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ABSTRACT

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)

United States
Environmental Protection
Agency

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

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February 1980

Air

APTI Course 450 Source Sampling for Particulate Pollutants

Instructor's Guide

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

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

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

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

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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 I

Employer	Course 450
Federal EPA	16%
Other Federal	5
State Government	12
Local Government	14
Industry	45
Consultant	6
Other	2

TABLE II

Occupation	Course 450
Administrator	3%
Chemist	14
Engineer	44
Ind. Hygenist	1
Phys. Scientist	3
Sanitarian	3
Technician	28
Other	4

TABLE III

Educational Background	Course 450
High School	24%
Bachelor	56
Master	18
PhD	2

TABLE IV

Years Experience	Course 450
0 - 1 years	48%
2 - 4	31
5 - 7	15
8 - 10	3
> 10	3

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:

	Percentile Rank
Verbal ability	78
Numerical	70
Spatial	35
Reasoning	51
Memory	47

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.

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

Day #3

Lesson #8	**Calculations and Interpretation of % Isokinetic**	1 hour 45 min
Lesson #9	Definition of a Particulate	15 min
Lesson #10	Discussion of Source Sampling Exercise	1 hr 15 min
Laboratory #3	RM5 Testing	3 hours

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 familar 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
6. Handout - reprint of article - Leland, Bernice J; Hall, Jerry L. "Correction of S-Type Pitot - Static Tube Coefficients When Used for Isokinetic Sampling from Stationary Sources." Environmental Science and Technology 11:694-700; July, 1977.
7. Handout - reprint of article - Midgett, M. Rodney. "How EPA Validates NSPS Methodology." Environmental Science and Technology 11:655 - 659; July 1977.
8. Handout - A Monograph - Shigehara, R. T. "A Guideline for Evaluating Compliance Test Results."
9. Handout - Calculation Form for Method 5 Particulate Test
10. Federal Register - Vol. 42, No. 160, August 18, 1977 "Standards of Performance for New Stationary Sources - Revision to Reference Methods 1-8."
11. Federal Register - Vol. 43, No. 37, February 23, 1978, Part V "Kraft Pulp Mills."

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:

Lesson 1	no slides	
Lesson 2	20 slides	L2-1a through 2-14
Lesson 3	no slides	Use L7-4, L7-5
Lesson 4	no slides	
Lesson 5	4 slides	L5-1 through L5-4
Lesson 6	21 slides	L6-1 through L6-21
Lesson 7	35 slides	L7-1 through L7-35
Lesson 8	12 slides	L8-1 through L8-12
Lesson 9	no slides	
Lesson 10	no slides	
Lesson 11	7 slides	L11-1 through L11-7
Lesson 12	6 slides	L12-1 through L12-6
Lesson 13	10 slides	L13-1 through L13-10
Lesson 14	no slides	
Lesson 15	3 slides	L15-1 through L15-3
Lesson 16	1 slide	L16-1
Lesson 17	6 slides	L17-1 through L17-6
Lesson 18	28 slides	L18-1 through L18-27

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.

____ 11. Obtain copies of EPA Manuals, and Pamphlets.

____ 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 and la [illegible] scriptions 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 new 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 similiar 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	folding 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
	miscl. 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" H_2O)
4	sets of manometer lines w/connectors
8	ring stands each with 3 finger clamps

WET BULB-DRY BULB EXPERIMENT

2 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

Acknowledgement
of role of other
agencies, if any,
in conduct or
support of
presentation.

Course location

Name of course
Director

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.

DAY & TIME	SUBJECT	SPEAKER
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	

DAY & TIME	SUBJECT	SPEAKER
WEDNESDAY (Continued)		
10:45	Discussion of Source Sampling Exercise 1. Experiment Design 2. EPA Method 5 3. Report Writing	
12:00	LUNCH	
12:45	Travel to Source Simulator	
1:00	Stack Test	
HOMEWORK:	Complete Stack Test Data Summary Form	
THURSDAY		
8:30	Concentration Corrections Class Problems	
10:00	Literature Sources	
10:30	F-Factor Method	
11:30	LUNCH	
12:15	1. Calculation Review - Hand in Stack Test Data Summary 2. Discussion of Laboratory Results 3. ERROR Analysis	
2:30	Source Sampling Quality Assurance and Safety on Site	
HOMEWORK:	Read Manual Selections	
FRIDAY		
8:30	Particle Sizing	
9:30	Transmissometers	
10:45	Post Test and Closing	

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 = .79?

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

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

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

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

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_s, 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% O_2, 14.2% CO_2, 0% CO, 79.6% N_2 and the % H_2O 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 $\Delta H_{@}$ 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^{o}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) x 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 Δp.
b. Orient the pitot tube parallel to the sides of the stack and the Δp 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 (Δp).
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 $\leq 40^{\circ}$
   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 = stack gas velocity

A_s = stack cross-sectional area

A_n = nozzle cross-sectional area

θ = sampling time (minutes)

V_m = standard volume metered at the dry gas meter

V_n = volume at stack conditions passing through the nozzle

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

a. $\% \text{ isokinetic} = \dfrac{A_s}{A_n} \times 100$

c. $\% \text{ isokinetic} = \dfrac{V_n}{\theta A_n v_s} \times 100$

b. $\% \text{ isokinetic} = \dfrac{V_n}{v_s A_s \theta}$

d. $\% \text{ isokinetic} = \dfrac{V_m}{\theta A_s v_s} \times 100$

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 $\leq 400^{\circ}F$

24. An Orsat analyzer is commonly used to determine the composition of a combustion effluent where N_2, 0_2, CO, and CO_2 are the principal constituents of the gas stream. It directly measures:

a. 0_2, N_2, CO, and $C0_2$

b. CO, $C0_2$, 0_2

c. $C0_2$, 0_2, N_2

d. N_2, 0_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. $C0_2$, 0_2, CO

b. 0_2, $C0_2$, CO, N_2

c. CO, 0_2, $C0_2$

d. N_2, 0_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 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. $$C_p = \frac{Q_s / A_s}{K_p \sqrt{\dfrac{T_s \Delta p}{P_s \; M_s}}}$$

b. $$C_p = \frac{Q_s / A_s}{K_p \sqrt{\dfrac{P_s \Delta p}{T_s \; M_s}}}$$

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

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

A_s stack cross-sectional area
C_p = pitot tube calibration coefficient
$C_{p(std)}$ = standard pitot-static tube calibration coefficient
K_p = dimensional constant
M_s = wet molecular weight of the gas
P_s = absolute pressure o the gas
Δp = pitot tube velocity pressure
$\Delta p(test)$ = test pitot tube velocity pressure
$\Delta p(std)$ = standard pitot static tube velocity pressure
Q_s = volumetric flow rate
T_s = absolute temperature 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. $M_d = \Sigma M_x B_x$

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} = 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})

a. $$B_{ws} = \frac{V_{wc}}{V_{wc} + V_m} + 0.02$$

b. $$B_{ws} = \frac{V_{wc(std)} + V_{wsg(std)}}{V_{wc(std)} + V_{sg(std)} + V_{m(std)}}$$

c. $$B_{ws} = \frac{1}{V_{wc} + V_m}$$

d. $$B_{ws} = 1 \left[- \frac{V_{wc}}{V_m} \right]$$

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

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 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 Δp is known, is:

$\Delta H = K \Delta p$.

34

ANSWER SHEET

Name ______________________________

Date ______________________________

1. a b c d
2. a b c d
3. a b c d
4. a b c d
5. a b c d
6. a b c d
7. a b c d
8. a b c d
9. a b c d
10. a b c d
11. a b c d
12. a b c d
13. a b c d
14. a b c d
15. a b c d
16. a b c d
17. a b c d
18. a b c d
19. a b c d
20. a b c d
21. a b c d
22. a b c d
23. a b c d
24. a b c d
25. a b c d
26. a b c d
27. a b c d
28. a b c d
29. a b c d
30. a b c d
31. a b c d
32. a b c d
33. a b c d
34. a b c d
35. a b c d
36. a b c d
37. a b c d
38. a b c d
39. a b c d
40. a b c d
41. T F
42. T F
43. T F
44. T F
45. T F
46. T F
47. T F
48. T F
49. T F
50. T F

ANSWER SHEET #450

Name KEY -- PRE-TEST

Date ____________

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

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_2O. 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. $0.998\ (0.7)^2$
   b. $0.998/\sqrt{0.7}$
   c. $0.998\ \sqrt{0.7}$
   d. $0.998/(0.7)^2$

February 14, 1980

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4. A Stack Test was performed at a wood fired boiler. The stack gas contained 10% H_2O 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 CO_2, O_2, and CO, dry gas molecular weight and percent excess air in the duct
   b. Percent excess air, CO_2, and volumetric flow rate (dry)
   c. Percent CO_2, O_2, 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 H_2O 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. $B_{ws} = \frac{V_{wc(std)} + V_{wsg(std)}}{V_{wc(std)} + V_{wsg(std)} + V_{m(std)}}$

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 sensors.
   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 $\Delta H \quad K \Delta p$, 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 Δp for the chosen sampling train. size.
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 ΔH from the observed Δp.
d. It is a type of slide rule used to determine a Δp from the observed ΔH.

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. $\Delta H_{@} = 0$
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 H_2O and CO_2
   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% CO_2 in the stack gas. What is the emission rate connected to 12% CO_2?

   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. $M_d = \Sigma M_x B_x$

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

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

   d. $M_s = M_d(1\text{-}B_{ws}) + B_{ws}$

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 Δp
   b. Orient the pitot tube parallel to the sides of the stack. The Δp reading is the upward vector of the velocity
   c. Measure the impact pressure and the static pressure separately and by difference obtain velocity head (Δp)
   d ll 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 lbs/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:

a. Would be rejected by EPA since it is not within ± 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 <u>false</u>.

