how to receive assistance in obtaining EPA publications and computerized literature searches.

Student Prerequisite Skills:

None

Level of Instruction:

Basic

Intended Student Professional Background:

Individual involved in air pollution control programs.

Support Materials and Equipment:

1. Course manual—Appendix B

2. Slide projector

3. Examples of literature—periodicals, books, etc., on air pollution control.

4. Brochure: "Need Air Pollution Information?" EPA office of Library Services
**Special Instructions:**

This lecture is easy and light-hearted. It provides a breather in the morning, but is greatly appreciated by the students, particularly the industrial people.

**References:**

None
I. Books on Air Pollution Control, Sources, and Engineering

A. Fundamentals of Air Pollution - Williamson Good
   Introductory Text

B. Industrial Source Sampling - Brenchley, Turley, Yarmac
   Written by 3 people who attended this course. Book now
   dated, but may have some good reference material

C. Air Pollution - Stern
   5 volumes - review articles on all aspects of air pollution.
   Good reference

D. Chemical Engineer's Handbook - Perry
   Good reference for practicing engineers

E. Source Testing for Air Pollution Control -
   Cooper and Rossano
   Professional type approach to source sampling - now
   dated, but has useful information

F. AP-40 Air Pollution Engineering Manual
   Basic Reference for Agency People -
   Beg, borrow or steal.

G. Others

II. Periodicals

A. Journal of the Air Pollution Control Association
   1. Very important - refereed articles
   2. Ask how many students belong to APCA
   3. Others should be encouraged to join APCA if they
      are serious about their professional work

B. Environmental Science and Technology
   1. ACS publication
   2. Refereed articles
   3. Articles on all areas of environmental control
C. Stack Sampling News
   1. Sometimes has tips and techniques on source sampling
   2. Contains announcements, etc.
   3. Articles are unrefereed

D. Pollution Engineering
   1. Freebee
   2. Articles on all areas of pollution

E. Staub Rheinhaltung der Luft
   1. Very important for articles on particulate control
   2. Unfortunately - in German - "staub" means "dust" - comes out 1 year later in English translation

F. Others: Power, TAPPI, Chemical Engineering, etc.

III. EPA Publications
   A. Many publications available - obtain through NTIS or EPA library
      EPA Cumulative Bibliography 1970-1976 Parts 1 and 2
      PB-265-720 and EPA Publications Bibliography Quarterly Abstracts Bulletin NTIS UB/D.342-01, 02, 03, etc., available from NTIS.
   B. Note brochure "Need Air Pollution Information?", and services available from EPA library
   C. Mention Federal Register and Code of Federal Regulations - their importance and the distinction between them.

IV. Newsletters
   A. Quick communication on a daily or weekly basis
   B. Expensive, but purchased by most libraries
      1. Environmental Reporter
      2. Air/Water Pollution Report
      3. Current contents
      4. IERL Report Abstracts
      NO\textsubscript{x} Control Review
      FGD Control Review, etc.
V. Other Periodicals on Environmental Topics
   A. Clean Air
   B. Environment
   C. Combustion
   D. etc. → Make your own list

VI. Freebees
   A. For people who like to get something in the mail
   B. Industrial Research, American Laboratory, Laser Focus, etc.
   C. Pollution Equipment News
Lesson Goal:

To introduce the student to the concept of the F-Factor Method. To show two methods of performing the emission rate calculation and various techniques that can be performed with F-factors.

Lesson Objectives:

The student will be able to:

1. Define the F-factor used in EPA Method 5 calculations
2. Discuss how the F-factor can give a value for the emission rate
3. Describe the requirements for using the F-factor in the EPA Method 5 test for new FFFSGs.
4. Recall alternate F-factor methods
5. Use F-factors for cross-checking Orsat and combustion data.

Student Prerequisite Skills:

Ability to multiply and divide

Level of Instruction:

College undergraduate science and math

Intended Student Professional Background:

General Science

Support Materials and Equipment:

1. Course workbook
2. Course manual
3. Slide projector
Special Instructions:

Not many students realize the importance of the $F_d$ factor in the NSPS requirements for performing Method 5. Stress should be placed on this calculation method.

References:

October 6, 1975  40FR46250
I. Emission in terms of lbs/10^6 Btu Heat Input

A. Previously expressed emissions in terms of

\[ E = \frac{pmr_s}{Q_H} - \frac{c_s Q_s}{Q_H} = \frac{\text{lbs}}{10^6 \text{Btu/hr}} \]

\[ = \frac{\text{lbs}}{10^6 \text{ Btu}} \]

B. Problems:

1. Uncertainty in \( Q_H \). What is \( Q_H \)?

(Fuel feed rate) x (fuel heating value)

Does EPA have a standarized fuel truck to check fuel feed meters? No. - have uncertainty here that can't check.

2. Too many variables in the equation for continuous monitoring applications.

II. F-Factor Method

A. Alternate Approach

\[ E = \bar{c}_s F \]

\( \text{dilution correction term} \)

B. Definition of the \( F_d \) factor

1. \( F_d = \frac{\text{volume of theoretical dry combustion products/lb}}{\text{heating value of fuel combusted (10^6 Btu/lb)}} \)

\[ = \frac{\text{ft}^3}{10^6 \text{Btu}} \]

dimensionally, then
2. the emission rate from A, is then

\[ E = \frac{\text{lbs}}{10^6 \text{ Btu}} \frac{10^6 \text{ Btu}}{\text{ft}} \]

dilution correction term is dimensionless.

3. F-factors are relatively constant values for specific categories of fuels.

C. \( F_d \) factor method

1. \[ E = \frac{C_s F_d}{20.9} \left( \frac{20.9 - 20.9}{20.9 - 20.9} \right) \]

uses \( \%O_2 \) for dilution correction.

2. This is the equation must use in EPA Method 5.

3. Examples of F-factors

Note more extensive list in manual - numbers in parentheses, Turn to page 9-11 of manual. Give \( \% \) deviation from the mean of data sets for which the F-factors were calculated.

4. EPA Method 5 and the \( F_d \) factor method

Required to use this calculation method. Also, required to perform oxygen traverse while doing Method 5 test. Note boxes - not too many students realize this. Draw sample into bag and analyze by Orsat or using continuous oxygen monitor if approved by administrator. Suggest follow procedures by Mitchell and Midget - have two analysis agree to within .3%.

D. \( F_c \) factor method

1. \[ F_c = \frac{\text{volume of theoretical CO}_2}{\text{generated by combustion/lb}} \frac{\text{heating value of fuel}}{\text{combusted}} \left( 10^6 \text{ Btu/lb} \right) \]

2. the \( F_c \) factor method

1. \[ E = \frac{C_s F_c}{20.9} \left( \frac{20.9}{20.9} \right) \]

Point out the small deviations.

Refer to page 9-12 of manual.
E. Using $F_d$ factor to calculate $E$ from data given on a wet basis

$$E = \frac{20.9}{20.9(1-B_{ws})-\%O_2(w)}$$

$B_{ws}$ = fractional moisture content of stack gas

F. the wet $F$ factor method $F_w$

$$E = \frac{20.9}{20.9(1-B_{wa})-\%O_2(w)}$$

where $B_{wa}$ = fractional moisture content in air

Method used in continuous monitoring applications. $B_{wa}$ can be determined by several methods.

G. Use of f-factors for cross checks

1. $F_d(calc) = \frac{Q_{sd}}{Q_H} \left( \frac{20.9 - \%O_2}{20.9} \right)$

Stoichiometric combustion check. If have all of data, a useful calculation to do. If $F_d(calc)$ differs appreciably from tabulated values, have a problem either in $Q_{sd}, Q_H,$ or $\%O_2$. Many people use this method to check their data.

2. Alternate expression

$$F_w(calc) = \frac{Q_{ws}}{Q_H} \left[ \frac{20.9(1-B_{wa})-\%O_2(w)}{20.9} \right]$$

3. Alternate expression

$$F_c(calc) = \frac{Q_{ws}}{Q_H} \left( \frac{\%CO_2(w)}{100} \right)$$

Define $\%O_2(w)$ - Oxygen concentration on a wet basis
H. F factor

1. Great help in checking Orsat data

$$F_o = \frac{20.9 \, F_d}{100 \, F_c}$$

$$F_o = \frac{20.9 - \% \, O_2(d)}{\% \, CO_2(d)}$$

2. If value not within 3 + 5% of that tabulated, have a problem with the Orsat data

I. Correcting for incomplete combustion

1. F-factor method assumes complete combustion of fuel

2. Can make corrections, but normally CO levels are on ppm levels and do not greatly affect values

$$\% \, CO_2 \, \text{adj} = \% \, CO_2 + \% \, CO$$

$$\% \, O_2 \, \text{adj} = \% \, O_2 - .5(\% \, CO)$$
Lesson Goal:

To present clean-up procedures for the RM5 sampling system; review source test calculations and be sure all students can perform these; discussion the results of the source test as an introduction to the Error Analysis lecture.

Lesson Objectives:

The student should be able to:

1. List the clean-up procedures for the RM5 sampling train
2. Make all calculations for an RM5 stack test
3. Distinguish the difference between sampling precision and sampling accuracy
4. Answer all questions on the pre-test

Prerequisite Skills:

None

Level of Instruction:

College undergraduate science

Intended Student Professional Background:

General Science

Support Materials:

1. Manual page 5-12
2. Workbook page 113
3. Programmed calculation sheet
4. Pre-test and answer key

Special Instructions:

Lecture is followed easily in the manual and workbook
References:

None

We shall start this lesson by reviewing the pre-test since the laboratory did not allow time for a complete clean-up procedure of the RM5 sampling train. We will go through the flow chart in the manual on the clean-up procedures to be sure everyone can do this. We will then go through the calculations for the RM5 test and compare test results.
CLEAN-UP PROCEDURES FOR RM5 TEST
CALCULATIONS AND PRE-TEST REVIEW
DISCUSSION OF LABORATORY RESULTS

I. Review Pre-test

II. RM5 Clean-up procedures - discuss procedures as given on page 5-12 of manual.

III. Calculations review
   A. Ask class for any questions on the calculations
   B. Go through calculations on programmed calculation sheet

IV. Class laboratory results - using page 13 of the workbook ask laboratory groups to give values they calculated.
   A. Generally
      1. Groups will get similar
         a. Velocity data
         b. Volumetric flowrate data
      2. Some groups will be out of isokinetic limit 90-110%
      3. Pollutant mass rate data and concentration data will vary but still be comparable
   B. Point out the similarities and discrepancies in the laboratory results
   C. Introduce ERROR analysis topic
Lesson Goal:

To provide the student with an understanding of the distinctions between error and precision and to review the types of error that can occur in source sampling.

Lesson Objectives:

1. The student will be able to explain the difference between precision and accuracy.

2. The student will be able to list and describe three categories of error. (systematic, random, illegitimate)

3. The student will be able to discuss the relative precision of EPA reference methods 2-5.

4. The student will be able to use the concepts of this lecture and not misapply the terminology in discussions of source sampling results.

Student Prerequisite Skills:

None

Level of Instruction:

College entry level science

Support Materials and Equipment:

1. Course workbook
2. Course manual
3. Slide projector
Special Instructions:
None

References:
I. The true value
   A. True value is what is wanted. Impossible to know what this is in source sampling
   B. Collaborative tests may be close to true value, but not certain. Can only talk about deviations

II. Difference between precision and accuracy
   A. Precision refers to reproducibility
      Accuracy refers to correctness — closeness to true value
   B. Bull's eye
      1. Closely spaced shot give estimate of good precision, but if any from bull’s eyes, have poor accuracy
      2. Shot near bull's eye means good accuracy, but can have good or poor precision
      3. The 3 method 5 tests give only an estimate of precision — tells nothing of accuracy. One value is no more valid than another if each test was done the same

III. Classification of errors
   A. Errors can arise from three basic reasons
      1. Can be systematic — calibration problem, error in adjustment, consistent error in reading, etc. — may be corrected in some instances
      2. Random errors — errors resulting from fluctuation, chance. Cannot remove. Idea is to eliminate all errors except random errors and keep these at a minimum.
      3. Illegitimate errors — blunders, things which should not happen. Dropping the filter, leaks, misreading a dry gas meter, etc.
   B. Emphasize that it is hard to remove all errors. Difficult to get estimate of error of test. Zi does not give this. Average of three tests only gives an estimate of the precision, not the accuracy of the test.

Errors can affect both precision and accuracy.
IV. Estimates of precision for EPA reference methods

A. Refer to paper by R. Midgett-
11, #7, (1977) p.657 Table 2 - Within laboratory deviation
of the reference methods
1. Method 2 - 3.9%
2. Method 5 - 10.4%
3. Method 6 - 4.0%
4. Method 7 - 6.6%

B. Between laboratory deviation
1. Method 2 - 5.0
2. Method 5 - 12.1
3. Method 6 - 5.8
4. Method 7 9.5

C. Note: Estimates are for precision, not accuracy. Discuss results of laboratory in terms of the above concepts.
Lesson Goal:

Stimulate students to be aware of all aspects of the sampling procedure which effect the quality of the data and the safety of the sampler at the sampling site.

Lesson Objectives:

The student should be able to:

1. Recall the important aspects of an accident analysis program
2. List the 10 causes of accidents
3. List some personal safety equipment for a source sampler
4. List the important items necessary to assure good quality test data

Prerequisite Skills:

The course up to this point

Level of Instruction:

College science

Intended Student Professional Background:

General Science

Support Materials:

1. Blackboard and chalk or overhead projector and pens
2. Slide projector
3. Workbook - page 119
Special Instructions:

Let the students think up the quality assurance points with help from the instructor.

References

CRC Handbook of Laboratory Safety

This lecture is devoted to the safety of sampling personnel at the site and points of quality assurance for source sampling using RM5. The major aspects of an accident analysis program and the 10 common causes of accidents are presented. The class will then list the major points to evaluate in assuring good quality source test data for both the tester and observer.
I. Accident analysis
   A. Accidents are caused therefore they can be prevented
   B. The best system for preventing accidents is an accident analysis program
      1. Analyze all possible causes of an accident before it happens
      2. Take measures to eliminate possible causes of accidents
      3. Ask personnel working in the area for suggestions
      4. If an accident does occur
         a. Find out how it happened
         b. Ask the injured person(s) how it happened
         c. Ask the injured person(s) for suggestions on how to prevent a reoccurrence

II. Causes of accidents
   A. Poor instructions
      1. Supervisory personnel must give adequate instructions for
         a. Job performance
         b. Safety requirements
      2. Supervisor should inspect job site for all applicable concerns and safety
         a. Before
         b. During and
         c. After the job
B. Poor planning
   1. The person-in-charge must properly plan and conduct the activity
   2. Experiment design and performance are extremely important for job success and safety
   3. Specifically for stack test - adequate manpower to do the job

C. Improper design - the experiment must be designed with proper equipment, layout, and construction for completion of the job

D. Proper equipment not provided
   1. Safety equipment must be available
   2. Proper tools and other equipment must be on hand - Jury rigging is poor practice

E. Failure to follow instructions
   1. All personnel must follow safety rules
   2. Explicit instructions must be given to all personnel involved at the job

F. Neglect or improper use of equipment
   1. All personnel must use the proper safety equipment
   2. Do not try to use a piece of equipment for a purpose for which it was not intended (i.e. do not try to drill a 1/2" hole with a 1/4" drill bit)

G. Faulty equipment - poorly maintained equipment is inexcusable

H. Untrained personnel
   1. All personnel should have adequate training before their participation at the job site
   2. Trainees should be closely supervised
I. Uncooperative personnel
   1. Persons in poor physical condition or poor mental attitude should be given different assignments
   2. This applies to attitudes about co-workers, supervisor, the job, or working conditions

J. Unpredictable outside agents
   1. Agents outside the control of the sampling team
   2. Can mean anything such as bad weather or a stinging insect which may startle someone and cause an accident

III. Personal safety equipment
   A. Hard hat
   B. Safety glasses
   C. Safety shoes
   D. Respirators
   E. First aid kit
   F. Gloves
      1. Leather work gloves
      2. Heat protective gloves
   G. Proper clothing
      1. No shorts
      2. Longsleeve shirts
      3. Appropriate for weather conditions
   H. Plenty of drinking water and some snack food to prevent fatigue. No salt tablets - They are bad for you
   I. Safety belts
      Maintain the discussion as long as students make responses

Ask the class to describe these. It is more useful than a simple listing.
IV. Quality Assurance

A. Introduction

This lecture is to be held as an interactive student-teacher discussion session. Have the students contribute ideas towards the development of a QA program. List points on the board and have the students list in their workbooks.

B. Equipment Calibrations

1. Nozzle
2. Pitot tube
3. Heaters - probe and filter
4. Dry gas meter
5. Orifice meter

C. Observations that can be made by the agency observer at the sampling site.

1. Leak checks - before and after sampling
2. Reference Method 1 requirements
3. Probe alignment
4. Precise meter console operation - data recording
5. Reference Method 3 requirements
6. Overall competency of sampling team
   a. Experience
   b. Education
   c. Professionalism
7. Coordination with source operation
8. Parameter checks on stack gas
   a. Stack gas temperature
   b. Preliminary traverse for cyclonic gas flow and
   c. Moisture content of the gas
9. Adherence to reference method procedures
10. System vacuum

Ask students what would make good quality assurance checks for a stack test. They will, by this point, be able to list the items given.
Lecture Title: SOURCE SAMPLING QUALITY ASSURANCE AND SAFETY ON THE SAMPLING SITE

11. Sampling system temperatures
   a. Filter
   b. Impingers
   c. Dry gas meter

12. ΔH calculation from Δp

C. Parameters the control agency observes should record
   1. Test start and end times
   2. "S" type pitot tube C_p
   3. Nozzle diameter
   4. Leak rate of the train
      a. Initial leak rate
      b. Leak rate anytime train is disassembled
      c. Post-test leak rate
   5. Dry gas meter volume
   6. K factor for nomograph or calculator
   7. Average square root of the Δp readings
   8. Average ΔH
   9. Volume of H_2O trapped in the sample train
   10. Filter tare weights
   11. Orsat data

D. Process operation data (as applicable)
   1. Materials feed rate
   2. Production rate
   3. Fuel feed rate
   4. Shift changes
   5. Upsets
E. Analytical procedures

1. Clean-up techniques for the RM5 sample train
   a. Care taken
   b. Thoroughness of clean-up
   c. Careful labeling of all samples
   d. If sample to be shipped for analysis sample volume should be marked

2. Laboratory staff
   a. Bachelor degree chemist
   b. Certified technician

3. Sample analysis
   a. Sample solvent blank taken
   b. Sample dried at room temperature or heated to no more than filter temperature during sampling
   c. All data carefully recorded

4. Weighing and desiccating
   a. Scale sensitivity within 0.5 mg
   b. Sensitivity checked routinely
   c. All tare weights carefully recorded
   d. Sample desiccated 24 hours then weighed to nearest 0.5 mg
   e. Sample desiccated and weighed at six hour intervals to constant weight ± 0.5 mg.

5. Overall laboratory observations
   a. Cleanliness
   b. Order
   c. Equipment in good condition

All these observations are important in good quality assurance assessment for the RM5 test.
We have covered safety at the source with emphasis on accident analysis and preventing the most common causes of accidents. We have, also, listed the major items for good quality assurance of a RMS test. This concludes this lecture.
Lesson Goal:

To familiarize students with the basic principles of inertial particle sizing techniques and the use of in-stack cascade impactors for gathering particle size data.

Lesson Objectives:

The student should be able to:

1. Describe the equation of continuity for a flowing ideal fluid
2. List several particle properties and give the most important property of particles with regard to sizing devices.
3. Define effective particle size
4. Define particle aerodynamic diameter
5. Describe the relationship between particle diameter and its physical properties
6. List several methods of determining particle diameter other than inertial sizing
7. Recognize the importance of particle size data
8. Describe the operation of a cascade impactor
9. Define the $D_{50}$ for an impactor collection stage
10. Describe the sampling procedures used for an in-stack cascade impactor

Prerequisite Skills:

The course to this point.

Level of Instruction:

College undergraduate science
Intended Student Profession Background:

General Science

Support Materials and Equipment:

1. Manual page 9-16
2. Workbook page 123
3. Slide projector
4. Cascade impactor

Special Instructions:

None

References:

Laple, C. E., Fluid and Particle Mechanics, University of Delaware; Newark, Delaware; 1956

Particle sizing is becoming increasingly important in source sampling. The high cost of particulate control equipment and tighter regulations have put great pressure on equipment designers. The design of particulate control equipment is very much dependent upon good particle size data. A manufacturer can develop better equipment when the actual size distribution of particles in the gas stream is known. For this reason in-stack particle sizing has received increased interest.

Particle size data is also important in developing new instrumentation for source monitoring. In this course we shall deal with particle size as related to plume opacity measurements. Research is also being conducted on instruments that continuously measure mass emissions from a source. The optical techniques used for these instruments require valid particle size data.
I. Particle properties

A. A particle has several important properties

1. Mass
2. Dimension
3. Chemical composition
4. Aerodynamic properties
5. Optical properties

B. The primary distinguishing characteristic of any particle is particle size

II. Size determination

A. Several methods for determining particle size

1. Microscopic
   a. Taking a measurement of the particle dimensions
      1) Martin's Diameter — measures the diameter across the middle of the particle
      2) Feret's Diameter — measures the longest linear dimension of the particle
      3) Equivalent projected area — compares an irregular particle's diameter to a sphere that seems to approximate the particle size
   b. These give precise particle dimensions as viewed under the microscope
   c. There are several drawbacks
      1) The procedure is expensive when done often enough for a statistically representative sample
      2) Taking samples can cause fracturing and agglomeration of particles
      3) Always an uncertainty of the microscopic data as related to actual in-stack particle size distribution
2. Sedimentation and Elutriation
   a. Again requires an extracted sample with the uncertainties involved in taking the sample from the stack
   b. These require very large samples for obtaining sizing data
3. Out of stack inertial techniques
   a. Bacho sizer is the most commonly used.
   b. Many improvements have been made in these techniques
   c. An out of stack analysis always carries the problem of relating results to actual in-stack particle distribution

B. In-stack particle sizing when properly conducted provides the most useful, valid data. We will concentrate on this method.

C. All techniques used for particle sizing incorporate empirical relationships and theoretical principles to describe particle size
   1. Size is not really determined
   2. These techniques assign the particle an "effective size" based on observations of the particle properties

D. Any technique used for particle size analysis will yield unique data
   1. Data gathered by different techniques does not necessarily agree
   2. Data gathered by different designs of instrumentation using the same principle may not agree
   3. These uncertainties require that
      a. Careful consideration be given to objectives for the experiment
      b. Cost for the analysis be weighed in conjunction with the use of the data.

III. Particle physical properties
   A. Particle size generally refers to an "effective size"
1. Described as equivalent or effect diameter

2. Great deal of information has been gathered on spheres of unit density in dry air.

B. Particle sizing techniques seek to define particle size in terms equivalent to these spheres

1. The most commonly used term is particle diameter

2. Assuming a particle's physical properties will be equivalent to those of a sphere of the same diameter

3. And that a physical property is proportional to some power of the diameter

\[(d)Q = a d^N\]

\(d =\) diameter
\(a =\) shape factor
\(N = a number\)
\(Q = physical property\)

4. Then particle behavior may be predicted for a given set of conditions

5. This is an essential factor in designing control equipment

We can see the importance of particle size data from this discussion. Now let us move to learning how an in-stack cascade impactor works to give particle size data.

IV. Particle Motion

A. The most useful particle sizing methods for stack sampling purposes define particle size as an "aerodynamic diameter"

1. Allows prediction of particle aerodynamic properties

2. These are extremely important in designing control equipment

a. Electrostatic precipitators

b. High energy scrubbers

B. Fluid dynamics and Stokes Law -- These principles will aid in understanding the operation of a cascade impactor

1. The tube of fluid flow

a. The fluid is ideal - incompressible and non viscous
b. Flowing from P to Q

c. The mass flux at P is described
\[ \frac{dm}{dt} = \rho_1 A_1 v_1 \]
\[ \text{as } t \rightarrow 0 \]
\[ \Delta m_1 = \rho_1 A_1 v_1 \]

d. We can describe the mass flux at Q as
\[ \frac{dm_2}{dt} = \rho_2 A_2 v_2 \]
\[ \text{as } t \rightarrow 0 \]
\[ \Delta m_2 = \rho_2 A_2 v_2 \]

e. We stated before that our fluid is incompressible and non-viscous. This means \( \rho \) does not change and \( \Delta m \) at both points is equal.
1) \[ \frac{dm_1}{dt} = \frac{dm_2}{dt} \]
\[ \text{as } t \rightarrow 0 \]
\[ \Delta m_1 = \Delta m_2 \]
2) \[ \rho_1 A_1 v_1 = \rho_2 A_2 v_2 \]
3) \[ A_1 v_1 = A_2 v_2 \]

f. We see that velocity is changing to get the same mass flux at both points

h. If we go from Q to P, what happens?
\( v_1 \) is greater than \( v_2 \)

2. Fluid flow around a submerged particle (The slide shows fluid streamlines around the particle. Show the students how the velocity of the fluid changes from point I, II and III)

a. At Point I we have fluid moving toward the particle
1) Fluid pressure = \( P_T \)
2) Velocity = \( v_1 \)

b. At Point II
1) The fluid streamlines come closer together
2) By the equation of continuity we know that for an ideal fluid the fluid velocity must increase to maintain the same mass flux.

3) The energy to increase velocity must come from somewhere. Where?

4) The needed energy is coming from the pressure in the system.

5) So $P_T$ decreases at Point II and velocity increases.

6) This can be proven from Bernoulli's Theorem.

(The Intention here is to go over the relationships shown at the bottom of the slide - not a complete mathematical proof)

c. At Point III in our ideal fluid $P_T$ would return to the value at Point I and $V_{II}$ would return to $V_I$.

d. In a real system we would not have a complete return to the original values at Point I

1) Some energy would be dissipated as heat because of friction around the particle.

2) The pressure at Point III would not return to $P_T$ (It would be some distance down stream).

3) The net effect would be the lower pressure fluid at Point II being pushed back by the higher pressure fluid behind Point III.

4) This creates vortices which create a net pressure drag on the particle.

3. Stokes Law - Gravitational force versus frictional force

a. The motion of our submerged particle will be determined by the forces acting upon it.

b. A particle will remain at rest in relation to the fluid until acted upon by some external force - Newton's first law.

c. Newton's 2nd Law - acceleration caused by a force acting upon a body is proportional and parallel to the resultant of that force and is inversely proportional to the mass of the body.
d. Newton's 3rd Law of Motion - a body exerting a force on another body encounters an equal and opposite force.

e. Stokes applied these laws to the motion of a particle submerged in a fluid and proved mathematically that a body falling in a fluid is

1) accelerated by gravity \( F_g \)
2) acted upon by an equal and oppositely directed frictional force \( F_R \)
3) that when \( F_g = F_R \) the net acceleration on the particle is zero
4) the particle therefore reached a terminal or settling velocity
5) the particle mass and its terminal velocity determined its ability to move through the fluid - overcome the fluid friction.

V. The cascade impactor

A. These principles are used in the cascade impactor

B. The fluid velocity at each stage in the impactor is governed by the diameter of the stage orifice

C. Particles are accelerated through the orifice and reach a terminal velocity when the forces acting on it are equal

D. The particle then has a momentum proportional to its mass which may allow it to impact on to the collection stage

E. The particles are fractionated into various size ranges based upon orifice velocity and particle mass

1. This defines the aerodynamic diameter of the particle
   a. An effect diameter based upon the assumption that large particles have more mass than small particles
   b. Assumes uniform particle density

2. The aerodynamic diameter of the particle allows correlation of empirical data to the unknown particle size for prediction of its physical properties

F. This procedure yields useful data though there are some problems
1. Particles may not have uniform density so the size predicted by the impactor may not be accurate

2. Particles may bounce in the impactor and land on inappropriate stages

3. Particles may break on impacting a collection stage and be reentrained - biasing small size fractions

4. No collection stage will be 100% efficient in collecting particles for which it is designed

G. Collection stage efficiency

1. Impactors sold commercially are generally supplied with stage cut points developed from theoretical calculations

2. These are not necessarily valid
   a. Each impactor even within a given design may have different fractional characteristics for a collection stage
   b. Impactors should be accompanied by calibration data developed by the manufacturer using monodisperse aerosols to obtain actual fraction sizes for a stage.
   c. The most common expression of fraction size for a collection stage is the $D_{50}$
      1) The $D_{50}$ is the particle size for which the stage has at least a 50% collection efficiency.
      2) This is usually called the cut point diameter

H. Data Presentation

1. The most common and useful presentation is a cumulative distribution plot on log-probability graph paper
Lecture Title: Particle Sizing Using a Cascade Impactor

2. The graph is plotted

% of total of particles collected on a stage

which should show a straight line on log-probability paper

VI. Impactor Sampling Procedures

A. The standard sampling train can be used

1. This is the easiest way to do the sampling because you can operate it just like

2. The impactor is positioned at the probe end then a nozzle is attached to the impactor head

3. A pitot tube may or may not be necessary
   a. It is usually easier to get the impactor into the sample point without the pitot tube
   b. Though we have spent the entire course addressing isokinetic sampling we may not be doing this with an impactor since it loads up so quickly.

B. Non-isokinetic sampling

1. The sampling train is prepared as in RMS

2. The nomograph or calculator is used to determine the $\Delta H$ for the $\Delta v$ in the duct

3. A preliminary test should be run to determine if isokinetic sampling is appropriate
   a. The isokinetic flow rate through the impactor may be too high
   b. If the flow rate is too high errors occur in the impactor
Impactor

1) Scouring of collection stages

2) Reentrainment of particles

4. If the impactor does not show discrete clean particulate catches flow rate will have to be lowered
   a. This does bias the sample but not as much as scouring and reentrainment
   b. It will change stage cut points some
   c. These are uncertainties that are still being researched

C. Repetitions — it can require as many as 30 sample runs to get valid data
   1. 3 runs should be minimum
   2. 9 runs is probably a practical limit

Particle sizing is a complex endeavor. Cascade impactors give the most useful data for stack samplers but they are not perfect. Always assess the need and uses of the data before planning a program for sizing particles in a duct.
Lesson Goal:

To introduce the student to the field of continuous opacity monitoring using transmissometers. To show instrument design characteristics, typical installations, and the relationship of opacity to particulate mass measurements.

Lesson Objectives:

The student will be able to:

1. Define the terms opacity, transmittance, and transmissometer.
2. Express the relationship between opacity and transmittance.
3. Recognize the proper expression for optical density.
4. Discuss the EPA requirements for the design and performance of transmissometers placed on sources regulated by NSPS.
5. Define the meaning of photopic and give at least two reasons why light in the photopic region is to be used in transmissometer design.
6. Explain that optical density is proportional to grain loading and discuss the advantages and limitations of correlating optical density to grain loading.
7. List several uses of opacity monitors.

Student Prerequisite Skills:

Some concept of logarithms and exponential functions (note: students do learn about logarithms in high school)

Level of Instruction:

College undergraduate physics
Intended Student Professional Background:
General Science

Support Materials and Equipment:
1. Course workbook
2. Course manual
3. Slide projector
4. Demonstration transmissometer, if available

Special Instructions:
This is the last lecture in the course. Some students may be restless by this time, eager to take the post-test and go home. The lecture should be given to the point, meeting the objectives, without elaborating on details.

References:
I. Definition of opacity
   A. Opacity is the percentage of visible light attenuated due to the absorption and scattering of light by particulate matter in the flue gas.
   B. Relationship between % opacity and % transmittance
      \[ \% \text{ opacity} = 100\% - \% \text{ transmittance} \]
   C. Opacity monitor = transmissometer.
      Transmissometer stands for transmission meter.

II. Single-pass transmissometer
   A. Light source, detector, blowers
   B. Point out collimating lenses, fact that light source and detector are on opposite sides of lenses
   C. Blowers used to keep optics clean

III. Double-pass transmissometers
   A. Point out features
   B. Note that lamp and detector are on same side of stack, allowing for simulated zero and calibration check.
   C. Double pass systems more expensive than single pass systems, but more likely to meet EPA design and performance specifications.

IV. Commercially available transmissometers
   A. Many vendors - single pass and double pass
   C. Single pass others on list
   D. List changes frequently - not up to date, vendors go in and out of business.

V. Opacity monitor specifications
   A. Have two types of specifications for monitors required under NSPS and STP's
      1. Design specifications
      2. Performance specifications
B. Design specifications

1. Spectral response must be in photopic region.
2. Angle of view and angle of projection limited to 5°.
3. Calibration error — limited to 3% opacity
4. Response time — 10 seconds maximum from 0 to 95% of Cal. value.
5. Must have facility for system zero and span check.

C. Performance Specification

1. To be performed with monitor placed on stack.
2. 24 hour zero drift < 2% opacity
3. 24 hour calibration drift < 2% opacity

VI. Photopic region — design specification

A. Photopic region—visible region of the spectrum 400–700nm, corresponds to wavelengths the human eye is sensitive to. Might have correlations to Method 9.

B. Chosen since have H2O and CO2 interference in IR region. H2O not a pollutant.

C. Smaller particles attenuate light better at shorter wavelengths. Hence the light wavelengths are limited to the photopic region.

VII. Angle of projection and angle of view

A. Angle of projector — Angle of the cone of light projected by the lamp.

B. Angle of view — Angle of the cone sensed by the detector

C. Limitation necessary, so they don't get contribution of light from outside volumes.

D. Most instruments meet or exceed these specifications.

VIII. Transmissometer siting

A. Transmissometers are to be placed at a point which will give a representative value for the opacity.

B. Must be placed in the plane of the bend

C. Should be in accessible location to allow good servicing of the instrument.
IX. Relationship between emission opacity and monitor opacity  
   A. \( O_1 = 1 - (1 - O_2)^{L_1/L_2} \)  
      \( L_1 \) = emission outlet pathlength  
      \( L_2 \) = monitor pathlength  
      \( O_1 \) = emission opacity  
      \( O_2 \) = monitor opacity  

   B. Used to correlate opacity at stack exit with that seen across transmissometer pathlength.  

   C. Necessary in terms of regulation may or may not correlate with EPA Method 9 observation.  

X. Transmissometer Applications  
   A. Installation to satisfy EPA continuous monitoring requirements - 40 CFR 60.  
   C. Installation for control equipment operation - ESP tuning, broken bag detector.  
   D. Correlation with particulate concentration  
   E. Maintenance of a continuous emission record.  