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 = $\log_{10} \frac{1}{(1\text{-opacity})}$
b. transmittance/opacity = – naql
c. % opacity = 100% – % transmittance
d. % opacity = % transmittance – naql

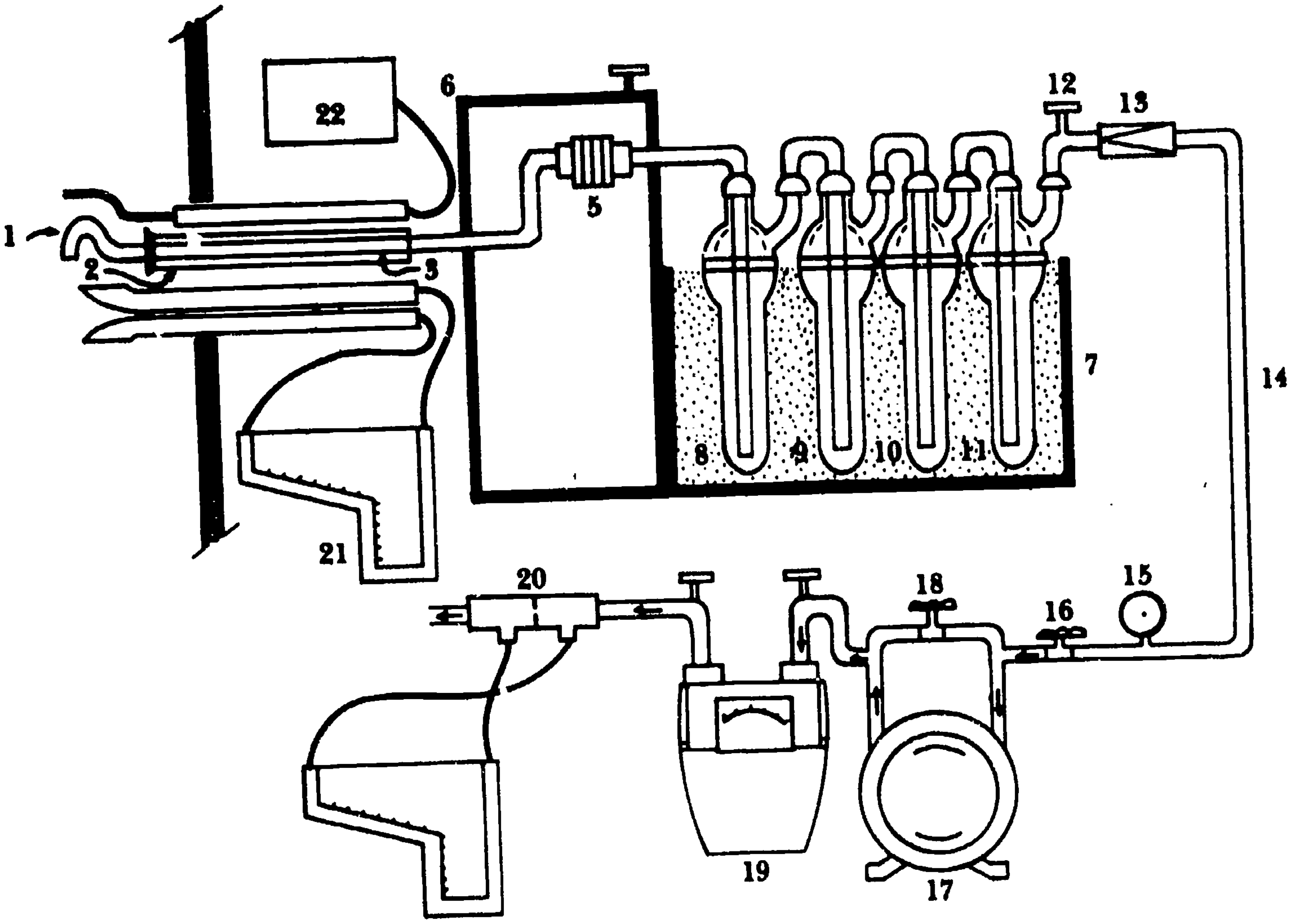
36. A transmissometer will provide information on mass emissions from a pollutant source for a given time period if:

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 .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 H_20, 2 – Dry, 3 – 100cc H_20, 4 – Silica Gel (100g)
b. 1 – 100cc H_20, 2 – 200cc H_20, 3 – Dry, 4 – Silica Gel (200g)
c. 1 – 100cc H_20, 2 – 100cc H_20, 3 – Dry, 4 – Silica Gel (200g)
d. 1 – 200cc H_20, 2 – 200cc H_20, 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 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. $\leq 250^\circ F$
b. $\geq 250^\circ F$
c. No greater than $248^\circ F \pm 25^\circ F$
d. $250^\circ F$

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 $68^\circ F$ and 29.92 in. Hg. These conditions are designated by a single term $\Delta H_@$. Solving the orifice meter flow rate equation for a $\Delta H_@$ that meets the stated conditions we find:

a. $\Delta H_@ = \dfrac{Q_m^{\ 2}}{K_m^{\ 2}}$

b. $\Delta H_@ = \dfrac{1}{K_m^{\ 2}}$

c. $\Delta H_@ = \dfrac{0.9244}{K_m^{\ 2}}$

d. $\Delta H_@ = \dfrac{Q_m}{K_m} \left[\dfrac{P_m}{T_m}\right]^2$

ANSWER SHEET #450

Name KEY -- POST TEST

Date ______________________

3 pts each

all others 2 pts

1. ● b c d
2. a ● c d
3. a b ● d
4. a ● c d
5. ● b c d
6. ● b c d
7. a b c ●
8. a b ● d
9. a b ● d
10. a ● c d
11. a b ● d
12. a ● c d
13. a b ● d
14. ● b c d
15. a ● c d
16. a b ● d
17. a b c ●
18. ● b ● d
19. a ● c d
20. ● b c d
21. a ● c d
22. a ● c d
23. ● b c d
24. a ● c d
25. a b c ●
26. ● b c d
27. a ● c d
28. a b c ●
29. a b ● d
30. a ● c d
31. ● b c d
32. a b ● d
33. a b c ●
34. a b c ●
35. a b ● d
36. a b c ●
37. a b ● d
38. a ● c d
39. a b ● d
40. a b ● d
41. ● b c d
42. a b ● d
43. a b c ●
44. ● b c d
45. a ● c d
46. a b ● d
47. ● b c d
48. a b ● 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.

$\therefore$ choose 12 traverse pts. Because the number has to be a multiple of 4.

	Sample Point Number		Circular Stack % Diameter	Distance from Sample Port Opening in.
1st Traverse Diameter	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"
2nd Traverse Diameter	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"

PROBLEM #2

$$v_s = K_p \, C_p \sqrt{\frac{T_s \Delta p}{P_s M_s}}$$

$K_p = 85.49$

$C_p = 0.845$

$T_s = 303 + 460 = 763\ ^{\circ}R$

$\Delta p = 0.15$

$P_s = 30.3''\ Hg$

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

$M_d = 0.44\ (14.2) + 0.32\ (5.0) + 0.28\ (80.8)$

$M_d = 6.248 + 1.6 + 22.62$

$M_d = 30.47$

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

$M_s = (30.47)(1-0.07) + 18(0.07)$

$= 28.34 + 1.26$

$= 29.59$

$$v_s = (85.49)(0.845) \sqrt{\frac{(763)(0.15)}{(30.3)(29.59)}}$$

$$= 72.24 \sqrt{\frac{114.45}{896.79}}$$

$$= 72.24 \sqrt{0.128}$$

$$= \boxed{25.81\ ft/sec.}$$

$$Q_s = 3600\ (1-B_{ws})\ v_s\ A \left(\frac{T_{std}}{T_{s(avg)}}\right)\left(\frac{P_s}{P_{std}}\right)$$

$$= 3600\ (1-0.07)(25.81)\ (A) \left(\frac{528}{763}\right)\left(\frac{30.3}{29.92}\right)$$

$\text{Diameter} = \frac{16''}{2} = 8''$ radius

$\text{Area} = \pi\ r^2$

$$= (3.14)(8)^2 = \frac{201\ sq.\ in.}{144\ sq.\ in./sq.\ ft} = 1.40\ ft^2$$

$$= 3600\ (1-0.07)(25.81)\ (1.40)\left(\frac{528}{763}\right)\left(\frac{30.3}{29.92}\right)$$

$$= 8.48 \times 10^4\ ft^3/hr.$$

$Q_A = (v_s)(A) = (25.65\ ft/sec)(1.40\ ft^2)$

$= 35.91\ ft^3/sec.$

$(35.91\ ft^3/sec)(3600\ sec/hr.) = \boxed{1.29 \times 10^5\ ft^3/hr.}$

PROBLEM #3

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

$K_p = 85.49$

$C_p = 0.842$

$T_s = 300 + 460 = 760\ ^{o}R$

$\Delta p = 2.5"\ H_2O$

$P_s = 30.1 + \left(\frac{-15.0}{13.6}\right)$

$= 28.99$

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

$\%\ CO_2 = 17$

$\%\ O_2 = 2$

$\%\ N = 100 - 19 = 81$

$= 0.44\ (17) + 0.32\ (2) + 0.28(81)$

$= 7.48 + .64 + 22.68$

$= 30.8$

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

$= (30.8)\ (1-0.12) + 18\ (.12)$

$= 27.10 + 2.16$

$= 29.26$

$$v_s = (85.49)(0.842)\sqrt{\frac{(760)(2.5)}{(28.99)(29.26)}}$$

$$= (71.9826)\sqrt{\frac{1900}{848.36}}$$

$$= (71.9826)(1.4965) = \boxed{107.72\ \text{ft/sec.}}$$

PROBLEM #4

H_2O collected in impingers: 75 ml

H_2O collected in the silica gel: 25 g

Volume = 40.20 ft^3

P_m = 30.0" Hg

T_m = 100 °F + 460 = 560 °R

(a) $V_{m(std)} = K_3 Y \dfrac{V_m P_m}{T_m} = (17.64)(1) \dfrac{(40.20)(30.0\text{" Hg})}{560}$

$= 37.991$ SCF

(b) $V_{wc(std)} = K_1 \; (V_f - V_i)$

$= (0.04707 \; ft^3/ml)\; (75 ml)$

$= 3.53 \; ft^3$

(c) $V_{wsg(std)} = K_2 \; (W_f - W_i)$

$= (0.04715 \;\; ft^3/g)(25 \; g)$

$= 1.18 \; ft^3$

(d) $B_{ws} = \dfrac{V_{wc(std)} + V_{wsg(std)}}{V_{wc(std)} + V_{wsg(std)} + V_{m(std)}}$

$= \dfrac{3.53 + 1.18}{3.53 + 1.18 + 37.99} = \dfrac{4.71}{42.70} = .1103$

$.1103 \times 100\% = 11.03\%$

PROBLEM #5

(a) $$C_{p(s)} = C_{p(std)} \sqrt{\frac{\Delta p_{(std)}}{\Delta p_{(s)}}}$$

$$= 0.99 \sqrt{\frac{0.31}{0.42}} = 0.851$$

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

$$= 0.44\ (13) + 0.32(6) + 0.28\ (80)$$

$$= 5.72 + 1.92 + 22.4$$

$$= \boxed{30.04\ \text{lb/lb-mole}}$$

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

$$= (1-.1)\ 30.04 + 18(.10)$$

$$= 27.036 + 1.8$$

$$\boxed{28.84\ \text{lb/lb-mole}}$$

(d) $$\bar{v}_s = K_p C_p \sqrt{\frac{T_{s(avg)}}{P_s M_s}} \sqrt{\Delta p}$$

$$= (85.49)(0.851) \sqrt{\frac{810}{(29.00)(28.84)}} \sqrt{0.59}$$

$$= (72.75)\left(\sqrt{\frac{810}{836.36}}\right)\left(\sqrt{0.59}\right)$$

$$= (72.75)\ (0.984)(0.768)$$

$$= \boxed{54.98\ \text{ft/sec}}$$

(e) $$Q_s = 3600\ (1-B_{ws})\ v_s\ A \left(\frac{T_{std}}{T_{s(avg)}}\right)\left(\frac{P_s}{P_{std}}\right)$$

$$= 3600\ (.9)(54.98)(1200) \left(\frac{528}{810}\right)\left(\frac{29.00}{29.92}\right)$$

$$= 3600\ (.9)(54.98)(1200)(.652)(0.969)$$

$$= \boxed{1.35 \times 10^8\ \text{DSCFH}}$$

PROBLEM #6

(a) $V_{m(std)} = K_1 Y V_m \dfrac{P_{Bar} + \dfrac{\Delta H}{13.6}}{T_m} = (17.64)(1)(50) \dfrac{(29.5) + \dfrac{1.5}{13.6}}{560}$

$= 46.64$ DSCF

$V_{ws} = K_1 (V_f - V_i)$

$= 0.04707\ (100) = 4.707$ SCF

(b) $B_{ws} = \dfrac{4.707}{4.707 + 46.64} = \dfrac{4.707}{51.343} = .0919$

$.0919 \times 100\% = 9.19\%$

(c) $C_s = \dfrac{100 \text{ mg}}{46.46 \text{ ft}^3} = \dfrac{.100}{46.46 \text{ ft}^3} = 0.00215 \text{ g/ft}^3$

$(0.0215 \text{ g/ft}^3)(15.43) = 0.033$ gr/DSCF

(d) $\%I = 100 \times \dfrac{T_s V_{m(std)} P_{std}}{T_{std} \bar{v}_s \bar{P}_s \theta \text{ min. } (60 \text{ sec/min}) A_n (1 - B_{ws})}$

$= 100 \dfrac{(760)(46.64)(29.92)}{(528)(48)(29)(60)(60)(.00034)(1-.0919)}$

$= \dfrac{1.06 \times 10^8}{8.17 \times 10^5} = 0.1297 \times 10^3$

$= 129.7\ \%I$

LESSON PLAN

AIR POLLUTION
TRAINING INSTITUTE

TOPIC: WELCOME AND REGISTRATION

COURSE 450 - Lecture 1
LESSON TIME: 30 minutes
PREPARED BY DATE 10/2/78
Giuseppe J. Aldina

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY

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 grad
    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

CONTENT OUTLINE

Course: 450 Lecture 1
Lecture Title: WELCOME AND REGISTRATION

Page 1 of 3

NOTES

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

CONTENT OUTLINE

Course: 450 Lecture 1
Lecture Title: WELCOME AND REGISTRATION

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY

Page 3 of 3

NOTES

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 PLAN

AIR POLLUTION TRAINING INSTITUTE

TOPIC: INTRODUCTION TO SOURCE SAMPLING

COURSE: 450 - Lecture 2
LESSON TIME: 1 hour - 15 minutes
PREPARED BY: J. A. Jahnke
DATE: 9/20/78

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. Define 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 flowrate, 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.

CONTENT OUTLINE

Course: 450 Lecture 2
Lecture Title: INTRODUCTION TO SOURCE SAMPLING

Page 1 of 5

NOTES

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

students to turn to page 3 workbook

- A. Symbols and terms - objectives
- B. Calculations
- C. Equipment familiarity
- D. Isokinetic sampling
- E. Doing the source test
- F. New methods

II. Methods of source sampling

- A. Methods of monitoring source emissions

slide L2-1a-f

Turn to page 14 of workbook

  - 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

L2-2

Diagram on page 18

- 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

L2-3
L2-4
L2-5
L2-6

III. Nomenclature

A. Symbols and subscripts

L2-7
L2-8

1. Review symbols and subscripts - defining important terms such as Δp, ΔH, $\Delta H_@$, etc.

Nomenclature on pages 10-13 of workbook

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

Write on chalkboard or OH projector

$$c_s = \frac{\text{quantity of pollutant (mass)}}{\text{quantity of effluent gas (volume)}}$$

units: grains/ft^3 lbs/ft^3 $\frac{\text{grams}}{M^3}$

note: 7000 grains = 1 lb

b) Stack gas volumetric flow rate $\overline{Q}_s$

Write on chalkboard

$$\overline{Q}_s = \frac{\text{quantity of effluent gas passing up stack (volume)}}{\text{time}}$$

$\frac{ft^3}{hr}$, etc.

$$Q_s = \underset{\text{area of stack}}{A_s}\ \underset{\text{stack gas velocity}}{v_s} = ft^2 \times \frac{ft}{hr} = \frac{ft^3}{hr}$$

c) Pollutant mass rate $\overline{pmr}_s$

$$\overline{pmr}_s = \frac{\text{quantity of pollutant (mass) passing up stack}}{\text{time}}$$

$$\frac{lbs}{hr}, \quad \frac{grains}{hr}, \quad \frac{grams}{hr}$$

d) Relationship of the three units

$$\overline{pmr}_s = \overline{c}_s \, \overline{Q}_s$$

$$= \underset{\uparrow \; \frac{m}{V}}{\frac{lbs}{\cancel{ft^3}}} \; \underset{\nwarrow \; A_s v_s}{\frac{\cancel{ft^3}}{hr}} = \frac{lbs}{hr}$$

Stress units and unit cancellation

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

$$E = \frac{\overline{pmr}_s}{Q_H} = \frac{\overline{c}_s \; \overline{Q}_s}{Q_H}$$

$$Q_H = \text{heat input rate} = \frac{10^6 \text{Btu}}{\text{Hr}}$$

See course manual Page 9-5

$$E = \frac{\frac{lbs}{\cancel{ft^3}} \; \frac{\cancel{ft^3}}{\cancel{hr}}}{\frac{10^6 \; Btu}{\cancel{hr}}} = \frac{lbs}{10^6 \; Btu}$$

f) Review of pollutant mass rate — L2-9

1. Refer to slide - pointing out the large number of variables in the test — Page 14 of workbook

2. Point out necessity for isokinetic sampling — L2-10

3. Point out pitot tube equation - make no attempt to derive - point out variables — L2-11

[Memorize]

Comes from Bernoulli's principle

$$v_s = \underset{\text{EPA M2}}{\underbrace{K_p C_p}} \sqrt{\frac{\overset{\text{M2}}{T_s}\,\overset{\text{M2}}{\Delta p}}{\underset{\text{M2}}{P_s}\,\underset{\text{M3 M4}}{M_s}}}$$

Will do these in the laboratory

4. Re-emphasize importance of emission rate calculation - This is the <u>END RESULT</u> — L2-12

$$E = \frac{c_s\,\bar{Q}_s}{\bar{Q}_H}.$$

IV. Gas physics - review of concepts

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

A. Ideal gas law

1. Important in course

$$PV = \frac{m}{M}RT \qquad PV = nRT$$

review terms $R = 21.83\ \frac{(\text{in. Hg})(\text{ft}^3)}{\text{lb-mole }^\circ\text{R}}$

Write on board

review mole concept

mole = molecular weight in grams or pounds

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

2. A trick

$$p = \frac{m}{V}\,\frac{RT}{M} = c\,\frac{RT}{M} \qquad c \equiv \text{concentration}$$

Ask students what c is

B. Correcting pressure or volume to standard conditions - very important

1. Do this derivation

$$V_{\substack{corr\\to\\std}} = nR\frac{T_{std}}{P_{std}} \qquad V_{stack} = nR\frac{T_s}{P_s}$$

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

12-13

$$\frac{V_{corr}}{V_s} = \frac{\dfrac{nRT_{std}}{P_{std}}}{\dfrac{nR\,T_s}{P_s}} = \frac{P_s\,T_{std}}{P_{std}\,T_s}$$

$$V_{corr} = V_s\,\frac{P_s\,T_{std}}{P_{std}\,T_s}$$

Very important to understand this - essential for understanding operation of Method 5 train

C. Other terminology of gas physics

12-14

1. Bernoulli's principle

$$1/2\ m\Delta v^2 + mg\,\Delta h + V\Delta p = 0$$

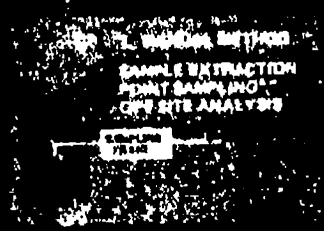
Pitot tube equation derived from this expression

2. Viscosity - μ

3. Reynolds' number - N_{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 easing off
Note: Students who have had no previous experience in source sampling will forget what [illegible] or E mean, by Tuesday afternoon-Review the definitions on occasion throughout the course.