XI. Correlation of opacity with particulate concentration  
   A. The Beer-Lambert-Bouger relationship  
      \[ 1 - O = T = e^{-naq} \]  
      \( T \) = transmittance  
      \( n \) = number of particles/unit volume  
      \( a \) = mean particle projected area  
      \( q \) = particle extinction coefficient  
      \( e \) = effluent path-length  

   B. Optical density  
      \[ 1. \text{O.D.} = \log_{10} \frac{1}{1 - \text{opacity}} = Kc \]  
      \( K \) = a constant  
      \( c \) = concentration  
      \( e \) = path-length
2. Optional density is a measure of the ability of an aerosol to attenuate light.

3. Optical density is proportional to both pathlength and particulate concentration, so long as the particle characteristics remain the same.

4. Can make correlation between EPA Method 5 and optical density

   Examples: Lignite for boilers
              Cement kiln emissions
              Bituminous coal-fired boilers

XII. Examples of opacity monitoring installations
A. Durag analyzer on power plant duct
B. Durag analyzer on power plant duct
C. Retro-reflector for Durag opacity monitor
D. Transmissometer and blower assembly on EPA stationary source simulator facility
E. Lear-Siegler Model #RM4 transmissometer on power plant stack
F. Lear-Siegler Model #RM4 retroreflector assembly on power plant stack
G. Protective shrouds on transmissometer located on stack
H. Portable transmissometer, Lear-Siegler RM41P on EPA stationary source simulator

XIII. Course closing
A. This is the last lecture in the course. Have the students take a break and then proceed with the post-test.
B. Post-test
   Students need to achieve 70% on post-test before certificates will be awarded. Certificates will be mailed. Have answer sheet available so that students may check answers.
C. Hand out course critiques. No student will receive certificate unless critique is returned.
D. Collect post-test answer sheets and critiques
LESSON PLAN

TOPIC:  MONDAY LABORATORY INSTRUCTIONS

COURSE:  450  Laboratory 1
LESSON TIME:  2 1/2 hours
PREPARED BY:  Giuseppe J. Aldina
DATE:  10/2/78

Topics: Laboratories

1. Reference Method 1
2. Pitot tube calibration
3. Wet bulb-dry bulb moisture estimate
4. Orifice meter calibration

Lesson Goal:

Give students hands-on experience with RM5 equipment and procedures.

Lesson Objectives:

1. Layout, diagram, and make all necessary decisions and calculations for RM1
2. Collect calibration data for an "S" type pitot tube and calculate C for legs A and B
3. Estimate moisture in the stack gas using the wet bulb-dry bulb technique
4. Calibrate the meter console orifice meter for a ΔH of 0.75 CFM at 29.92 in. Hg and 68°F

Prerequisite Skills:

None

Level of Instruction:

College undergraduate science

Intended Student Professional Background:

General Science
Support Materials and Equipment:

1. 450 Workbook
   a. RMI pages 20-23; Pre-survey 137-140
   b. Pitot tube calibration pages 24-26
   c. Wet bulb-dry bulb pages 27-32
   d. Orifice meter calibration pages 33-36

2. Laboratory duct - see equipment list (Introductory section of this Guide).

3. Laboratory equipment - see equipment list (Introductory section of this Guide)
   a. Meter consoles
   b. Standard pitot tubes
   c. Inclined manometers and ring stands
   d. Assembled sampling probes with "8" type pitot and nozzle
   e. Tubing
   f. Thermometers
   g. Cotton wicks and a beaker of H₂O
   h. Stopwatches
   i. Extension cords
   j. Rulers
   k. Tools
   l. Duct tape

4. Calculators

5. Pencils
Figure 1. Laboratory Duct.
Special Instructions:

1. Assemble duct work before the laboratory is scheduled to begin
2. Seal all joints in the duct work with duct tape
3. Label all equipment with a group number
4. Put wicks on 2 thermometers
5. Arrange meter consoles on tables so there is plenty of room around the calibration duct
6. Plug equipment into as many different electrical lines as possible to prevent overloading circuit breakers
7. Be sure manometers have proper fluid levels
8. Provide space and platforms so manometers can be leveled on a stable surface
9. Support long duct sections: top sections from ceiling

References:

None

Instructor Preparations:

1. Read all the laboratory procedures and corresponding lectures
2. Check all equipment operations in advance
3. Arrange pitot tube experiments at horizontal ports
4. Arrange meter consoles with stopwatches so there is plenty of room around the duct
5. Using laboratory procedures check orifice meter calibrations. Record the data as reference. \( \Delta H_\text{wd} \) should be 1.5-2.1 in. H₂O
6. Determining the dry gas meter correction factor using a spirometer would be good practice, but it is not necessary for this laboratory exercise. Assume DCMCF = 1.0.
7. Note: When the DCMCF is known the laboratory orifice meter calibration is accurate. APTD - 0576 should be the procedure used by the student as a standard practice unless DCMCF is determined by spirometer
8. Divide the students into groups of 6 (unless the student/equipment ratio will allow smaller groups) before class starts on Monday.

9. Label each experiment so students can easily identify what exercise to read in the workbook.

10. Heat and moisture can be added to the duct with a small propane torch and pyrex beaker with H₂O but it is not necessary.

11. A schedule for each group at an experiment may be desirable, however, laboratory generally proceeds well without it. The schedule would diminish student anxiety about finishing the lab. At a stack test no schedule exists so it may be most beneficial to allow students to get a feel for the real times required at a test. They will prefer a structure but will undoubtedly not keep it.

12. Post the barometric pressure (for the laboratory) for each lab in inches and millimeter of Hg.

Instructions to the Students:

1. All students should read the laboratory exercises in the workbook first. (Generally they will not follow this direction so be prepared to answer many questions).

2. Be sure to perform all required experiments (many students will try to skip RM1 or the wet bulb-dry bulb).

3. Approach RM1 as if no ports were cut into the duct - choose the best and easiest sampling location.

4. Students should not wait around with nothing to do. There are enough experiments and equipment to keep them working. If an experiment is occupied, they should do another. The meter console and RM1 are always available if one of the others is full.

5. Students should not beat an experiment to death - collect the data and move on.

6. The molecular weight of dry air is 29 g/g-mole (lb/lb-mole). Less than 3% moisture can be considered dry air.

7. Pages 40 and 41 of the workbook should be completed. Page 41 is to be handed in on Wednesday morning.
Lesson Goal:

To familiarize students with the operation of the orsat analyzer and the calculation of stack gas molecular weight

Lesson Objectives:

The student should be able to

1. List the absorbing chemicals used in the orsat and the action of each
2. Perform a leak test on the orsat analyzer
3. Analyze a gas sample for CO₂, O₂, and CO using the orsat

Prerequisite Skills:

None

Level of instruction:

College undergraduate science

Intended Student Professional Background:

General Science

Support Materials and Equipment:

1. 450 workbook page 66
2. 4 orsat analyzers

Special Instructions:

1. Leak check analyzers before class
2. Check reagent efficiency — it should not take more than 6-8 passes of air through the O₂ bubbler to show 20.9% O₂ in the air sample.
Instructor:

Demonstrate orsat operation and explain bubbler chemicals

1. Chemicals
   
   A. Burette solution — Na₂SO₄, saturated H₂O with methyl orange on red indicator and H₂SO₄ to keep it acidic. The burette solution is made this way to keep stack gases from dissolving in it.

   B. CO₂ Bubbler — 42-46% KOH or NaOH

   C. O₂ Bubbler — 42-46% KOH on NaOH and about 10-12 gms of pyrogallic acid (for 1 bubbler)

   D. CO Bubbler — Cuprous chloride (Cu⁺Cl⁻) dissolved in a solution that keeps a high hydrogen ion concentration such as acid or ammonia with some solid copper to maintain Cu ions in solution. This prevents oxidation of the solution before CO is bubbled through it.

2. Operation of the orsat
   
   A. Leak Test
      
      1. Use the burette solution as a sort of pump
      2. Fill the burette with the red solution
      3. Open the CO₂ bubbler and bring it to the reference mark
      4. Repeat for O₂ and CO bubbler
      5. Be sure all valves are closed
      6. Bring the burette solution to the mid point on the scale with the level bottle and solution at the same height — equal pressure on both sides. Record the reading chosen.
      7. Close the burette valve and set the leveling bottle on the table.
      8. After 4 minutes check all liquid levels. If the level drops find the leak.
B. Gas analysis

1. Carefully bring 100 cc of gas into the calibrated burette
2. Push the gas into the CO₂ bubbler then ring it back to the burette
3. Proceed carefully -- do not mix the chemicals
4. After 3 passes read the CO₂ scrubbed by leveling the burette solution and leveling bottle.
5. Record the reading then confirm it by one more pass through CO₂ bubbler. Once is enough. If the reading is constant go on to O₂
6. O₂ — analyze as for CO₂ but
   a. allow the gas to reside longer in the bubbler
   b. make 5-8 passes before the first reading
7. CO is analyzed as for CO₂.

C. Calculations

\[ M_d = \sum M_x B_x \] (see RM3 lesson outline)

\[ M_s = M_d (1-B_{ws}) + 18 (B_{ws}) \]
COURSE 450
SOURCE SAMPLING FOR PARTICULATE POLLUTANTS
INSTRUCTOR'S GUIDE

WEDNESDAY LABORATORY
RM5 Testing
Lesson Goal:

To give students practice in performing an RM5 source test.

Lesson Objectives:

The student should be able to:

1. Apply RM1 for particulate sampling and mark the sampling probe
2. Calibrate the sampling nozzle
3. Determine probe-pitot tube alignment in the sampling duct
4. Record RM5 data on appropriate forms
5. Assemble and disassemble RM5 equipment.
6. Solve the isokinetic sampling rate equation using a nomograph or calculator
7. Operate the RM5 source sampling train
8. Analyze RM5 samples collected by these procedures
9. Make all calculations to determine RM5 pollutant emission rate

Prerequisite Skills:

Monday and Tuesday laboratory

Level of Instruction:

College undergraduate science

Intended Student Professional Background:

General Science
Support Materials and Equipment:

1. 450 Workbook, pages 82-93

2. Source Sampling Train
   a. Nozzle - to be calibrated before the test
   b. Pitot tube - calibrated by student group on Monday
   c. Probe
   d. Sample case and glassware
   e. Tared glass mat filter
   f. Umbilical cord
   g. Tools
   h. Meter console - calibrated by student group on Monday

3. 500 gm of fly ash

4. Laboratory duct

5. Tables and supports for placing sample trains into the duct. Use ports cut for Monday lab.
Special Instructions:

1. Instruct students to organize their experiment properly before the laboratory following the lab exercise and flow charts.

2. Give the following assumed Orsat data and moisture estimate for the test, unless a real stack is being used, then give data for same, if known.

   \[ \begin{align*}
   \text{CO}_2 &= 12.5\% \\
   \text{O}_2 &= 6.2\% \\
   \text{CO} &= 0.1\% \\
   \text{Approximate } \text{H}_2\text{O} &= 5\%
   \end{align*} \]

3. Assemble the sampling trains for the students (they can get experience with hands-on while disassembling.)

4. Impingers and silica gel should be:
   a. 120 ml \text{H}_2\text{O}
   b. 100 ml \text{H}_2\text{O}
   c. Dry
   d. 200 gm silica gel

   but tell the students to assume that there is only 100 ml \text{H}_2\text{O} in each impinger (1 and 2) (if they sample about 30-35 cubic feet this will yield 3-5% moisture in the sample).

   If a real stack is being sampled, use 100 ml.

5. Analysis for the lab - students should:
   a. Weigh silica gel after the test
   b. Measure \text{H}_2\text{O} in the impingers
   c. Weigh the filter with the particulate catch
   d. Weigh probe wash after dried over-night. If this can't be done because of time, one of the instructors, or his assistant, should do it and provide students with the data.

References

Instructors should:

1. **Encourage students to work out their own sampling team assignments**
2. Read the lecture and laboratory exercises
3. Be available for questions and to help students perform the test
4. Check student calculations of K or nomograph settings
5. Work out with students how sampling will be done. Suggested method is to have one team start at the far points in the duct and work outward while the other works its way in. This has proven good practice in past courses.
6. Try to put the equipment on separate electrical circuits to prevent power outages. If the load frequently trips the circuit breaker turn off the probe and filter heaters in the trains
7. Add fly ash to the duct in small amounts until several hundred grams have been fed in. One way of adding the fly ash is to punch a hole in the duct, and supply the ash using a funnel or some other apparatus. Note: Don't add too much or it might start leaking out of the cracks in the duct. The concentration of particulate can be approximated from the weight added to the duct and the volume of ductwork system.
Method 5 Particulate Test
Calculation Form

1. Necessary Data

A. Reference Method #1
   - Area of stack ______ ft$^2$
   - No. of equivalent diameters upstream ______
   - No. of equivalent diameters downstream ______
   - No. of traverse points ______
   - Total test time ($\theta$) ______ minutes

B. Reference Method #2
   - Average stack temperature $T_s$ ______ °F + 450 - ______ °R
   - Stack absolute pressure ______ in. Hg.
   - Barometric Pressure ______ in. Hg.
   - ($\sqrt{\Delta p}$)ave ______ (in. H$_2$O)$^{1/2}$

C. Reference Method #3
   - %CO$_2$ ______; %O$_2$ ______; %CO ______, %N$_2$ ______

D. Reference Method #4
   - Water collected
     Impinger H$_2$O ______ ml
     Silica Gel ______ gm

E. Reference Method #5
   - Area of nozzle ______ ft$^2$
   - Average $\Delta H$ ______ in. H$_2$O
   - Average meter temperature $T_m$ ______ °F + 460 = ______ °R
   - Dry gas meter correction factor ______
   - Volume metered $V_m$ = ______ CF
   - Particulate Weight ______ gm

2. Calculations

A. Standard Volume Metered

\[
V_{m(std)} = V_m Y \frac{T_{std}}{P_{std}} \left( \frac{\Delta H}{P_b + 13.6} \right)
\]

\[
V_{m(std)} = \text{CF} \left( \frac{29.912 \text{ in. Hg}}{29.92 \text{ in. Hg}} \right) \left( \text{in. Hg} \right) = \text{dscf}
\]
B. Moisture Content of Stack Gas

1. \( \text{H}_2\text{O} \) collected in impingers in standard cubic feet
   \[ V_{wc}(\text{std}) = K (V_f - V_i) \]
   \[ V_{wc} = 0.04707 \text{ ft}^3/\text{ml} (\text{ml}) = \text{scf} \]

2. \( \text{H}_2\text{O} \) collected in silica gel in standard cubic feet
   \[ V_{wsg}(\text{std}) = K (W_f - W_i) \]
   \[ V_{wsg}(\text{std}) = 0.04715 \text{ ft}^3/\text{gm} (\text{gm}) = \text{scf} \]

3. Moisture content of stack gas \( (B_{ws}) \)
   \[ B_{ws} = \frac{V_{wc}(\text{std}) + V_{wsg}(\text{std})}{V_{wc}(\text{std}) + V_{wsg}(\text{std}) + V_m(\text{std})} \]
   \[ B_{ws} = \frac{(\text{scf}) + (\text{scf})}{(\text{scf}) + (\text{scf}) + (\text{scf})} = \text{scf} \]

C. Molecular Weight of Stack Gas (lb/lb-mole)

1. \( \text{Md} \) (Dry molecular weight) = \( \Sigma M_X B_X \)
   \[ M_d = (\cdot44) \%\text{CO}_2 + (\cdot32) \%\text{O}_2 + \]
   \[ (\cdot28) \%\text{CO} + (\cdot28) \%\text{N}_2 = \text{lb/lb-mole} \]

2. \( \text{Ms} \) (Wet Molecular Weight) = \( M_d (1 - B_{ws}) + 18 B_{ws} \)
   \[ M_s = (1 - \text{scf}) + 18(\text{scf}) = \text{lb/lb-mole} \]

D. Average Stack Gas Velocity

\[ \bar{v}_s = K_p C_p \sqrt{\frac{T_s}{P_s M_s}} \left( \sqrt{\frac{\Delta P}{\text{ave}}} \right) \]
\[ \bar{v}_s = 85.49 \text{ ft/sec} \left( \frac{\text{lb/lb-mole (in. Hg)}}{\text{°R(in.H} \text{H}_2\text{O})} \right)^{\frac{1}{2}} \]
\[ \sqrt{(\ldots)\text{°R}} \left( \frac{\text{in. Hg}}{\text{lb-lb mole}} \right) \]

E. Average Stack Gas Volumetric Flow Rate

\[ Q_s = (3600 \text{ sec/hr})(v_s)(A_s)(1 - B_{ws}) \frac{T_{std} P_s}{P_{std} T_s} \]
\[ Q_s = (3600 \text{ sec/hr})(\text{scf})(\text{ft}^2/\text{hr})(1 - \text{scf}) \frac{528 \text{°R}}{29.92 \text{ in. Hg}} \text{ in. Hg} \]
\[ Q_s = \text{scf/hr} \]
F. Pollutant Mass Rate

\[ \text{PMR} = \frac{\text{mass.}}{V_{\text{m(std)}}} \times Q_s \]

\[ \text{PMR} = \left( \frac{\text{gm}}{\text{dscf}} \right) \times \text{dscf/hr} \times \frac{1}{454 \text{ gm/lb}} = \text{lb/hr} \]

G. % Isokinetic Variation (Intermediate Data)

\[ \% \text{I} = \frac{T_s V_{\text{m(std)}} P_{\text{std}}}{A_n \theta_s P_s T_{\text{std}} 60 (1 - B_{WS})} \times 100 \]

\[ \% = \frac{(____^\circ \text{R})(____ \text{dscf}) (29.92 \text{ in. Hg})}{(____ \text{ft}^2)(____ \text{min})(____ \text{ft/sec})(____ \text{in. Hg})(528^\circ \text{R})(60 \text{ sec/min})(1 - ____)} \]
Assembled sampling duct constructed of 12 inch galvanized ductwork
Laboratories 1 and 3

Apparatus for Wet Bulb-Dry Bulb moisture estimation experiment
Inclined oil manometer and Prandtl tube for calibration of the Type S pitot tube

RAT. (left) and Nutech (right) Meter Consoles
Blower section for sampling duct

Hayes Orsat
Screw-joint compression seal glassware
Ground glass ball-joint glassware

Nutech Sample Case with glassware and sampling probe
RAC Sample Case with glassware and sampling probe
HANDOUTS FOR COURSE 450

SOURCE SAMPLING FOR PARTICULATE POLLUTANTS
The Instructor's Guide for Air Pollution Training Institute Course 450 "Source Sampling for Particulate Pollutants" contains guidelines for conducting a four and one-half day course in source sampling. The Guide contains lesson plans, laboratory instructions, exams, copies of handout materials, and solutions to problem sets. The lesson plans include keys to APTI audio visual materials and suggested instructional techniques. These materials are intended for use in conjunction with Student Manual EPA 450/2-79-006 and Student Workbook EPA 450/2-79-007.
ENVIRONMENTAL PROTECTION AGENCY

KRAFT PULP MILLS

Standards of Performance for New Stationary Sources and Availability of Draft Guideline Document
The Standards

The standards limit emissions of particulate matter from three affected facilities at Kraft pulp mills. The limits are 0.10 gram per dry standard cubic meter (g/dscm) at 8 percent oxygen for recovery furnaces, 0.16 gram per kilogram of fuel or stock liquor solids (dry weight) (g/kg BLS) for smelt dissolving tanks, 0.15 g/dscm at 10 percent oxygen for lime kilns when burning gas, and 0.30 g/dscm at 10 percent oxygen for lime kilns when burning oil. Visible emissions from recovery furnaces are limited to 35 percent opacity.

The standards also limit emissions of TRS from eight affected facilities at Kraft pulp mills. The limits are: 6 parts per million (ppm) by volume at 10 percent oxygen from the digester systems, multiple-effect evaporator systems, brown stock washer systems, black liquor oxidation systems, and condensate stripper systems and 3 ppm by volume at 8 percent oxygen from straight Kraft recovery furnaces, 8 ppm by volume at 10 percent oxygen from lime kilns, and 25 ppm by volume from 8 percent oxygen from cross recovery furnaces, which are defined as furnaces burning at least 7 percent neutral sulfite semi-chemical (NASC) liquor and having a green liquor sulfidity of at least 28 percent. In addition, TRS emissions from smelt dissolving tanks are limited to 0.0084 g/kg BLS.

The proposed TRS standard for the lime kiln has been changed, a separate TRS standard for cross recovery furnaces has been developed, and the proposed format of the standards for smelt dissolving tanks, digesters, multiple-effect evaporators, brown stock washers, black liquor oxidation and condensate strippers have been changed. The TRS particulate matter standards for the other facilities, however, are essentially the same as those proposed.

It should be noted that standards of performance established under section 111 of the Clean Air Act reflect emission limits achievable with the best adequately demonstrated technological system of continuous emission reduction considering the cost of achieving such emission reductions and any nonair quality health, environmental, and energy impacts which the permitting authority, on a case-by-case basis, taking into account energy, environmental, and economic impacts and other costs, determines it achievable for such facility through application of production processes and available methods, systems, and techniques, including fuel cleaning or treatment of innovative fuel combustion technologies for control of each pollutant. No event shall application of best available control technology (BACT) result in emissions of any pollutant which will exceed the emissions allowed by any applicable standard established pursuant to sections 111 or 112 of this Act.

Standards of performance should not be viewed as the ultimate in achievable emission control and should not prejudice the imposition of any more stringent standard, where appropriate. For example, cost of achievement may be an important factor in determining standards of performance applicable to all areas of the country (clean as well as dirty). Costs must be accorded far less weight in determining the "lowest achievable emission rate" for new or modified sources located in areas violating statute-mandated health and welfare standards. Although there may be emission control technologies available that can reduce emissions below those levels required to comply with standards of performance, this technology might not be selected as the basis of standards of performance due to costs associated with its use. This is no way should prejudice its use in situations where cost is a lesser consideration, such as determination of the "lowest achievable emission rate".

In addition, States are free under section 116 of the Act to establish even more stringent emission limits than

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those established under section 111 or those necessary to attain or maintain the NAAQS under section 110. Thus, new sources may in some cases be subject to limitations more stringent than standards of performance under section 111, and prospective owners and operators of new sources should be aware of this possibility in planning for such facilities.

ENVIRONMENTAL AND ECONOMIC IMPACT

The promulgated standards will reduce particulate emissions about 50 percent below requirements of the average existing State regulations. TRS emissions will be reduced by about 80 percent below requirements of the average existing State regulations, and this reduction will prevent odor problems from arising at most new Kraft pulp mills. The secondary environmental impacts of the promulgated standard will be slight increases in water demand and wastewater treatment requirements. The economic impact of the promulgated standards will be small, increasing national energy consumption in 1980 by the equivalent of only 1.4 million barrels per year of No. 6 oil. The economic impact will be small with fifth-year annualized costs being estimated at $33 million.

PUBLIC PARTICIPATION

Prior to proposal of the standards, interested parties were advised by public notice in the Federal Register of a meeting of the National Air Pollution Control Techniques Advisory Committee. In addition, copies of the proposed standards and the Standards Support and Environmental Impact Statement (SSEIS) were distributed to members of the Kraft pulp industry and several environmental groups at the time of proposal. The public comment period extended from September 24, 1976, to March 14, 1977, and resulted in 42 comment letters with 28 of these letters coming from the industry, 12 from various regulatory agencies, and two from U.S. citizens. Several comments resulted in changes to the proposed standards. A detailed discussion of the comments and changes which resulted is presented in Volume 2 of the SSEIS. A summary is presented here.

SIGNIFICANT COMMENTS AND CHANGES MADE IN THE PROPOSED REGULATIONS

Most of the comment letters received contained multiple comments. The most significant comments and changes made to the proposed regulations are discussed below.

IMPACTS OF THE PROPOSED STANDARDS

Several commenters expressed concern about the increased energy consumption which would result from compliance with proposed standards. These commenters felt that this would conflict with the Department of Energy's goal to reduce total energy consumption in the pulp and paper industry by 14 percent. This factor was considered in the analysis of the energy impact associated with the standards and is discussed in the SSEIS. Although the standards will increase the difficulty of attaining this energy reduction goal, the 4.3 percent increase in energy usage that will be required by new, modified, or reconstructed Kraft pulp mills to comply with the standards is considered reasonable in comparison to the benefits which will result from the corresponding reduction in TRS and particulate matter emissions.

EMISSION CONTROL TECHNOLOGY

Most of the comments received regarding emission control technology concerned the application of this technology to either lime kilns or recovery furnaces. A few comments, however, expressed concern with the oxygen correction factor included in the proposed standards for both lime kilns and recovery furnaces. These commenters pointed out that adjusting the concentration of particulate matter and TRS emissions to 10 percent oxygen for lime kilns and 8 percent oxygen for recovery furnaces only when the oxygen concentration exceeded these values effectively placed more stringent standards on the most energy-efficient operators. To ensure that the standard is equitable for all operators, these commenters suggested that the measured particulate matter and TRS concentrations should always be adjusted to 10 percent oxygen for the lime kiln and 8 percent oxygen for the recovery furnace.

These comments are valid. Requiring a lime kiln or recovery furnace with a low oxygen concentration to meet the same emission concentration as a lime kiln or recovery furnace with a high oxygen concentration would effectively place a more stringent emission limit on the kiln or furnace with the low oxygen concentration. Consequently, the promulgated standards require correction of particulate matter and TRS concentrations to 10 percent or 8 percent oxygen, as appropriate, in all cases.

Lime Kilns

Numerous comments were received on the emission control technology for lime kilns. The main points questioned by the commenters were: (a) Whether caustic scrubbing is effective in reducing TRS emissions from lime kilns; (b) whether an overdesign of the mud washing facilities at lime kiln E is causing TRS emissions during normal operation at lime kiln E when caustic is being added to the scrubber. These observations clearly indicate that TRS emissions would be higher if caustic was not used in the scrubber. The ability of caustic scrubbing to reduce TRS emissions is substantiated by the experience of operators of new sources which employed only efficient mud washing and good lime kiln process control, clearly showing that caustic scrubbing reduces TRS emissions.

The mud washing facilities at lime kiln E are larger than those of other lime kilns of equivalent capacity. This "overdesign" resulted from initial plans of the company to process lime mud from waste water treatment. These waste water treatment plans were later abandoned. Since the quality or efficiency of mud washing has been shown to be a significant factor in reducing TRS emissions from lime kilns, the larger mud washing facilities at lime kiln E undoubtedly contributed to the low TRS emissions observed at this kiln. With the data available, however, it is not possible to separate the relative contribution of these mud washing facilities to the low TRS emissions observed from the relative contributions of good process operation of the lime kiln and caustic scrubbing.

Comments questioning the adequacy of the data base used in developing the standard were mainly directed toward the following points: the TRS standard was based on only one lime kiln: sampling losses which may have occurred during testing were not taken into account; and no lime kiln met both the TRS standard and the particulate standard.

As mentioned above, the TRS standard is based upon the emission control system installed at lime kiln E (i.e., efficient mud washing, good lime kiln process operation, and caustic scrubbing). While it is true that no other lime kiln in the United States is currently achieving the TRS emission levels observed at lime kiln E, there is no other lime kiln in the United States which is using the same emission control system that is employed at this facility. As discussed in the SSEIS, an analysis of the various parameters influencing TRS emissions from lime kilns indicates that this system of emission reduction could be applied to
all new, modified, or reconstructed lime kilns and achieve the same reduction in emissions as observed at lime kiln E. Section 111 of the Clean Air Act requires that data reflecting the degree of emission reduction achievable through the application of the best system of continuous emission reduction which (taking into consideration the cost of achieving such emission reduction, and any nonair quality health and environmental impact and energy requirements) the Administrator determines has been adequately demonstrated for that category of sources. Litigation of standards of performance has resulted in clarification of the term adequately demonstrated." In Portland Cement Association v. Ruckelshaus (486 F. 2d 375, D.C. Circuit, 1973), the standards of performance were viewed by the Court as "technology-forcing." Thus, what system of emission reduction must be available for use to be considered adequately demonstrated, it does not have to be in routine use. However, to ensure that the numerical emission limit selected was consistent with proper operation and maintenance of the emission control system on lime kiln E, continuous monitoring data was examined. This analysis indicated that an emission source test of lime kiln E would have found TRS emission above 5 ppm greater than 5 percent of the time. This analysis indicated, however, that it was very unlikely that an emission source test of lime kiln E would have found TRS emissions above 8 ppm. Thus, it appeared that the 5 ppm TRS numerical emission limit included in the proposed standard for lime kilns was too stringent. Accordingly, the numerical emission limit included in the promulgated standard for lime kilns has been revised to 8 ppm. As discussed later in this preamble, consistent with this change in the numerical emission limit, the excess emissions allowance included within the emission monitoring requirements has been eliminated. This does not reflect a change in the basis for the standard. The standard is still based on the best system of emission reduction, considering costs, for controlling TRS emissions from lime kilns (i.e., efficient mud washing, good lime kiln process operation, and caustic scrubbing). This system, or one equivalent to it, will still be required to comply with the standard.

Since proposal of the standards, sample losses of up to 20 percent during emission source testing have been confirmed. Although these losses were not considered in selecting the numerical emission limit included in the proposed TRS emission standard, they have been considered in selecting the numerical emission limit included in the promulgated standard. Also, since the amount of sample loss that occurs within the TRS emission measurement system during source testing can be determined, procedures have been added to Reference Method 18 requiring determination of these losses during each source test and adjustment of the emission data obtained to take these losses into account.

With respect to a lime kiln to comply with both the TRS emission standard and the particulate emission standard simultaneously, caustic scrubbing will tend to increase particulate emissions due to release of sodium fume from the scrubbing liquor. Compared to the concentration of particulate matter permitted in the gases discharged to the atmosphere, however, the potential contribution of sodium fume from caustic scrubbing is quite small. Consequently, with proper operation and maintenance, sodium fume due to caustic scrubbing will not cause particulate emissions from a lime kiln to exceed the numerical emission limit included in the promulgated standard.

Recovery Furnace. A number of comments were received regarding both the proposed TRS emission standard and the proposed particulate emission standard for recovery furnaces. Basically, the major issue was whether a cross recovery furnace could comply with the 5 ppm TRS standard or whether a separate standard was necessary.

Review of the data and information submitted with these comments indicated that the operation of cross recovery furnaces is substantially different from that of straight kraft recovery furnaces. The sulfidity of the black liquor burned in cross recovery furnaces and the heat content of the liquor, both of which are significant factors influencing TRS emissions, are considerably different from the levels found in straight kraft recovery furnaces.

Analysis of the data indicated that TRS emissions were generally less than 25 ppm, with only occasional excursions exceeding this level. Consequently, the promulgated TRS emission standard has been revised to include a separate TRS numerical emission limit of 25 ppm for cross recovery furnaces.

Smelt Dissolving Tank. Numerous comments were received concerning the format of the proposed TRS and particulate emission standards for smelt dissolving tanks. These comments pointed out that standards in terms of emissions per unit of air-dried pulp were inequitable for kraft pulp mills which produced low-yield pulp. Consequently, the standard for particulate emissions from the smelt dissolving tanks is proportional to the tons of black liquor solids fed into the tanks. Thus, black liquor solids produced per ton of air-dried pulp, however, can vary substantially from mill to mill. A standard in terms of emissions per unit of air-dried pulp, therefore, requires greater control of emissions at kraft pulp mills which use high-yield pulps (higher solids-to-pulp ratio).

Review of these comments does indeed indicate that the format of the proposed standards was inequitable. The format of the promulgated standards, therefore, has been revised to emissions per unit of black liquor solids fed to the smelt dissolving tanks. Since the percent solids and black liquor flow rate to the recovery furnace is routinely monitored at kraft pulp mills, the weight of black liquor solids corresponding to a particular emissions period will be easy to determine.

Brown Stock Washers. Several comments expressed concern about combustion of the high-volume-low TRS concentration gases discharged from brown stock washers and black liquor oxidation facilities. Recovery furnaces without facing a risk of explosions. As discussed in the SSEIS, information obtained from two kraft pulp mill operators indicates that this practice is both safe and reliable when it is accompanied by careful engineering and operating practices. Danger of an explosion occurring is essentially eliminated by introducing the gases high in the furnace. Since some older furnaces do not have the capability to accept large volumes of gases at higher combustion ports, this practice may not be safe for some existing furnaces. In addition, the costs associated with altering these furnaces to accept these gases are frequently prohibitive. Consequently, the promulgated standards include an exemption for new, modified, or reconstructed brown stock washers and black liquor oxidation facilities at existing kraft pulp mills where combustion of these gases in an existing facility is not feasible from a safety or economic standpoint.

CONTINUOUS MONITORING

Numerous comments were received concerning the proposed continuous monitoring requirements. Generally, these comments questioned the requirement to install TRS monitors in light of the absence of performance specifications for these monitors.

At the time of proposal of the standards, both EPA and the kraft pulp mill industry were engaged in developing performance specifications for TRS continuous emission monitoring systems. It was agreed that this work would lead to performance specifications for these monitoring systems by the time the standards of performance were promulgated. Unfortunately, this is not the case. In a joint EPA-industry effort, the compatibility of various TRS emission monitoring...
methods with Reference Method 18, which is the performance test method to determine TRS emissions, is still under study. There is little doubt that these TRS emission monitoring systems will be required to be comparable with Reference Method 18, and that performance specifications for these systems will be developed. Consequently, the promulgated standards will include TRS continuous emission monitoring requirements. These requirements, however, will not become effective until performance specifications for TRS continuous emission monitoring systems have been developed. To accommodate this situation, not only for the promulgated standards for kraft pulp mills, but also for standards of performance that may be developed in the future that may also face this situation, section 60.13 of the General Provisions for subpart B is amended to provide that continuous monitoring systems need not be installed until performance specifications for these systems are promulgated under Appendix B to Part 60. This will ensure that all facilities which are covered by standards of performance will eventually install continuous emission monitoring systems where required.

**EXCESS EMISSIONS**

Numerous comments were received which were concerned with the excess emission allowances and the reporting requirements for excess emissions. Consequently, a brief review of this concept is appropriate.

Standards of performance have two major objectives. The first is installation of the best system of emission reduction, considering costs; and the second is continued proper operation and maintenance of the system throughout its useful life. Since the numerical emission limit included in standards of performance is selected to reflect the performance of the best system of emission reduction under conditions of proper operation and maintenance, the testing method described in 40 CFR 60.8 represents the ability of the source to meet these objectives. Performance tests, however, are often time consuming and complex. As a result, while the performance test is an excellent mechanism for achieving these objectives, it is rather cumbersome and expensive for continuously achieving these objectives. Therefore, the Agency believes that continuous monitors must play an important role in meeting these objectives.

Excess emissions are defined as emissions exceeding the numerical emission limit included in a standard of performance. Continuous emission monitoring, therefore, identifies periods of excess emissions and when combined with the requirement that these periods be reported to EPA, it provides the Agency with a useful mechanism for achieving the previously mentioned objectives.

Continuous emission monitoring, however, will identify all periods of excess emissions, including those which are not the result of improper operation and maintenance. Excess emissions due to start-ups, shutdowns, and malfunctions, for example, are unavoidable or beyond the control of the owner or operator and cannot be attributed to improper operation and maintenance. Similarly, excess emissions as a result of some inherent variability within a process which influences emissions cannot be attributed to improper operation and maintenance, unless these fluctuations could be avoided by attending to those process operating parameters during routine operation which have little effect on operation of the process, but which may have a significant effect on emissions.

To quantify the potential for excess emissions due to inherent variability in a process, continuous monitoring data are used whenever possible to calculate an excess emission allowance. For TRS emissions at kraft pulp mills, this allowance is defined as follows: if a calendar quarter is divided into discrete 12-hour time periods, the excess emission allowance is expressed as the percentage of these time periods. Excess emissions may occur as the result of unavoidable variability within the kraft pulping process. Thus, the excess emission allowance represents the potential for excess emissions under conditions of proper operation and maintenance in the absence of start-ups, shutdowns, and malfunctions, and is used as a guideline or screening mechanism for interpreting the excess emission reporting requirements.

Although the excess emission reporting requirements provide a mechanism for achieving the objective of proper operation and maintenance of the best system of emission reduction, this mechanism is not necessarily a direct indicator of improper operation and maintenance. Consequently, excess emission reports must be reviewed and interpreted for proper decisionmaking.

In general, the comments received concerning the excess emission reporting requirements questioned: (1) The adequacy of the TRS excess emission allowance for lime kilns and (2) the lack of a TRS excess emission allowance for recovery furnaces. With regard to the adequacy of the TRS excess emission allowance for lime kilns, a recently more careful examination of the TRS emission data from lime kilns led the Agency to the conclusion that, for a TRS emission limit of 5 ppm, an excess emission allowance of 3 percent was appropriate. However, a similar analysis also indicates that an excess emission allowance is not appropriate at a TRS emission level of 8 ppm. Accordingly, the excess emission reporting requirements included in the proposed standard for lime kilns contain no excess emission allowance. This does not represent a change in the basis of the standards, however, will still require installation of the best system of emission reduction, considering costs (i.e., efficient mud washing, good lime kiln process operation, recovery furnace, or an alternative system equivalent to the performance of this system).

With regard to the lack of a TRS excess emission allowance for recovery furnaces, at the time of proposal of the standards, no TRS continuous emission monitoring data were available from a well-controlled and well-operated recovery furnace which could be used to determine an excess emission allowance. Several months of TRS continuous emission monitoring data, however, were submitted with the comments received from the operator of recovery furnace D concerning this point.

A review of the data indicates that while some of the excursions of TRS emissions above 5 ppm reflected either improper operation and maintenance or start-ups, shutdowns, or malfunctions, most of these excursions reflected unavoidable variability in the operation of a kraft pulp mill recovery furnace. Discounting those excursions in emissions from the data which were due to improper operation and maintenance, or start-ups, shutdowns, or malfunctions indicates that an excess emission allowance of 1 percent is appropriate for all recovery furnaces.

Including an excess emissions allowance in the promulgated standards for recovery furnaces, but not for lime kilns, is a reversal of the proposed requirements. Including such an allowance for recovery furnaces but not for lime kilns, however, is consistent with the nature of the different emission control systems which were selected as the bases for these standards. The emission control system upon which the TRS standard for recovery furnaces is based consists of black liquor oxidation and good process operation of the recovery furnace and good process operation alone for indirect recovery furnaces. Neither of these emission control systems are particularly well suited to controlling fluctuations in the kraft pulping process. Thus, fluctuations in the process will tend to pass through the emission control system and show up as fluctuations in TRS emissions.

The emission control system upon which the TRS standard for lime kilns
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A high SO₂ concentration levels were observed in only one EPA emission source test. Consequently, high SO₂ concentration levels are probably not a frequent occurrence within Kraft pulp mills. More importantly, however, high SO₂ concentrations only interfere with the determination of methyl mercaptan in the emission measurement system outlined in Reference Method 16. Since methyl mercaptan is usually only a small contributor to total TRS emissions, neglecting methyl mercaptan where this interference occurs should not seriously affect the determination of TRS emissions. Consequently, Reference Method 16 can be used to enforce the promulgated standards without major difficulties.

Microanalysis: The effective date of this regulation is February 24, 1976. Section 111(b)(1)(B) of the Clean Air Act provides that standards, if performance or revisions of them become effective upon promulgation and apply to affected facilities, construction or modification of which was commenced after the date of proposal (September 24, 1976).

Note - An economic assessment has been prepared under section 317 of the Act. This also satisfies the requirements of Executive Orders 11821 and OMB Circular A 107.


BARBARA BIRM
Acting Administrator

Part 60 of Chapter I, Title 40 of the Code of Federal Regulations is amended as follows:

Subpart A—General Provisions

1. Section 60.13 is amended to clarify the provisions in paragraph (a) by revising paragraph (a) to read as follows:

§ 60.13 Monitoring requirements.

(a) For purposes of this section, all continuous monitoring systems required under applicable subparts shall be subject to the provisions of this section upon promulgation of performance specifications for continuous monitoring systems under Appendix B to this part, unless:

(I) The continuous monitoring system is subject to the provisions of paragraphs (a)(2) and (a)(3) of this section or

(2) otherwise operated in an applicable subpart or by the Administrator.

(b) Part 60 is amended by adding subpart B as follows:

Subpart B—Standards for Kraft Pulp Mills

§ 60.280 Standard for particulate matter.

§ 60.282 Standard for total reduced sulfur (TRS).

§ 60.284 Monitoring of emissions and operations.

§ 60.286 Test methods and procedures.

Authority: Secs. 111, 301(a) of the Clean Air Act, as amended (42 U.S.C. 7411, 7413), and additional authority as noted below.

Subpart BB—Standards of Performance for Kraft Pulp Mills

§ 60.288 Applicability and designation of affected facility.

(a) The provisions of this subpart are applicable to the following affected facilities in Kraft pulp mills: digestion system, brown stock washer system, multiple-effect evaporator system, black liquor oxidation system, recovery furnace, smelt dissolving tank, lime kiln, and condensate stripper system. In pulp mills where Kraft pulp is combined with neutral sulfite semi-chemical pulp, the provisions of this subpart are applicable when any portion of the material charged to an affected facility is produced by the Kraft pulp operation.

(b) Any facility under paragraph (a) of this section that commences construction or modification after September 24, 1976, is subject to the requirements of this subpart.

§ 60.281 Definitions.

As used in this subpart, all terms not defined herein shall have the same meaning given them in the Act and in Subpart A.

(a) "Kraft pulp mill" means any stationary source which produces pulp from wood by cooking (digesting) wood chips in a water solution of sodium hydroxide and sodium sulfide (white liquor) at high temperature and pressure. Regeneration of the cooking chemicals through a recovery process is also considered part of the Kraft pulp mill.

(b) Neutral sulfite semichemical pulp mill: means any operation in which pulp is produced from wood by cooking (digesting) wood chips in a solution of sodium sulfite and sodium carbonate, followed by mechanical delignification (grounding).

(c) Total reduced sulfur (TRS): means the sum of the sulfur compounds hydrogen sulfide, dimethyl sulfide, and dimethyl disulfide, that are released during the Kraft pulp operation and measured by Reference Method 16.

(d) "Digesting system": means the continuous digester or each batch digester used for the cooking of wood in sulfate liquor and associated hot and cold dissolving tanks, chip storage, and condensate systems.

Break stock washer system: means brown stock washers and associated knotters, vacuum pumps and fi
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§ 60.281 Monitoring of emissions and operations.

(a) Any owner or operator subject to the provisions of this subpart shall install, calibrate, maintain, and operate the following continuous monitoring systems:

(1) A continuous monitoring system to monitor and record the opacity of the gases discharged into the atmosphere from any recovery furnace. The span of this system shall be set at 70 percent opacity.

(2) Continuous monitoring systems to monitor and record the concentration of TRS emissions on a dry basis and the percent of oxygen by volume on a dry basis in the gases discharged into the atmosphere from any lime kiln, recovery furnace, digester system, brown stock washer system, multiple-effect evaporator system, black liquor oxidation system, or condensate stripper system, except where the provisions of § 60.283(a)(1), (3), or (4) apply. These systems shall be located downstream of the control device(s) and the span(s) of these continuous monitoring systems shall be set at 30 ppm.

(b) Any owner or operator subject to the provisions of this subpart shall install, calibrate, maintain, and operate the following continuous monitoring devices:

(1) A monitoring device that measures the combustion efficiency of any gas stream from a lime kiln or recovery furnace. The monitoring device shall be certified by the manufacturer to be accurate within ±1 percent of the temperature being measured.

(2) For any lime kiln or smelt dissolving tank using a scrubber emission control device:

(i) A monitoring device for the continuous measurement of the pressure loss of the gas stream through the control equipment. The monitoring device is to be certified by the manufacturer to be accurate to within ±500 pascals (ca. ± 2 inches water gauge pressure) and the owner or operator shall calibrate the device to this accuracy before it is placed in service and every 30 days thereafter.

(ii) A monitoring device for the continuous measurement of the scrubbing liquid supply pressure to the control equipment. The monitoring device is to be certified by the manufacturer to be accurate within ±15 percent of design scrubbing liquid supply pressure. The pressure sensor or tap is to
be located close to the scrubber liquid discharge point. The Administrator may be consulted for approval of alternative locations.

(c) Any owner or operator subject to the provisions of this subpart shall, except where the provisions of §60.283(a)(1) or §60.283(a)(4) apply:

(1) Calculate and record on a daily basis 12-hour average TRS concentrations for each of the periods of each operating day. Each 12-hour average shall be determined as the arithmetic mean of the appropriate 12 contiguous 1-hour average total reduced sulfur concentrations provided by each continuous monitoring system installed under paragraph (a)(2) of this section.

(2) Calculate and record on a daily basis 12-hour average oxygen concentrations for the two consecutive periods of each operating day. Each 12-hour average shall correspond to the 12-hour average TRS concentrations under paragraph (c)(1) of this section and shall be determined as an arithmetic mean of the appropriate 12 contiguous 1-hour average oxygen concentrations provided by each continuous monitoring system installed under paragraph (a)(2) of this section.

(3) Correct all 12-hour average TRS concentrations to 10 volume percent for periods during which all 12-hour average TRS concentrations from a recovery furnace shall be corrected to a 8 volume percent using the following equation:

\[
\text{corrected} = \text{measured} \times \frac{21}{23}
\]

where:

\( C_{\text{corrected}} \) = corrected concentration for oxygen

\( C_{\text{measured}} \) = concentration measured for oxygen

\( X \) = the volumetric oxygen concentration in percentage to be corrected to 18 percent for recovery furnaces and 10 percent for lime kilns, incinerators, or other devices

\( Y \) = the measured 12-hour average volume

\( N_{\text{oxygen concentration}} \) = oxygen concentration

(4) For the purpose of reporting required under §60.7(c), any owner or operator subject to the provisions of this subpart shall report periods of excess emissions as follows:

(i) For emissions from any recovery furnace periods of excess emissions are:

(a) All 12-hour averages of TRS concentrations above 5 ppm by volume for straight Kraft recovery furnaces and above 25 ppm by volume for cross recovery furnaces.

(b) All 6 minute average opacity that exceed 25 percent

(2) For emissions from any lime kiln periods of excess emissions are all 12-hour average TRS concentration above 8 ppm by volume.

(3) For emissions from any digester system, brown stock washer system,

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multiple-effect evaporator system, black liquor oxidation system, or condensate stripper system periods of excess emissions are:

(1) All 12-hour average TRS concentrations above 5 ppm by volume unless the provisions of §60.283(a)(1), (4), or (14) apply.

(2) All periods in excess of 5 minutes and their duration during which the combustion temperature at the point of incineration is less than 1200°F, where the provisions of §60.283(a)(11) apply.

(c) Any owner or operator may be consulted for approval of the provisions of this subpart shall.

(1) Method 18 for the concentration of TRS

(2) Method 3 for gas analysis, and

(3) When determining compliance with §60.283(a)(4), use the methodologies of Method 2, Method 16, and the black liquor solids feed rate in the following equation to determine the TRS emission rate.

\[
E = (C_{\text{parallel}} + C_{\text{sequential}} + C_{\text{5}} + C_{\text{7}})/E_{\text{LS}}
\]

Where:

\( E \) = mass of TRS emitted per unit of black liquor solids (lbs/hr)

\( C_{\text{parallel}} \) = average concentration of hydrogen sulfide (H2S) during the testing period, ppm

\( C_{\text{sequential}} \) = average concentration of methyl mercaptan (MeSH) during the testing period, ppm

\( C_{\text{5}} \) = average concentration of dimethyl sulfoxide (DMS) during the testing period, ppm

\( C_{\text{7}} \) = average concentration of dimethyl disulfide (DMDS) during the testing period, ppm

\( E_{\text{LS}} \) = dry volumetric stack gas flow rate corrected to standard conditions, dscm/hr (dry ft³/hr)

\( Q_{\text{black liquor solids feed rate, kg/hr}} \),

(d) For the purpose of determining whether a furnace is straight Kraft recovery furnace or a cross recovery furnace, Method 2, Method 16, and Method 7 shall be used to determine sodium sulfide, sodium hydroxide and carbon dioxide. These determinations shall be made three times daily from the green liquor and the daily average values shall be converted to sodium oxide (Na2O) and substituted into the following equation to determine the high sodium content.

\[
Q_{\text{black liquor solids feed rate, kg/hr}} = \frac{E_{\text{LS}} \times 100 \times C_{\text{Na2O}} + C_{\text{SO}2}}{C_{\text{SO2}}}
\]

Where:

\( Q_{\text{black liquor solids feed rate, kg/hr}} \) = dry volumetric stack gas flow rate corrected to standard conditions, dscm/hr (dry ft³/hr)

\( C_{\text{Na2O}} \) = percent green liquor sulfidity

\( C_{\text{SO2}} \) = percent green liquor sulfidity

**Methods and procedures.**

(a) Reference methods in Appendix A of this part, except as provided under §60.8(b), shall be used to determine compliance with §60.282(a) as follows:

(1) Method 5 for the concentration of particulate matter and the associated moisture content.

(2) Method 1 for simple and velocity traverses.

(3) When determining compliance with §60.282(a): Method 2 for velocity and volumetric flow rate.

(4) Method 3 for gas analysis, and

(5) Method 9 for visibility emissions.

(6) For Method 5, the sampling time for each run shall be at least 60 minutes and the sampling rate shall be at least 0.85 dscm/hr (0.53 dscf/minute), except that shorter sampling times, when necessary by process variables or other factors, may be approved by the Administrator. Water shall be used as the cleanup solvent instead of acetone in the sample recovery procedure outlined in Method 5.

(b) Method 17 (in-stack filtration) may be used as an alternate method for Method 5 for determining compliance with §60.282(a) as Provided. This constant value of 0.009 g/dscm is added to the results of Method 17 and the stack temperature is less than 105°F (ca. 40°C). Water shall be used as the cleanup solvent instead of acetone in the sample recovery procedure outlined in Method 17.

(e) The Administrator will not consider periods of excess emissions reported under paragraph (d) of this section to be indicative of a violation of §60.11(d) provided that:

(1) The percent of the total number of possible contiguous periods of excess emissions in a quarter (excluding periods of startup, shutdown, or malfunction and periods when the facility is not operating) during which excess emissions occur does not exceed:

- One percent for TRS emissions from recovery furnaces.
- Six percent for average opacities from recovery furnaces.

(2) The Administrator determines that the affected facility, including air pollution control equipment, is maintained and operated in a manner which is consistent with good air pollution control practice for minimizing emissions during periods of excess emissions.

§60.285 Test methods and procedures.

(a) Reference methods in Appendix A of this part, except as provided under §60.8(b), shall be used to determine compliance with §60.282(a) as follows:

(1) Method 5 for the concentration of particulate matter and the associated moisture content.

(2) Method 1 for simple and velocity traverses.

(3) When determining compliance with §60.282(a): Method 2 for velocity and volumetric flow rate.

(4) Method 3 for gas analysis, and

(5) Method 9 for visibility emissions.

(b) For Method 5, the sampling time for each run shall be at least 60 minutes and the sampling rate shall be at least 0.85 dscm/hr (0.53 dscf/minute), except that shorter sampling times, when necessary by process variables or other factors, may be approved by the Administrator. Water shall be used as the cleanup solvent instead of acetone in the sample recovery procedure outlined in Method 5.

(c) Method 17 (in-stack filtration) may be used as an alternate method for Method 5 for determining compliance with §60.282(a) as Provided. This constant value of 0.009 g/dscm is added to the results of Method 17 and the stack temperature is less than 105°F (ca. 40°C). Water shall be used as the cleanup solvent instead of acetone in the sample recovery procedure outlined in Method 17.

(1) Method 16 for the concentration of TRS.

(2) Method 3 for gas analysis, and

(3) When determining compliance with §60.282(a)(4), use the methodologies of Method 2, Method 16, and the black liquor solids feed rate in the following equation to determine the TRS emission rate.

\[
E = (C_{\text{parallel}} + C_{\text{sequential}} + C_{\text{5}} + C_{\text{7}})/E_{\text{LS}}
\]

Where:

\( E \) = mass of TRS emitted per unit of black liquor solids (lbs/hr)

\( C_{\text{parallel}} \) = average concentration of hydrogen sulfide (H2S) during the testing period, ppm

\( C_{\text{sequential}} \) = average concentration of methyl mercaptan (MeSH) during the testing period, ppm

\( C_{\text{5}} \) = average concentration of dimethyl sulfide (DMS) during the testing period, ppm

\( C_{\text{7}} \) = average concentration of dimethyl disulfide (DMDS) during the testing period, ppm

\( E_{\text{LS}} \) = dry volumetric stack gas flow rate corrected to standard conditions, dscm/hr (dry ft³/hr)

(4) When determining whether a furnace is straight Kraft recovery furnace or a cross recovery furnace, Method 2, Method 16, and Method 7 shall be used to determine sodium sulfide, sodium hydroxide and carbon dioxide. These determinations shall be made three times daily from the green liquor and the daily average values shall be converted to sodium oxide (Na2O) and substituted into the following equation to determine the high sodium content.

\[
Q_{\text{black liquor solids feed rate, kg/hr}} = \frac{E_{\text{LS}} \times 100 \times C_{\text{Na2O}} + C_{\text{SO2}}}{C_{\text{SO2}}}
\]
shall be corrected to 8 volume percent oxygen. These corrections shall be made in the manner specified in §60 284(e)(3).

Appendix A Reference Methods

1 Method 16 and Method 17 are added to Appendix A as follows.

Methods for the Determination of Sulfur Dioxide

Introduction

The method described below uses the principle of gas chromatographic separation and flame photometric detection. Since there are many systems or sets of operating conditions that represent usable methods of determining sulfur emissions, all systems which employ this principle, but differ only in details of equipment and operation, may be used as alternative methods, provided that the criteria set below are met.

1 Principle and Applicability

1.1 Principle. A gas sample is extracted from the emission source and diluted in clean dry air. An aliquot of the diluted sample is then analyzed for hydrogen sulfide (H2S), methyl mercaptan (MeSH), dimethyl sulfide (DMS), and dimethyl disulfide (DMDS) by gas chromatographic (GC) separation and flame photometric detection (FPD).

1.2 Conditions. These four compounds are known collectively as total reduced sulfur (TRS). The procedures must demonstrate that they have been designed to eliminate such interferences as may be present in the sample.

1.3 Application. This interferences must be eliminated by use of a probe filter.

2 Range of Detection

2.1 Range Coupled with a gas chromatographic system utilizing a ten milliliter sample size, the maximum limit of the FPD for each sulfur compound is approximately 1 ppb total sulfur compounds and less than 10 ppm for each compound at a dilution level between 10 and 100 ppm, the detectable range can be extended by reducing the sample size to 1 milliliter.

2.2 Using the sample size, the minimum detectable concentration is approximately 50 ppb.

3 Interferences

3.1 Moisture Condensation. Moisture condensation in the sample delivery system, for the analyser column, or in the FPD burner will cause losses or interferences. This potential is eliminated by heating the sample line and by conditioning the sample with dry dilution air to lower its dew point below the operating temperature of the GC/FPD analytical system prior to analysis.

3.2 Carbon Monoxide and Carbon Dioxide. CO and CO2 have substantial desensitizing effect on the flame photometric detector used in these systems. Acceptable systems must demonstrate that they have eliminated this interference by some procedure and that all sample contacts are made of inert materials (e.g., stainless steel or Teflon). It must be heated to 120°C and be capable of accurately indicate an 8 hour period shall not exceed ± 1%.

4 Oven of the GC/FPD System Calibration Drift. The calibration drift determined from the mean of four injections made at the beginning and the end of any 8 hour period shall not exceed ± 1%.

4.3 System Calibration Accuracy. The complete system must quantitatively transport and analyze with an accuracy of 20 percent. A correction factor is developed to adjust calibration accuracy to 100 percent.

5 Apparatus

5.1.2 Power Supply. Capable of delivering 750 ampere.

5.1.3.4 Flame Photometric Detectors. Scale amplification of linear ranges of 105 to 107 amperes full scale.

5.2.4 Recorder. Capable of delivering up to 750 volts.

5.3.4 Function of the Electrode. electrodes. The output voltage range of the electrode is ± 10 volts.

5.4.4 Gas Chromatography Column. The column system must be demonstrated to be capable of resolving the four major reduced sulfur compounds, H2S, MeSH, DMS, and DMDS. It must also demonstrate freedom from known interferences.

To demonstrate that adequate resolution has been achieved, the test must submit a chromatograph of a calibration gas containing all four of the TRS compounds in the concentration range of the applicable standards. Adequate resolution will be defined as baseline separation of adjacent peaks when the amplifier attenuation is set so that the smaller peak is at least 50 percent of full scale. Base line separation is defined in Section 3.4. Systems not meeting this criteria may be considered alternate methods subject to the approval of the Administrator.

5.5.4 Gas Chromatography System, the complete system must contain the following components:

5.5.1 Tube Chamber. Chamber of glass or Teflon of sufficient dimensions to house permeation tubes.

5.5.2 Flow System. To measure air flow over permeation tubes at ± 2 percent. Each flowmeter shall be calibrated after a complete test series with a wet test meter. If the flow measuring device differs from the wet test meter by 5 percent, the completed test shall be discarded. Alternatively, the wet meter may be used to confirm the flow data that would yield the lowest flow measurement. Calibration with a wet test meter before a test is optional.

5.5.3 Temperature Bath. Device capable of maintaining the permeation tubes at the calibration temperature within ± 0.1°C.

5.5.4 Temperature Gauge. Thermometer or equivalent to monitor bath temperature within ± 0.1°C.

6 Reagents

6.1 Fuel, Hydrogen (H2) prepurified grade or better.

6.2 Combustion Gas. Oxygen (O2) or air, research purity or better.

6.3 Carrier Gas. Prepurified grade or better.

6.4 Diluent. Air containing less than 5 ppm total sulfur compounds and less than 10 ppm each of moisture and total hydrocarbons. This gas must be heated prior to mixing with the sample to avoid water condensation at the point of contact.

6.5 Calibration Gases. Permeation tubes, one each of H2S, MeSH, DMS, and DMDS, gravimetrically calibrated and certified at some convenient operating temperature. These tubes consist of hermetically sealed FEP Teflon tubing in which a liquefied gaseous substance is enclosed. The enclosed gas permeates through the tubing wall at a constant rate. When the permeation is constant, calibration gases covering a wide range of known concentrations can be generated by varying and accurately measuring the flow rate of dilute gas passing over the tube. These calibration gases are used to calibrate the GC/FPD system and the dilution system.

Per Test Procedures. The following procedure are optional but useful in preventing any problem which might occur later and invalidate the entire test
7.1 After the complete measurement system has been set up at the site and deemed to be operational, the following procedure should be completed before sampling is initiated.

7.1.1 Leak Test. Appropriate leak test procedures must be employed to verify the integrity of all components, sample lines, and connections. The following leak test procedure is used for components of the system, i.e., the suction line, and then stop the pump and insert the test leak for 1 minute. If any of the components leak, apply a slight positive pressure and check for leaks by applying a liquid (detergent) at the leak point. Bubbling indicates the presence of a leak.

7.2 System Performance. Since the system has been calibrated following each test, the precision of each component is not critical. However, the test results should be verified to be operating properly. The verification can be performed by observing the response of flowmeters or flowmeters in the dilution system, or if the system fails to respond in a normal and predictable manner, the source of the discrepancy must be identified and corrected before proceeding.

8.1 General Considerations. This section outlines steps to be followed for use of the GC/FPD and the dilution system. The procedure does not include detailed instructions because the operation of these systems is complex, and it requires a thorough understanding of the individual system being used. Each system should include a written operating manual. The procedure describes the operating procedures and associated with each component in the measurement system. In addition, the operator should be familiar with the operating procedures associated with the measurement system, particularly the GC/FPD. The instructions at the end of this section are recommended for review for this purpose.

8.2 Calibration Procedure. Insert the permeation tubes into the tube chamber. Check the bath temperature to assure agreement with the calibration temperature of the tubes within 0.1°C. Allow 24 hours for the tubes to equilibrate. Alternatively, equilibration may be verified by inserting samples of calibration gas at 1 hour after sampling the permeation tubes can be assumed to have reached equilibrium when consecutive hourly samples agree within the precision limits of Section 4.1.

8.2.1 Calibration of Analysis System. Generate a series of one or more known concentrations spanning the linear range of the FPD (approximately 0.05 to 10 ppm) for each of the four sulfur compounds. Bypassing the calibration system, inject into the GC/FPD system and monitor the responses. Three injections for each concentration must yield the precision described in Section 4.1. Failure to attain this precision is an indication of a problem in the calibration or analytical system. Any such problem must be identified and corrected before proceeding.

8.2.2 Calibration of Dilution System. Generate a known concentration of hydrogen sulfide using the permeation tube system. Adjust the flow rate of diluent gas for the first dilution stage so that the desired level of dilution is approached. In Section 4.1, failure to attain this precision is an indication of a problem in the dilution system. Any such problem must be identified and corrected before proceeding. Using the calibration data for H2S developed under 8.3, determine the dilution calibration gas concentration in ppm. Then calculate the dilution factor as the ratio of the calibration gas concentration before dilution to the diluent calibration gas concentration determined under this paragraph. Repeat this procedure for each stage of dilution required. Alternatively, the GC/FPD system may be calibrated by varying a series of one or more concentrations of each sulfur compound detected at the end of each sample run in a manner as specified in Section 8.4. Failure to attain this precision is an indication of a problem in the dilution system. Any such problem must be identified and corrected before proceeding. Using this precision in ppm, the known gas sample may be used to determine the sampling system loss. A sample run is performed using a permeation tube. Alternatively, cylinders of hydrogen sulfide mixed in air may be used to verify the permeation tube. The optional pretest procedures provide a good guideline for determining if there are leaks in the sampling system.

8.2.3 Observation for Clogging of Probe. If reductions in sample concentrations are observed during a sample run that cannot be explained by process conditions, the sampling system must be interrupted for use of the sample probe is clogged with particulate matter. If the probe is found to be clogged, the sampling system must be cleaned. After cleaning the probe or replacing it with a new one. Each run, the sample probe must be inspected and decontaminated.

10 Post Test Procedures.

10.1 Sample Loss. A known concentration of hydrogen sulfide is injected into the sampling system at the opening of the probe in sufficient quantity to assure that there is an excess of sample which must be vented to the atmosphere. The sample must be transported through the sampling system in the normal manner. The resulting measured concentration should be compared to the known value to determine the sampling system loss. A sampling system loss of more than 20 percent is unacceptable. Any sampling system loss may be corrected for by dividing the resulting sample concentration by the fraction of recovery. The known gas sample may be used to determine the sampling system loss. Alternatively, cylinders of hydrogen sulfide mixed in air may be used to determine the sampling system loss.

11 Calculations.

11.1 Determine the concentrations of each reduced sulfur compound detected directly from the calibration curves. Alternatively, the concentrations may be calculated using the equation for the least square line. The total reduced sulfur will be determined for each analysis using the equation for the least square line. The total reduced sulfur will be determined for each analysis using the equation for the least square line.
11.3 Average TRS. The average TRS will be determined as follows:

\[
\text{Average TRS} = \frac{N \cdot \text{TRS} + \text{ometric}}{N} 
\]

where:

- S = Concentration of any reduced sulfur compounds injected from the 1st sample injection, ppm.
- C = Concentration of any one of the reduced sulfur compounds for the entire run, ppm.
- N = Number of injections in any run period.

12. Example of System. Described below is a system utilized by EPA in analyzing NSPS data. This system does not now reflect all the latest developments in equipment and column technology, but it does represent one system that has been demonstrated to work.

12.1 Apparatus.

12.1.1 Sampling System.

12.1.1.1 Probe. Figure 16-1 illustrates the probe used in lime ligns and other sources and shows a PFA sample line. The probe is designed such that all sample contacts the deflector shield placed between the sample point and the sample line is heated to prevent adsorption of sample gas. The exposed portion of the probe between the sample port and the sample line is heated with a heating tape.

12.1.2 Sample Line. The inside diameter of the Teflon tubing is 2.16 mm (0.085 in). This is the same as in 12.1.4 and 12.1.5.

12.1.3 Sample Valve. Two-port gas sampling valve, equipped with a 10 ml sample loop, actuated by compressed air (Figure 16-5).

12.1.4 Oven. For containing sample valve, stripper column and separation column. The oven is capable of maintaining an elevated temperature ranging from ambient to 100°C, constant within ±2°C.

12.1.5 Temperature Monitor. Thermocouple pyrometer to measure column oven, detector, and exhaust temperature ±1°C.

12.1.6 Flow System. Gas metering system to measure sample flow, hydrogen flow, and oxygen flow (and nitrogen carrier gas flow rate). The flow meters are calibrated and certified to ±3% of reading.

12.1.7 Detector. Flame photometric detector.

12.1.8 Electrometer. Capable of full scale amplification of linear ranges of 10⁻¹⁰ to 10⁻⁸ amps.

12.1.9 Power Supply. Capable of delivering up to 500 volts.

12.1.10 Recorder. Compatible with the output voltage range of the electrometer.

12.1.12 High Molecular Weight Compounds Column (GC/FPD-11). The column is 6 feet (3.65 meters) long and 0.32 mm (0.0125 inches) inside diameter. The column is packed with 30/60 mesh Teflon bonded to 15% polyethylene glycol and 95% polypropylene glycol. The oven temperature is maintained constant at 109°C.

12.2 Calibration.

12.2.1 Hardware. The hardware includes a glass column packed with 30/60 mesh Teflon bonded to 15% polyethylene glycol and 95% polypropylene glycol. The oven temperature is maintained constant at 109°C.

12.2.2 Software. The software includes a glass column packed with 30/60 mesh Teflon bonded to 15% polyethylene glycol and 95% polypropylene glycol. The oven temperature is maintained constant at 109°C.

12.3 Operating Parameters.

12.3.1 Low-Molecular Weight Sulfur Compounds. The operating parameters for the GC/FPD system used for low molecular weight compounds are as follows: nitrogen carrier gas flow rate of 80 cc/min, hydrogen flow rate of 80 cc/min, and sample flow rate of 20 and 80 cc/min.

12.3.2 High-Molecular Weight Sulfur Compounds. The operating parameters for the GC/FPD system used for high molecular weight compounds are the same as in 12.3.1 except, oven temperature at 250°C, and nitrogen carrier gas flow rate of 100 cc/min.

12.4 Analysis Procedure.

12.4.1 Analysis of Diluted Sample. The diluted sample is injected simultaneously into both GC/FPD analyzers for analysis. GC/FPD-1 is used to measure the low-molecular weight reduced sulfur compounds, while GC/FPD-11 is used to measure the high-molecular weight compounds. The high-molecular weight compounds are the same as in 12.3.2 except for the elevated temperature of 250°C.

12.4.2 Analysis of Low-Molecular Weight Sulfur Compounds. The sample is injected into the stripper column and analytical column. The gas is then directed to the analysis of the high-molecular weight compounds. The high-molecular weight compounds are the same as in 12.3.2 except for the elevated temperature of 250°C.

13 Bibliography


Figure 16-1. Probe used for sample gas containing high particulate loadings.
Figure 16-2. Sampling and dilution apparatus.
Figure 16-3. Gas chromatographic-flame photometric analyzers.
Figure 16-4. Apparatus for field calibration.
Figure 18-5. Determination of sample line loss.
METHOD 17. DETERMINATION OF PARTICULATE EMISSIONS FROM STATIONARY SOURCES (IN-STACK FILTRATION METHOD)

Introduction

Particulate matter is not an absolute quantity, rather it is a function of temperature and pressure. Therefore, to prevent variability in particulate matter emission regulations and/or associated test methods, the temperature and pressure at which particulate matter is to be measured must be carefully defined. Of the two variables (temperature and pressure), temperature has the greater effect upon the amount of particulate matter in an effluent gas stream. In most stationary source categories, the effect of pressure appears to be negligible.

In method 5, 250°F is established as a nominal reference temperature. Thus, where Method 5 is specified in an applicable subpart of the standards, particulate matter is defined with respect to temperature. In order to maintain a collection temperature of 250°F Method 5 employs a heated glass sample probe and a heated filter holder. This equipment is somewhat cumbersome and requires careful operation. Therefore, where particulate matter concentrations above the normal range of temperature associated with a specified source category are known to be independent of temperature, it is desirable to eliminate the glass probe and heating systems, and sample at stack temperature.

This method describes an in-stack sampling system and sampling procedure for use in such cases. It is intended to be used only when specified by an applicable subpart of the standards, and only within the applicable temperature limits of specified or when otherwise approved by the Administrator.