12/79 450 LESSON 2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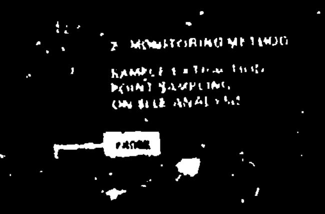
SAMPLE EXTRACTION
POINT SAMPLING
OFF SITE ANALYSIS

1a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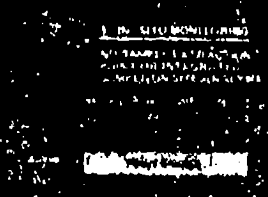
SAMPLE EXTRACTION
POINT SAMPLING
ON SITE ANALYSIS

1b


3. IN SITU MONITORING

1c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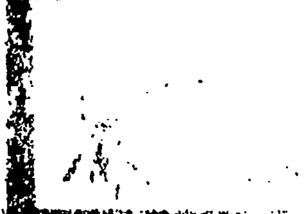

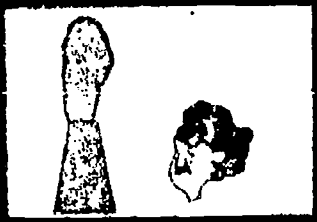
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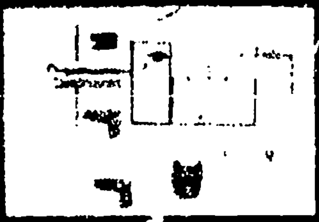
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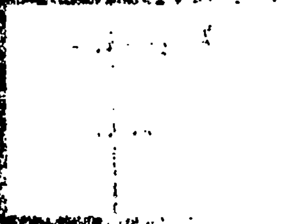

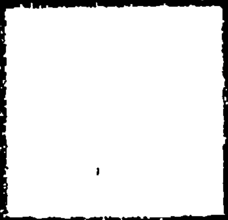
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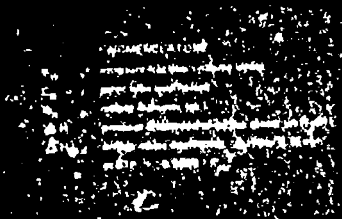
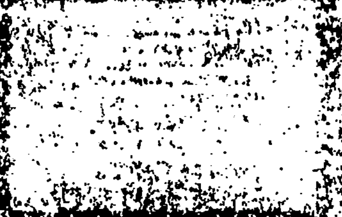

NOMENCLATURE

7


7a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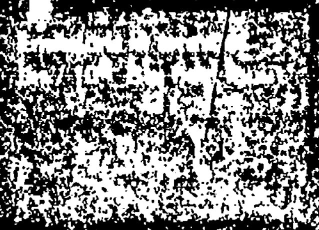
ISOKINETIC CONDITION

10


11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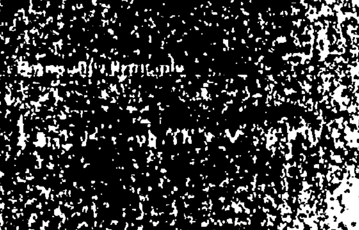
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LESSON PLAN

AIR POLLUTION TRAINING INSTITUTE

TOPIC: EPA METHOD 5 SAMPLING TRAIN

COURSE: 450 - Lecture 3
LESSON TIME: 1 hour
PREPARED BY: Giuseppe J. Aldina
DATE 9/15/78

UNITED STATES · ENVIRONMENTAL PROTECTION AGENCY ·

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 nomograph 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:

Federal Register - Vol. 42, No. 160, August 18, 1977. "Standards of Performance for New Stationary Sources - Revision to Reference Methods 1-8."

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 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 nomograph and calculator

CONTENT OUTLINE

Course: 450 Lecture 3
Lecture Title: EPA Method 5 Sampling Train

NOTES

I. The Sampling Nozzle

Ref. FR 8/18/77 page 41777, paragraph 2.1.1 and p 41781 paragraph 5.1 (Calibration)

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

Show nozzle during discussion and illustrate calibration

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 41764 FR 8/18/77)

L3-1

(use slide L7-4)

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

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

L3-2
(use slide L7-5)

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.

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.

illustrate points discussed with a sampling probe

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

Refer to RM 2 discussion of pitot tube misalignment error

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

Compare Nutech Probe - Sample Case interface to some other. Nutech System works very well.

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

Reference: page 41777 FR 8/18/77, paragraph 2.1.2

A. Must be borosilicate or quartz glass tubing

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

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

Nutech Sample case incorporates many of these features. It is good for class illustrations.

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 ± $3^{o}C$ ($5.4^{o}F$))

    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 PLAN

TOPIC: DISCUSSION OF LABORATORY EXERCISES

COURSE: 450 - Lecture 4
LESSON TIME: 90 minutes
PREPARED BY: DATE: 10/2/78
Giuseppe J. Aldina

4

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
2. Blackboard and chalk
3. slide projector
4. 450 workbook

Special Instructions:

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

References:

Federal Register - Vol. 42, No. 160, August 18, 1977. "Standards of Performance for New Stationary Sources - Revision to Reference Methods 1-8."

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

CONTENT OUTLINE

Course: 450 Lecture 4
Lecture Title: Discussion of Laboratory Exercises

Page 1 *of* 10

NOTES

I. Reference Method 1

Lab exercise covered on page 21 in the workbook

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:

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

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

A description is covered in the procedures section of this lecture (E1).

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

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

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

This should remain simple - try not to get bogged down in fluid dynamics

b. The layer of gas above the boundary layer proceeds to give up some energy contacting the slower more viscous boundary layer

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

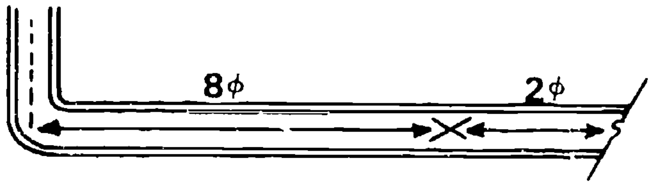
   a. Velocity head profile is assumed to resemble Laminar conditions

   b. The minimum number of sample points may be used

Note: Laminar flow may not exist ever but at 8ϕ and 2ϕ the assumption is made that the flow reasonably resembles Laminar

3. Draw flow disturbance at 8ϕ and 2ϕ

ϕ = diameter



Point out that these are minimum criteria. There can be more than 8ϕ and 2ϕ

When sampling at this point the minimum # of pts may be used - 12 pts.

4. When sampling at a site other than 8ϕ and 2ϕ

    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 2ϕ downstream and 0.5ϕ 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

    Use pitot tube for demonstration; See page 41758 (directly below Figure 1.4)

        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° 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

a. Choose the most convenient site

b. 8ϕ and 2ϕ not always possible

c. 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 <u>upstream</u> and <u>downstream</u> 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.

Refer to Figure 1-3 on page 41758.

   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 ϕ by the decimal % shown

EXAMPLE:

duct ϕ = 100 cm

total traverse pts = 12

traverse pts/diameter = 6

1st pt = 100 cm x 0.044 = 4.4 cm from stack wall into the duct

2nd pt = 100 cm x 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

Refer to page 41757 paragraph 2.3.1 for details

6. 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

$$D_E = \frac{2\ LW}{L+W}$$

3. Determine the duct diameters of straight run

4. Use the appropriate graph on page 41756 to determine No. of traverse pts.

5. Refer to Table 1-1 for the required Balanced Matrix

Check 450 workbook problem section which describes balanced matrix procedure page 165

II. Calibration of the "S" type pitot tube

Lab exercise covered on page 24 in the workbook

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 Prandtl 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 m/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

workbook page 26

C. Procedures

1. Record identification numbers of all equipment used

2. Level and zero the manometer

3. 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) H_2O.
   - 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

Make sure students keep all pitots properly level and aligned in the duct.

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

15. Calculate

a. C_p for the "S" tube for each reading

$C_{p(std)} = 0.99$

$$C_{p(s)} = C_{p(std)} \sqrt{\frac{\Delta p_{(std)}}{\Delta p_{(s)}}}$$

b. Calculate average Cp for leg A and leg B

c. Average deviation for leg A and B

$$\sigma = \frac{\Sigma \left| C_{p(s)} - \bar{C}_p \right|}{3} \leq 0.01$$

d. Deviation between leg A and B

$$\sigma = \left| \bar{C}_{p_A} - \bar{C}_{p_B} \right| \leq 0.01$$

16. Calculate

a. velocity (m/sec)

M_s = 29 for dry air

$$\bar{v}_s = K_p C_p \sqrt{\frac{T_s}{P_s M_s}} \quad \sqrt{\Delta p}_{avg}$$

b. Volumetric flow rate (m^3/Hour)

Assume $B_{ws} = 0$ for this calculation

$$Q_s = 3600 \, (v_s) \, A_s \, (1 - B_{ws}) \left(\frac{T_{std}}{P_{std}} \right) \left(\frac{P_s}{T_s} \right)$$

page 27 in workbook

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 H_2O content of the stack gas

B. The % H_2O in the stack is by Dalton's Law of Partial Pressure

1. $B_{ws} = \frac{V.P._{H_2O}}{P_{abs}}$ Ratio of component partial pressure to total system pressure

2. The workbook shows the calculation for the actual $V.P._{H_2O}$ using knowledge of

a. The saturated V.P.$_{H_2O}$ at constant temperature and pressure

b. Latent heat of vaporization for H_2O

Note: The wet bulb-dry bulb procedure does not work in acid gas streams

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 B3. Cross check procedures for agreement if interested

IV. Orifice Meter Calibration

A. APTD - 0576 calibration procedures is recommended calibration for

workbook page 33

1. Orifice meter

2. Dry gas meter

B. Laboratory exercise will differ only slightly

The lab procedure works well when the DGMCF is known. Assume DGMCF = 1 for these lab