1 Principle and Applicability

1.1 Principle Particulate matter is drawn isokinetically from the source and collected on a glass fiber filter maintained at stack temperature. The particulate matter is determined gravimetrically after removal of uncombined water.

1.2 Applicability This method applies to the determination of particulate emissions from stationary sources for determining compliance with new source performance standards, only when specifically provided for an applicable subpart of the standards. This method shall not be used as written if the projected cross-sectional area of the probe extension filter holder assembly is greater than 5 percent of the stack cross-sectional area. See Section 41.

2 Apparatus

2.1 Sampling Train A schematic of the sampling train used in this method is shown in Figure 17-1. Construction details, except for those not specified, are given in APTD 0881. Conversion factors and for a new construction to be used in sampling, consult the Administrator.
Figure 17-1. Particulate Sampling Train, Equipped with In-Stack Filter.

*SUGGESTED (INTERFERENCE-FREE) SPACINGS*
The operating and maintenance procedures for many of the sampling train components are described in APTD 0576 (Section 3 in Betaken 7). Since correct usage is important for obtaining valid results, all users should read the APTD 0576 document and adopt the operating and maintenance procedures as noted for each unit, with exceptions otherwise specified herein. The sampling train consists of the following components:

- 2.1 Probe Nozzle Stainless steel (316) or glass, with sharp, tapered leading edge. The angle of taper shall be 0.30° or shall be made to a constant internal diameter. The probe nozzle shall be of the button-hook or elbow design, unless otherwise specified by the Administrator. If made of stainless steel, the nozzle shall be constructed from seamless tubing. Other materials of construction may be used subject to the approval of the Administrator.
- 2.1.1 Filter Holder. The stack filter holder shall be constructed of boro-silicate glass or quartz glass, or stainless steel, if aasket is used, it shall be made of silicone rubber, Teflon, or stainless steel. Other holder andasket materials may be used subject to the approval of the Administrator. The filter holder shall be designed to provide a positive seal against leakage from the outside or around the filter.
- 2.1.2 Extension. Any suitable rigid probe extension may be used after the filter holder.
- 2.1.3 Pitot Tube Type: S as described in Section 2.1.4 of Method 2, or other device approved by the Administrator: the pitot tube shall be attached to the probe extension to allow constant monitoring of the stack gas velocity (see Figure 17.1). The impact (high pressure) opening plane of the pitot tube shall be level with or above the nozzle entry plane during sampling (see Method 2, Figure 2-16). It is recommended (11 that the angle between the impact plane and the pitot tube shall be 0.30° or shall be made to a constant internal diameter. The probe nozzle shall be of the button-hook or elbow design, unless otherwise specified by the Administrator. If made of stainless steel, the nozzle shall be constructed from seamless tubing. Other materials of construction may be used subject to the approval of the Administrator.
- 2.1.4 Pitot Tube Type: S as described in Section 2.1.4 of Method 2, or other device approved by the Administrator: the pitot tube shall be attached to the probe extension to allow constant monitoring of the stack gas velocity (see Figure 17.1). The impact (high pressure) opening plane of the pitot tube shall be level with or above the nozzle entry plane during sampling (see Method 2, Figure 2-16). It is recommended (11 that the angle between the impact plane and the pitot tube shall be 0.30° or shall be made to a constant internal diameter. The probe nozzle shall be of the button-hook or elbow design, unless otherwise specified by the Administrator. If made of stainless steel, the nozzle shall be constructed from seamless tubing. Other materials of construction may be used subject to the approval of the Administrator. The filter holder shall be designed to provide a positive seal against leakage from the outside or around the filter.

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2.2 Wash Bottles—Two Glass wash bottles are recommended for use in this test. Ten milliliters of distilled water may be used at the option of the tester. It is recommended that acetone be stored in polyethylene bottles for 1 month or less. Acetone bottles shall have no more than a 2 ml leakage. (Narrow mouth glass bottles have been found to be less prone to leakage.) Alternatively, polyethylene bottles may be used.

2.2.2 Glass Sample Storage Containers. Chemically resistant, borosilicate glass bottles for acetone, each containing 500 ml or 1000 ml. Screw cap liners shall either be rubber-bonded Teflon or shall be constructed to be leak-free and resistant to chemical attack by acetone. Narrow mouth glass bottles have been found to be less prone to leakage. Alternatively, polyethylene bottles may be used.

2.2.4 Petri Dishes. For filter samples, glass or polyethylene, unless otherwise specified by the Administrator.

2.2.5 Graduated Cylinder and/or Balance. To measure condensed water to within 1 ml or less. Graduated cylinders shall have subdivisions no greater than 0.2 ml. Most laboratory balances are capable of weighing to within 0.05 g or less. Any of these balances is suitable for use here and in Section 4.

2.2.6 Plastic Storage Containers. Air tight containers to store silica gel.

2.2.7 Funnel and Rubber policeman. To aid in transfer of silica gel to containers. Silicone rubber is not recommended. Polyethylene, glass, or polypropylene, to aid in sample recovery.

2.3 Analysis

2.3.1 Glass Weighing Dishes

2.3.2 Desiccator

2.3.3 Analytical Balance. To measure to within 0.01 mg.

2.3.4 Balance. To measure to within 0.5 mg.

2.3.5 Beakers 250 ml

2.3.6 Hygrometer. To measure the relative humidity of the laboratory environment.

2.3.7 Temperature (Dome To measure the temperature of the laboratory environment.

3 Reagents

3.1 Sampling

3.1.1 Filters. The stack filters shall be of a durable filter material, without organic binders, and shall exhibit at least 95.95 percent efficiency for the penetration of diotyl phthalate smoke particles. The filter efficiency tests shall be conducted in accordance with standard method D 2371. Two data from the supplier's quality control program are sufficient for this purpose.

3.1.2 Silica Gel, indicators type, 6 to 16 mesh. If previously used, dry at 175°C (350°F) for 2 hours. New silica gel may be used as received. Alternatively, other types of desiccant readily or better may be used, subject to the approval of the Administrator.

3.1.3 Crushed Ice

3.1.4 Stopcock Grease. Acetone soluble, moisture resistant, suitable for use with Teflon sleeves or similar, are used. Alternatively, other types of stopcock grease may be used, subject to the approval of the Administrator.

3.2 Sample Receivers. Acetone resistant grade, high quality, moisture resistant, glass bottles from metal containers. The Acetone from metal containers general has a high residue blank and should not be used. Sometimes, acetone in chemical bottles is not an acceptable substitute for glass bottles from metal containers. Thus, Acetone blanks shall be run prior to test use and only Acetone with low blank...
values (0.001 percent) shall be used. In no case shall a blank value of greater than 0.001 percent of the weight of acetone used be subtracted from the sample weight.

3.3 Analysis.

3.3.1 Acetone. Same as 3.2.

3.3.2 Desiccant. Anhydrous calcium sulfate, indicating type. Alternatively, other types of desiccants may be used, subject to the approval of the Administrator.

4 Procedure.

4.1 Sampling. The complexity of this method is such that, in order to obtain reliable results, testers should be trained and experienced with the test procedures.

4.1.1 Pretest Preparation. All components shall be maintained and calibrated according to the procedure described in APTD 0576, unless otherwise specified herein.

Weigh several 200 to 300 g portions of silica gel in air-tight containers to the nearest 0.5 g. Record the total weight of the silica gel plus container, on each container. Alternatively, the silica gel need not be prec weighed, but may be weighed directly in its impinger or sampling holder, just prior to train assembly.

Check filters visually against light for irregularities and flaws or pinhole leaks. Label filters of the proper size on the back side near the edge using numbering machine ink. Alternatively, label the shipping containers (glass or plastic petri dishes) and keep the filters in these containers at all times except during sampling and weighing.

Dehydrate the filters at 20.5 ± 1°C and ambient pressure for at least 24 hours and weigh at intervals of at least 6 hours to a constant weight, i.e., 0.05 mg change from previous weighing. Record results to the nearest 0.1 mg. During each weighing, the filter must not be exposed to the laboratory atmosphere for a period greater than 2 minutes and a relative humidity above 50 percent. Alternatively (unless otherwise specified by the Administrator), the filters may be oven dried at 105°C for 2 to 3 hours, desiccated for 2 hours, and weighed. Procedures other than those described, which account for relative humidity effects, may be used, subject to the approval of the Administrator.

4.1.2 Preliminary Determinations. Select the sampling site and the minimum number of sampling points according to Method 1 or as specified by the Administrator. Make a projected area model of the probe extension-filter holder assembly, with the pilot tube face openings positioned along the centerline of the stack, as shown in Figure 17.2. Calculate the estimated cross-section blockage, as shown in Figure 17.2. If the blockage exceeds 5 percent of the duct cross sectional area, the tester has the following options:

1. a suitable out-of-stack filtration method may be used instead of in-stack filtration.
2. a special in-stack arrangement, in which the sampling and velocity measurement sites are separate, may be used; for details concerning this approach, consult with the Administrator (see also Citation 10 in Section 7). Determine the stack pressure, temperature, and the range of velocity heads using Method 2. It is recommended that a leak check of the pitot lines (see Method 2, Section 3.1) be performed. Determine the moisture content using Approximation Method 4 or its alternatives for the purpose of making isokinetic sampling rate settings. Determine the stack gas dry molecular weight, as described in Method 2, Section 3.6; if integrated Method 3 sampling is used for molecular weight determination, the integrated bag sample shall be taken simultaneously with, and for the same total length of time as, the particular sample run.
Figure 17.2. Projected area model of cross section blockage (approximate average for a sample traversal) caused by an in-stack filter holder probe extension assembly.

\[
\text{ESTIMATED BLOCKAGE (\%)} = \left(\frac{\text{SHADED AREA}}{\text{DUCT AREA}}\right) \times 100
\]
Select a nozzle size based on the range of velocity heads such that it is not necessary to change the nozzle size in order to maintain isokaytine sampling rates. During the run, do not change the nozzle size. Ensure that the proper differential pressure gauge is chosen for the range of velocity heads covered in Section 2 of Method 2.

So a probe extension length such that all the orifices can be sampled. For large stacks, consider sampling from opposite sides of the stack to reduce the length of run.

Select a total sampling time greater than or equal to the maximum total sampling time specified in the test procedure for the specific industries such that (1) the sample time per point is not less than 2 minutes or

The probe extension should be used with at least one 400 mm long probe, 250 g or less, depending on the proper distance into the stack or duct of the sample point.

Assemble the train as in Figure 17 4., using a very light coat of silicone grease on all ground glass joints and greasing only the outer portion of the impinger. Use市570 to avoid possibility of contamination by the silicone grease. Place the train around the impingers.

4.1.4 Leak Check Procedures

4.1.4.1 Pretest Leak Check. A pretest leak check is recommended, but not required. If the tester opts to conduct the pretest leak check, the following procedure shall be used:

After the sampling train has been assembled plug the inlet to the probe nozzle with a material that will be able to withstand the stack temperature. Insert the filter holder into the stack and wait approximately 5 minutes or longer, if necessary, to allow the system to come to equilibrium with the temperature of the stack gas stream. Turn on the pump and draw a vacuum of at least 300 mm Hg in 15 min. Note that a lower vacuum may be used, provided that it is not exceeded during the test. Determine the leakage rate. A leakage rate in excess of 4.15 ml per minute after the filter is removed shall be considered evidence that a leak is present. Leaks shall be considered a sampling failure. If the leakage rate is less than 0.00057 m³/min (0.02 cfm) or 4 percent of the average sampling rate whichever is less, the results are acceptable, and no correction need be applied to the total volume of gas measured. If, however, a higher leakage rate is obtained, the tester shall either record the leakage rate and plot the sample volume as shown in Section 6.3 of this method, or shall void the sampling run.

Immediately after component changes, leak checks are optional. If such leak checks are done, the procedure outlined in Section 4.1.4.1 above shall be used.

4.1.4.3 Post Test Leak Check. A leak check is mandatory at the conclusion of each sampling run. The leak check shall be conducted in accordance with the procedure outlined in Section 4.1.4.1, except that it shall be conducted at a vacuum equal to or greater than the maximum value reached during the sampling run. If the leakage rate is found to be no greater than 0.00057 m³/min (0.02 cfm) or 4 percent of the average sampling rate whichever is less, the results are acceptable, and no correction need be applied to the total volume of gas measured. If, however, a higher leakage rate is obtained, the tester shall either record the leakage rate and correct the sample volume as shown in Section 6.3 of this method, or shall void the sampling run.

4.1.5 Particulate Train Operation. During the sampling run maintain a sampling rate equal to or greater than 10 percent of isokaytine, unless otherwise specified by the Administrator.

For each run, record the data required on the example data sheet shown in Figure 17.3 Be sure to record the initial dry gas meter reading. Record the dry gas meter readings at the beginning and end of each sampling time increment. When changes in flow rates are made, before and after each leak check, and when sampling is halted. Take other readings required by Figure 17.3 at least once at each sample point during each time increment and additional readings when significant changes 10 percent variation in velocity head readings, calibrations, or the meter, or large variations in velocity due to sampling head readings, necessitate additional adjustments in flow rate or the velocity head reading level, and zero the meter. If the meter is zeroed during the sampling run, it is not necessary to record the point rate, and zero the meter.
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<th>TRAVERSE POINT NUMBER</th>
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<th>PRESSURE DIFFERENTIAL ACROSS ORIFICE METER, mm H2O (in. H2O)</th>
<th>GAS SAMPLE VOLUME m³ (ft³)</th>
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**Figure 17.3: Particulate field data**

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Clean the portholes prior to the test run to minimize the chance of sampling the deposited material. To begin sampling, remove the nozzle from the nozzle holder by washing these components with acetone and placing the wash in a glass container. Rinse each surface three times or more if needed to remove visible particulate. Make final rinse of the brush and filter holder. After all acetone washings and particulate matter are collected in the sample container, tighten the lid on the container so that the condenser will not leak out when it is shipped to the laboratory. Mark the height of the fluid level to determine whether or not no change occurred during shipping. Label the container to clearly identify its contents.

**Sampling of Percol Isokinetic**

Calculate percent isokinetic (see Section 6.11) to determine whether another test run should be made. If there are difficulties in maintaining isokinetic rates due to source conditions, consult with the Administrator for possible variations from those listed in the nomographs. If, after repositioning and checking the probe, it is determined that the rate is still not acceptable, additional sampling may be performed. To make final rinse of the inside surface with acetone.

Brush and rinse with acetone the inside part of the fitting in a similar way until no visible particles remain. A funnel (glass or polyethylene) may be used to aid in transferring liquid washes to the container. Rinse the brush with acetone and quantitatively collect these washings in the sample container. Between sampling runs, keep brushes clean and protected from contamination.

After ensuring that all joints are wiped clean of silicone grease (if applicable), clean the inside of the front half of the filter holder by rubbing the surfaces with a nylon brush and rinsing with acetone. Rinse each surface three times or more if needed to remove visible particulate. Make final rinse of the brush and filter holder. After all acetone washings and particulate matter are collected in the sample container, tighten the lid on the container so that the condenser will not leak out when it is shipped to the laboratory. Mark the height of the fluid level to determine whether or not no change occurred during shipping. Label the container to clearly identify its contents.

**Container No. 3**

If silica gel is used in the condenser system for moisture content determination, note the color of the gel to determine if it has been completely spent, make a notation of its condition. Transfer the silica gel back to its original container and seal. A funnel may make it easier to pour the silica gel without spilling, and a rubber policeman may be used as an aid in removing the silica gel. It is not necessary to remove the small amount of dust particles that may adhere to the walls and are difficult to remove. Since the gain in weight is to be used for moisture calculations, do not use any water or other liquids to transfer the silica gel. If a balance is available in the field, follow the procedure for Container No. 3 under "Analysis." No. 3. Carefully remove the probe nozzle and clean the inside surface by washing these components with acetone from a wash bottle and brushing with a nylon brush brush. Brush until acetone rinse shows no visible particles. Carefully remove the final rinse of the inside surface with acetone.

Brush and rinse with acetone the inside part of the fitting in a similar way until no visible particles remain. A funnel (glass or polyethylene) may be used to aid in transferring liquid washes to the container. Rinse the brush with acetone and quantitatively collect these washings in the sample container. Between sampling runs, keep brushes clean and protected from contamination.

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105° C (220° F), whichever is less, for 2 to 3 hours. The tester may also opt to oven dry the sample at the average stack temperature or 105° C (220° F), whichever is less, for 2 to 3 hours, weigh the sample, and use this weight as a final weight.

Plant ____________________________
Date ____________________________
Run No. __________________________
Filter No. _________________________
Amount liquid lost during transport __________________________
Acetone blank volume, ml __________________________
Acetone wash volume, ml __________________________
Acetone black concentration, mg/mg (equation 17-4) __________________________
Acetone wash blank, mg (equation 17-5) __________________________

<table>
<thead>
<tr>
<th>CONTAINER NUMBER</th>
<th>WEIGHT OF PARTICULATE COLLECTED. mg</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>FINAL WEIGHT</td>
</tr>
<tr>
<td>1</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td></td>
</tr>
<tr>
<td>TOTAL</td>
<td></td>
</tr>
</tbody>
</table>

Less acetone blank
Weight of particulate matter

<table>
<thead>
<tr>
<th>VOLUME OF LIQUID WATER COLLECTED</th>
</tr>
</thead>
<tbody>
<tr>
<td>IMPINGER VOLUME ml</td>
</tr>
<tr>
<td>---------------------</td>
</tr>
<tr>
<td>FINAL</td>
</tr>
<tr>
<td>INITIAL</td>
</tr>
<tr>
<td>LIQUID COLLECTED</td>
</tr>
<tr>
<td>TOTAL VOLUME COLLECTED</td>
</tr>
</tbody>
</table>

* CONVERT WEIGHT OF WATER TO VOLUME BY DIVIDING TOTAL WEIGHT INCREASE BY DENSITY OF WATER (1g/ml)

\[
\text{INCREASE} \frac{g}{1\text{g/ml}} = \text{VOLUME WATER} \text{ ml}
\]

Figure 17.4 Analytical data

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Container No. 2. Note the level of liquid in the container and confirm on the analysis sheet whether or not leakage occurred during transport. If a noticeable amount of leakage has occurred, either send the sample or use methods, subject to the approval of the Administrator, to correct the final results. Measure the liquid in this container either volumetrically to ±1 ml or gravimetrically to ±0.5 g. Transfer the contents to a tared 250 ml beaker and evaporate to dryness at ambient temperature and pressure. Desiccate for 24 hours and weigh to a constant weight. Report the results to the nearest 0.1 mg.

Container No. 3. This step may be conducted in the field. Weigh the spent silica gel (or silica gel plus impingers) to the nearest 0.5 g using a balance.

“Acetone Blank”. Container. Measure acetone in this container either volumetrically or gravimetrically. Transfer the acetone to a tared 250 ml beaker and evaporate to dryness at ambient temperature and pressure. Desiccate for 24 hours and weigh to a constant weight. Report the results to the nearest 0.1 mg.

Note. At the option of the tester, the contents of Container No. 2 as well as the acetone blank container may be evaporated at temperatures higher than ambient. If evaporation is done at an elevated temperature, the temperature must be below the boiling point of the solvent, also, to prevent bubbling. The evaporation process must be closely supervised, and the contents of the beaker must be swirled occasionally to maintain an even temperature. Use extreme care, as acetone is highly flammable and has a low flash point.

5. Calibration. Maintain a laboratory log of all calibrations.

5.1 Probe Nozzle. Probe nozzles shall be calibrated before their initial use in the field. Using a micrometer, measure the inside diameter of the nozzle to the nearest 0.025 mm (0.001 in.). Make three separate measurements using different diameters each time, and obtain the average of the measurements. The difference between the high and low number shall not exceed 0.1 mm (0.004 in.). When nozzles become nicked, dented, or corroded, they shall be reshaped, sharpened, and recalibrated before use. Each nozzle shall be permanently and uniquely identified.

5.2 Pitot Tube. If the Pitot tube is placed in an interference free arrangement with respect to the other probe assembly components, its baseline (isolated tube) coefficient shall be determined as outlined in Section 4 of Method 2. If the probe assembly is not interference-free, the Pitot tube assembly coefficient shall be determined by calibration, using methods subject to the approval of the Administrator.

5.3 Metering System. Before its initial use in the field, the metering system shall be calibrated according to the procedure outlined in APTD-0576. Instead of physically adjusting the dry gas meter dial readings to correspond to the wet test meter readings, calibration factors may be used to mathematically correct the gas meter dial readings to the proper values.

Before calibrating the metering system, it is suggested that a leak-check be conducted. For metering systems having diaphragm pumps, the normal leak-check procedure will not detect leaks within the pump. For these cases the following leak-check procedure is suggested: make a 10-minute calibration run at 0.00057 m³/min (0.02 cfm) at the end of the run, take the difference of the measured wet test meter and dry gas meter volumes, divide the difference by 10, to get the leak rate. The leak rate should not exceed 0.00057 m³/min (0.02 cfm).

After each field use, the calibration of the metering system shall be checked by performing three calibration runs at a single intermediate orifice setting (based on the previous field test), with the vacuum set at the maximum value reached during the test series. To adjust the vacuum, insert a valve between the wet test meter and the inlet of the sampling train. Calculate the average value of the calibration factor. If the calibration has changed by more than 5 percent, recalibrate the meter over the full range of orifice settings as outlined in APTD-0576.

Alternative procedures, e.g., using the orifice meter coefficients, may be used, subject to the approval of the Administrator.

Note: If the dry gas meter coefficients obtained before and after a test series differ by more than 5 percent the test series shall either be voided, or recalculations for the test series shall be performed using whichever meter coefficient value (i.e., before or after) gives the lower value of total sample volume.

5.4 Temperature Gauges. Use the procedures in Section 4.3 of Method 2 to calibrate stack temperature gauges. Dial thermometers, such as are used for the dry gas meter and condenser outlet shall be calibrated against mercury-in-glass thermometers.

5.5 Leak Check of Metering System. Shown in Figure 17.1 That portion of the sampling train from the pump to the orifice manometer should be leak checked prior to initial use and after each shipment. Leakage after the pump will result in less volume being recorded than is actually sampled. The following procedure is suggested (see Figure 17-5). Close the main valve on the meter box. Insert a one-hole rubber stopper with rubber tubing attached into the orifice exhaust pipe. Disconnect and vent the low side of the orifice manometer. Close off the low side orifice tap. Pressurize the system to 13 to 18 cm (5 to 7 in.) water column by blowing into the rubber tubing. Pinch off the tubing and observe the manometer for one minute. A loss of pressure on the manometer indicates a leak in the meter box. Leaks, if present, must be corrected.
Figure 17-5. Leak check of meter box.
6.6 Barometer. Calibrate against a mercury barometer.

6. Calculations. Carry out calculations, retaining at least one extra decimal figure beyond that of the acquired data. Round off figures after the final calculation. Other forms of the equations may be used as long as they give equivalent results.

6.1 Nomenclature.

A = Cross-sectional area of nozzles. m² (ft²).

B. = Water vapor in the gas stream, proportional by volume.

C. = Acetone blank concentration. mg/g.

c. = Concentration of particulate matter in stack gas. dry basis, corrected to standard conditions, g/dcm (g/dash).

I = Percent of isokinetic sampling.

L. = Maximum acceptable leakage rate for either a pretest leak check or for a leak check following a component change. equal to 0.00087 m3/min (0.02 cfm) or 4 percent of the average sampling rate, whichever is less.

L. = Individual leakage rate observed during the leak check conducted prior to the "new" component change (t = 1, 2, 3, ... n). mg/min (cfm).

L = Leakage rate observed during the post-test leak check, mg/min (cfm).

m. = Total amount of particulate matter collected, mg.

M. = Molecular weight of water. 18.0 g/mole.

m. = Mass of acetone after evaporation, mg.

P. = Barometric pressure at the sampling site, mm Hg (in. Hg).

P. = Absolute stack gas pressure, mm Hg (in. Hg).

P. = Standard absolute pressure. 760 mm Hg (29.92 in. Hg).

R. = Ideal gas constant. 0.08206 mm Hg m³/.760 lb-mole.

T. = Absolute average dry gas meter temperature (see Figure 17-3), °K (°R).

T. = Absolute average stack gas temperature (see Figure 17-3), °K (°R).

T = Standard absolute temperature. 293 K (528 °R).

V. = Volume of acetone blank, ml.

V. = Volume of acetone used in wash, ml.

V. = Individual volume of liquid collected in impingers and silica gel (see Figure 17-4), ml.

V. = Volume of gas sample as measured by dry gas meter, dcm (dfc).

V = Volume of acetone concentrations as measured by dry gas meter, dcm (dfc).

V. = Volume of water vapor in the gas sample, corrected to standard conditions. dcm (dfc).

V. = Volume of water vapor measured by the dry gas meter to standard conditions. dcm (dfc).

V = Stack gas velocity, calculated by Method 2. Equation 2-9, using data obtained from Method 17. m/sec (ft/sec).

V. = Weight of residue in acetone wash, mg.

V. = Dry gas meter calibration coefficient.

V. = Average pressure differential across the orifice meter (see Figure 17-3), mm Hg (in. H₂O).

V. = Density of dry gas meter calibration coefficient.

V. = Density of water. 0.9982 g/ml 1.0002201 lb/ml.

V. = Total sampling time, min.

V. = Sampling time interval, from the beginning of a run until the first component change.

V. = Sampling time interval, between two successive component changes, beginning with the interval between the first and second changes.

RULES AND REGULATIONS

6.6 Sample Blank Concentration.

\[ C_d = \frac{n}{V_d} \]

Equation 17-4

6.6 Acetone Blank Concentration.

\[ C_d = \frac{m}{V_d} \]

Equation 17-5

6.8 Total Particulate Weight. Determine the total particulate catch from the sum of the weights obtained from containers 1 and 2 less the acetone blank (see Figure 17-4).

Nore.—Refer to Section 4.1.5 to assist in calculation of results involving two or more filter assemblies or two or more sampling trains.

6.9 Particulate Concentration.

\[ c_p = \frac{m}{V_{std}} \]

Equation 17-6

6.10 Conversion Factors.

<table>
<thead>
<tr>
<th>From</th>
<th>To</th>
<th>Multiply by</th>
</tr>
</thead>
<tbody>
<tr>
<td>mg</td>
<td>mg/g</td>
<td>1000</td>
</tr>
<tr>
<td>mg</td>
<td>g</td>
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</tr>
<tr>
<td>m³</td>
<td>ft³</td>
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</tr>
<tr>
<td>ft³</td>
<td>m³</td>
<td>0.0283</td>
</tr>
</tbody>
</table>

6.11 Isokinetic Variation.

6.11.1 Calculation from Raw Data.

\[ V_{sw} = \frac{V_{std}}{I} \]

Equation 17-7

where:

K. = 0.3858 K/mm Hg for metric units. 17.64 R/in. Hg for English units.

Note.—Equation 17-1 can be used as written unless the leakage rate observed during any of the mandatory leak checks (i.e., the post-test leak check or leak checks conducted prior to component changes) exceeds L. If L. or L. exceeds L., Equation 17-1 must be modified as follows:

(a) Case I: No component changes during sampling run. In this case, replace V. in Equation 17-1 with the expression:

\[ V_{sw} \]

(b) Case II: One or more component changes made during the sampling run. In this case, replace V. in Equation 17-1 by the expression:

\[ V_{sw} = \frac{V_{std}}{I} \]

6.4 Volume of water vapor

\[ V_{w} = \frac{V_{std}}{I} \]

Equation 17-8

where:

K. = 0.001434 mm Hg mm/m²-K for metric units. 0.001669 in. Hg ft²/m²-K for English units.

6.12 Calculation from Intermediate Values.

\[ V_{w} = \frac{V_{std}}{I} \]

Equation 17-9

\[ V_{w} = \frac{V_{std}}{I} \]

Equation 17-10

\[ V_{w} = \frac{V_{std}}{I} \]

Equation 17-11

\[ V_{w} = \frac{V_{std}}{I} \]

Equation 17-12

where:

K. = 4.320 for metric units. 0.09450 for English units.

6.12 Acceptable Results. If 90 percent or more of the readings are acceptable, and the results are low in comparison to the standard and 1 is beyond the acceptable range, or if L. is less than 90 percent, the administrator may accept the results and note when Section 7 is to be made mandatory. Otherwise reject the results and repeat the test.

7. Bibliography
RULES AND REGULATIONS

SUMMARY: This action announces the availability of a draft guideline document for the control of total reduced sulfur (TRS) emissions from existing kraft pulp mills, and invites public comments on the contents of the document. Standards of performance for control of TRS from new, modified, and reconstructed kraft pulp mills are being promulgated elsewhere in this issue of the FEDERAL REGISTER. Under the Clean Air Act, the Administrator must issue this draft document, consider the public comments received on the draft, and publish a final guideline document. Publication of the final document will trigger the development of State plans to control TRS emissions from existing kraft pulp mills.

DATE: Comments must be received on or before April 24, 1978. (60 days after this publication).

ADDRESS: Comments should be submitted, preferably in triplicate, to the Emission Standards and Engineering Division, Environmental Protection Agency, Research Triangle Park, N.C. 27711. Attention: Mr. Don R. Goodwin.

A copy of the draft guideline document may be obtained from the U.S. EPA Library (MD-35), Research Triangle Park, N.C. 27711; "Draft Guideline Document: Control of TRS Emissions from Existing Kraft Pulp Mills".

The draft guideline document and all public comments received will be available for inspection and copying during normal business hours at the Public Information Reference Unit, 401 M Street SW, Washington, D.C.

FOR FURTHER INFORMATION CONTACT:


SUPPLEMENTARY INFORMATION: The Clean Air Act applies to three general categories of pollutants: (1) those that cause adverse effects on public health; (2) those that cause adverse effects on public welfare; and (3) those that are harmful substances. The first category consists of pollutants often referred to as criteria pollutants for which quality criteria have been established. The second category consists of pollutants that are (or may be) harmful to public health or welfare but are not or cannot be controlled under sections 108-110 or 112 Section 111(d) requires control of existing sources of such pollutants whenever standards of performance (for those pollutants) are established under section 111(b) for new sources of the same type. For convenience of reference, such pollutants are referred to as "designed pollutants," and existing facilities whose emissions of such pollutants must be controlled under section 111(d) are referred to as "designed facilities.

On November 17, 1975 (40 FR 53340), EPA promulgated a new subpart B to 40 CFR Part 60 establishing procedures and requirements for submittal of State plans for control of designated pollutants from designated facilities under section 111(d). A summary of subpart B and a discussion of the basic concepts underlying it appear in the preamble published in connection with its promulgation. In brief, subpart B provides that after a standard of performance applicable to emissions of a designated pollutant from new sources is promulgated, the Administrator will publish a draft guideline document containing information pertinent to the control of the same pollutant from designated (i.e., existing) facilities. He will also publish a notice of availability of the draft guideline document and invite comments on its contents. After consideration of these comments, the Administrator will promulgate a final guideline document for the pollutant in question, and the States will then have nine months to develop and submit plans for control of that pollutant from designated facilities. Within four months after the date for submission of plans, the Administrator will approve or disapprove each plan (or portion thereof). If a State plan (or portion thereof) is disapproved, the Administrator will promulgate a plan (or portion thereof) within six months after the date for plan submission.

These and related provisions of subpart B are basically patterned after section 110 of the Act and 40 CFR Part 51 concerning adoption and submittal of State implementation plans under section 110.

As discussed in the preamble to subpart B, a distinction is drawn between designated pollutants, which may cause adverse effects on public health referred to as "health-related pollutants," and those for which adverse effects on public health have not been demonstrated (referred to at "welfare-related pollutants"). For health-related pollutants, emission standards and compliance schedules in State plans must be at least as stringent as the corresponding emission guidelines and compliance times in EPA's guideline document. As provided in subpart B, States may apply less stringent requirements when economic considerations or other factors, such as the remaining useful life of a designated facility, make such requirements significantly more reasonable. For welfare-related pollutants, States may balance the emission guidelines, compliance times, and other information in EPA's guideline documents against other factors of public concern in developing their plans, as explained more fully in the preamble to subpart B and in the introductory portion of each guideline document. Thus, the States have more flexibility in establishing plans for welfare-related pollutants than is provided for plans involving pollutants that may affect public health.

For reasons explained in the draft guideline document, the Administrator has determined that atmospheric TRS emissions from the industrial and energy requirements of such systems can be purchased and installed. The emission guidelines presented in the document for control of TRS emissions from existing facilities at kraft pulp mills are 5 parts per million (ppm) of TRS from digester systems, 5 ppm of TRS from multiple-effect evaporator systems, 5 ppm of TRS from straight kraft recovery furnace systems designed for low TPS emissions (the basis for this design is defined in the guideline document). 20 ppm of TRS from all other straight kraft recovery furnace systems. 25 ppm of TRS from kraft recovery furnace systems. 20 ppm of TRS from kraft recovery furnace systems. These standards are all on a hot basis. The recommended...
emission guideline for the smelt dissolving tank is 0.0084 gram of ERS per kilogram of black honor solids sent.

The amount of time to retrofit an existing flue can vary widely depending upon such factors as site location, weather conditions, lack of available facilities, delays in equipment delivery, and time required to develop engineering data. Subject to these considerations, the approximate times necessary to retrofit existing facilities are 3 years for recovery furnaces, 2 years for digesters, multiple effect evaporators, smelt dissolving tanks, and condensate strippers; and 2 years for lime kilns. The rationale for the selection of these guidelines, including emission test data and control technology, is discussed in the draft guideline document.

The final draft guideline document has been prepared by consultation with appropriate advisory committees, independent experts, and Federal departments and agencies. Interested persons are invited to participate in the development of these guidelines. The Administrator welcomes comments on all aspects of the draft guideline document, including economic and technological issues, the selection of technology, and the criteria used to develop the emissions limits.

Authority: This rule is made pursuant to the Act, 40 CFR part 60. The guideline document has been preceded by consultation with appropriate advisory committees, independent experts, and Federal departments and agencies. The Administrator welcomes comments on all aspects of the draft guideline document, including economic and technological issues, the selection of technology, and the criteria used to develop the emissions limits.

Barbara Blum, Acting Administrator
AMENDMENTS TO KRAFT PULP MILLS

STANDARD AND REFERENCE METHOD 16
PART 60—STANDARDS OF PERFORMANCE FOR NEW STATIONARY SOURCES

Amendments to Kraft Pulp Mills

Standard and Reference Method 16

ACTION: Final rule.

SUMMARY: The amendments in this final rule establish standards of performance for Kraft pulp mills. The amendments revise Test Methods for the determination of 

PART 60—STANDARDS OF PERFORMANCE FOR NEW STATIONARY SOURCES

SUPPLEMENTARY INFORMATION

The standards for Kraft pulp mills are promulgated on February 23, 1978. These standards for Kraft pulp mills are promulgated on February 23, 1978. The National Council for Air and Stream Improvement (NCASI) requested two changes to the standards to permit the testing procedure in a manner which was consistent with the intent of the standards. These changes are reflected in the NCASI-pointed-out provisions. The following sections of the standards are amended to read as follows:

1. In §60.283, paragraph (a)(4) is amended to read as follows:

$60.283 Standard for total reduced sulfur (TRS)

(a) . . .

(b) . . .

(c) . . .

The gas from the digester system, brown stock washer system, condensate stripper system, or black liquor oxidation system is controlled by means other than combustion. In this case, these systems shall not discharge any gases to the atmosphere which contain TRS in excess of 5 ppm by volume on a dry basis, corrected to the actual oxygen content of the untrated gas stream.

2. In appendix A, paragraph 10.1 of method 16 is amended to read as follows:

10 POST TEST PROCEDURES

10.1 Sample line loss. A known concentration of hydrogen sulfide at the level of the applicable standard, ± 20 percent, must be introduced into the sampling system in sufficient quantity to assure that there is an excess of sample which must be vented to the atmosphere.

For sampling losses greater than 20 percent in a sample run, the sample run is not to be used when determining the arithmetic mean of the performance test. For sampling losses of 0-20 percent, the sample concentration must be corrected by dividing the sample concentration by the fraction of recovery. The fraction of recovery is equal to one minus the ratio of the measured concentration to the known concentration of hydrogen sulfide in the sample line loss procedure. The known sample may be generated using permeation tubes. Alternative cylinders of hydrogen sulfide may be used provided they are traceable to permeation tubes. The test gas used to generate the standard should be corrected to 1 atmosphere and 20°C.

FEDERAL REGISTER, VOL. 43, NO. 152—MONDAY, AUGUST 7, 1978
ENVIRONMENTAL PROTECTION AGENCY

STANDARDS OF PERFORMANCE FOR NEW STATIONARY SOURCES

Revision to Reference Method 1-8
Title 40—Protection of Environment

CHAPTER I—ENVIRONMENTAL PROTECTION AGENCY

[FR 75-4] PART 60—STANDARDS OF PERFORMANCE FOR NEW STATIONARY SOURCES

Revision to Reference Methods 1–8

AGENCY: Environmental Protection Agency.

ACTION: Final Rule.

SUMMARY: This rule revises Reference Methods 1 through 8, the detailed requirements used to measure emissions from affected facilities to determine whether they are in compliance with a standard of performance. The methods were originally promulgated December 23, 1971, and since that time several revisions became apparent which would clarify, correct and improve the methods. These revisions make the methods easier to use, and improve their accuracy and reliability.


ADDRESSSES: Copies of the comment letters are available for public inspection and copying at the U.S. Environmental Protection Agency, Public Information Reference Unit (EPA Library), Room 2922, 401 M Street, S.W., Washington, D.C. 20460. A summary of the comments and EPA's responses may be obtained upon written request from the EPA Public Information Center (PM-215), 401 M Street, S.W., Washington, D.C. 20460 (specify "Public Comment Summary: Revisions to Reference Methods 1–8 in Appendix A of Standards of Performance for New Stationary Sources").

FOR FURTHER INFORMATION CONTACT:


SUPPLEMENTARY INFORMATION: The amendments were proposed on June 8, 1978 (43 FR 23060). A total of 55 comment letters were received during the comment period—34 from industry, 15 from governmental agencies, and 6 from other interested parties. They contained numerous suggestions which were incorporated in the final revisions.

Changes common to all eight of the reference methods are: (1) the clarification of procedures and equipment specifications resulting from the comments, (2) the addition of guidelines for alternative procedures and equipment to make prior approval of the Administrator unnecessary and (3) the addition of an introduction to each reference method discussing the general use of the method and delineating the procedure for using alternative methods and equipment.

Specific changes to the methods are:

METHOD 1

1. The provision for the use of more than two traverse diameters, when specified by the Administrator, has been deleted. If one traverse diameter is in a plane containing the greatest expected concentration variation, the intended purpose of the deleted paragraph will be fulfilled.

2. Based on recent data from Fludyne (Particulate Sampling Strategies for Large Power Plants Including Nonuniform Flow, EPA-600/2-78-170, June 1970) and Entropy Environmentalists (Determination of the Optimum Number of Traverse Points for Field Determination of Concentration, draft, Contract No. 68-01-3172), the number of traverse points for velocity measurements has been reduced and the 2:1 length to width ratio requirement for cross-sectional layout of rectangular ducts has been replaced by a "balanced matrix" scheme.

3. Guidelines for sampling in stacks containing cyclonic flow and stacks smaller than about 0.31 meter in diameter or 0.071 meter in cross-sectional area will be published at a later date.

4. Clarification has been made as to when a check for cyclonic flow is necessary; also, the suggested procedure for determination of unacceptable flow conditions has been revised.

METHOD 2

1. The calibration of certain pitot tubes has been made optional. Appropriate construction and application guidelines have been included.

2. A detailed calibration procedure for temperature gauges has been included.

3. The leak check procedure for pitot lines has been included.

METHOD 3

1. The applicability of the method has been confined to fossil-fuel combustion processes and to other processes where it has been determined that components other than O<sub>2</sub>, CO, CO<sub>2</sub>, and N<sub>2</sub> are not present in concentrations sufficient to affect the final results.

2. Based on recent research information (Particulate Sampling Strategies for Large Power Plants Including Nonuniform Flow, EPA-600/2-73-170, June 1976), the requirement for proportional sampling has been dropped and replaced with the requirement for constant rate sampling. Proportional and constant rate sampling have been found to give essentially the same result.

3. The "three consecutive" requirement has been replaced by "any three" for the determination of molecular weight, CO, and O<sub>2</sub>.

4. The equation for excess air has been revised to account for the presence of CO.<sub>2</sub>

5. A clearer distinction has been made between molecular weight determination and emission rate correction factor determination.

6. Single point, integrated sampling has been included.

METHOD 4

1. The sampling time of 1 hour has been changed to a total sampling time which, when multiplied by the length of time the point of emission rate is being determined or such time as allowed in an applicable subpart of the standards, 2. The requirement for proportional sampling has been dropped and replaced with the requirement for constant rate sampling.

3. The leak check before the test run has been made optional; the leak check after the run remains mandatory.

METHOD 5

1. The following alternatives have been included in the method:

a. The use of metal probe liners.

b. The use of other materials of construction for filter holders and probe liner parts.

c. The use of polyethylene wash bottles and sample storage containers.

d. The use of desiccants other than silica gel or calcium sulfate, when appropriate.

e. The use of stopcock grease other than silicone grease, when appropriate.

f. The drying of filters and probe-filter catches at elevated temperatures, when appropriate.

g. The combining of the filter and probe washes into one container.

2. The leak check prior to a test run has been made optional. The post-test leak check remains mandatory. A method for correcting sample volume for excessive leakage rates has been included.

3. Detailed leak check and calibration procedures for the metering system have been included.

METHOD 6

1. Possible interfering agents of the method have been delineated.

2. The options of: (a) using a Method 8 impinger system, or (b) determining SO<sub>2</sub>, simultaneously with particulate matter, have been included in the method.

3. Based on recent research data, the requirement for proportional sampling has been dropped and replaced with the requirement for constant rate sampling.

4. Tests have shown that isopropanol obtained from commercial sources occasionally has peroxides impurities that will cause erroneously low SO<sub>2</sub> measurements. Therefore, a test for detecting peroxides in isopropanol has been included in the method.

5. The leak check before the test run has been made optional; the leak check after the run remains mandatory.

6. A detailed calibration procedure for the metering system has been included in the method.

METHOD 7

1. For variable wave length spectrophotometers, a scanning procedure for determining the point of maximum absorbance has been incorporated as an option.

METHOD 8

1. Known interfering compounds have been listed to avoid misapplication of the method.

2. The determination of filterable particulate matter containing and/or containing SO<sub>2</sub> and SO<sub>3</sub> has been allowed where applicable.

3. Since occasionally some commercially available quantities of sulfuric
RULES AND REGULATIONS

have peroxide impurities that will cause erroneously high sulfuric acid test results, and peroxide impurities have been specifically described in the methods.

4. The gravimetric technique for moisture content (rather than volumetric) has been specified because a mixture of isopropyl alcohol and water will have a volume less than the sum of the contents of the volumes involved.

5. A closer correspondence has been made between similar parts of Methods 8 and 6.

MISCELLANEOUS

Several commenters questioned the meaning of the term “subject to” in the approval of the Administrator in relation to using alternate test methods. As defined in §62.2 of subpart A, the “Administrator” includes any authorized representative of the Administrator of the Environmental Protection Agency. Authorized representatives are EPA officials in EPA Regional Offices or State, local, and regional governmental officials who have been delegated the responsibility of enforcing regulations under 40 CFR Part 60. These officials are in consultation with other staff members familiar with technical aspects of source testing and will render decisions regarding acceptable alternative test procedures.

In accordance with section 117 of the Act, publication of these methods was preceded by consultation with appropriate advisory committees, independent experts, and Federal departments and agencies.


DOUGLAS M. COSTEL. Administrator.

Part 60 of Chapter I of Title 40 of the Code of Federal Regulations is amended by revising Methods 1 through 8 of Appendix A—Reference Methods as follows:

A. Alteration of Methods

The following is a list of methods which are to be altered in accordance with the Performance Test and 60.111 (1) to be subject to the standards and maintenance requirements of 40 CFR Part 60, Subpart A (General Premises). Specific use of these reference methods are described in the standards and maintained in the manual, beginning with Subpart D. The method which is subject to the maintenance requirements is the test method as prescribed in the standards and the maintenance requirements of 40 CFR Part 60, Subpart A (General Premises).

The method which is subject to the maintenance requirements is the test method as prescribed in the standards and the maintenance requirements of 40 CFR Part 60, Subpart A (General Premises). The method which is subject to the maintenance requirements is the test method as prescribed in the standards and the maintenance requirements of 40 CFR Part 60, Subpart A (General Premises).
Figure 1-1. Minimum number of traverse points for particulate traverses.

where L is length and W is width.

2.2 Determining the Number of Traverse Points

2.2.1 Particulate Traverses. When the height and two-diameter criterion are met, the minimum number of traverse points shall be 412. For circular or rectangular stacks with diameters of equivalent diameter greater than 0.61 meter (24 in.), 0.61 meter (24 in.) or circular stacks with diameters between 0.06 and 0.1 meter (24 in.), 0.06 and 0.1 meter (24 in.), for rectangular stacks with equivalent diameters between 0.06 and 0.1 meter (24 in.), the minimum number of traverse points shall be determined from Figure 1-1. Before referring to the figure, however, determine the diameters from the downstream measurement to the nearest upstream and downstream control points, and divide each by the stack diameter or equivalent diameter, to determine the distance to one of the smaller diameters. Then, determine from Figure 1-1 the minimum number of traverse points that correspond to the number of duct diameters upstream, and 2 to the number of diameters downstream. Select the higher of the two minimum numbers of traverse points, or water-soluble substrates for virtual stacks the number equal to 0.5 for rectangular stacks, or circular stacks, as shown in Table 1-1.
Figure 1-2. Minimum number of traverse points for velocity (nonparticulate) traverses.

2.2.2 Velocity (Non Particulate) Traverses. When velocity or volumetric flow rate is to be determined (but not particulate matter), the same procedure as that for particulate traverses (Section 2.2.1) is followed, except that Figure 1-2 must be used instead of Figure 1-1.

3.1 Cross Sectional Layout and Location of Traverse Points

3.1.1 Circular Stacks. Locate the traverse points on two perpendicular diameters, as indicated in Figure 1-2 and the example shown in Figure 1-3. Any equation, the example, or Table 2 may be used in lieu of Table 1-2.

2.2 Particulate Traverses. One of the diameters, but the one plane containing the greater expected cross-sectional area at the stack, shall be the plane of the stack. The traverse shall be located at a distance from the stack center line, equal to the distance from the stack centerline to the point at which the stack centerline is normal to the particulate matter trajectory, and not subject to appreciable dust or particles.

The traverse shall be conducted at a point on the stack wall and for stack walls inclined at an angle, the traverse shall be conducted at the same location on the same wall of the stack for the determination of the particulate matter concentration.
Table 1-2. LOCATION OF TRAVERSE POINTS IN CIRCULAR STACKS

<table>
<thead>
<tr>
<th>Traverse point number on a diameter</th>
<th>Number of traverse points on a diameter</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>4</td>
</tr>
<tr>
<td>1</td>
<td>14.6</td>
</tr>
<tr>
<td>2</td>
<td>65.4</td>
</tr>
<tr>
<td>3</td>
<td>75.0</td>
</tr>
<tr>
<td>4</td>
<td>93.3</td>
</tr>
<tr>
<td>5</td>
<td>85.4</td>
</tr>
<tr>
<td>6</td>
<td>95.6</td>
</tr>
<tr>
<td>7</td>
<td>98.5</td>
</tr>
<tr>
<td>8</td>
<td>96.8</td>
</tr>
<tr>
<td>9</td>
<td>91.8</td>
</tr>
<tr>
<td>10</td>
<td>97.4</td>
</tr>
<tr>
<td>11</td>
<td>93.3</td>
</tr>
<tr>
<td>12</td>
<td>97.9</td>
</tr>
<tr>
<td>13</td>
<td>94.3</td>
</tr>
<tr>
<td>14</td>
<td>98.2</td>
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<tr>
<td>15</td>
<td>95.1</td>
</tr>
<tr>
<td>16</td>
<td>98.4</td>
</tr>
<tr>
<td>17</td>
<td>95.6</td>
</tr>
<tr>
<td>18</td>
<td>99.6</td>
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<tr>
<td>19</td>
<td>96.1</td>
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<td>20</td>
<td>98.7</td>
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<td>21</td>
<td>96.5</td>
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<tr>
<td>22</td>
<td>93.9</td>
</tr>
<tr>
<td>23</td>
<td>96.8</td>
</tr>
<tr>
<td>24</td>
<td>98.9</td>
</tr>
</tbody>
</table>

2.2.13 Stacks With Diameters Equal to Less Than 0.61 m (24 in). Follow the procedure in Sections 2.2.11, noting only that any "adjusted" points should be relocated away from the stack walls to a distance of 1.37 m (54 in). If a distance equal to the mean stack diameter, whichever is larger.

2.2.14 Rectangular Stacks Determine the number of traverse points as explained in Sections 2.2.1 and 2.2.2 of this method. From Table 1, determine the grid coordinates inside the stack cross section to many equal rectangular elemental areas as traverse points, and then locate a traverse point at the center of each equal area according to the example in Figure 14.

The location of traverse points being located in the stack wall is expected to use with rectangular stacks. If this problem should ever arise, the atmosphere must be contacted for resolution of the matter.

2.3.4 Determination of Average Flow Rate. In all stationary sources the direction of stack gas flow is essentially parallel to the stack's axis. However, situations may exist that it affects stack walls or other structural elements following certain procedures. If in stacks having tangential inlets or other duct configurations which tend to induce swirling, in those instances, the presence or absence of a cyclonic flow at the sampling location must be determined. The following technique is acceptable for this determination.

Level and zero the manometer. Connect a Type B pitot tube to the manometer. Position the Type B pitot tube in the direction of flow perpendicular to the stack's axis. The pitot tube is in this position, it is at 0° reference. Note the differential pressure (Ap) reading at each traverse point. If a null (zero) pitot reading is obtained at 0° reference at a given traverse point, an acceptable flow condition exists at that point. If the pitot reading is not zero at 0° reference, rotate the pitot tube (up to 90° new angle) until a reading is obtained. Carefully determine and record the value of the rotation (aoa) to be the degree. After the null technique has been applied at each traverse point, calculate the average of the absolute value of Ap at all traverse points for which no rotation was required, and include these in the overall average. If the average is not 0, the overall flow condition in the stack is unacceptable and alternative methodology, subject to the approval of the Administrator, must be used to perform accurate sample and velocity traverses.

3. Philosophy


1. Type S Pitot Tube. The Type S pitot tube (Figure 2-1) shall be made of metal tubing (e.g., stainless steel). It is recommended that the external tubing diameter (dimension A, Figure 2-2) be between 0.45 and 0.96 centimeters (9/16 and 5/8 inch). There shall be an equal distance from the base of each leg of the pitot tube to its face-opening plane (dimensions P1 and P2, Figure 2-2); it is recommended that this distance be between 1.00 and 1.00 times the external tubing diameter. The face openings of the pitot tube shall, preferably, be aligned as shown in Figure 2-2; however, slight misalignments of the openings are permissible (see Figure 2-3).

The Type S pitot tube shall have a known coefficient, determined as outlined in Section 4. An identification number shall be assigned to the pitot tube; this number shall be permanently marked or engraved on the body of the tube.

Figure 2-1. Type S pitot tube manometer assembly.
Figure 2-2. Properly constructed Type S pitot tube, shown in: (a) end view; face opening planes perpendicular to transverse axis; (b) top view; face opening planes parallel to longitudinal axis; (c) side view; both legs of equal length and centerlines coincident, when viewed from both sides. Baseline coefficient values of 0.84 may be assigned to pitot tubes constructed this way.
Figure 2-3. Types of face-opening misalignment that can result from field use or improper construction of Type S pitot tubes. These will not affect the baseline value of $C_{ps}$ so long as $a_1$ and $a_2 < 10^\circ$, $\beta_1$ and $\beta_2 < 5^\circ$, $z < 0.32$ cm (1/8 in.) and $w < 0.08$ cm (1/32 in.) (citation 11 in Section 6).
A standard pitot tube may be used instead of a Type 4, provided that it meets the specifications of Section 2.7 and 2.8, and the standard pitot tube is not susceptible to plugage in particulate-laden gas streams. Therefore, whenever a standard pitot tube is used to perform a traverse, adequate proof must be furnished that the openings of the pitot tube have not pluged up during the traverse period; this can be done by using a velocity head AP reading at the final traverse point, checking out the impact and static holes of the standard pitot tube by "black-purging" with pressurized air, and then taking another AP reading. If the AP readings made before and after the air purge are the same (or percent, the traverse is acceptable. Otherwise, reject the run. Note that if AP at the final traverse point is momentarily low, another arrow may be selected. If "black-purging" at regular intervals is part of the procedure, the AP readings shall be taken, as above, for the last two back pressures at which suitably high AP readings are observed.

2.2 Differential Pressure Gauges. An inclined manometer or equivalent device is used. Most sampling trains readings shall be taken, as above, for the last two back pressures at which suitably high AP readings are observed. The AP readings at the traverse points in the stack shall be no less than 1.5 (0.06 in.) Hg. However, a differential pressure gauge of greater sensitivity shall be used (subject to the approval of the Administrator), if any of the following conditions are true: (i) the settings of all AP readings at all traverse points in the stack is less than 1.3 (0.05 in.) Hg; (2) if traverses of 10 or more points, more than 95 percent of the individual AP readings are below 1.3 (0.05 in.) Hg, (3) for traverses of 12 or more points, more than one AP reading is below 1.5 (0.06 in.) Hg; (4) traverses of fewer than 10 points, more than 90 percent of the individual AP readings are below 1.3 (0.05 in.) Hg. The AP readings shall be taken at the approximate average of AP readings at the traverse points in the stack, and also at the same traverse point in the stack. The AP readings shall be taken at the approximate average of AP readings at the traverse points in the stack, and also at the same traverse point in the stack. The AP readings shall be taken at the approximate average of AP readings at the traverse points in the stack, and also at the same traverse point in the stack. The AP readings shall be taken at the approximate average of AP readings at the traverse points in the stack, and also at the same traverse point in the stack. The AP readings shall be taken at the approximate average of AP readings at the traverse points in the stack, and also at the same traverse point in the stack. The AP readings shall be taken at the approximate average of AP readings at the traverse points in the stack, and also at the same traverse point in the stack.
Figure 2.5. Velocity traverse data.
5.3 Determine the stack gas dry molecular weight. For combustion processes or processes that emit essentially only CO, CO₂, and N₂, use Method 3. For processes emitting essentially air, an analysis need not be conducted; use a dry molecular weight of 29.0. For other processes, other methods, subject to the approval of the Administrator, must be used.

3.7 Determine the moisture content from Reference Method 4 or an equivalent or from Method 5.

4.1 Type S Pitot Tube. Before its initial use, care fully calibrate the Type S pitot tube in top, side, and end views to verify that the face openings of the tube are aligned within the specifications illustrated in Figure 2-3 or 2-4. The pitot tube shall not be used if it fails to meet these alignment specifications.

After verifying the face opening alignment, measure and record the following dimensions of the pitot tube:

(a) the external tubing diameter (dimension D, Figure 2-25); and
(b) the base-to-opening plane distance (dimensions P₁ and P₂, Figure 2-25). If D₁ is between 0.48 and 0.95 cm (3/16 and 3/8 in.) and if P₁ and P₂ are equal to 1.00 and 1.00 ft, there are two possible options: (1) the pitot tube may be calibrated according to the procedure outlined in Sections 4.1.2 through 4.1.5 below, or (2) a baseline (isolated tube) coefficient value of 0.44 may be assigned to the pitot tube. Note, however, that if the pitot tube is part of an assembly, calibration may still be required, despite knowledge of the baseline coefficient value (see Section 4.1.1). If D₁, P₁, and P₂ are outside the specified limits, the pitot tube must be calibrated as outlined in 4.1.2 through 4.1.5 below.

4.1.1 Type S Pitot Tube Assembly. During sample and velocity traverses, the isolated Type S pitot tube is not always used; in many instances, the pitot tube is used in combination with other upstream sampling components (thermocouple, sampling probe, nozzle) as part of an "assembly." The presence of other sampling components can sometimes affect the baseline coefficient value of the Type S pitot tube if the components are flush mounted. (See Section 6, therefore an assigned (or otherwise known) baseline coefficient value may or may not be valid for a given assembly. The baseline and assembly coefficient values will be determined only when the relative placement of the components in the assembly is such that aerodynamic interference effects are minimized. Figures 2-6 through 2-8 illustrate interference-free component arrangements for Type S pitot tubes having external tubing diameters between 0.48 and 0.95 cm (3/16 and 3/8 in.) Type S pitot tube assemblies that fail to meet any of the specifications of Figures 2-6 through 2-8 shall be calibrated according to the procedure outlined in Sections 4.1.2 through 4.1.5 below, and prior to calibration, the values of the intercomponent separations (pitot-nozzle, pitot-thermocouple, pitot-probe) should be measured and recorded.

Note.—Do not use any Type S pitot tube assembly which is not illustrated and specified in this section or which is not aerodynamically interference free.

4.1.2 Calibration Setup. If the Type S pitot tube is to be calibrated, one leg of the tube shall be permanently marked A, and the other, B. Calibration shall be done in a flow system having the following essential design features:

(a) the external tubing diameter (dimension D, Figure 2-25); and
(b) the base-to-opening plane distance (dimensions P₁ and P₂, Figure 2-25). If D₁ is between 0.48 and 0.95 cm (3/16 and 3/8 in.).
4.1.2.1 The flowing gas stream must be confined to a duct of definite cross-sectional area, either circular or rectangular. For circular cross-sections, the minimum duct diameter shall be 30.5 cm (12 in.) for rectangular cross-sections, the width (shorter side) shall be at least 25.4 cm (10 in.).

4.1.2.2 The cross-sectional area of the calibration duct must be constant over a distance of 10 or more duct diameters. For a rectangular cross-section, the width (shorter side) must be constant over a distance of 10 or more duct diameters. For circular cross-sections, the diameter shall be 30.5 cm (12 in.) at the calibration point.

4.1.2.3 The flow system shall have the capability to generate at least four distinct, time-invariant test-section velocities above 0.48 and 0.96 cm (19.6 and 3.8 in.) per minute (0.50 and 1.00 ft/min). If a more precise correlation between test-section velocity and pitot-sample probe coefficient is required, the flow system shall have the capability to generate at least four distinct, time-invariant test-section velocities covering the velocity range from 180 to 305 m/min (600 to 1,000 ft/min) and at within 4 or 5 percent for the measurement of velocities between 180 and 305 m/min (600 and 1,000 ft/min), if a more precise correlation between test-section velocity and pitot-sample probe coefficient is required. The flow system shall have the capability to generate at least four distinct, time-invariant test-section velocities covering the velocity range from 180 to 305 m/min (600 to 1,000 ft/min), and calibration data shall be taken at regular velocity intervals over this range (see Citations 4 and 14 in Section 6 for details).

4.1.2.4 Two entry ports, one each for the standard and Type S pitot tubes, shall be cut in the test section; the standard pitot entry port shall be located slightly downstream of the Type S port, so that the standard and Type S standard port readings will be in the same cross-sectional plane during calibration. To facilitate alignment of the pitot tubes during calibration, it is advisable that the test section be constructed of plastic or some other non-reflective material.

4.1.2.5 Calibration Procedure. Note that this procedure is a general one and that its use will depend on the specifications. For the special conditions presented in Section 4.1.5, note also that the pitot tube(s) may be used only to obtain calibration data for the A and B sides of the Type S pitot tube, proceed as follows:

4.1.3.1 Level and zero the manometer. Turn on the fan and allow the flow to stabilize. Seal the Type S entry port.

4.1.3.2 Ensure that the manometer is level and zeroed.

4.1.4.1 Level and zero the manometer. Turn on the fan and allow the flow to stabilize. Seal the Type S entry port.

4.1.4.2 Seal the Type S entry port, check the manometer level and zero port, and align the Type S pitot tube so that its A side impacts on the same point as was the standard pitot tube and is pointed directly into the flow. Make sure that the entry port surrounding the tube is properly sealed.

Figure 2-7. Proper thermocouple placement to prevent interference; \( D_t \) between 0.48 and 0.95 cm (3/16 and 3/8 in.).

Figure 2-8. Minimum pitot-sample probe separation needed to prevent interference; \( D_t \) between 0.48 and 0.95 cm (3/16 and 3/8 in.).
4.1.4.3 Calculate the deviation of each of the three \( A \)-side values of \( C_p(A) \) from \( C_p \) (side A), and the deviation of each \( B \)-side value of \( C_p(B) \) from \( C_p \) (side B). Use the following equation:

\[
\text{Deviation} = \sqrt{\frac{\sum\left[C_p(s) - C_p(A \text{ or } B)^3\right]}{3}}
\]

**Equation 2-3**

4.1.4.4 Calculate \( \sigma \), the average deviation from the mean, for both the \( A \) and \( B \) sides of the pitot tube. Use the following equation:

\[
\sigma = \text{AVEDEV} 
\]

**Equation 2-4**

4.1.5 Use the Type S pitot tube only if the values of \( \sigma \) (side A) and \( \sigma \) (side B) are less than or equal to 0.01 and if the absolute value of the difference between \( C_p(A) \) and \( C_p(B) \) is 0.01 or less.

### Special Considerations

4.1.5.1 Selection of calibration point.

4.1.5.1.1 When an isolated Type S pitot tube is calibrated, select a calibration point at or near the center of the duct, and follow the procedures outlined in sections 4.1.3 and 4.1.4 above. The Type S pitot coefficients as obtained, i.e., \( C_p \) (side A) and \( C_p \) (side B), will be valid, so long as either: (1) the isolated pitot tube is used; or (2) the pitot tube is used with other components (nozzle, thermocouple, sample probe) in an arrangement that is free from aerodynamic interference effects (see Figures 2-6 through 2-9).

4.1.5.1.3 For Type S pitot tube-thermocouple combinations (without sample probe), select a calibration point at or near the center of the duct, and follow the procedures outlined in Sections 4.1.3 and 4.1.4 above. The coefficients so obtained will be valid so long as the pitot tube-thermocouple combination is used by itself or with other components in an interference-free arrangement (Figures 2-6 through 2-8).

4.1.5.2 For assemblies with sample probes, the calibration point should be located at or near the center of the duct; however, insertion of a probe sheath into a small duct may cause significant cross-sectional area blockage and yield incorrect coefficient values (Citation 9). Therefore, to minimize the blockage effect, the calibration point may be a few inches off-center if necessary. The actual blockage effect will be negligible when the theoretical blockage, as determined by the projected area model of the probe sheath, is 2 percent or less of the duct cross-sectional area for assemblies Without external sheaths (Figure 2-10a), and 8 percent or less for assemblies with external sheaths (Figure 2-10b).

4.1.5.3 For those probe assemblies in which the pitot tube nozzle interference is a factor, i.e., those in which the pitot-nozzle separation distance falls to meet the specification illustrated in Figure 2-9a, the value of \( C_{p(i)} \) depends upon the amount of free-space between the tube and nozzle, and therefore is a function of nozzle size. In these instances, separate calibrations shall be performed with each of the commonly used nozzle sizes in place. Note that the single-velocity calibration technique is acceptable for this purpose, even though the largest nozzle (size 20.46 mm) is kept outside of the range used for isokinetic sampling at velocities around 3 ft/min, which is the calibration velocity noted also that it is not necessary to draw no mixing sample during calibration see Citation 7 in Section 6.

4.1.5.3.1 For a probe assembly constructed such that its pitot tube is always used in the same orientation, only one side of the pitot tube need be calibrated (see Figure 2-10c), which will face the flow. The pitot tube must still meet the minimum specifications of Section 4.1.4.1, but need not have average deviation in value of 0.01 or less as shown in Section 4.1.4.1.
Figure 2-10. Projected area models for typical pitot tube assemblies.

Method S-01: Analysis for Carbon Dioxide, Oxygen, Excess Air, and Dry Molecular Weight

1. Principle and Applicability

1.1 Principle. A gas sample is extracted from a stack, by one of the following methods: (a) single-point, grab sampling; (b) single-point, integrated sampling; or (c) multi-point, integrated sampling. The gas sample is analyzed for percent carbon dioxide (CO2), percent oxygen (O2), and, if necessary, percent carbon monoxide (CO). If a dry molecular weight determination is to be made, either an orifice or a Fyrite sampler may be used for the analysis; for excess air or emission rate correction factor determination, an Fyrite sampler must be used.

1.2 Applicability. This method is applicable for determining CO2 and O2 concentrations, excess air, and dry molecular weight of a sample from a gas stream of a fossil-fuel combustion process. The method may also be applicable to other situations where it has been determined that compounds other than CO2, O2, CO, and H2 are not present in concentrations sufficient to affect the results.

Other methods, as well as modifications to the procedure described herein, are also applicable for some or all of the above determinations. Examples of specific methods and modifications include: (1) a multi-point sampling method using an on-line analyzer to analyze individual grab samples obtained at each point; (2) a method using CO2 or O2 and stoichiometric calculations to determine dry molecular weight and excess air; (3) assigning a value of 8000 for dry molecular weight, in lieu of actual measurements, for processes burning natural gas, coal, or oil. These methods and modifications may be used, but are subject to the approval of the Administrator.

2. Apparatus

As an alternative to the sampling apparatus and systems described herein, other sampling systems (e.g., liquid displacement) may be used provided such systems are capable of obtaining a representative sample and maintaining a constant sampling rate, and are otherwise capable of yielding acceptable results. Use of such systems is subject to the approval of the Administrator.

2.1 Probe. The probe should be made of stainless steel or moderate grades of Inconel 600 should be equipped with an inner-slip or outer-slip filter to remove particulate matter in the gas stream. In any case, the probe should be heated to a temperature sufficient to eliminate condensation. Any other material must be O2, CO2, CO, and H2 and resistant to temperature and sampling condition. Use of such material may be used for the probe. Examples of such material are aluminum, copper, quartz glass and Teflon.

2.1.1 Pump. A pump equipped, or equivalent, is used to transport the gas sample to the analyzer.

2.2 Integrated Sampling. (Figure 1.2)

2.2.1 Probe. A probe such as that described in Section 2.1.1 is desirable.

*Note: In using trade names or specific products does not constitute endorsement by the Environmental Protection Agency.*
Figure 3.1. Grab sampling train.

Figure 3.2. Integrated gas sampling train.
4.2.3 Sample at the same rate, or as specified by the Administrator. The sampling rate must be uniform and with, and for the same total length of time as the pollutant, and emission rate determination. Collect at least 0.1 lb/Lb-mole.

4.2.4 Obtain one integrated gas sample during each pollutant, emission rate determination. Within an hour after the sample is taken, analyze it for percent CO2, percent CO, and percent O2. Obtain a gas sample from a FYrite-type combustion gas analyzer, as described in Section 5. For the results of the analysis to be valid, the sample must pass this test, and be analyzed within 4 hours after the sample is taken.

4.2.5 The results of the analysis shall be obtained by a single, standard, uniform procedure and shall be analyzed for percent CO2, percent CO, and percent O2. The results shall be obtained within 4 hours after the sample is taken. The results shall be obtained by a single, standard, uniform procedure and shall be analyzed for percent CO2, percent CO, and percent O2. The results shall be obtained within 4 hours after the sample is taken.

4.2.6 To ensure complete absorption of (CO2, CO, or if applicable, CO2, CO, or CO2), make repeated passes through each absorbing solution until two consecutive readings are the same. Several passes (three or four) should be made within 4 hours after the sample is taken. If the results are not obtained within 4 hours after the sample is taken, the results shall be obtained within 4 hours after the sample is taken. If the results are not obtained within 4 hours after the sample is taken, the results shall be obtained within 4 hours after the sample is taken.

4.2.7 The results of the analysis shall be obtained by a single, standard, uniform procedure and shall be analyzed for percent CO2, percent CO, and percent O2. The results shall be obtained within 4 hours after the sample is taken. The results shall be obtained by a single, standard, uniform procedure and shall be analyzed for percent CO2, percent CO, and percent O2. The results shall be obtained within 4 hours after the sample is taken.

4.2.8 Repeat the analysis until the following criteria are met:

3.1.1 The sampling point in the duct shall either be at the control of the cross section or at a point no closer to the wall than 0.61 m (2 ft), unless otherwise specified by the Administrator.

3.1.4 These procedures for other purposes must be used. For example, the probe and sampling bag shall be replaced at each sampling point. The sampler shall remain stable for at least 0.6 minute. Evacuate the flexible bag. Connect the analyzer and place the bag in the stack, with the tip of the probe and place the bag in the stack, with the tip of the probe.