1. Wet test meter will not be used

2. Dry gas meter correction factor (DGMCF) has been determined against a spirometer

3. We will calibrate orifice meter for the desired flow rate

C. Orifice meter $\Delta H_@$ 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^oF.

D. Workbook shows equations used

Workbook page 33

1. $$Q_m = K_m \left[\frac{T_m\ {}^oR\ \Delta H}{P_m\ M_m}\right]^{1/2}$$

2. Solving for ΔH at given conditions

$$\Delta H_@ = \left(\frac{0.75\ \text{CFM}}{\text{Km}}\right)^2 \frac{(29.92)\ (29)}{528} = \frac{0.9244}{K_m^{\ 2}}$$

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_2O 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

Experience has shown this is very true

2. DO NOT become discouraged

B. Laboratory will be

1. Hectic

2. Noisy

C. Instructors will help with all problems

D. You will get as much out of the lab as you put in so apply yourself

E. Be sure to read the workbook carefully. You will be doing:

1. Site pre-survey - fill out forms

Reference Method 1 - complete all drawings

Either have students do this for the best possible situation at the duct or for condition existing

CONTENT OUTLINE

Course: 450 Lecture 4

Lecture Title: Discussion on Laboratory Exercises

Page 10 of 10

NOTES

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 PLAN

AIR POLLUTION
TRAINING INSTITUTE

TOPIC: ISOKINETIC SOURCE SAMPLING

COURSE 450 - Lecture 5
LESSON TIME 1 hour 15 minutes
PREPARED BY
J. A. Jahnke
DATE 9/20/78

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY

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

CONTENT OUTLINE

Course: 450 Lecture 5
Lecture Title: Isokinetic Source Sampling

NOTES

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 $\Delta H_@$? — students did this Monday laboratory, but were not formally presented with it in lecture.

$$Q_m = K_m \sqrt{\frac{T_m \Delta H}{P_m M_m}}$$

$$\Delta H_@ = \frac{Q_m^2}{K_m^2} \frac{P_m M_m}{T_m}$$

$$\Delta H_@ = \frac{(.75)^2}{K_m^2} \frac{(29.92)\,(29.0)}{(460 + 68)}$$

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?

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.

L5-1

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

II. Isokinetic sampling

A. Definitions and principles

1. Isokinetic

a. "Iso" - denotes equality, similarity, uniformity

b. "kinetic" - pertains to motion

L5-2
Turn to page 45 of workbook.

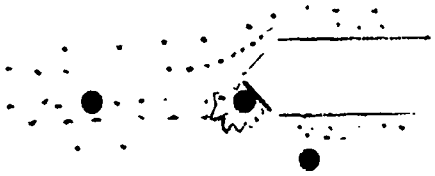
c. Isokinetic sampling is where velocity of gas through probe nozzle is equal to stack gas velocity

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.



Draw on chalk board

   d. This is watered down aerodynamics for purpose of this lecture – a large particle >5 μm in diameter – small particle <1 μm in diameter (This corresponds with EPA's feelings for large and small particle definitions – but you may get some argument)

B. The Example

Refer back to I.5-2

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 .03

$v_n = v_s$

Mass rate $= M_n = (4x6)+(3x.03)\ \frac{\text{mass units}}{\text{minute}}$

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

$\therefore \text{concentration} = \frac{\text{mass rate through nozzle}}{\text{volumetric flow rate through nozzle}}$

$$= \frac{24.1 \text{ mass units}/\cancel{\text{minute}}}{1 \text{ ft}^3/\cancel{\text{minute}}}$$

$$= 24.1\ \frac{\text{mass units}}{\text{ft}^3}$$

2. 200% Isokinetic L5-3

Larger volume collected per unit time - large particles not sliced out by nozzle, are lost. All smaller particles in volume are collected.

$v_n = 2v_s$

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

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

$$= \frac{24.2}{2} = 12.1\ \frac{\text{mass units}}{\text{ft}^3}$$

Over isokinetic sampling gives concentration lower than true

3. 50% Isokinetic L5-4

Smaller volume collected per unit time large particles don't follow streamlines, but punch into nozzle.

$v_n = \frac{1}{2}\ v_s$

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

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

$$= 48.2\ \frac{\text{mass minutes}}{\text{ft}^3}$$

Under isokinetic sampling gives higher concentration than true.

4. Generalizations;

   a. 100% Isokinetic gets representative particulate distribution on filter

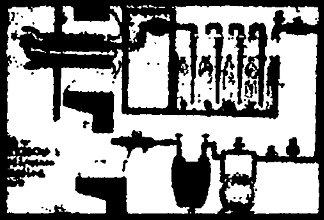
   b. Over isokinetic -get lower weight of particles per amount of volume due to loss of large particles through inertia effects.

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 $v_n = v_s$?

Go immediately on to next lecture. Class should still be fresh and interested. Don't take a break, or attention will be lost.



91/92

LESSON PLAN

AIR POLLUTION TRAINING INSTITUTE

TOPIC: THE ISOKINETIC RATE EQUATION

COURSE: 450 - Lecture 6
LESSON TIME: 1 hour 15 minutes
PREPARED BY: J. A. Jahnke **DATE** 9/20/78

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_n must equal v_s, 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 ΔH, given the appropriate input data, using a calculator or a slide rule
7. Calculate values of D_n, K, and ΔH 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 ΔH 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

Course: 450 Lecture 6

Lecture Title: The Isokinetic Rate Equation

L6-1

I. Derivation of the Isokinetic Rate Equation

A. $\Delta H = K \Delta p$ — The relationship between v_s and v_n. Note that get Δp from pitot tube — Set the ΔH 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 Δp?
   Ans. - red
2. On what oil manometer do we read ΔH?
   Ans. - Yellow oil manometer
3. How is the ΔH set? Ans. - with fine control knob. (students should know this from lab, but ∿ ½ the class will not understand it yet)

This is the core o course. Once the student understands this concept, he is half way home to doing the method. Slower students may not grasp this until Wednesday afternoon.

L6-2

B. $Q_n = A_n v_n = A_n v_s$ under isokinetic conditions

What is the area of the nozzle?

$$A_n = \pi \left(\frac{D_n}{2} \right)^2$$

Therefore

$$Q_n = \frac{\pi D_n^2}{4} v_s$$ is the volumetric flow rate through the nozzle

L6-3

C. What is the volumetric flow rate through the orifice meter?

$$Q_m = k_m \sqrt{\frac{T_m \Delta H}{P_m M_m}}$$

This equation was used in Monday afternoon lab and should have been reviewed in 1st ½ hour Tuesday morning

L6-4

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

$$P_s V_n = n_s R T_s \qquad P_m V_m = n_m R T_m$$

$$n_s = n_m \text{ (since have no } H_2O)$$

$$V_n = \frac{P_m}{P_s} \frac{T_s}{T_m} V_m \text{ or } Q_n = \frac{P_m T_s}{P_s T_m} Q_m$$

E. Now, if stack contains moisture

L6-5

$$n_s (1 - B_{ws}) = n_m (1 - B_{wm})$$

$n_s (1 - B_{ws}) = n_m$ 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 $(1 - B_{ws})$ times n_s, gives n_m.

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

L6-6

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

Since

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.

$$P_s V_n = n_s R T_s \qquad P_m V_m = n_m R T_m$$

$$n_s = \frac{(1 - B_{wm})}{(1 - B_{ws})} n_m$$

$$P_s V_n = \frac{(1 - B_{wm})}{(1 - B_{ws})} n_m R T_s$$

$$\text{but } n_m = \frac{P_m V_m}{R T_m}$$

therefore

$$\left[\begin{aligned}
P_s V_n &= \frac{(1 - B_{wm})}{(1 - B_{ws})} \frac{P_m V_m}{\cancel{R} T_m} \cancel{R} T_s \\[1em]
V_n &= \frac{(1 - B_{wm})}{(1 - B_{ws})} \frac{P_m T_s}{P_s T_m} V_m \\[1em]
Q_n &= \frac{(1 - B_{wm})}{(1 - B_{ws})} \frac{T_s}{T_m} \frac{P_m}{P_s} Q_m
\end{aligned}\right]$$

G. Solution is then:

$$Q_n = \frac{(1 - B_{wm})}{(1 - B_{ws})} \frac{T_s P_m}{T_m P_s} K_m \sqrt{\frac{T_m \Delta H}{P_m M_m}}$$

substituting for Q_m

H. Now substitute for Q_n L6-8

$$\frac{\pi D_n^2}{4} v_s = \frac{(1 - B_{wm})}{(1 - B_{ws})} \frac{T_s P_m}{T_m P_s} K_m \sqrt{\frac{T_m \Delta H}{P_m M_m}}$$

I. What is the pitot tube equation? L6-9

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

J. Substitute L6-10

$$\frac{\pi D_n^2}{4} K_p C_p \sqrt{\frac{T_s \Delta p}{P_s M_s}} = \frac{(1-B_{wm})}{(1-B_{ws})} \frac{T_s}{T_m} \frac{P_m}{P_s} K_m \sqrt{\frac{T_m \Delta H}{P_m M_m}}$$

K. Simplifying L6-11

$$\Delta H = \left\{ D_n^4 \left(\frac{\pi K_p C_p}{4K_m} \right) \frac{(1-B_{ws})^2}{(1-B_{wm})^2} \frac{M_m}{M_s} \frac{T_m P_s}{T_s P_m} \right\} \Delta p$$

L. Note moisture relationships for molecular weight L6-12

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

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

M. Substitute to obtain Isokinetic rate equation L6-13

$$\Delta H = \left\{ D_n^4 \left(\frac{\pi K_p C_p}{4K_m} \right)^2 \frac{(1-B_{ws})^2}{(1-B_{wm})^2} \left[\frac{M_d(1-B_{wm}) + 18\, B_{wm}}{M_d(1-B_{ws}) + 18\, B_{ws}} \right] \frac{T_m P_s}{T_s P_m} \right\} \Delta p$$