3.2.1 The sampling point in the duct shall either be at the control of the cross section or at a point no closer to the wall than 0.61 m (2 ft), unless otherwise specified by the Administrator.

3.2.1.1 The sampling point in the duct shall either be at the control of the cross section or at a point no closer to the wall than 0.61 m (2 ft), unless otherwise specified by the Administrator.

3.2.2 The sampling point in the duct shall either be at the control of the cross section or at a point no closer to the wall than 0.61 m (2 ft), unless otherwise specified by the Administrator.

3.2.2.1 Set up the equipment as shown in Figure 3-3, making sure all connections are tight and leak free. If an analyzer is used, it is recommended that the analyzer be a single, standard, uniform procedure and shall be analyzed for percent CO2, percent CO, and percent O2. The results of all connections are tight and leak free.

3.2.2.2 Set up the equipment as shown in Figure 3-3, making sure all connections are tight and leak free. If an analyzer is used, it is recommended that the analyzer be a single, standard, uniform procedure and shall be analyzed for percent CO2, percent CO, and percent O2. The results of all connections are tight and leak free.

3.2.2.3 Set up the equipment as shown in Figure 3-3, making sure all connections are tight and leak free. If an analyzer is used, it is recommended that the analyzer be a single, standard, uniform procedure and shall be analyzed for percent CO2, percent CO, and percent O2. The results of all connections are tight and leak free.
RULES AND REGULATIONS

Federal Register, Vol. 47, No. 160, Thursday, August 18, 1982

1. Calculations

6.1 Nomenclature

6.1.1 Percent of

6.1.2 Moisture (d.b. or a.b.)

6.1.3 Moisture (ring kiln)

6.1.4 Moisture (oven-dried)

6.1.5 Percent moisture (oven-dried)

6.1.6 Percent moisture (ring kiln)

6.1.7 Percent moisture (oven-dried)

6.1.8 Percent moisture (ring kiln)

6.1.9 Percent moisture (oven-dried)

6.1.10 Percent moisture (ring kiln)

6.1.11 Percent moisture (oven-dried)

6.1.12 Percent moisture (ring kiln)

6.1.13 Percent moisture (oven-dried)

6.1.14 Percent moisture (ring kiln)

6.1.15 Percent moisture (oven-dried)

6.1.16 Percent moisture (ring kiln)

6.1.17 Percent moisture (oven-dried)

6.1.18 Percent moisture (ring kiln)

6.1.19 Percent moisture (oven-dried)

6.1.20 Percent moisture (ring kiln)

6.1.21 Percent moisture (oven-dried)

6.1.22 Percent moisture (ring kiln)

6.1.23 Percent moisture (oven-dried)

6.1.24 Percent moisture (ring kiln)

6.1.25 Percent moisture (oven-dried)

6.1.26 Percent moisture (ring kiln)

6.1.27 Percent moisture (oven-dried)

6.1.28 Percent moisture (ring kiln)

6.1.29 Percent moisture (oven-dried)

6.1.30 Percent moisture (ring kiln)

6.1.31 Percent moisture (oven-dried)

6.1.32 Percent moisture (ring kiln)

6.1.33 Percent moisture (oven-dried)

6.1.34 Percent moisture (ring kiln)

6.1.35 Percent moisture (oven-dried)

6.1.36 Percent moisture (ring kiln)

6.1.37 Percent moisture (oven-dried)

6.1.38 Percent moisture (ring kiln)

6.1.39 Percent moisture (oven-dried)

6.1.40 Percent moisture (ring kiln)

6.1.41 Percent moisture (oven-dried)

6.1.42 Percent moisture (ring kiln)

6.1.43 Percent moisture (oven-dried)

6.1.44 Percent moisture (ring kiln)

6.1.45 Percent moisture (oven-dried)

6.1.46 Percent moisture (ring kiln)

6.1.47 Percent moisture (oven-dried)

6.1.48 Percent moisture (ring kiln)

6.1.49 Percent moisture (oven-dried)

6.1.50 Percent moisture (ring kiln)

6.1.51 Percent moisture (oven-dried)

6.1.52 Percent moisture (ring kiln)

6.1.53 Percent moisture (oven-dried)

6.1.54 Percent moisture (ring kiln)

6.1.55 Percent moisture (oven-dried)

6.1.56 Percent moisture (ring kiln)

6.1.57 Percent moisture (oven-dried)

6.1.58 Percent moisture (ring kiln)

6.1.59 Percent moisture (oven-dried)

6.1.60 Percent moisture (ring kiln)

6.1.61 Percent moisture (oven-dried)

6.1.62 Percent moisture (ring kiln)

6.1.63 Percent moisture (oven-dried)

6.1.64 Percent moisture (ring kiln)

6.1.65 Percent moisture (oven-dried)

6.1.66 Percent moisture (ring kiln)

6.1.67 Percent moisture (oven-dried)

6.1.68 Percent moisture (ring kiln)

6.1.69 Percent moisture (oven-dried)

6.1.70 Percent moisture (ring kiln)

6.1.71 Percent moisture (oven-dried)

6.1.72 Percent moisture (ring kiln)

6.1.73 Percent moisture (oven-dried)

6.1.74 Percent moisture (ring kiln)

6.1.75 Percent moisture (oven-dried)

6.1.76 Percent moisture (ring kiln)

6.1.77 Percent moisture (oven-dried)

6.1.78 Percent moisture (ring kiln)

6.1.79 Percent moisture (oven-dried)

6.1.80 Percent moisture (ring kiln)

6.1.81 Percent moisture (oven-dried)

6.1.82 Percent moisture (ring kiln)

6.1.83 Percent moisture (oven-dried)

6.1.84 Percent moisture (ring kiln)

6.1.85 Percent moisture (oven-dried)

6.1.86 Percent moisture (ring kiln)

6.1.87 Percent moisture (oven-dried)

6.1.88 Percent moisture (ring kiln)

6.1.89 Percent moisture (oven-dried)

6.1.90 Percent moisture (ring kiln)

6.1.91 Percent moisture (oven-dried)

6.1.92 Percent moisture (ring kiln)

6.1.93 Percent moisture (oven-dried)

6.1.94 Percent moisture (ring kiln)

6.1.95 Percent moisture (oven-dried)

6.1.96 Percent moisture (ring kiln)

6.1.97 Percent moisture (oven-dried)

6.1.98 Percent moisture (ring kiln)

6.1.99 Percent moisture (oven-dried)

6.1.100 Percent moisture (oven-dried)
2.1 Probe. The probe is constructed of stainless steel or glass tubing, sufficiently heated to prevent water condensation, and is equipped with a valve in-stack (e.g., a plug of glass wool inserted into the end of the probe) or housing out-stack (e.g., as described in Method 3), to confine particulate matter.

When stack conditions permit, other metals or plastic tubing may be used for the probe, subject to the approval of the Administrator.

2.1.2 Condenser. The condenser consists of four impingers connected in series with ground glass, leak-free fittings or similar leak-free non-contaminating fittings. The first, third, and fourth impingers shall be of the Veriberg-Smith design, enclosed by removing 1 1/2 in. (0.69 cm) from the bottom of the tank. The second impinger shall be of the Veriberg-Smith design with the standard top. Modifications, e.g., using flexible connections between the impingers, using materials other than glass, or using flexible vacuum lines to connect the inlet holder to the condenser may be used, subject to the approval of the Administrator.

The first two impingers shall contain known volumes of water, the third shall be dry, and the fourth shall contain a known weight of 5 to 10 g indicating type silica gel, or equivalent desiccant. If the silica gel has been previously used, dry at 175°C (347°F), and determine the weight.

2.1.3 Conditioning System. An ice bath contains and creates ice (or equivalent) to aid condensing moisture.

2.1.4 Metering System. This system includes a vacuum gauge, leak-free pump, thermometers capable of measuring temperature to within 0.1°C (0.1°F), dry gas meter capable of measuring volume to within 2 percent, and related equipment, as shown in Figure 4-1. Other metering systems capable of maintaining a constant sampling rate and determining sample gas volume may be used, subject to the approval of the Administrator.

2.1.5 Barometric, THERMOMETERS, and other barometric capable of measuring atmospheric pressure is subject 25 mm Hg. (1 in. Hg) may be used. In many cases, the 1 in. mercury reading may be obtained from a nearby national weather service station, in which case the station value (which is the absolute barometric pressure) shall be requested and an adjustment for elevation differences between the weather station and the sampling point will be applied at rate of at 1.033 mm Hg (0.04 in. Hg) per 200 ft altitude increase of 100 ft above sea level.

2.1.6 Air-Tight Vacuum Gauge. Air-tight vacuum gauge is shown in Figure 4-1.

2.2 Procedure. The following procedure is written for a condenser system such as the Veriberg system described in Section 2.1.2 incorporating volumetric analysis to measure the condensed moisture, and silica gel and gravimetric analysis to measure the moisture leaving the condenser.

2.2.1 Unless otherwise specified by the Administrator, a minimum of eight traverse points shall be used for circular stacks having diameters less than 0.61 m (24 in.) and a minimum of twelve traverse points shall be used in all other cases. The traverse points shall be located according to Method 1. The use of lower points is subject to the approval of the Administrator.

Select a suitable probe and probe height such that all traverse points can be sampled. Consider sampling from opposite sides of the stack, using standard sampling ports for large stacks, and using traverse points for smaller stacks, subject to the approval of the Administrator.

2.2.2 Select a sampling time such that a minimum total sample volume of 0.8 to 2.0 l will be collected, at a rate no greater than 0.002 m3/min (0.05 scfm). When both moisture content and pollutant emission rate are to be determined, the moisture determination shall be simultaneous with, and for the same total length of time as, the pollutant determination; full-time or intermittent sampling shall be used in accordance with the standards.

2.2.3 Select the sampling train as shown in Figure 4-1. The sampling train for any filter, except for the filter sampling system, shall be as follows: probe, probe heater and/or air conditioner, and the filter housing system for temperatures of about 135°F (57°C) be kept at or below 180°F (82°C) to prevent water condensation and subsequent evaporation of the sample from the filter media. The filter sampling system shall be used in accordance with the standards.
RULES AND REGULATIONS

2.2.3. Record the leak rate. If the leakage rate exceeds the allowable rate, the tester shall either reject the test results or shall correct the sample volume as in Section 6.3 of Method 3. Next, measure the volume of the moisture condensed to the nearest ml. Determine the increase in weight of the silica gel or weighed filter paper strips to the nearest 0.01 g. Record this information on the example data sheet, Figure 4.3 and calculate the moisture percentage, as described in Section 2.3 below.

2.3. Calculations. Carry out the following calculations, retaining at least one extra decimal figure beyond that of the acquired data. Round off figures after final calculations.

---

Figure 4.2. Field moisture determination reference method.
Figure 4.2. Analytical data-reference method.

### Volume of water vapor condensed corrected to standard conditions, \( \text{ml} \): where:

\[ V_{\text{w}, \text{mp}} = V_{\text{w}, \text{in}} \left( \frac{P_{\text{atm}}}{P_{\text{in}}} \right) \left( \frac{T_{\text{atm}}}{T_{\text{in}}} \right) \]

\[ K = \frac{V_{\text{w}, \text{mp}}}{V_{\text{w}, \text{in}}} \]

Equation 4.2

where:

- \( K \): Constant
- \( V_{\text{w}, \text{mp}} \): Volume of water vapor condensed corrected to standard conditions, \( \text{ml} \)
- \( V_{\text{w}, \text{in}} \): Volume of water vapor collected in silica gel, \( \text{ml} \)
- \( P_{\text{atm}} \): Absolute pressure, \( \text{mm} \) Hg
- \( P_{\text{in}} \): Initial pressure, \( \text{mm} \) Hg
- \( T_{\text{atm}} \): Absolute temperature, \( ^\circ \text{C} \)
- \( T_{\text{in}} \): Initial temperature, \( ^\circ \text{C} \)

### Volume of water vapor collected in silica gel, \( \text{ml} \):

\[ V_{\text{w}, \text{sil}} = \frac{(W_f - W_i)RT_{\text{atm}}}{P_{\text{atm}}M_w} \]

\[ K = \frac{V_{\text{w}, \text{sil}}}{V_{\text{w}, \text{in}}} \]

Equation 4.1

where:

- \( K \): Constant
- \( V_{\text{w}, \text{sil}} \): Volume of water vapor collected in silica gel, \( \text{ml} \)
- \( V_{\text{w}, \text{in}} \): Initial volume of water vapor, \( \text{ml} \)
- \( W_f \): Final weight of silica gel, \( \text{mg} \)
- \( W_i \): Initial weight of silica gel, \( \text{mg} \)
- \( P_{\text{atm}} \): Absolute pressure, \( \text{mm} \) Hg
- \( M_w \): Molecular weight of water, 18.0 \( \text{g/mol} \)
- \( R \): Gas constant, 0.08208 \( \text{L atm} / \text{mol K} \)
- \( T_{\text{atm}} \): Absolute temperature, \( ^\circ \text{C} \)

### 3. Apparatus Method

The approximation method described below is presented only as a suggested method (see Section 1.2). A dry gas meter, equipped with a filter (either in-stack or heated and stacked) to remove particulate matter, a plug of glass wool, inserted into the end of the probe, is a satisfactory filter.

### 3.1.1 Impingers

Two impingers, each with 30 mL capacity, are equivalent.

### 3.1.3 Jumps

Vacuum, to regulate the dry gas flow rate.

### 3.1.7 Volume of water vapor condensed correct to standard conditions, \( \text{ml} \):

\[ V_{\text{w}, \text{mp}} = V_{\text{w}, \text{in}} \left( \frac{P_{\text{atm}}}{P_{\text{in}}} \right) \left( \frac{T_{\text{atm}}}{T_{\text{in}}} \right) \]

Equation 4.2
HEATED PROBE
SILICA GEL TUBE
RATE METER
VALVE
MIDGET IMPINGERS
PUMP

Figure 4-4. Moisture sampling train - approximation method.

<table>
<thead>
<tr>
<th>LOCATION</th>
<th>COMMENTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>TEST</td>
<td></td>
</tr>
<tr>
<td>DATE</td>
<td></td>
</tr>
<tr>
<td>OPERATOR</td>
<td></td>
</tr>
<tr>
<td>BAROMETRIC PRESSURE</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>CLOCK TIME</th>
<th>GAS VOLUME THROUGH METER, ((V_m)), (m^3 (ft^3))</th>
<th>RATE METER SETTING (m^3/min. (ft^3/min.))</th>
<th>METER TEMPERATURE, (^\circ C (^\circ F))</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
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</tbody>
</table>

Figure 4-5. Field moisture determination - approximation method.
3.3.2 Connect the probe, insert it into the stack, and sample at a constant rate of 2 liters per minute (L/min). Continue sampling until the dry gas meter registers about 30 liters (L) or until visible liquid droplets are carried over from the first impinger to the second. Record temperature, pressure, and dry gas meter readings as required by Figure 4-5.

3.3.3 After collecting the sample, combine the contents of the two impingers and measure the volume to the nearest 0.5 ml. Calculate the determination of moisture content, for the purpose of determining moisture content, other data, which are only necessary for accurate moisture determinations, are not collected. The amount of moisture is designed to estimate the moisture in the stack gases; therefore, other data, which are only necessary for accurate moisture determinations, are not collected. The following equations adequately estimate the moisture content:

\[ V_{v} = \frac{V_{w} - V_{m}}{V_{v} + V_{m} + (0.025)} \]

Equation 4-7

4. Calibration

4.1 For the reference method, calibrate equipment as specified in the following sections of Method 5: Section 5.2 (metering system); Section 5.5 (temperature gauges); and Section 5.7 (barometer). The recommended test check of the metering system (Section 5.2 of Method 6) also applies to the reference method. For the approximation method, use the procedure outlined in Section 6.1.1 of Method 6 to calibrate the metering system, and the procedure of Method 5, Section 5.7 to calibrate the barometer.

5. Bibliography


2.1.1 Probe Nozzle. Stainless steel (316) or glass with sharp, tapered leading edge. The angle of taper shall be 30° and the taper shall be on the outside to preserve an inherent internal diameter. The nozzle shall be of the button-hook or elbow design, unless otherwise specified by the Administrator. If made of stainless steel, the nozzle shall be constructed from seamless tubing; other materials of construction may be used, subject to the approval of the Administrator.

A range of nozzle sizes suitable forokinetic sampling should be available, e.g., 0.32 to 2.27 cm (1/8 to 9 in.) or larger if higher volume sampling is required, to the approval of the Administrator. If made of glass, the nozzle shall be constructed according to the procedure outlined in Section 5.2.1.2.1.2.1.2 Probe Liner. Borosilicate or quartz glass tubing with a heating system capable of maintaining a gas temperature at the outlet of the probe, during sampling of 102.9° C (207±2°F), or such other temperature as specified by an applicable subpart of the standards or approved by the Administrator for a particular application. (The lower limit may be less than the limit specified.) Since the actual temperature at the outlet of the probe is not usually monitored during sampling, probes constructed according to APT-1067 or utilizing the calibration curves of APT-2067 shall be considered acceptable.

Either borosilicate or quartz glass probe liners may be used for stack temperatures up to 648° C (1210°F) and 482° C (900°F), respectively. For temperatures between 482° C (900°F) and 648° C (1210°F), both types of liners may be used at higher temperatures than specified for short periods of time, subject to the approval of the Administrator. The heating temperature for borosilicate glass shall be 1148° C (2100°F), and for quartz it is 1800° C (3272°F). When practical, every effort should be made to use boreless or quartz glass probe liners. Alternatively, metal liners (e.g., 316 stainless steel, Inconel 600, or other corrosion-resistant metal) made of seamless tubing may be used, subject to the approval of the Administrator.

2.1.3 Filter Holder. Borosilicate glass, with a glass frit filter support and a silicone rubber seal or equivalent, may be used, subject to the approval of the Administrator. The holder design shall provide a positive seal against leakage from the outside or around the filter. The holder shall be attached immediately at the outlet of the probe (or system, if used).

2.1.4 Filter Housing. Any heating system capable of maintaining a temperature around the filter holder during sampling or 102.9° C (207±2°F), or such other temperature as specified by an applicable subpart of the standards or approved by the Administrator for a particular application. Alternatively, the temperature gauge or thermometer may be regulated at temperatures lower than that specified. A temperature gauge capable of measuring temperature to within 1° C (2°F) shall be installed so that the temperature around the filter holder can be regulated and monitored during sampling. Heating systems other than the ones shown in APT-2067 may be used.

2.1.5 Condenser. The following system shall be used to determine the stack gas moisture content. Four impingers connected in series with no more than one condenser in the system shall be used. Alternatively, the condenser may be omitted.

- Mercury manometer, thermometer, or other instrument capable of measuring temperature within 5° C (9°F).
- Vacuum pump, leak-free pump, or other equivalent capable of measuring velocity within ±(3%) of the metered velocity.
- A filter holder with a filter of known performance, filter holder, and vacuum gauge.
- A sample collection system capable of measuring moisture within ±(3%) of the metered velocity.

2.1.6 Filter Housing System. Any heating system capable of maintaining a temperature around the filter holder during sampling or 102.9° C (207±2°F), or such other temperature as specified by an applicable subpart of the standards or approved by the Administrator for a particular application. Alternatively, the temperature gauge or thermometer may be regulated at temperatures lower than that specified. A temperature gauge capable of measuring temperature to within 1° C (2°F) shall be installed so that the temperature around the filter holder can be regulated and monitored during sampling. Heating systems other than the ones shown in APT-2067 may be used.

2.1.7 Condenser. The following system shall be used to determine the stack gas moisture content. Four impingers connected in series with no more than one condenser in the system shall be used. Alternatively, the condenser may be omitted.

- Vacuum pump, leak-free pump, or other equivalent capable of measuring velocity within ±(3%) of the metered velocity.
- A filter holder with a filter of known performance, filter holder, and vacuum gauge.
- A sample collection system capable of measuring moisture within ±(3%) of the metered velocity.

2.2 Impingement Train. In Method 2, one manometer shall be used or velocity ororifices may be used, subject to the approval of the Administrator. Acceptable manometers are those that are specifically recognized by the applicable subpart or approved by the Administrator. Additionally, if means other than silica gel are used to remove moisture from the sample gas, the procedures and devices used shall be approved by the Administrator. When the system is operated in the manner specified by the method, the probe shall be attached to the probe manifold, in accordance with the Table 2 setup.

2.2.1 Impingement Train Assembly. The impingement train assembly shall have a known coefficient, determined as outlined in Section 4 of Method 2.
3.3 Analyze. Two reagents are required for the analysis:

3.3.1 Acetone. Same as 3.2.

3.3.2 Dimethyldiethylamine sulinate, indicator type. Alternatively, other types of indicators may be used, subject to the approval of the Administrator.

4. Procedure

4.1 Sampling. The complexity of this method is such that, in order to obtain reliable results, tests should be carried out preferably in the laboratory. Precautions to minimize the influence of all conditions, such as the type of sampler and its position, the type of filter, the temperature, and the sampling rate, are particularly important.

4.1.1 Temperature. All the components shall be maintained and calibrated according to the procedure described in APTD-8373, unless otherwise specified herein.

Note: Several types of silicone gaskets are available on all ground glass joints, including only the outer portion. APTD-655 may be used to avoid possibility of contamination by the silicone gasket. Subject to the approval of the Administrator, a Teflon gasket may be used between the probe and filter holder when the total particulate rate is expected to exceed 100 mg/h or when water droplets are present in the air stream.

4.1.2 Location. A proper location is recommended, but not required, to conduct the test setup, the sampling train, and the subsequent analysis.

4.1.3 Temperature. A proper location is recommended, but not required, to conduct the test setup, the sampling train, and the subsequent analysis.

4.1.4 Note. A proper location may be used, provided that it is not exposed during the test.

If an adjustable system is used, the test setup, the sampling train, and the subsequent analysis shall be conducted in a manner that is not exposed during the test.

4.1.5 Set-up. The sampling train as Figure 5,4.1.1, is used, and the sampler shall be connected to the probe, the sampling line, and the filter holder. The filter holder shall be connected to the test setup, and the sampling train shall be connected to the filter holder.

4.1.6 Note. A proper location may be used, provided that it is not exposed during the test.

If an adjustable system is used, the test setup, the sampling train, and the subsequent analysis shall be conducted in a manner that is not exposed during the test.
**RULES AND REGULATIONS**

**AMBIENT TEMPERATURE**

<table>
<thead>
<tr>
<th>BAROMETRIC PRESSURE</th>
<th>ASSUMED MOISTURE, %</th>
</tr>
</thead>
<tbody>
<tr>
<td>PROBE LENGTH, m (m)</td>
<td>PROBE HEATER SETTING</td>
</tr>
<tr>
<td>NOZZLE IDENTIFICATION NO.</td>
<td>LEAK RATE, m/min (cc/min)</td>
</tr>
<tr>
<td>AVERAGE CALIBRATED NOZZLE DIAMETER, cm (in.)</td>
<td>PROBE LINER MATERIAL</td>
</tr>
<tr>
<td>VOLUME</td>
<td>STATIC PRESSURE, mm Hg (in. Hg)</td>
</tr>
<tr>
<td>GAS SAMPLE TEMPERATURE AT DRY GAS METER</td>
<td>FILTER HOLDING TEMPERATURE, °C (°F)</td>
</tr>
<tr>
<td>GAS SAMPLE VOLUME, m³ (ft³)</td>
<td>TEMPERATURE OF GAS LEAVING COOLER OR LAST IMPACT, °C (°F)</td>
</tr>
</tbody>
</table>

**TOTAL**

<table>
<thead>
<tr>
<th>AVERAGE</th>
</tr>
</thead>
</table>

**Figure 5-2. Particulate field data.**

When sampling for particulate matter, it is important to ensure that the sampling equipment is properly calibrated and that the sampler is set up correctly. The sampling equipment should be checked for leaks and the filter holder should be clean and dry. The ambient temperature and humidity should be recorded to ensure accurate results.

**Schematic of Stack Cross Section**

- Clean the probes prior to the test run to minimize the chance of sampling deposits. Material to begin the test run, the probe line and probe holder systems are at the desired temperature, and the probes are properly aligned. The probes are then lowered into the stack and the probes are properly aligned.

- Net samples are available, which are not adjusted for the loss due to sample collection.

**General Notes**

- When sampling for particulate matter, it is important to ensure that the sampling equipment is properly calibrated and that the sampler is set up correctly. The sampling equipment should be checked for leaks and the filter holder should be clean and dry.

- The ambient temperature and humidity should be recorded to ensure accurate results.
filing, probe liner, and front half of the filter holder by brushing with acetone. Place the sample in a clean container and shall be used in transporting the sample; it is recommended that two people be used to clean the probe to minimize sample losses. Between sampling runs, keep brushes clean and protected from contamination.

After ensuring that all joints have been wiped clean of silicone grease, clean the inside of the front half of the filter holder by brushing with a flexible brush and residue with acetone. Secure each surface with a rubber band or film in the liquid catch. Measure the volume or weight, unless analysis of the incoming catch is required (see Note, Section 2.1.7). The height of the fluid level to determine whether or not the analysis occurred during transport. Label the container to clearly identify its contents.

Container No. 3. Note the color of the indicating silica gel to determine if it has been completely spent and make a notation of its condition. Transfer the silica gel from the fourth impinger to its original container and seal. A funnel may be made to pour the silica gel without spilling. A rubber band may be used to hold the lid on the sample container so that acetone will not leak out when it is subjected to laboratory. Mark the height of the fluid level to determine whether or not the analysis occurred during transport. Label the container to clearly identify its contents.

4.3 Analysis. Record the data required on a sheet such as the one shown in Figure 5-3. Include each container as follows:

**CONTAINER NUMBER**

<table>
<thead>
<tr>
<th>WEIGHT OF PARTICULATE COLLECTED, mg</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
</tr>
<tr>
<td>2</td>
</tr>
<tr>
<td>TOTAL</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>CONTAINER NUMBER</th>
<th>WEIGHT OF PARTICULATE COLLECTED, mg</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>2</td>
</tr>
<tr>
<td>TOTAL</td>
<td></td>
</tr>
</tbody>
</table>

*Total particulate matter

Add the liquid which is in the first three impingers to within +1 ml by using a graduated cylinder or by weighing it to within +0.5 mg by using a balance if one is available. Record the volume or weight of liquid present. This information is required to calculate the moisture content of the effluent gas.

Discard the liquid after measuring and recording the volume or weight, unless analysis of the impinger catch is required (see Note, Section 2.1.7).

4.3.1 Analysis. Record the data required on a sheet such as the one shown in Figure 5-3. Include each container as follows:

**CONTAINER NUMBER**

<table>
<thead>
<tr>
<th>WEIGHT OF PARTICULATE COLLECTED, mg</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
</tr>
<tr>
<td>2</td>
</tr>
<tr>
<td>TOTAL</td>
</tr>
</tbody>
</table>

*Total particulate matter

Add the liquid which is in the first three impingers to within +1 ml by using a graduated cylinder or by weighing it to within +0.5 mg by using a balance if one is available. Record the volume or weight of liquid present. This information is required to calculate the moisture content of the effluent gas.

Discard the liquid after measuring and recording the volume or weight, unless analysis of the impinger catch is required (see Note, Section 2.1.7).

If a different type of condenser is used, measure the amount of moisture condensed either volumetrically or gravimetrically.
Alternatively, the sample may be oven-dried at 105°C (221°F) for 2 to 3 hours, cooled in the desiccator, and weighed under constant weight, unless otherwise specified by the Administrator. The tester may also opt to oven-dry the sample (see Table 200°F for 2 hours, weigh the sample, and use this weight as a final weight.

For all tests, the sample must be dried to constant weight (or, if practical, the solvent will be evaporated at temperatures higher than that of the solvent. The use of higher temperatures will result in the removal of water or oil from the sample, and in the occurrence of decomposition or other changes in the sample. The precision of the test results will be improved by using the same method of drying as that specified by the Administrator.

Table 3. Weight of the sample for volumetric or gravimetric determination.

<table>
<thead>
<tr>
<th>Solvent</th>
<th>Weight of Sample (mg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acetone</td>
<td>2.5</td>
</tr>
<tr>
<td>Methanol</td>
<td>2.5</td>
</tr>
<tr>
<td>Ethanol</td>
<td>2.5</td>
</tr>
<tr>
<td>Chloroform</td>
<td>2.5</td>
</tr>
</tbody>
</table>

Weight of sample containers: The containers used for weighing the sample must be accurately weighed and not allowed to remain in the desiccator longer than necessary.
where:

\[ m = \frac{0.00183}{2} \text{mg/m}^3 \text{ for metric units} \]
\[ = \frac{0.00450}{2} \text{mcg/gal} \text{ for English units} \]

**Notes.**—Equation 6-1 can be used as written unless the leakage is observed during any of the mandatory leak checks, and it is not to be used if the leak check is conducted prior to component changes, or if \( L_2 \) exceeds \( L_0 \). Equation 6-1 must be modified as follows:

(a) Case I. No component changes during the sampling run. In this case, replace \( V_m \) in Equation 6-1 with the expression:

\[ V_m = (L_0 - L_2) / \theta_1 \]

(b) Case II. One or more component changes during the sampling run. In this case, replace \( V_m \) in Equation 6-1 by the expression:

\[ V_m = (L_0 - L_2) / \theta_1 \]

\[ - \sum_{i} \left( L_i - L_0 \right) / \theta_i - \sum_{i} \left( L_i - L_0 \right) / \theta_i \]

and substitute only for those leakage rates \((L_i \text{ or } L_0) \) which exceed \( L_0 \).

6.4 Volume of water vapor.

\[ V_w = V_{w,1} \left( \frac{P_{w,1}}{P_w} \right)^{\frac{R T_w}{R T_{w,1}}} = K_1 V_{w,1} \]

where:

\[ K_1 = 0.00183 \text{ mm Hg} / \text{mg} \text{ for metric units} \]
\[ = 0.00450 \text{ in. Hg} / \text{mg} \text{ for English units} \]

6.5 Moisture Content.

\[ B_m = \frac{V_{w,1}}{V_{w,1} + V_{m,1}} \]

Equation 6-2

**Notes.**—In case \( 1 \text{) in Equation 6-2 \} \), use the expression:

\[ V_{w,1} = 100 T_i \left( K_1 V_{w,1} + (V_m / T_w) \left( P_{w,1} + \Delta H / 13.6 \right) \right) \]

Equation 6-3

where:

\[ K_1 = 1.50 \text{ for metric units} \]
\[ = 0.0130 \text{ for English units} \]

6.16 Acceptable Results. If 90 percent < \( f \) < 110 percent, the results are acceptable. If the results are less than 90 percent, the Administrator may opt to accept the results. Use Citation 4 to make judgment. Otherwise, reject the results and repeat the test.

7. Bibliography


METHOD 6—DETERMINATION OF PARTICLE POLLUTANT EMISSIONS FROM STATIONARY SOURCES

1. Principle and Applicability

1.1 Principle. A gas sample is extracted from the sampling point in the stack. The sulfuric acid mist (including sulfuric acid and the sulfur dioxide are separated. The sulfur dioxide content is measured by the barium-thorin titration method. The sulfur dioxide concentration is measured by the sulfuric acid mist and calcium chloride test. The concentration limit in a 20-liter sample is about 93.300 mg/l.

1.2 Applicability. This method is applicable for the determination of sulfur dioxide emissions from stationary sources. The minimum detectable limit of the method has been determined to be 0.5 milligrams per cubic meter (mg/m²). Although no upper limit has been established, tests have shown the concentrations as high as 80,000 micromg/m² at 90%. Calcium chloride test can be used in two or more filter assemblies or two or more sampling points.

1.3 Applicability. This method is applicable for the determination of sulfur dioxide emissions from stationary sources. The minimum detectable limit of the method has been determined to be 0.5 milligrams per cubic meter (mg/m²). Although no upper limit has been established, tests have shown the concentrations as high as 80,000 micromg/m² at 90%. Calcium chloride test can be used in two or more filter assemblies or two or more sampling points.

1.3.1.7 Acceptable Results. If 90 percent < \( f \) < 110 percent, the results are acceptable. If the results are less than 90 percent, the Administrator may opt to accept the results. Use Citation 4 to make judgment. Otherwise, reject the results and repeat the test.

7. Bibliography

2.1 Sampling. The sampling train is shown in Figure 6-1, and companion parts are discussed below. The train includes, in addition to the sampling equipment described in Method 6, a filter for condensation and a heated filter system in the train. The sampling train must be modified to include a heated filter between the probe and impinger, and the operation of the sampling train and sample analysis must be at the same flow rate and solution volume defined in Method 6.

The test also has the option of determining SO₂ simultaneously with particulate matter and moisture determinations by (1) replacing the water in a Method 5 impinger with particulate matter and the flow rate and volume defined in Method 5. This requires, in addition to the Method 5 impinger, a small tank to pull gas through the train. Install a small tank to pull gas through the train. Install a small tank of distilled water and a meter to measure the pressure of the train. The meter should be connected in series with leak-free glass connectors. Bubbling and midget impingers must be connected in series with a glass frit and borosilicate or equivalent capable of measuring pressure to within 5°C (9°F).

2.1.1 Temperature. (A) Dial thermometer, or equivalent, capable of measuring temperature to within 2°C (3°F).

2.1.10 Volume Meter. Dry gap, meter, sufficiently accurate to measure sample volumes within 2 percent, calibrated at the selected flow rate and conditions actually encountered during sampling. The volume meter must be connected in series with leak-free glass connectors. Silica gel is required, in addition to the volume meter, a midget impinger may be used in place of the midget impinger. Other collection effluent and flow rates may be used, subject to the approval of the Administrator, approximately 5-liters per minute, with a device system to prevent water condensation and a filter (either in-stack or heated or heated) to remove particulate matter, including sulfuric acid mist. A glass of glass wool is a satisfactory filter.

2.3.2 Volumetric Flasks. 100-nil size (one per sample).

2.3.5 Dropping Bottle. 125-nil size, to add indicator.

2.3.7 Spectrophotometer. To measure absorbance at 487 nanometers.

2.3.10 Volume Meter. Dry gap, meter, sufficiently accurate to measure sample volumes within 2 percent, calibrated at the selected flow rate and conditions actually encountered during sampling. The meter should be capable of measuring pressure to within 5°C (9°F) of the ambient temperature.

2.3.11 Barometer. Mercury, aneroid, or other barometer capable of measuring atmospheric pressure to within 2 mm Hg (0.1 in. Hg). In many cases, the barometric reading may be obtained from a nearby national weather service station, in which case the station value (which is the absolute barometric pressure) shall be requested. If the barometric pressure is not available, use the barometric pressure measured at the test site.

2.3.12 Water. Deionised, distilled as in 3.1.1.

2.3.14 Potassium thiosulfate Solution, 10 Percent. Dissolve 2.0 grams K₂S₂O₃ in 1 liter of distilled water and dilute to 1 liter.

2.3.15 Indicator. Phenol red 0.1 percent. Prepare fresh daily.

2.3.16 Hydrogen peroxide 1:9 (v/v) with deionised, distilled water (90 ml is needed per sample). Prepare fresh daily.

2.3.17 Sodium hydroxide solution, 0.1 N. Dissolve 4.0 grams NaOH in 0.1 N NaOH solution and dilute to 1 liter. Prepare fresh daily.

2.3.18 Water. Deionised, distilled, as in 3.1.1.

2.3.19 Hydrogen peroxide 1:9 (v/v) with deionised, distilled water (90 ml is needed per sample). Prepare fresh daily.

2.3.20 Sodium hydroxide solution, 0.1 N. Dissolve 4.0 grams NaOH in 0.1 N NaOH solution and dilute to 1 liter. Prepare fresh daily.

2.3.21 Water. Deionised, distilled, as in 3.1.1.

2.3.22 Hydrogen peroxide 1:9 (v/v) with deionised, distilled water (90 ml is needed per sample). Prepare fresh daily.

2.3.23 Sodium hydroxide solution, 0.1 N. Dissolve 4.0 grams NaOH in 0.1 N NaOH solution and dilute to 1 liter. Prepare fresh daily.

2.3.24 Water. Deionised, distilled, as in 3.1.1.

2.3.25 Hydrogen peroxide 1:9 (v/v) with deionised, distilled water (90 ml is needed per sample). Prepare fresh daily.

2.3.26 Sodium hydroxide solution, 0.1 N. Dissolve 4.0 grams NaOH in 0.1 N NaOH solution and dilute to 1 liter. Prepare fresh daily.

2.3.27 Water. Deionised, distilled, as in 3.1.1.

2.3.28 Hydrogen peroxide 1:9 (v/v) with deionised, distilled water (90 ml is needed per sample). Prepare fresh daily.

2.3.29 Sodium hydroxide solution, 0.1 N. Dissolve 4.0 grams NaOH in 0.1 N NaOH solution and dilute to 1 liter. Prepare fresh daily.

2.3.30 Water. Deionised, distilled, as in 3.1.1.

2.3.31 Hydrogen peroxide 1:9 (v/v) with deionised, distilled water (90 ml is needed per sample). Prepare fresh daily.

2.3.32 Sodium hydroxide solution, 0.1 N. Dissolve 4.0 grams NaOH in 0.1 N NaOH solution and dilute to 1 liter. Prepare fresh daily.

2.3.33 Water. Deionised, distilled, as in 3.1.1.

2.3.34 Hydrogen peroxide 1:9 (v/v) with deionised, distilled water (90 ml is needed per sample). Prepare fresh daily.

2.3.35 Sodium hydroxide solution, 0.1 N. Dissolve 4.0 grams NaOH in 0.1 N NaOH solution and dilute to 1 liter. Prepare fresh daily.
3.3.5 Sulfate Acid Standard. 0.010 N. Purchase or standardise to a.0002 N against 0.010 N NaOH which has been standardized against potassium acid phthalate (primary standard grade).

4. Procedure

4.1 Sampling

4.1.1 Preparation of collection train. Measure 15 ml of 80 percent isopropanol into the midget bubbler and 15 ml of 3 parts hydrogen peroxide and 1 part of the first two midget impingers. Leave the last midget impinger free. Add the isopropanol to the bubbler, and the isopropanol to the midget impingers. The isopropanol to the bubbler, and the isopropanol to the midget impingers shall be at least 30 ml. Carefully release the vacuum gauge before releasing the flow meter end to prevent water condensation. Place crushed ice and water around the impingers.

4.1.2 Leak-check procedure. A leak check prior to the sampling run is mandatory; however, a leak check after the sampling run is optional. The leak-check procedure is as follows:

With the probe disconnected, place a vacuum gauge at the outlet of the bubbler, and pull a vacuum of 250 mm (10 in.) Hg, plug or pinch off the outlet of the flow meter, and then push the pump. The vacuum shall remain stable for at least 30 seconds. Carefully release the vacuum gauge before releasing the flow meter end to prevent water condensation. Place crushed ice and water around the impingers.

4.1.3 Sample collection. Record the initial dry gas meter reading and barometric pressure. To begin sampling, position the tip of the probe at the sampling point, connect the probe to the bubbler, and start the pump. Adjust the sample flow to a constant rate of approximately 1 liter/min as indicated by the rotameter. Maintain this constant flow rate during the entire sampling run. Take readings (dry gas meter, temperature at dry gas meter and at impinger outlet and rate meter) at least every 3 minutes. Add more ice during the run to keep the temperature of the gases leaving the last impinger at 20°C (68°F) or less. At the conclusion of each run, turn off the pump; remove probe from the sample system; and clean the system. Conduct a leak check as in Section 4.1.2. (This leak check is mandatory.) If a leak is found, void the test run. Drain the ice bath, and purging the remaining part of the train by drawing clean ambient air through the system for 15 minutes at the sampling rate.

Clean ambient air can be provided by passing air through a charcoal filter or through an extra midget impinger with 15 ml of 3 percent H20. The test can be resubmitted when the calibration factor deviates by more than 5 percent from the initial calibration factor. If a leak is found, void the test run. Drain the ice bath, and purging the remaining part of the train by drawing clean ambient air through the system for 15 minutes at the sampling rate.

4.2 Calibration

4.2.1 Barium Perchlorate Solution. Standards: Barium perchlorate solution against 25 ml of standard sulfuric acid to which 100 ml of 100 percent isopropanol has been added.

4.2.2 Calculations

4.2.2.1 Nomenclature

\[ C = \text{Concentration of sulfate ion, mg/L} \]
\[ N = \text{Normality of barium perchlorate titrant, mEq/mL} \]
\[ P_{\text{ref}} = \text{Pressure at the exit orifice of the dry gas meter, mm Hg (in. Hg)} \]
\[ P_{\text{atm}} = \text{Pressure at the entrance orifice of the dry gas meter, mm Hg (in. Hg)} \]
\[ T = \text{Average dry gas meter absolute temperature, °K (°R)} \]
\[ V_{\text{std}} = \text{Standard absolute temperature, °K (°R)} \]
\[ V_{\text{cal}} = \text{Volume of sample aliquot titrated, ml} \]
\[ V_{\text{wet}} = \text{Volume of wet sample gas volume (corrected to standard conditions), ml} \]
\[ V_{\text{dry}} = \text{Volume of dry sample gas volume, ml} \]
\[ V_{\text{wet}} = V_{\text{cal}} - V_{\text{wet}} \]

4.2.2.2 Calculation

\[ C_{\text{water}} = \frac{V_{\text{wet}}}{V_{\text{cal}}} \]

Equation 6-2

where:

- \( V_{\text{wet}} \) is the volume of sample gas volume (corrected to standard conditions).
- \( V_{\text{cal}} \) is the volume of sample gas volume.
- \( C_{\text{water}} \) is the concentration of water.

4.2.2.3 Determination

4.2.2.3.1 Dry Gas Meter Calibration

- Transfer the contents of the storage container to a 100-ml volumetric flask and dilute to exactly 100 ml with distilled water.
- Save 20 ml of this solution in a 250-ml Schlenkline flask, add 80 ml of 10 percent isopropanol and two to four drops of rosin ainit to the storage container. Maintain this container at 20°C (68°F) or less.
- Chill and identify the sample container.

4.2.2.3.2 Wet Gas Meter Calibration

- Follow the procedure for the dry gas meter calibration.

4.3 Sample Analysis

4.3.1 Sample Collection

- Note level of liquid in container, record the initial dry gas meter reading and barometric pressure. To begin sampling, position the tip of the probe at the sampling point, connect the probe to the bubbler, and start the pump. Adjust the sample flow to a constant rate of approximately 1 liter/min as indicated by the rotameter. Maintain this constant rate (1 percent) during the run to keep the temperature of the gases leaving the last impinger at 20°C (68°F) or less. At the conclusion of each run, turn off the pump; remove probe from the sample system; and clean the system. Conduct a leak check as in Section 4.1.2. (This leak check is mandatory.) If a leak is found, void the test run. Drain the ice bath, and purging the remaining part of the train by drawing clean ambient air through the system for 15 minutes at the sampling rate.

Clean ambient air can be provided by passing air through a charcoal filter or through an extra midget impinger with 15 ml of 3 percent H20. The test can be resubmitted when the calibration factor deviates by more than 5 percent from the initial calibration factor. If a leak is found, void the test run. Drain the ice bath, and purging the remaining part of the train by drawing clean ambient air through the system for 15 minutes at the sampling rate.

4.3.2 Calculations

4.3.2.1 Nomenclature

\[ C_{\text{wet}} = \frac{V_{\text{cal}}}{V_{\text{std}}} \]

Equation 6-1

where:

- \( V_{\text{cal}} \) is the volume of sample gas volume (corrected to standard conditions).
- \( V_{\text{std}} \) is the volume of sample gas volume (corrected to standard conditions).
5.1.5 Collection Flask. Two-liter borosilicate, round-bottomed, short neck and 24/40 standard taper joint. Required for sample recovery: the flask valve stopcock should be of the brass variety connected to a burette type buret, with a volume of 50 ml (3 in.) absolute pressure, with a 10 cm (4 in.) capillary opening, protected against implosion or breakage.

5.1.6 Vacuum Line. Tubing capable of withstanding a pressure of 20 mm Hg (0.8 in.) and connected to the vacuum pump. Required for sample recovery: the flask valve stopcock should be of the brass variety connected to a burette type buret, with a volume of 50 ml (3 in.) absolute pressure, with a 10 cm (4 in.) capillary opening, protected against implosion or breakage.

5.1.7 Pump. Capable of evacuating the collection flask to a pressure equal to or less than 75 mm Hg (3 in.) absolute. Required for sample recovery: the flask valve stopcock should be of the brass variety connected to a burette type buret, with a volume of 50 ml (3 in.) absolute pressure, with a 10 cm (4 in.) capillary opening, protected against implosion or breakage.

5.1.8 Glass Stirring Rod. Required for sample recovery: the flask valve stopcock should be of the brass variety connected to a burette type buret, with a volume of 50 ml (3 in.) absolute pressure, with a 10 cm (4 in.) capillary opening, protected against implosion or breakage.

5.2.8 Pipette 25 ml of boiling solution into a 1000-ml volumetric flask.

5.2.9 Graduated Pipette. 10 ml with 0.1-ml divisions. Required for sample recovery: the flask valve stopcock should be of the brass variety connected to a burette type buret, with a volume of 50 ml (3 in.) absolute pressure, with a 10 cm (4 in.) capillary opening, protected against implosion or breakage.

5.2.10 Test Paper for Indicating pH. To cover the pH range of 7 to 14.

5.3.7 Water. Deionized, distilled at a rate of 2.5 mm Hg (0.1 in.) absolute pressure, with a 10 cm (4 in.) capillary opening, protected against implosion or breakage.

5.4 Procedures

5.4.1 Sampling. To prepare the absorbing solution into a sample flask, retaining a sufficient quantity for use in preparing the calibration standards. Insert the flask valve stopcock into the flask valve. Fill the flask valve and the pump valve to their "evacuate" positions. Evacuate the flask to 75 mm Hg (3 in.) absolute pressure, with a 10 cm (4 in.) capillary opening, protected against implosion or breakage. Then evacuate to a pressure approaching the vapor pressure of water at the sampling temperature is desirable. Any variation...
5. Chilbrefton dried residue and titration thoroughly. Pipette 12& dilute rinse the container twice. Bring the shipping container to a steady prior to analysis, the Administrator, to catch any noticeable amount of liquid. Rinse the container twice, allowing the solution to cool and then touching the rod. When the pH is between 9 and 12 (about 25 to 35 drops each). Add 0.0, 1.0, 2.0, 5.0, and 10 ml of the KNO₃ working standard solution (1 ml = 0.05, μg NO₂ for a series of five porcelain evaporating dishes. To each add 10 ml of distilled, distilled water, and sodium hydroxide (IN), dropwise, until the pH is between 9 and 12 (about 25 to 35 drops each). Begin with the evaporation step, follow the analytical procedure, but has been transferred to the 100 ml volumetric flask and diluted to the mark. Measure the absorption of each solution, the optimum wavelength, as determined in Section 5.2.1. This calibration procedure must be repeated on each day that samples are analyzed. Calculate the spectrophotometer calibration factor as follows:

\[
K_0 = 100 \frac{A - A_1}{A_2 - A_1} + 3 A_3 + 4 A_4 + A_0
\]

**Equation 7-1**

where:

- \( A \) is the absorbance of the sample.
- \( A_1 \) is the absorbance of the 1000 ppm NO₂ standard solution.
- \( A_2 \) is the absorbance of the 500 ppm NO₂ standard solution.
- \( A_3 \) is the absorbance of the 200 ppm NO₂ standard solution.
- \( A_4 \) is the absorbance of the 100 ppm NO₂ standard solution.
- \( A_0 \) is the absorbance of the 25 ml blank solution.

5.2.1 Spectrophotometer Calibration.

When fixed and variable wavelength spectrophotometers are used, calibration against the standard, as described in Section 5.2.2, is required. If a peak does not occur, the spectrophotometer must be checked again, and should be recalculated. When a peak is obtained within the 400 to 450 mm range, the wavelength used is that at which the peak occurs. As the band occurs during the optimum wavelength for the measurement of absorbance for both the standards and the samples.

5.2.2 Determination of Spectrophotometer Calibration.

1. Place the spectrophotometer on a solid, vibration-free, and stainless steel pan and turn the instrument off. Place the solution in the sampling flask and shake well. Establish a new background (for English units), corrected for standard conditions.

\[
V_s = \frac{T_f}{V_f} (V_f - V_b) = \frac{P_f - P_b}{T_f - T_b} = K_1 (V_f - 25) \frac{P_f - P_b}{T_f - T_b}
\]

**Equation 7-2**

where:

- \( T_f \) is the temperature of the sample.
- \( V_f \) is the volume of the sample.
- \( V_b \) is the volume of the blank.
- \( V_s \) is the volume of the sample.
- \( T_b \) is the temperature of the blank.

\( K_1 \) is the calibration factor and must be known prior to running any identity tests. Its value is not to exceed 1.000 cm⁻¹, and should be recalculated. Be sure to consult Table 7.3, which gives the conversion factors for spectrophotometer calibration. The sensitivity values are based on the sample being a 26 ml aliquot of water. If the spectrophotometer is being used, then the sample should be rechecked for 25 ml aliquots. If other than a 26 ml aliquot is used for analysis, the corresponding factor must be substituted.

6. Calculations.

- Carry out the calculations, relating at least one extra decimal place beyond that of the required data. Round off only at the final result.

**Equation 7-3**

\[ mX = \frac{K_2 V_s}{A_s} \]

**Equation 7-4**

where:

- \( K_2 \) is the slope of the calibration curve.
- \( V_s \) is the volume of the sample.
- \( A_s \) is the absorbance of the sample.

6.4 Sample concentration, dry basis, corrected to standard conditions.

\[ C = \frac{K_2 V_s}{A_s} \]

**Equation 7-4**

7. Bibliography


**Method 8—DETERMINATION OF AROMATIC AND NITROGEN COMPOUNDS IN AIR EMISSIONS FROM STATIONARY SOURCES**

1. Principle and Applicability

Aromatic hydrocarbons (PAH) are extracted kinetically from the stack. The sulfuric acid mist (including sulfur trioxide) and the sulfur dioxide are separated, and both fractions are measured separately by the sulfur-atomic absorption method.

**Equation 7-4**

2. Apparatus

2.1 Sampling. A schematic of the sampling train used in this method is shown in Figure 8-1. It is similar to the Method 5 train except that the filter position is changed from Method 5 to Method 5A. Commercial models of this train are available. For those who desire to build their own, complete construction details are described in APTD-366. Changes from the APTD-366 document and allowable modifications are described in Section 8-4. Additional information is given in Method 5 and should be followed whenever they are applicable.

2.1.1 Probe Nozzle. Same as Method 5, Section 2.1.1.

2.1.2 Probe Liner. Porous or quartz glass, with a heating system to prevent condensation during sampling. Do not use metal probe liners.

2.1.3 Probe Tube. Same as Method 5, Section 2.1.3.
Figure 8-1. Sulfuric acid mist sampling train.
4. Procedure

4.1 Sampling

4.1.1 Pretest Preparation. Follow the procedure outlined in Method 5, Section 4.1.1; filters should be prewet, weighed, or identified. If the effluent gas can be considered dry, i.e., moisture-free, the silica gel need not be weighed.

4.1.2 Preliminary Determinations. Follow the procedure outlined in Method 5, Section 4.1.3, containing the following special instructions. Data shall be recorded on a sheet similar to the one in Figure 8-2. The sampling rate shall not exceed 0.030 m/s (0.1 ft/min) during the run. Periodically during the test, observe the connecting line between the probe and first impinger for signs of condensation. If it does occur, adjust the probe heater setting upward to the minimum temperature required to prevent condensation. If component changes become necessary during a run, a leak-check shall be done immediately before each change, according to the procedure outlined in Section 4.1.4 of Method 5 (with appropriate modifications, as mentioned in Section 4.1.5 of this method); record all leak rates. If the leakage rate(s) exceed the specified rate, the tester shall either void the run, or shall plan to correct the sample volume as outlined in Section 5.3 of Method 5. Immediately after component changes, leak-checks are optional. If these leak-checks are done, the procedure outlined in Section 4.1.4 of Method 5 (with appropriate modifications) shall be used.

4.2 Sample Recovery

4.2.1 Container No. 1. If a moisture content analysis is to be done, weigh the first impinger plus contents to the nearest 0.05 g and record the weight.

4.2.2 Container No. 2. In moisture content analysis, the contents of the first impinger plus contents to the nearest 0.05 g and record the weight. Also, weigh the spent silica gel in the first impinger up to the nearest 0.05 g and record the weight. The weight of the silica gel (or silica gel plus container) must also be determined to the nearest 0.05 g and recorded.

4.4 Project Leak-Check Procedure. Follow the basic procedure outlined in Method 5, Section 4.1.4.1, noting that the probe heater shall be adjusted to the minimum temperature required to prevent condensation, and also that there be also adjusted to the nearest 0.05 g and recorded.

4.5 Train Operation. Follow the basic procedure outlined in Method 5, Section 4.1.4.1, in conjunction with the following special instructions. Data shall be recorded on a sheet similar to the one in Figure 8-2. The sampling rate shall not exceed 0.030 m/s (0.1 ft/min) during the run. Periodically during the test, observe the connecting line between the probe and first impinger for signs of condensation. If it does occur, adjust the probe heater setting upward to the minimum temperature required to prevent condensation. If component changes become necessary during a run, a leak-check shall be done immediately before each change, according to the procedure outlined in Section 4.1.4.1 of Method 5 (with appropriate modifications, as mentioned in Section 4.1.5 of this method); record all leak rates. If the leakage rate(s) exceed the specified rate, the tester shall either void the run, or shall plan to correct the sample volume as outlined in Section 5.3 of Method 5. Immediately after component changes, leak-checks are optional. If these leak-checks are done, the procedure outlined in Section 4.1.4.1 of Method 5 (with appropriate modifications) shall be used.

5. Testing

5.1 Calculation of Percent Inorganic. Follow the procedure outlined in Method 5, Section 4.1.6.1. In moisture content analysis, the contents of the first impinger plus contents to the nearest 0.05 g and record the weight. The weight of the silica gel (or silica gel plus container) must also be determined to the nearest 0.05 g and recorded.

5.3.1 Container No. 1. If a moisture content analysis is to be done, weigh the second and third impingers to a 0.100 g graduated cylinder. Rinse all connecting glassware (including back half of filter holder) between the filter and silica gel impinger with deionized, distilled water, and add the rinse water to the cylinder. Place in a crock of ice water. Place in a crock of ice water. Place in a crock of ice water. Place in a crock of ice water. Place in a crock of ice water.
Rules and Regulations

Volume. The Results of titrations must agree within 1 percent or 0.5 ml, whichever is greater.

4.3 Container No. 2. Thoroughly mix the solution in the container holding the contents of the second and third impingers. Pipette a 10-ml aliquot of sample into a 50-ml Erlenmeyer flask. Add 9 ml of isopropanol. Titrates to a pink endpoint using 0.001-N N/10 sulfuric acid. Repeat this titration with a second aliquot of sample and average the titrations. Result of titrations shall agree within 1 percent or 0.5 ml, whichever is greater.

4.4 Reagents. Prepare blanks by adding 3 to 4 drops of indicator to 100 ml of 0 percent isopropanol. Titrates the blanks in the same manner as the samples.

5. Calibration

5.1 Calibrate equipment using the procedures specified in the following sections of Method 5: Section 5.6 (metering system); Section 5.5 (temperature gauges); Section 5.3 of Method 5, also applies to this method.

5.2 Standardise the barium perchlorate solution with 50 ml of standard sulfuric acid, to which 100 ml of 100 percent isopropanol has been added.

5.3 Calculation from raw data.

\[ I = \frac{T \cdot V_{\text{in}}} {P \cdot V_{\text{std}}} \]

where:

- \( I \) = 100 T \([K_{\text{at}} + (V_{\text{bar}} + 0.067)]\)
- \( K_{\text{at}} \) = K
- \( V_{\text{bar}} \) = V
- \( P \) = P
- \( V_{\text{std}} \) = V
- \( V_{\text{in}} \) = V

6. Calculations

Note—Carry out calculations remaining at least one extra decimal figure beyond that of the acquired data. Retain off figures after final calculation.

6.1 Nomenclature.

- 44 = Cross-sectional area of nozzle, m² (btv).
- 50 = Water vapor in the gas stream, proportion by volume.
- CH₂O₂ = Sulfuric acid (including 80%) concentration, g/dm³ (bdca).
- C₈₁ = Sulfur dioxide concentration, g/dm³ (bdca).
- F₄ = Percent of isokinetic sampling.
- N = Normality of barium perchlorate titrant, g-equiv/liter.
- \( P_{\text{bar}} \) = Barometric pressure at the sampling site, mm Hg (in. Hg).
- \( P_{\text{std}} \) = Absolute stack gas pressure, mm Hg (in. Hg).
- \( P_{\text{std}} \) = Standard absolute pressure, 760 mm Hg (0° C)
- \( T_{\text{bar}} \) = Average absolute stack gas temperature (see Figure 8-2, ° C (R)).
- \( T_{\text{std}} \) = Standard absolute temperature, 293° X (528° R).
- \( V_{\text{bar}} \) = Volume of sample aliquot titrated, 100 ml.
- \( V_{\text{in}} \) = Volume of gas samples measured by dry gas meter, dom (cd).
- \( V_{\text{std}} \) = Volume of gas samples measured by the dry gas meter corrected to standard conditions, dom (cd).
- \( N \) = Average stack gas velocity, calculated by Method 9, Equation 8-6, using data obtained from Method 8, Method 9.
- \( T_{\text{in}} \) = Total volume of solution in which the sulfuric acid or sulfur dioxide sample is contained, 250 ml or 1,000 ml, respectively, of barium perchlorate titrant used for the sample, ml.
- \( T_{\text{std}} \) = Volume of barium perchlorate titrant used for the blank, ml.
- \( V_{\text{in}} \) = Dry gas meter calibration factor.
- \( A_{\text{H₂O}} \) = Average pressure drop across orifice meter, mm (in.) H₂O.
- \( T \) = Total sampling time, min.
- 13.5 = Specific gravity of mercury.
- 90 = Second.
- 100 = Conversion to percent.

6.2 Averages dry gas meter temperature and average office pressure drop, see data sheet (Figure 8-2).

6.3 Dry Gas Volume. Correct the sample volume measured by the dry gas meter to standard conditions (20°C and 760 mm Hg or 68° F and 29.92 in. Hg) by using Equation 8-1.

\[ V_{\text{std}} = \frac{V_{\text{in}} \cdot T_{\text{std}} \cdot P_{\text{std}} + (\Delta H/13.6)} {T_{\text{in}} - P_{\text{bar}}} \]

where:

- \( K = 0.0013 \times 10^{-6} \) for metric units.
- \( K = 0.00048 \times 10^{-6} \) for English units.

Table of Nomenclature.

Note.--Carry calculations retaining at least one extra decimal figure beyond that of the acquired data. Retain off figures after final calculation.

8.5 Average absolute dry gas meter temperature (see Figure 8-2), ° C (R).

8.4 Calculation from raw data.

\[ I = \frac{T \cdot V_{\text{in}}} {P \cdot V_{\text{std}}} \]

where:

- \( I \) = 100 T \([K_{\text{at}} + (V_{\text{bar}} + 0.067)]\)
- \( K_{\text{at}} \) = K
- \( V_{\text{bar}} \) = V
- \( P \) = P
- \( V_{\text{std}} \) = V

8.6 Calculation from intermediate values.

\[ I = \frac{T \cdot V_{\text{in}}} {P \cdot V_{\text{std}}} \]

where:

- \( I \) = 100 T \([K_{\text{at}} + (V_{\text{bar}} + 0.067)]\)
- \( K_{\text{at}} \) = K
- \( V_{\text{bar}} \) = V
- \( P \) = P
- \( V_{\text{std}} \) = V

Bibliography

Method 5 Particulate Test
Calculation Form

I. Necessary Data

A. Reference Method #1
   - Area of stack _______ ft²
   - No. of equivalent diameters upstream _______
   - No. of equivalent diameters downstream _______
   - No. of traverse points _______
   - Total test time (θ) _______ minutes

B. Reference Method #2
   - Average stack temperature \( T_s \) _______ °F + 460 = _______ °R
   - Stack absolute pressure _______ in. Hg.
   - Barometric Pressure _______ in. Hg.
   - \( \sqrt{\Delta p} \) ave _______ (in. H₂O)\(^{1/2}\)

C. Reference Method #3
   - %CO₂ _______ ; %O₂ _______ ; %CO _______ ; %N₂ _______

D. Reference Method #4
   - Water collected
     Impinger H₂O _______ ml
     Silica Gel _______ gm

E. Reference Method #5
   - Area of nozzle _______ ft²
   - Average \( \Delta H \) _______ in. H₂O
   - Average meter temperature \( T_m \) _______ °F + 460 = _______ °R
   - Dry gas meter correction factor _______
   - Volume metered \( V_m = \) _______ CF
   - Particulate Weight _______ gm

II. Calculations

A. Standard Volume Metered

\[ V_m^{(\text{std})} = V_m Y \left( \frac{T_{\text{std}}}{P_{\text{std}}} \right) \left( \frac{\Delta H}{13.6} \right) \]

\[ V_m^{(\text{std})} \times \text{CF} \left( \frac{528 R}{29.92 \text{ in. Hg}} \right) \left( \frac{\text{in. Hg}}{\text{in. Hg}} \right) \times \frac{\text{dscf}}{\text{CF}} \]

3044
B. Moisture Content of Stack Gas

1. H₂O collected in impingers in standard cubic feet
   \[ V_{wc}(std) = K (V_f - V_i) \]
   \[ V_{wc} = 0.04707 \text{ ft}^3/\text{ml} ( \text{_____ ml}) = \text{_____ scf} \]

2. H₂O collected in silica gel in standard cubic feet
   \[ V_{wsg}(std) = K (W_f - W_i) \]
   \[ V_{wsg}(std) = 0.04715 \text{ ft}^3/\text{gm} (\text{_____ gm}) = \text{_____ scf} \]

3. Moisture content of stack gas \((B_{ws})\)
   \[ B_{ws} = \frac{V_{wc}(std) + V_{wsg}(std)}{V_{wc}(std) + V_{wsg}(std) + V_m(std)} \]
   \[ B_{ws} = \left( \frac{\text{_____ scf}}{\text{_____ scf}} + \frac{\text{_____ scf}}{\text{_____ scf}} \right) = \text{_____} \]

C. Molecular Weight of Stack Gas (lb/lb-mole)

1. \(M_d\) (Dry molecular weight) = \(\sum M_x B_x\)
   \[ M_d = (0.44) \%CO_2 + (0.32) \%O_2 + \]
   \[ (0.28) \%CO + (0.28) \%N_2 = \text{_____ lb/lb-mole} \]

2. \(M_s\) (Wet Molecular Weight) = \(M_d(1 - B_{ws}) + 18 B_{ws}\)
   \[ M_s = \text{_____} (1 - \text{_____ }) + 18(\text{_____}) = \text{_____ lb/lb-mole} \]

D. Average Stack Gas Velocity

\[ \bar{v}_s = K_p C_p \sqrt{\frac{T_s}{P_s M_s}} \sqrt{\frac{\Delta p}{\Delta v_c}} \]
\[ \bar{v}_s = 85.49 \text{ ft/sec} \left( \frac{\text{lb/lb-mole (in. Hg)}}{\text{°R(in.H₂O)}} \right)^{\frac{1}{2}} \]
\[ \sqrt{\frac{(\text{_____ °R})}{\text{in. Hg}((\text{_____ lb/lb-mole})}} \]

E. Average Stack Gas Volumetric Flow Rate

\[ Q_s = (3600 \text{ sec/hr})(v_s)(A_s)(1 - B_{ws}) \frac{T_{std}}{P_{std}} \frac{P_s}{T_s} \]
\[ Q_s = (3600 \text{ sec/hr})(\text{_____ ft sec})(\text{_____ ft}^2)(1 - \text{_____ }) \frac{528°R}{29.92 \text{ in. Hg}} \]
\[ Q_s = \text{_____ dscf hr} \]
F. Pollutant Mass Rate

\[ \text{PMR} = \frac{\text{mass}}{V_{m(\text{std})}} \times Q_s \]

\[ \text{PMR} = \left( \frac{\text{gm}}{\text{dscf}} \right) \times \frac{\text{dscf}}{\text{hr}} \times \frac{1}{454 \, \text{gm lb}} = \text{lb hr} \]

G. % Isokinetic Variation (Intermediate Data)

\[ \%I = \frac{T_s V_{m(\text{std})} P_{\text{std}} 100}{A_n \theta_s P_s T_{\text{std}} 60 (1 - B_{ws})} \]

\[ \% = \left( \frac{\text{°R}}{\text{dscf}} \right) \left( 29.92 \, \text{in. Hg} \right) \]

\[ \left( \frac{\text{ft}^2}{\text{min}} \right) \left( \text{ft sec} \right) \left( \text{in. Hg} \right) \left( 528 \, \text{°R} \right) \left( 60 \, \text{sec min} \right) \left( 1 - \frac{\theta_s}{\text{dscf}} \right) \]
A GUIDELINE FOR EVALUATING COMPLIANCE TEST RESULTS
(Isokinetic Sampling Rate Criterion)

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Emission Measurement Branch, ESED, OAQPS, EPA

Introduction

The sampling rate used in extracting a particulate matter sample is important because anisokinetic conditions can cause sample concentrations to be positively or negatively biased due to the inertial effects of the particulate matter. Hence, the calculation of percent isokinetic (I) is a useful tool for validating particulate test results. Section 6.12 of the recently revised Method 51 states, "If 90 percent < I < 110 percent, the results are acceptable. If the results are low in comparison to the standard and I is beyond the acceptable range, or, if I is less than 90 percent, the Administrator may opt to accept the results."

This guideline provides a more detailed procedure on how to use percent isokinetic to accept or reject test results when the sampling rate is beyond the acceptable range. The basic approach of the procedure is to account for the inertial effects of particulate matter and to make a maximum adjustment on the measured particulate matter concentration. Then, after comparison with the emission standard, the measured particulate matter concentration is categorized (1) as clearly meeting or exceeding the emission standard or (2) as being in a "gray area" zone. In the former category, the test report is accepted; in the latter, a retest should be done because of anisokinetic sampling conditions.

Procedure

1. Check or calculate the percent isokinetic (I) and the particulate
matter concentration \( c_s \) according to the procedure outlined in Method 5. Note that \( c_s \) must be calculated using the volume of effluent gas actually sampled (in units of dry standard cubic feet, corrected for leakage). Calculate the emission rate \( E \), i.e. convert \( c_s \) to the units of the standard. For the purposes of this guideline, it is assumed that all inputs for calculating \( E \) are correct and other specifications of Method 5 are met.

2. Compare \( E \) to the standard. Then accept or reject \( c_s \) using the criteria outlined below. (A summary is given in Table I):
   a. **Case 1 - \( I \) is between 90 and 110 percent.** The concentration \( c_s \) must be considered acceptable. A variation of \( \pm 10 \) percent from 100 percent isokinetic is permitted by Method 5.
   b. **Case 2 - \( I \) is less than 90 percent.**
      If \( E \) meets the standard, \( c_s \) should be accepted, since \( c_s \) can either be correct (if all particulate matter are less than about 5 micrometers in diameter) or it can be biased high (if larger than 5 micrometer particulate matter is present) relative to the true concentration; one has the assurance that \( c_s \) is yielding an \( E \) which is definitely below the standard.

(2) If \( E \) is above the standard, multiply \( c_s \) by the factor \((I/100)\) and recalculate \( E \). If, on the one hand, this adjusted \( E \) is still higher than the standard, the adjusted \( c_s \) should be accepted; a maximum adjustment which accounts for the inertial effects of particulate matter has been made and \( E \) still exceeds the standard. On the other hand, if the
adjusted E is lower than the standard, a retest should be done.

c. Case 3 - I is greater than 110 percent.

(1) If E exceeds the standard, \( c_s \) should be accepted, since
\( c_s \) can either be equal to the true concentration or biased low relative
to it; one has the assurance that E is definitely over the standard.

(2) If E is below the standard, multiply \( c_s \) by the factor
\((I/100)\) and recalculate E. If, on the one hand, this adjusted E is still
lower than the standard, the adjusted \( c_s \) should be accepted; a maximum
adjustment which accounts for the inertial effects of particulate matter
has been made and E still meets the standard. On the other hand, if the
adjusted E exceeds the standard, a retest should be done.