N. Now want to get above equation into a working form using all of our constants and variables /L6-14

Define $\Delta H_@$ as the orifice pressure differential that gives 0.75 cfm of air at 68°F and 29.92"Hg

O. Substitute values into orifice meter equation L6-15

$$\Delta H = \frac{Q_m^2}{K_m^2} \frac{P_m}{T_m} M_m$$

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

$$\Delta H_@ = \frac{.9244}{K_m^2}$$

P. Assume the following

L6-16

$B_{wm} = 0$

$\Delta H_@ = \frac{.9244}{K_m^2}$

$K_p = 85.49$

Q. Isokinetic rate equation working form

L6-17

$$\boxed{\Delta H = \left\{846.72\ D_n^4 \Delta H_@ C_p^2\ (1-B_{ws})^2 \frac{M_d}{M_s}\ \frac{T_m}{T_s}\ \frac{P_s}{P_m}\right\} \Delta p}$$

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

L6-18

$$\boxed{D_n = \sqrt{\left(\frac{0.035\ \ Q_m P_m}{T_m C_p}\right) \frac{(1-B_{wm})}{(1-B_{ws})} \sqrt{\frac{T_s M_s}{P_s \Delta p}}}}$$

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

Do not take a break

Ans:

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

$M_s = 29\ (1-.12) + 18\ (.12) = 27.7$

$$D_n = \sqrt{\left(\frac{0.0357\ Q_m P_m}{T_m C_p}\right) \frac{1}{(1-B_{ws})} \sqrt{\frac{T_s M_s}{P_s \Delta p}}}$$

$$= \sqrt{\frac{(0.0357)\ (.75)\ \ (30.0)}{(540)\ (.85)}\ \frac{1}{.88}\ \sqrt{\frac{(740)\ 27.7}{(29.6)\ (.80)}}}$$

$= \quad .241$

choose .25" nozzle

then

$$\Delta H = \left[846.72\, D_n^{\,4} \Delta H_@ C_p^{\,2}\, (1-B_{ws})^2 \frac{M_d}{M_s} \frac{T_m}{T_s} \frac{P_s}{P_m}\right] \Delta p$$

$$= \left\{846.72\, (.25)^4\, 1.85 (.85)^2 (.88)^2 \frac{29}{27.7} \left(\frac{540}{740}\right) \left(\frac{29.6}{30.0}\right)\right\} \Delta p$$

$$= 2.59\ \Delta p$$

$$\Delta H = 2.59\ \Delta p$$

Tell the class to choose a .25" nozzle after they have completed the first part of this calculation

T. Ask questions:

What do you do if Δp = 1.0
.80
.60

Say if moving probe from traverse point to traverse point – get new Δp's at each point, calculate and set new ΔH's at each point.

How do you set the ΔH?

Now take a break. Have each student pick up a nomograph during the break.

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

C_p = .85

T_m = 530°R

$\Delta H_@$ = 1.84" H_2O 100

$P_s = P_n = 29.92''\text{Hg}$

$M_d = 29.0$

$B_{ws} = .05$

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

L6-19

a. C factor corrects for $\Delta H_@$, T_m, % 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

Ask students value of C factor they obtain.

C should = .91 or .92

2. Turn nomograph over – compute nozzle diameter

$D_n = .241$

3. Compute K and ΔH using nomograph and choosing nozzle diameter of .25"

L6-20
work along with students. Ask students for values obtained.

K = 2.59 when Δp is set = 1

Show use of nomograph to obtain ΔH from Δp's

4. Nomograph check for scale alignment. Fill in table given in slide

L6-21
Ask for student comments.

D. Errors in calculating ΔH

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 ΔH 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

    a. Available through Radar - Glass Innovations.

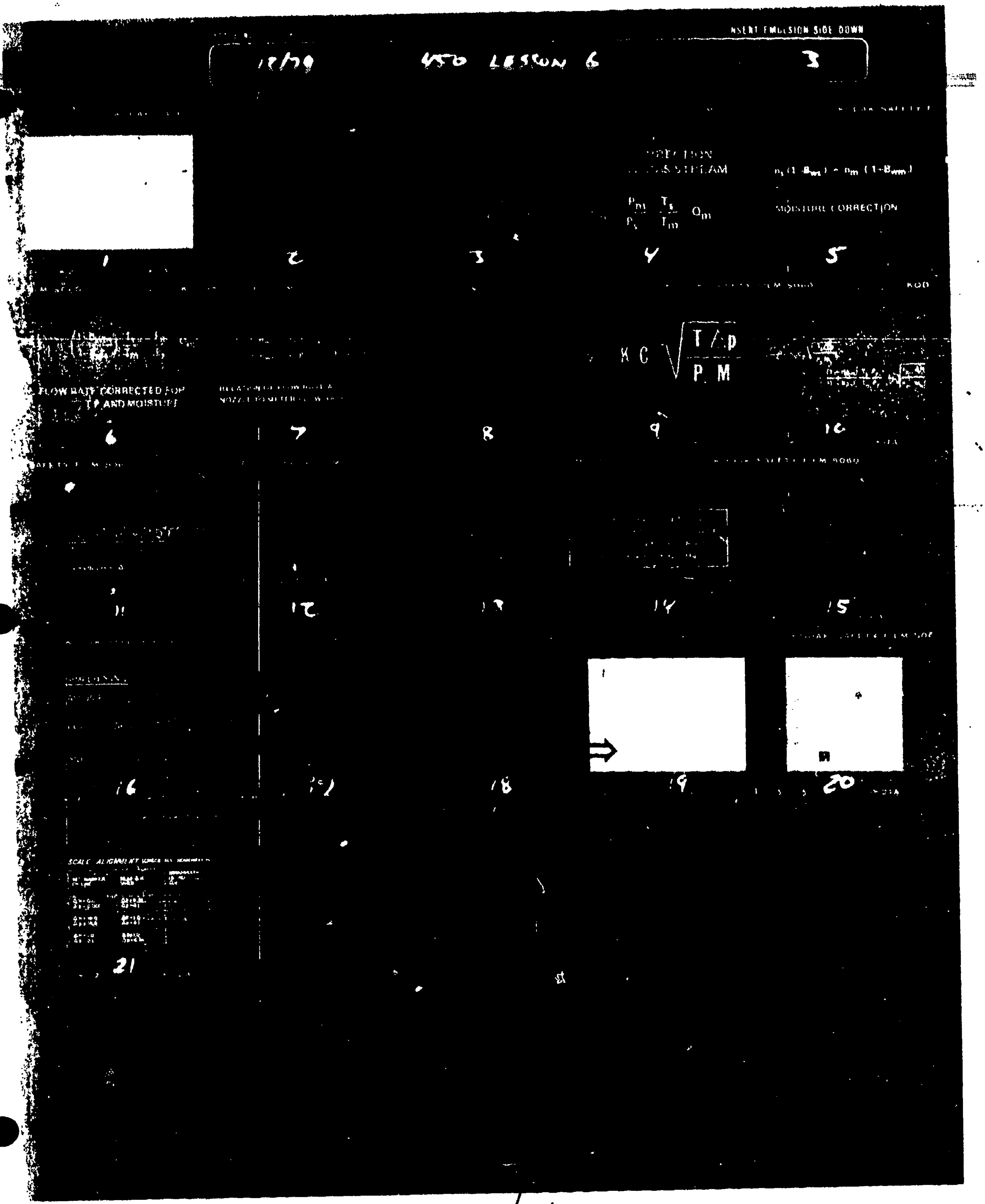
    b. Expensive.

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

5. Choice of ΔH 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.



INSERT EMULSION SIDE DOWN

12/79 450 LESSON 6 3

$$\frac{P_m}{P_s}\,\frac{T_s}{T_m}\,Q_m$$

$n_s(1-B_{ws}) = n_m(1-B_{wm})$

MOISTURE CORRECTION

1 2 3 4 5

$$K\,C\sqrt{\frac{T/p}{P\,M}}$$

FLOW RATE CORRECTED FOR T, P AND MOISTURE

6 7 8 9 10

11 12 13 14 15

16 17 18 19 20

SCALE ALIGNMENT

21

LESSON PLAN

TOPIC: **Review RM1; RM2; RM4; RM3**

COURSE: 450 Lecture 7
LESSON TIME: 2 hours 30 minutes
PREPARED BY: DATE:
Giuseppe J. Adlina 10/2/78

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 Profesional 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:

Federal Register - Vol. 42, No. 160, August 18, 1977. "Standards of Performance for New Stationary Sources - Revision to Reference Methods 1-8."

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 CO_2, 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.

CONTENT OUTLINE

NOTES

Course: 450 **Lecture** 7

Lecture Title: Review RM1; RM2; RM4; RM3

I. Review of RM1 procedures

(The review should be done with the instructor drawing the schematic diagrams necessary for RM1 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

$$\bar{v}_s = K_p C_p \sqrt{\frac{T_s}{P_s M_s}} \cdot \left[\Delta p\right]^{\frac{1}{2}}_{\text{Average}}$$

Note: v_s may be approximated

Assuming $P_s = 30$;
$M_s = 30$
$C_p = 0.85$
$v_s = 2.46\sqrt{T_s \Delta p}$

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

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

B. Applicability

1. Not applicable to sampling sites that do not meet RM1 criteria

2. If cyclonic flow exists

   a. Install gas straightening vanes

   b. Calculate the total volumetric flowrate stoichiometrically

   c. Move to another sampling site

109

C. Standard or Prandtl Pitot tube design specifications

Slide L7-1

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 it 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

Note: It is more convenient and clearer to students to refer to C_p as the calibration coefficient

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

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

Slide L7-2

2. The Federal Register describes

   a. Proper tube alignment

   b. Appropriate sizes of tubing for construction

   c. Preferred plane of the orifice openings

Slide L7-3

   d. Proper configuration with the probe and sampling nozzle to minimize aerodynamic interferences

Slides L7-4

L7-5

3. When all construction and placement requirements are met the baseline coefficient C_p for the "S" type may be assumed to be 0.84. (Refer to FR page 41764, paragraph 4.1 and 4.1.1)

Note: FR language states "eliminate" interferences, references specifically state "minimize"

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?

Students should recognize the need for calibration of the "S" tube C_p.

E. Calibration of the "S" type tube

Slide L7-6

1. Equipment

L7-7
L7-8

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 (2000ft/min) or about 30-40 ft/sec

b) 4 pt. calibration - variable from 180-1525 m/min(600-5000ft/min) at regular intervals

Note The single pt. calibration is accurate to ±3% above 305m/min and ± 6% from 180-305 m/min. A 4 pt. calibration is therefore preferable

b. Pitot tubes

L7-9

Inclined manometer - sensitivity is stated in paragraph 2.8 FR page 41762

L7-10 - No need to dwell on sensitivity just refer students to FR if necessary.

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.

L7-11; L7-12

2. Procedures

   a. Check for duct blockage

$$2\% \geq \frac{\left(\begin{array}{l}\text{length of Probe}\\ \text{in duct}\end{array}\right) \times \left(\begin{array}{l}\text{Probe}\\ \text{diameter}\end{array}\right)}{\text{Duct area}} \times 100$$

   b. Check for cyclonic flow - pitot tube may be used as in [illegible]R 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 Δp — L7-21

   g. Insert leg A of the "S" tube and record ΔP — L7-22

   h. Repeat this procedure for leg B

   i. Collect 3 sets of readings for leg A and B at each velocity used for the calibration — L7-23, 24, 25

   j. Plot the data for the readings — L7-26

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

$$C_p = \sqrt{\frac{1}{K}}$$

      b. K plotted against Reynold's Number gives a very detailed description of all gas parameters

      c. It is sufficient for source sampling purposes to plot K versus gas velocity — L7-27

3. Misalignment errors

   a. During the course to this point we have mentioned misalignment errors

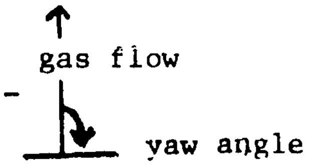
      L7-28

      L7-29

      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

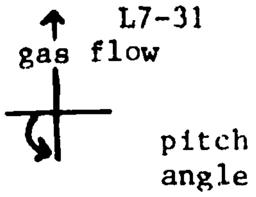
      L7-30

      2) Turning the pitot tube out of perpendicular - giving it a yaw angle - produces velocity measurement errors



L7-31

      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 ΔP readings we would get using an "S" type tube and rotating it through 90° of yaw angle we can plot the data

      L7-32

      L7-33

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

This should strongl point out to the student the need for careful alignment of the "S" tube and the problems caused by cyclonic flow.

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 follow 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 H_2O removed is measured volumetrically or gravimetrically

B. Appliciability

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 H_2O 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 H_2O 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 H_2O droplets

    a. Under these conditions a second H_2O determination is made

    b. The second H_2O 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 H_2O in the gas

        2) Quick

        3) Only H_2O in Method 5 is actual RM H_2O so wet bulb-dry bulb is a good way to

            a) Save time

            b) Get H_2O estimate for nomograph calculations

            c) Could be used as 2nd method for H_2O 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 = $0.021 m^3/min$ (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 alot 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

$$V_{wc(std)} = K_1 (V_f - V_1)$$

$$K_1 = 0.04707 \text{ ft}^3/\text{ml}$$

$$K_1 = 0.001335 \text{ m}^3/\text{ml}$$

5. The same equation is solved to convert grams of H_2O caught in the silica gel to vapor with the simplified equation written:

$$V_{wsg(std)} = K_2 (W_f - W_1)$$

$$K_2 = 0.04715 \text{ ft}^3/\text{ml}$$

$$K_2 = 0.001335 \text{ m}^3/\text{ml}$$

6. The dry gas volume metered at standard conditions is

$$V_{m(std)} = V_m \frac{\left(P_{bar} + \frac{\Delta H}{13.6}\right)\left(T_{std}\right)}{P_{(std)} \; T_m}$$

This is the equation in the Federal Register. To be completely correct it should include a dry gas meter correction factor (Y

7. The mole fraction of H_2O is then

$$B_{ws} = \frac{V_{wc(std)} + V_{wsg(std)}}{V_{wc(std)} + V_{wsg(std)} + V_{m(std)}}$$

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

Note: Tell the class that we will cover the sample procedure and calculations then go to the lab to practice the Orsat

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

2. The sample is analyzed for CO_2, O_2, CO using an Orsat analyzer or Fyrite

Slides
L7-34 = Orsat
L7-35 = Fyrite

   a. The Orsat must be used for

      1) Excess air calculations

      2) Emission rate calculations based on the F-Factor

F-Factor:

$$E = C_s F_d \left[\frac{20.9}{20.9-\%O_2}\right]$$

covered later in the course

   b. Fyrite may be used when only the dry molecular weight of the gas is needed

B. Applicability

1. Applicable for CO_2, O_2, 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 administator approval

C. Procedures - Emission Rate and Excess Air

1. Check the FR subparts for appropriate procedure

   a. Single pt. grab sample → Sample probe no closer than 1 meter to stack wall

   b. Multi pt. integrated sample

   c. Multi pt. grab sample

   (b and c) → At least 8 traverse pts in the duct. Follow RM1 procedures

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

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

   See workbook Page 67

      1) Bring bubbler solutions to reference marks

      2) Bring burette solution to mid scale and record reading

      This requires thorough instructor explanation

      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) CO_2 read directly as $\%CO_2$

      2) O_2 is cumulative so

         $\%O_2 = (CO_2 + O_2) - \%CO_2$

      3) CO is also cumulative so

         $\% CO = (CO_2 + O_2 + CO) - (\%O_2 + \%CO_2)$

      4) N_2 is determined by difference

         $100 - (CO_2 + O_2 + CO) = \% N_2$

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)

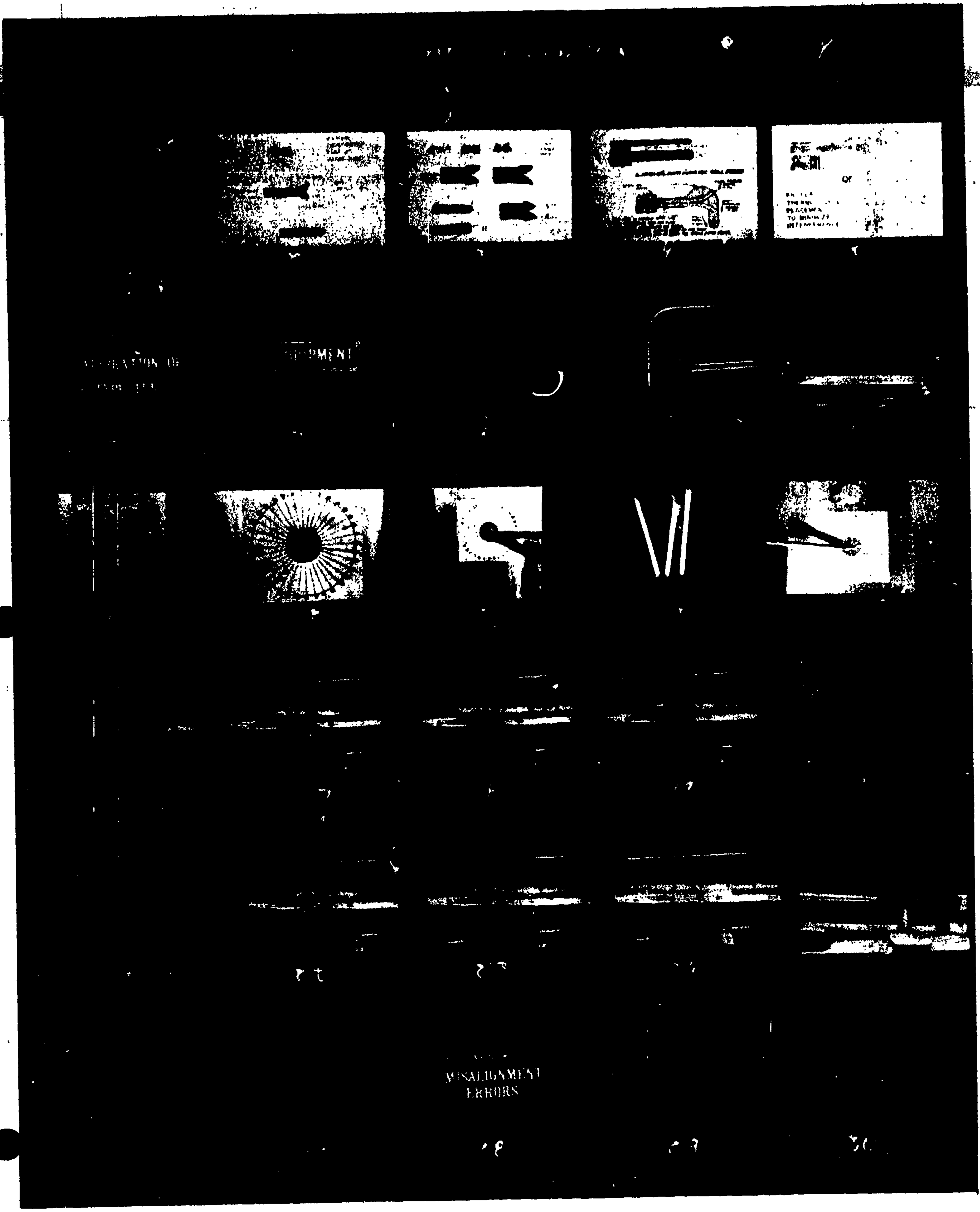
$$M_s = M_d(1-B_{w_s}) + 18(B_{w_s})$$

3. % Excess Air

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

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

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.