Table I. Summary of Procedure

<table>
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<th>Case</th>
<th>I</th>
<th>Category</th>
<th>Decision</th>
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<tr>
<td>1</td>
<td>90 - 110</td>
<td>( E \leq E_{\text{m Std.}} )</td>
<td>Accept</td>
</tr>
<tr>
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<td>&lt; 90</td>
<td>( c_s(I/100) + E_{\text{adj}} &gt; E_{\text{m Std.}} )</td>
<td>Accept</td>
</tr>
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<td></td>
<td></td>
<td>( c_s(I/100) + E_{\text{adj}} \leq E_{\text{m Std.}} )</td>
<td>Retest</td>
</tr>
<tr>
<td>3</td>
<td>&gt; 110</td>
<td>( E &gt; E_{\text{m Std.}} )</td>
<td>Accept</td>
</tr>
<tr>
<td></td>
<td></td>
<td>( c_s(I/100) + E_{\text{adj}} \leq E_{\text{m Std.}} )</td>
<td>Accept</td>
</tr>
<tr>
<td></td>
<td></td>
<td>( c_s(I/100) + E_{\text{adj}} &gt; E_{\text{m Std.}} )</td>
<td>Retest</td>
</tr>
</tbody>
</table>
Summary

A procedure for accepting or rejecting particulate matter test results based on percent isokinetic has been outlined. It provides a mechanism for accepting all data except where anisokinetic sampling might affect the validity of the test results. This procedure is one of several useful tools for evaluating testing results.

References


STUDENT HANDOUTS "HOW EPA VALIDATES NSPS METHODOLOGY" AND "CORRECTION OF S-TYPE PITOT-STATIC TUBE COEFFICIENTS WHEN USED FOR ISOKINETIC SAMPLING FROM STATIONARY SOURCES" REMOVED DUE TO COPYRIGHT RESTRICTIONS.
1. How would you correct the "C" factor of your nomograph if your pitot tube had a coefficient of $C_p = .79$?
   
   a. Take $C_{corr \, nomog} = 0.85/0.79C_{nomog}$
   
   b. Use $C_{corr \, nomog} = \frac{0.79}{0.85}C_{nomog}$
   
   c. The nomograph can't be corrected for a different $C_p$.
   
   d. Use $C_{corr \, nomog} = \frac{(0.79)^2}{(0.85)^2}C_{nomog}$

2. The Type S pitot tube has demonstrated several characteristics that are important in understanding its proper function and application in measuring gas velocity. Those characteristics which can affect its performance are:
   
   a. Tube length and diameter
   b. Sensing area and tube length
   c. Sensitivity to turbulence and orientation
   d. Sensitivity to temperature variation and abusive environments

3. What assumptions does the nomograph make about the stack gas molecular weight?
   
   a. The molecular weight can be corrected for %CO₂ and %O₂.
   b. The dry stack gas molecular weight is measured to be 29.
   c. The molecular weight (wet) is assumed to be 29.
   d. The stack gas molecular weight is directly related to $v_s$, the stack gas velocity.

4. Correcting pollutant concentrations to 12% CO₂ is applicable to:
   
   a. Non-combustion processes
   b. All chemical processes except oil refineries
   c. Combustion processes
   d. Only those processes burning No. 2 diesel oil
5. If the particulate concentration is measured as 0.1 grains per dry standard cubic foot (DSCF), and the stack gas flow rate is 70,000 DSCF per minute, what is the particulate emission rate in pounds per hour (7000 grains = 1 pound)?
   a. 60 pounds/hour
   b. 1 pound/hour
   c. 10 pounds/hour
   d. Need more information

6. If the gas analysis is 6.2% O₂, 14.2% CO₂, 0% CO, 79.6% N₂ and the % H₂O is 7.0%, the wet molecular weight of this mixture is:
   a. 29.6
   b. 23.8
   c. 9.0
   d. 30.9

7. The greatest source of experimental error for a stack test arises out of the measurements for:
   a. Moisture content of the stack gas
   b. Molecular weight of the stack gas
   c. Velocity of the stack gas
   d. Sample point position within the duct

8. The most important aspect of a safety evaluation procedure designed to prevent accidents is a continuous:
   a. Reminder to personnel of previous accidents
   b. Accident analysis program
   c. Safety indoctrination program
   d. Stronger enforcement of safety rules

9. The on-site sampling team should follow:
   a. Their developed safety methods
   b. Plant safety regulations and those guidelines given in the CRC safety handbook
   c. All plant safety guidelines in addition to those developed specifically for the sampling team
   d. Posted plant regulations

10. The Glass Fiber Filter used in Method 5 particulate sampling must:
    a. Exhibit at least 96.5% collection efficiency
    b. Be dessicated 24 hours and weighed to a constant weight
    c. Be dessicated 24 hours and weighed to the nearest 1.0 mg
    d. Be dessicated 6 hours and weighed
1. Turbulence is created by any accessory adjacent to the Type S pitot tube. The effect of turbulence upon the calibration of the Type S pitot tube is minimized when the accessory is separated from the pitot tube by a distance:

   a. 7.62 mm
   b. 3/4"
   c. 2"
   d. 3"

12. The term $\Delta H_g$ is defined as:

   a. The sum of the stagnation pressure and static pressure in the duct.
   b. The flow rate of dry air flowing through a flat, sharp-edged orifice
   c. Sampling Meter Console calibration factor
   d. The pressure differential across the sampling console orifice meter that creates a flow rate through the meter of 0.75 cfm dry air at 70°F and 29.92 in. Hg.

13. The Type S pitot tube must be properly oriented in the gas stream if it is to measure the correct gas velocity impact pressure. A serious drawback of sampling probe design in some equipment systems is:

   a. The pitot tube is permanently welded to the sampling sheath
   b. The pitot tube-probe sheath assembly can be accidentally twisted into misalignment in the gas stream
   c. The pitot tube is constructed of 316 stainless steel
   d. The pitot tube-probe sheath assembly is out of round

14. Blowers are necessary on transmissometers to:

   a. Prevent mirror lock-up
   b. Provide a purge system through the instrument to eliminate the effects of corrosive gases
   c. Air-condition the optical system
   d. Keep the optical windows free of particulates

15. How is transmittance related to opacity?

   a. $\%$ opacity = $\%$ transmittance – Ringelmann number
   b. Transmittance = $(1 - \%$ opacity) x 100
   c. Transmittance/opacity = Ringelmann number
   d. $\%$ opacity = 100% – $\%$ transmittance
16. The cascade impactor particle size can give representative particle size data if:
   a. It is properly calibrated and operated
   b. A cyclone is used to knock out large particle in the gas stream
   c. Only if it is not at stack temperature when sampling
   d. Agglomeration and fracturing of particles takes place in the device

17. For tangential cyclonic flow in a stack, the best way to determine the velocity is:
   a. Orient the pitot tube until maximum reading is obtained. This is the true \( \Delta p \).
   b. Orient the pitot tube parallel to the sides of the stack and the \( \Delta p \) reading is the upward vector of the velocity.
   c. Measure the impact pressure and the static pressure separately and by difference obtain the velocity head (\( \Delta p \)).
   d. Install gas flow straightening vanes and sample in the usual manner.

18. "Isokinetic," in stack sampling, means:
   a. The volumetric flow rate at the tip of the probe nozzle is equal to the volumetric flow rate at the metering device.
   b. The velocity at the tip of the nozzle is equal to the velocity at the metering device.
   c. The velocity at the tip of the nozzle is equal to the velocity of the approaching stack gas stream.
   d. A term used by stack samplers to impress plant personnel.

19. Cascade impactor particle sizing devices are subject to errors produced when the sample gas flow rate through the device is too high. These errors are caused by:
   a. Poor leak test procedures
   b. Process fan fluctuations
   c. Scouring and reentrainment of particles deposited on stage plates
   d. Under isokinetic flow through the impactor

20. The Type S pitot tube is the most commonly used device for the EPA Method 5 sampling train gas sensor. It aids in the measurement of the stack gas velocity. The Type S pitot tube directly measures:
   a. The gas velocity, impact pressure and static pressure
   b. Gas flow rate through the A and B legs of the tube
   c. Stack gas viscosity
   d. The difference between gas viscosity and gas density
21. Source sampling nozzles should be:

a. Tapered to ≤ 40°
b. Must not exceed 3/4" diameter
c. Calibrated regularly to the nearest (0.001 inch) 0.025 mm
d. Replaced at specific intervals

22. In the following equations:

\[ v_s = \text{stack gas velocity} \]
\[ A_s = \text{stack cross-sectional area} \]
\[ A_n = \text{nozzle cross-sectional area} \]
\[ \theta = \text{sampling time (minutes)} \]
\[ V_m = \text{standard volume metered at the dry gas meter} \]
\[ V_n = \text{volume at stack conditions passing through the nozzle} \]

The % isokinetic for a stack may be calculated using equation:

a. \[ \% \text{ isokinetic} = \frac{A_s}{A_n} \times 100 \]

b. \[ \% \text{ isokinetic} = \frac{V_n}{v_s A_s \theta} \times 100 \]

c. \[ \% \text{ isokinetic} = \frac{V_n}{\theta A_n v_s} \times 100 \]

d. \[ \% \text{ isokinetic} = \frac{V_m}{\theta A_s v_s} \times 100 \]

23. The New Source Performance Standards for a Fossil Fuel Fired Steam Generator define a particulate as:

a. Any solid or liquid in the stack gas
b. Any solid in the stack gas
c. Any solid or liquid other than uncombined water in the stack gas as measured by Method 5.
d. Any solid or liquid other than uncombined water as measured by Method 5 sampling train maintained at ≤ 400°F
24. An Orsat analyzer is commonly used to determine the composition of a combustion effluent where $N_2$, $O_2$, $CO$, and $CO_2$ are the principal constituents of the gas stream. It directly measures:

a. $O_2$, $N_2$, $CO$, and $CO_2$

b. $CO$, $CO_2$, $O_2$

c. $CO_2$, $O_2$, $N_2$

d. $N_2$, $O_2$, $CO$

25. An Orsat analyzer yields results on a:

a. Wet basis because it essentially is a wet chemical analysis.

b. Wet basis because the effluent usually contains moisture.

c. Dry basis because the moisture condenses until the effluent is dry.

d. Dry basis because the vapor pressure of water remains the same.

26. The order in which we analyze the components is:

a. $CO_2$, $O_2$, $CO$

b. $O_2$, $CO_2$, $CO$, $N_2$

c. $CO$, $O_2$, $CO_2$

d. $N_2$, $O_2$, $CO$

27. The Type S pitot tube must be calibrated while assembled in the sampling configuration for which its use is intended. This is necessary because:

a. The Type S pitot tube is not an accepted standard for gas velocity measurements.

b. It may be Reynolds's Number dependent

c. It is not manufactured according to an established National Standard

d. All the preceding reasons in conjunction with the dictates of good experimental procedure for preparation and use of any scientific measuring device.
28. Select the equation that best describes the calibration of a pitot tube using a known standard pitot tube.

a. \( C_p = \frac{Q_b / A_b}{K_p \sqrt{\frac{T_b \Delta p}{P_s M_s}}} \)

b. \( C_p = \frac{Q_b / A_b}{K_p \sqrt{\frac{P_s \Delta p}{T_s M_s}}} \)

c. \( C_p = \frac{C_p(\text{std}) \sqrt{\Delta p(\text{std})}}{\sqrt{\Delta p(\text{test})}} \)

d. \( C_p = \frac{C_p(\text{std}) \sqrt{\Delta p(\text{test})}}{\sqrt{\Delta p(\text{std})}} \)

\( \Delta p = \) pitot tube velocity pressure

\( \Delta p(\text{test}) = \) test pitot tube velocity pressure

\( \Delta p(\text{std}) = \) standard pitot static tube velocity pressure

\( Q_b = \) volumetric flow rate

\( T_s = \) absolute temperature of the gas

\( A_b = \) stack cross-sectional area

\( C_p = \) pitot tube calibration coefficient

\( C_p(\text{std}) = \) standard pitot-static tube calibration coefficient

\( K_p = \) dimensional constant

\( M_s = \) wet molecular weight of the gas

\( P_s = \) absolute pressure of the gas

29. The D$_{50}$ of a cascade impactor stage is defined as:

a. The particle diameter at which the stage is 50% efficient

b. The \( D_p \) of that stage

c. The particle diameter at which the stage is 50%

d. The D$_{50}$ aerodynamic diameter of the particles on that stage

30. The photopic region is

a. The region of the electromagnetic spectrum covered by the spectral output of a tungsten filament.

b. The effective sensing area of the detector on a transmissometer.

c. The range of particle sizes which scatter visible light.

d. The visible region of the electromagnetic spectrum.
31. The moisture content of the stack gas enters into calculation of the wet molecular weight of the gas, in the expression:

- **a.** \( M_d = \sum M_x u_x \)  
- **c.** \( M_s = M_d (1 - B_{ws}) + 0.025 \)
- **b.** \( M_s = M_d (1 - B_{ws}) + 18 (B_{ws}) \)  
- **d.** \( M_s = M_d (1 - B_{ws}) + B_{ws} \)

Where:  
- \( B_{ws} \) = mole fraction \( H_2O \) (% \( H_2O \))  
- \( M_s \) = weight molecular weight of the stack gas

32. What must you do if you encounter effluents other than \( CO_2, O_2, CO, \) or air in order to determine the molecular weight?

- **a.** Guess the molecular weight to be 29.
- **b.** Use appropriate analytical procedures to determine the mole fraction of each constituent of the effluent gas.
- **c.** Go ahead and use the Orsat anyway. The principle is “anything is better than nothing”.
- **d.** Use a Fyrite.

33. If you sample over-isokinetically, your particle concentration will be

- **a.** Less than the true concentration
- **b.** Greater than the true concentration
- **c.** The true concentration
- **d.** Greater than the true concentration only if large particles make up a significant percentage of the particle size distribution

34. A quick approximation of stack gas velocity in a duct can be made using the equation:

- **a.** \( v_s = 2.46 \sqrt{T_s \Delta p} \)
- **b.** \( v_s = 85.48 \sqrt{T_s \Delta p} \)
- **c.** \( v_s = K_p C_p \left[ \frac{T_s P_m}{T_m P_s} \right] \)
- **d.** \( v_s = K_p C_p \sqrt{\frac{T_s \Delta p}{P_s B_w}} \)
35. The ideal gas law states that:

\[ PV = \frac{m}{M} RT \]

Select the statement that is false.

a. The universal gas constant, \( R \), is dimensionless.
b. The above relationship can be used to find the density of a gas at any conditions of \( P, T, \) and \( M \).
c. Molecular weight is determined by knowing the composition of gas stream.
d. \( T \) must be in absolute units.

36. Why is the determination of moisture content of the effluent gas important in isokinetic sampling?

a. Because moisture tends to corrode the nozzle.
b. Because it enters as a variable in the isokinetic sampling equation and must be considered in setting the isokinetic flow rate.
c. It can dissolve particulates and yield low results.
d. It is not important in isokinetic sampling.

37. One of the important hydrodynamic principles used in isokinetic considerations, is

a. Large particles tend to move in their same initial direction.
b. Barriers to flow develop vortices.
c. Pressure is inversely related to volume.
d. A flowing gas stream will decrease the pressure in a tube normal to the flow direction.

38. Which one of the following relates pressure differential across a system to the flow rate of the gases in the system:

a. Stokes Law
b. Reynolds’ Number
c. Bernoulli’s Theorem
d. Avagadro’s Number
39. Reference Method 4 in the Federal Register outlines the procedures for determination of the moisture content of a stack gas. Moisture content is best determined from the equation: (Note $B_{wo}$ is the same as $B_{ws}$)

\[ B_{ws} = \frac{V_{wc}}{V_{wc} + V_{m}} + 0.02 \]

\[ B_{ws} = \frac{V_{wc(\text{std})} + V_{wag(\text{std})}}{V_{wc(\text{std})} + V_{ag(\text{std})} + V_{m(\text{std})}} \]

\[ B_{ws} = \frac{1}{V_{wc} + V_{m}} \]

\[ B_{ws} = 1 \left[ - \frac{V_{wc}}{V_{m}} \right] \]

40. The % isokinetic calculated at the end of a Method 5 test is a measure of:

a. The precision with which sampling rates were set based on test velocity and volumetric flow rate data

b. Experimental discrepancies

c. Experimental error

d. Accurate pollutant mass emissions

41. The static pressure of a duct is that pressure which would be indicated by a gage moving along with the gas stream in the duct.

42. The nomograph supplied with most commercial EPA trains is the most accurate method for setting isokinetic flow rate.

43. When any fuel is burned at 50% excess air, the flue gas will contain the same %O₂ and %CO₂.

44. An inclined manometer must always be leveled and properly zeroed if good Δp readings are expected.

45. Gas straightening vanes will assist in reducing gas turbulence within a duct.

46. The standard pitot tube has standard design criteria accepted by the National Bureau of Standards.

47. The analytical technique and properties of the pollutant and other constituents are of prime importance when designing sampling trains and experiments.

48. Sampling for the average pollutant concentration at the point of average velocity is common practice for isokinetic sampling.
49. The optical density measured across a stack can be correlated to mass emission concentration.

50. The relationship used to find the proper isokinetic sampling rate when the $\Delta p$ is known, is:

$$\Delta H = K \Delta p.$$
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DIRECTIONS: Circle the best answer (there is one and only one correct answer for each question). Mark answers both on your Exam Sheet and on the Answer Sheet. You will be asked to turn in only the Answer Sheet. The August 18, 1977 Federal Register and a scientific calculator may be used during this test.

1. If the particulate concentration is measured as 0.1 grains per dry standard cubic foot (DSCF), and the stack gas flow rate is 70,000 DSCF per minute, what is the particulate emission rate in pounds per hour (7000 grains = 1 pound)?
   a. 60 pounds/hour
   b. 1 pound/hour
   c. 10 pounds/hour
   d. need more information

2. A Stack Tester needs an estimated stack gas velocity for pre-survey information. He is told that the stack gas is exiting from a combustion source and that the average stack gas temperature is 440°F. A velocity traverse with a "D" type pitot tube (Cp = 0.85) gave the average Δp = 1.0 in H2O. Estimate the gas velocity in the duct.
   a. 69 ft./sec.
   b. 74 ft./sec.
   c. 60 ft./sec.
   d. 78 ft./sec.

3. A Type S pitot tube was calibrated against a standard pitot-static tube assigned a Cp = 0.998 by NBS. The Type S tube measured a Δp = 0.500. The standard tube measured a Δp = 0.350. What is the Cp of the Type S tube based on this data?
   a. 0.998 (0.7)^2
   b. 0.998/ √0.7
   c. 0.998 √0.7
   d. 0.998/(0.7)^2

February 14, 1980
4. A Stack Test was performed at a wood fired boiler. The stack gas contained 10% H₂O and traveled up the stack at 30 ft/sec. The stack had a cross-sectional area of 20 ft², average temperature of 335°F, and absolute pressure of 29.92 in. Hg. What was the volumetric flow rate in dry standard cubic feet per hour?

a. 144,000
b. 1,300,000
c. 130,000

5. Method 1 presents guidelines for the selection of a sampling site and minimum number of sampling points for a particulate traverse for a stack diameter greater than 24 inches. The criterion for using 12 sampling points in the duct states that the sampling site is at least:

a. 8 duct diameters downstream and 2 duct diameters upstream of a flow disturbance.
b. 2 duct diameters downstream and 8 duct diameters upstream of a flow disturbance.
c. 4 duct diameters downstream and 8 duct diameters upstream of a flow disturbance.
d. 6 duct diameters downstream and 2 duct diameters upstream of a flow disturbance.

6. The Code of Federal Regulations outlines the procedures for Method 3. The method gives details on how to analyze the gas for its major components using the Orsat. Orsat analysis makes possible the calculation of:

a. Mole fraction of CO₂, O₂, and CO, dry gas molecular weight and percent excess air in the duct
b. Percent excess air, CO₂, and volumetric flow rate (dry)
c. Percent O₂, CO₂, and CO, and moisture content
d. Only the percent oxygen present in the dry gas

7. Method 1 guidelines suggest that all sampling points in a rectangular duct be located at the centroid of an equal area so that:

a. There is a length to width ratio of 1:4
b. There is a length to width ratio of 2:1
c. Two and five are concentric equal areas
d. There is a balanced matrix
8. Using Method 1 guidelines it is necessary to calculate an equivalent diameter (D_e) for rectangular stacks to be sampled. This is done using:

a. \[ D_e = \frac{(L)(W)}{(L)^2} \]

b. \[ D_e = \frac{(L)(W)}{(W)^2} \]

c. \[ D_e = \frac{2(L)(W)}{L + W} \]

d. \[ D_e = \frac{4(L)(W)}{W + L} \]

9. If fibers from a filter adhere to the gasket part of the filter assembly a proper procedure to follow would be to:
   a. Wash the gasket in an acetone/water rinse.
   b. Retain the fibers on the gasket for the next run.
   c. Scrape off the fibers into the filter recovery dish.
   d. Wipe the fibers off with a Kimwipe.

10. The mole fraction of H₂O in a stack gas as calculated by the Reference Method, is:

a. \[ B_{ws} = \frac{V_{wc}}{V_{wc} + 0.02} \]

b. \[ B_{ws} = \frac{V_{wc}(\text{std}) + V_{ws}(\text{std})}{V_{wc}(\text{std}) + V_{ws}(\text{std}) + V_{m}(\text{std})} \]

c. \[ B_{ws} = \frac{V_{wc}}{V_{wc} + V_{m}} \]

d. \[ B_{ws} = \frac{1}{V_{wc} + V_{m}} \]
11. The following statements give some of the advantages gained by using a Type S pitot tube. Which statement is not always true?
   a. The Type S pitot tube is easy to use in small sampling ports.
   b. The Type S pitot tube resists abusive environments and holds its calibration.
   c. The Type S pitot tube consistently calibrates to a known $C_p$ value of 0.84, therefore, individual calibration is not necessary.
   d. The large gas sensing orifices of the Type S pitot tube help prevent clogging in heavily loaded particulate gas streams.

12. The standard pitot-static tube has small openings surrounding the tube for measuring:
   a. Standard pressure
   b. Static pressure
   c. Rotational gas velocity vector
   d. Parallel gas axis angle

13. The small opening surrounding the standard pitot-static tube may clog with particulate in a heavily loaded gas stream. For this reason the standard pitot-static tube should:
   a. Never be used for this type situation
   b. Used only to calibrate a Type S pitot tube
   c. Be a second choice to a well calibrated Type S tube in this situation
   d. Protected from clogging by adding isolation between the small opening

14. The Type S pitot tube is the most commonly used device for the EPA Method 5 Sampling Train gas sensor. It aids in the measurement of the stack velocity. The Type S pitot tube directly measures:
   a. The difference between total pressure and static pressure
   b. Gas flow rate through the A and B legs of the tube
   c. Stack gas viscosity
   d. Difference between gas viscosity and gas density

15. The requirements concerning minimum distances for separation of the Type S pitot tube and any accessory on the sampling probe are established because:
   a. The Type S pitot tube has a slow response time when gas turbulence exists about the sensor.
   b. The Type S pitot tube has exhibited a sensitivity to gas turbulence that can affect its calibration coefficient.
   c. The Type S pitot tube must be isolated from the sampling nozzle to ensure that the volume at the nozzle equals the velocity of the approaching gas stream.
   d. Manufacture calibration guarantees are void if the pitot tube is too close to other train components.
16. In the isokinetic rate equation \( \Delta H = K \Delta p \), \( K \) is:
   a. Always equal to 1.84
   b. Only a function of the stack temperature
   c. A function of many variables
   d. Independent of the \( C_p \) value

17. Isokinetic sampling is:
   a. Used only for gas sampling from stationary sources
   b. Necessary when sampling for gases as well as for particulates to obtain the proper influx of pollutant
   c. The same as proportional sampling
   d. Is necessary to obtain a particulate sample having the same size distribution as that occurring in the stack

18. What is the purpose of the Method 5 nomograph?
   a. It is a type of slide rule used to determine the \( \Delta p \) for the chosen sampling train.
   b. It is a type of slide rule used to correct the nozzle velocity to standard conditions.
   c. It is a type of slide rule used to determine \( \Delta H \) from the observed \( \Delta p \).
   d. It is a type of slide rule used to determine \( \Delta \rho \) from the observed \( \Delta H \).

19. In the expression \( \Delta H = K \Delta p \), \( K \) represents the reduction of several variables into a constant term that may be calculated for the existing conditions at the source. Which of the following variables is assumed to be zero in the reduction of terms to \( K \)?
   a. \( \Delta H_d = 0 \)
   b. \( B_{wm} = 0 \)
   c. \( B_{ws} = 0 \)
   d. \( (1-B_{ws}) = 0 \)

20. A Source Test was performed at an isokinetic rate of 86%. The emissions calculated from this test are biased:
   a. By large particulates and a higher emission rate than true
   b. By large particulates and a lower emission rate than true
   c. Small particulates and a higher emission rate than true
   d. Small particulates and a lower emission rate than true
21. A transmissometer measures the opacity of an effluent stream using light with wave lengths between 500-600 nm. These wave lengths are chosen for which of the following reasons?

a. These wave lengths are specific to fly ash particles

b. Transmissometer opacity readings in this area of the electromagnetic spectrum are free from 

H₂ and CO₂

c. Present technology does not allow economical construction of instruments employing other wave lengths

d. Combustion sources emit light in this region of the spectrum

22. The percent isokinetic should be 100%, and if it is:

a. It ensures sampling accuracy.

b. It means only that, based on the volumetric and velocity data, the proper sampling rates were used.

c. It means that the source is in compliance with regulations.

d. It means that only the pollutant mass rate will be accurate.

23. In the clean-up procedures of an EPA particulate train, acetone is used to wash all internal surfaces of:

a. Nozzle, probe, and front half of filter holder

b. Answer “a,” except the probe is rinsed only if the liner is glass

c. Probe and filter holder only

d. Acetone is not used because it is highly volatile

24. A sampling team performed reference method 5 particulate test at a municipal incinerator. Test results showed an emission rate of 0.01 lb./dscf with 8% CO₂ in the stack gas. What is the emission rate connected to 12% CO₂?

a. 0.010 lb./dscf

b. 0.015 lb./dscf

c. 0.020 lb./dscf

d. 0.025 lb./dscf
25. Error analysis of the Method 5 sampling system suggests that the greatest errors occur in determination of:

a. Stack gas velocity and dry molecular weight
b. Stack gas velocity and sampling site selection
c. Stack gas velocity and wet molecular weight
d. Stack gas velocity and moisture content

26. If entrained water is observed in the stack, which of the following methods would give the best estimate for \( B_{wa} \)?

a. Just use the saturated moisture value at the stack temperature
b. Use the wet bulb–dry bulb method
c. Use Method 4
d. Just use the saturated moisture value at the ambient temperature

27. The moisture content of the stack gas enters into the calculation of the wet molecular weight of the gas, in the expression:

a. \( M_d = \sum M_x \times B_x \)

b. \( M_s = M_d(1-B_{ws}) + 18(B_{ws}) \)

c. \( M_w = M_d(1-B_{ws}) + 0.025 \)

d. \( M_w = M_d(1-B_{ws}) + B_{ws} \)

28. For tangential cyclonic flow in a stack, the best way to determine the velocity is:

a. Orient the pitot tube until maximum reading is obtained. This is the true \( \Delta p \)
b. Orient the pitot tube parallel to the sides of the stack. The \( \Delta p \) reading is the upward vector of the velocity
c. Measure the impact pressure and the static pressure separately and by difference obtain the velocity head (\( \Delta p \))
d. Install gas flow straightening vanes and sample in the usual manner
29. Hest Tester sampling team had just completed a Method 5 test at a cost of $2000 to the source. The value obtained for the emissions, $E$, in lba/10^6 Btu, was below the standard, indicating that the source was in compliance. The test itself, however, was only 80% isokinetic. This test data:

- would be rejected by EPA since it is not within ±10% of 100% isokinetic.
- could be easily corrected to give the value of $E$ at 100% isokinetic conditions.
- could be accepted by EPA since the value of $E$ would be even lower at 100% isokinetic conditions.
- could be accepted by EPA since the value of $E$ would be even higher at 100% isokinetic conditions.

30. Correcting pollutant concentrations to 12% CO₂ is applicable to:

- all processes
- incineration processes and other combustion sources
- sources in operation prior to April 1, 1970
- sources covered by State Implementation Plans

31. The ideal gas law states that:

$$ PV = \frac{n}{M} RT $$

Select the statement that is false:

- The universal gas constant, $R$, is dimensionless.
- The above relationship can be used to find the density of a gas at any conditions of $P$, $T$, and $M$.
- Molecular weight is determined by knowing the composition of gas stream.
- $T$ must be in absolute units.

32. The $D_{50}$ of a cascade impactor stage is defined as:

- the average aerodynamic diameter of the particles on that stage
- the physical diameter of the particles on that stage
- the particle diameter at which the stage is 50% efficient
- calibration coefficient of that stage
33. Cascade Impactor particle sizing devices are subject to errors produced when the sample gas flow rate through the device is too high. These errors are caused by:

a. Anisokinetic flow through the impactor
b. Over isokinetic flow through the impactor
c. Under isokinetic flow through the impactor
d. Scouring and reentrainment of particles deposited on stage plates

34. The maximum total angle of radiation that can be projected by the lamp assembly of the transmissometer is known as:

a. The angle of trajectory
b. The angle of declination
c. The light scattering angle
d. The angle of projection

35. How is transmittance related to opacity?

a. \[ \text{transmittance} = \log_{10} \frac{1}{(1 - \text{opacity})} \]
b. \[ \text{transmittance/opacity} = \frac{\text{opacity}}{1 - \text{opacity}} \]
c. \[ \% \text{opacity} = 100\% - \% \text{transmittance} \]
d. \[ \% \text{opacity} = \% \text{transmittance} - \% \text{opacity} \]

36. A transmissometer will provide information on mass emissions from a pollutant source for a given time period if:

a. The neutral density filters are calibrated to 3% and the particle characteristics do not change.
b. A reference light source is used and the particle characteristics do not change.
c. The manufacturer supplies a calibration chart.
d. The optical density can be correlated to grain loading and the particle characteristics remain unchanged.

37. If a post-leak check of a Method 5 train gives a value of 0.032 cfm, the test should be:

a. Rejected without question.
b. Accepted without question.
c. Accepted, if \( V_m \) is corrected, using the leak rate value.
d. Accepted, if \( V_m \) is modified by averaging the pre-test and post-test leak rates.
The following questions are related to the diagram of the Method 5 Sampling Train. Questions vary in complexity from simple identification of equipment to others that test understanding and comprehension of equipment use.

38. When performing an EPA Method 5 test, in order to draw a sample through the sampling train at a controlled rate, the by-pass valve is:

a. Turned all the way off  
b. Turned clockwise from a fully open position  
c. Turned counterclockwise from an off position  
d. Turned to a fully open position
39. What is the function of the orifice meter in a Method 5 test?
   a. It is used to eliminate correcting the sample volume to standard conditions
   b. It is used to determine the value of K of the isokinetic rate equation during the test
   c. It is used to determine the flow rate of the gas through the sampling train
   d. It is used to determine the flow rate of the gas in the stack

40. In the EPA Method 5 Sampling Train, what are each of the impingers filled with and what is the correct order?
   a. 1 – 100cc H₂O, 2 – Dry, 3 – 200cc H₂O, 4 – Silica Gel (100g)
   b. 1 – 100cc H₂O, 2 – 200cc H₂O, 3 – Dry, 4 – Silica Gel (200g)
   c. 1 – 100cc H₂O, 2 – 100cc H₂O, 3 – Dry, 4 – Silica Gel (200g)
   d. 1 – 200cc H₂O, 2 – 200cc H₂O, 3 – Dry, 4 – Silica Gel (100g)

41. All leak checks for the sample train should be conducted:
   a. From the nozzle inlet with all train components at operating temperature
   b. From the filter inlet at room temperature
   c. From the probe inlet at ambient temperature
   d. From the nozzle inlet at ambient temperature

42. The post-test leak check at the stack test is:
   a. An unnecessary and useless procedure because it is not required by present regulations
   b. A possible source of error creating particulate penetration through the glass mat filter
   c. Required in the August 18, 1977 Federal Register revisions to Method 5
   d. The work of a novice tester unaware of the possible problems

43. The August 18, 1977 Federal Register gives guidelines on the type of sampling probe liner that may be used in the Method 5 sampling system. It recommends that probe liners be:
   a. Borosilicate glass
   b. Borosilicate glass or stainless steel
   c. Quartz glass or stainless steel
   d. Borosilicate or quartz glass; stainless steel with the approval of the administrator
44. The Federal Register guidelines for Method 5 suggest a pre-test leak check of the sampling train. The test recommendations are:

   a. A leak check of the entire system at operating temperature and a vacuum gage reading of 15 in. Hg
   b. A leak check of the entire system at a vacuum gage reading of 14 in. Hg
   c. A leak check at the filter inlet at a vacuum gage reading of 14 in. Hg and maximum leak rate of 0.02 cfm
   d. A leak check at the filter inlet at a vacuum gage reading of 15 in. Hg and maximum leak rate of 0.25 cfm

45. The F-Factor is:

   a. Used to determine the concentration of the stack gas.
   b. Permitted by the Federal Register to convert emissions data for FFFSG into the units lb/10^6 Btu.
   c. Used to calculate the stack gas volumetric flow rate.
   d. Used to determine the (pmr) pollutant mass rate.

46. The EPA Method 5 Sampling procedure specifies that the out-of-stack filter temperature (unless stated otherwise in the subparts) be maintained at:

   a. \( \leq 250^\circ\text{F} \)
   b. \( \geq 250^\circ\text{F} \)
   c. No greater than 248°F \( \pm \) 25°F
   d. 250°F

47. Maintaining the filter at this temperature is:

   a. Part of the definition of "particulate" as the method is written
   b. Necessary to prevent sulfate formation on the glass mat
   c. The best temperature to assure a leak-tight filter holder
   d. Easier than setting it at any other temperature.

The desired flow rate through the Method 5 Sampling Train is 0.75 cfm dry air at 68°F and 29.92 in. Hg. These conditions are designated by a single term \( \Delta H_{\text{op}} \). Solving the orifice meter flow rate equation for \( \Delta H_{\text{op}} \) that meets the stated conditions we find:

   a. \( \Delta H_{\text{op}} = \frac{Q_m^2}{K_m^2} \)
   b. \( \Delta H_{\text{op}} = \frac{1}{K_m^2} \)
   c. \( \Delta H_{\text{op}} = \frac{0.9244}{K_m^2} \)
   d. \( \Delta H_{\text{op}} = \frac{Q_m}{K_m \left[ \frac{P_m}{T_m} \right]^2} \)
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