MISALIGNMENT
ERRORS

LESSON PLAN

AIR POLLUTION TRAINING INSTITUTE

TOPIC: CALCULATION AND INTERPRETATION OF % ISOKINETIC

COURSE: 450 - Lecture 8
LESSON TIME: 1 hour 45 minutes
PREPARED BY: J. Jahnke DATE: 9/21/78

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY

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
2. Federal Register - Vol. 42, No. 160, August 18, 1977. "Standards of Performance for New Stationary Sources - Revision to Reference Methods 1-8."
3. "A Guideline for Evaluating Compliance Test Results"- A Monograph by R. Shigehara
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:

CONTENT OUTLINE

Page 1 of 6

NOTES

Course: 450 · Lecture 8

Lecture Title: Calculation and Interpretation of % Isokinetic

I. Derivation of the % Isokinetic Equation

L8-1
Page 72 in workbook

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 ΔH's required for isokinetic sampling.

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

Stress Point C.

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 $90 \leq \%I \leq 110$ 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)

These concepts are difficult for some students. Explain later, at end of lecture.

E. Derivation

1. $\%I = \frac{v_n}{v_s} \times 100$ "definition"

L8-2

2. From the equation of continuity

$$v_n = \frac{Q_n}{A_n}$$

L8-3

3. Q_n from collected data

L8-4

$$Q_n = \frac{V_{sw} + V_{\text{meter corrected}}}{\theta}$$

where θ = sampling time period

4. Correction of volume metered at orifice, to stack conditions

$$V_{\text{orifice corrected to stack conditions}} = \left(\frac{T_s}{P_s}\;\frac{\left(P_b + \frac{\Delta H}{13.6}\right)}{T_m}\right) V_{meter}$$

L8-5

stress that all ar really doing is relating the volum of gas going through the orifice meter to that going through the nozzle

5. Correction for water collected in impingers

$$V_{1c}\,\rho_{H_2O} = M_{H_2O}$$

$$P_s V_{sw} = \frac{m}{M} RT_s$$

and

$$V_{sw} = m_{H_2O} \frac{RT_s}{M_{H_2O}P_s}$$

$$V_{sw} = V_{1c}\,\rho_{H_2O} \frac{RT_s}{M_{H_2O}P_s}$$

= the volume of water vapor at stack conditions.

Note:
V_{LC} = volume of liquid collected i impingers and silica gel. Silica gel volume obtained from weight difference using Fig. 5-3 42 FR 41780 Aug. 18, 1977.

L8-6

6. Substituting T & P correction into Q_n

L8-7

$$Q_n = \frac{T_s}{P_s}\,\frac{\left[V_{1c}K_3 + \frac{V_m}{T_m}\left(P_b + \frac{\Delta H}{13.6}\right)\right]}{\theta}$$

where $K_3 = \frac{\rho_{H_2O}R}{M_{H_2O}} = .00267$ in Hg ft^3/ml °R

point out value of K_3 in paragraph 6.12 so they will believe you.

7. Substituting into %I expression

L8-8

$$\%I = \frac{v_n}{v_s} 100 = \frac{Q_n}{v_s A_n} 100$$

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

8. %I - Federal Register Expression

L8-9

$$\%I = \frac{100\ T_s \left[V_{1c} K_3 + \frac{V_m}{T_m}\left(P_b + \frac{\Delta H}{13.6}\right)\right]}{60\ \theta\ v_s P_s A_n}$$

9. %I FR expression from intermediate data

L8-10

$$\%I = K_4 \frac{T_s V_{m(std)}}{P_s v_s A_n \theta (1 - B_{ws})}$$

$K_4 = 0.09450$ for English units

Note that all this is, is

$$\frac{v_n}{v_s} \times 100$$

where v_n is obtained from V_m which is corrected back to nozzle conditions.

10. Special features of the expression

a. A_n is in ft^2 or m^2

(42 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_{LC}, 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.

CONTENT OUTLINE

NOTES

Course: 450 **Lecture** 8

Lecture Title: Calculation and Interpretation of % Isokinetic

F. Acceptable results

L8-11

1. Review of $\overline{pmr}$

$$pmr = \frac{m_n}{V_n}\underbrace{A_s v_s}_{Q_s}$$

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

2. Effect of non-isokinetic conditions on the $pmr_{measured}$ value

L8-12

a. First consider small particles < 1 μm under or over isokinetic sampling will not matter, since particles will follow streamlines and $\frac{m}{v}$ will not vary

good review of Tuesday morning concepts

b. Second, consider large particles > 5 μm 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 $\frac{pmr_{measured}}{pmr_{true}}$ vs the % isokinetic, obtain the plot of given on page 76 of Workbook

L8-12

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

This is an extremely important point. Efforts should be made to see that the students understand this.

Point out on graph, difference of

$pmr_{meas.}$ at 80% > $pmr_{measured}$ at 100%

f. Question:

same comment

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 120

<

$pmr_{measured}$ at 100

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_s 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_s, 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.

CONTENT OUTLINE

NOTES

Course: 450 **Lecture 8**

Lecture Title: Calculation and Interpretation of % Isokinetic

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)

H. Handout -- "A Guideline for Evaluating Compliance Test Results" - A Monograph by R. T. Shigehara.

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

[illegible] [illegible] LESSON 8 6

[illegible] Expectations from Intermediate data

LESSON PLAN

AIR POLLUTION TRAINING INSTITUTE

TOPIC: SAMPLING TRAIN CONFIGURATIONS: DEFINITION OF A PARTICULATE

COURSE: 450 Lecture 9
LESSON TIME: 15 minutes
PREPARED BY: Giuseppe J. Aldina
DATE: 10/2/78

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY

9

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:

1. Federal Register – Vol 43, No. 37, February 23, 1978, Part V, "Kraft Pulp Mills"
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.

CONTENT OUTLINE

Page 1 of 4

NOTES

Course: 450 Lecture 9

Lecture Title: SAMPLING TRAIN CONFIGURATIONS: DEFINITION OF A PARTICULATE

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."

Ask if anybody knows this for Federal and state regulations

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

Ask if anyone readily distinguishes the difference

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 SO$_2$ 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. SO$_2$ can form sulfates on the filter mat at temperatures below approximately 270°F

    c. H$_2$SO$_4$ can be condensed on the filter mat and in the probe at temperatures below 250°F

    d. 320°F assures neither SO$_2$ or H$_2$SO$_4$ 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)

Get the class to join in describing the particulate catch for each system

1. Reference Method 5 - Particulate defined

a. Probe - filter temperature

b. Analysis procedures

2. Configuration 1 - Particulate defined

a. Condenser conditions

b. Analysis procedure

3. Configuration 2
    a. Probe-filter temperature
    b. Second filter may have particulate at condenser conditions
    c. Analysis
4. Method 17 (Configuration 2)
    a. Stack temperature
    b. Analysis
    c. May yield results significantly lower than RM5

Hand out Feb 23, 1978 FR on Kraft Pulp Mills at this point.

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.

LESSON PLAN

TOPIC: DISCUSSION OF SOURCE SAMPLING EXERCISES

COURSE: 450 Lecture 10
LESSON TIME: 1 hour 15 minutes
PREPARED BY: DATE:
Giuseppe J. Aldina 10/02/78

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 out 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.

CONTENT OUTLINE

Course: 450 **Lecture 10**

Lecture Title: DISCUSSION OF SOURCE SAMPLING EXERCISES

Page 1 of 6

NOTES

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

Use flowchart and these notes for the discussion

  B. Research the literature - Refer to flow chart section

    1. This is extremely important

    2. Provides information as given in flow chart

  C. State 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

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.

  D. Design the experiment - follow the flow chart descriptions

  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

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 straight forward 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 m^3/min (0.02 cfm)

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.

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 RM1 requirements

        c. Team leader prepare data forms and equations

    3. After taking RM1 data

        a. Team leader makes RM1 calculations

        b. Technicians assemble traversing system

4. RM1 data completed
   - a. Mark traverse points on probe
   - b. Do velocity traverse - quick preliminary
   - c. Do H_2O 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. ΔH versus Δp 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

Clean-up is not done in lab except for measuring H_2O. Procedures are given in manual page 5-12.

III. Data sheet and calculations

A. Data averages

1. Dry gas meter volume sampled - V_m = final - initial dry gas meter reading
2. Average ΔH - straight arithmetic average
3. Average square root of the Δp readings
4. Average stack temperature

B. Calculations - use programmed sheet and explain to students

IV. Report writing - manual page 7-1.

A. This is straight forward and can be done by following the manual sections.

B. If time is tight instruct students to read the section as homework

LESSON PLAN

AIR POLLUTION TRAINING INSTITUTE

TOPIC: CONCENTRATION CORRECTIONS AND PROBLEM SESSION

COURSE: 450 - Lecture 11
LESSON TIME: 1 hour 15 minutes
PREPARED BY: J.A. Jahnke DATE: 10/2/78

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY

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, % O_2, and % CO_2
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% CO_2
6. Correct a particulate concentration to 6% O_2

Student Prerequisite Skills:

Ability to multiply and divide

Intended Background:

General Science

Level of Instructions:

College undergraduate math

Materials:

1. Workbook
2. Manual
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

CONTENT OUTLINE

Page 1 of 4

NOTES

Course: 450 - Lecture 11
Lecture Title: CONCENTRATION CORRECTIONS AND PROBLEM SESSION

I. Correction of concentration to standard temperature and pressure

Page 98 Workbook
L11-1

A. Did this in first lecture, using ideal gas law derivation is:

$$V_{corr\ std} = \frac{mRT_{std}}{MP_{std}} \qquad V_s = \frac{mRT_s}{MP_s}$$

$$\frac{V_{corr\ std}}{V_s} = \frac{\frac{T_{std}}{P_{std}}}{\frac{T_s}{P_s}} = \frac{T_{std}P_s}{T_sP_{std}}$$

$$V_{corr} = V_s \frac{P_sT_{std}}{P_{std}T_s}$$

$$C_{corr} = \frac{M}{V_{corr}} = C_s \frac{P_{std}T_s}{P_sT_{std}}$$

$$C_{corr} = C_s \frac{P_{std}T_s}{P_sT_{std}}$$

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 CO_2 and N_2 left over.

L11-2

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.

Course: 450 — Lecture 11

Lecture Title: CONCENTRATION CORRECTIONS AND PROBLEM SESSION

3. When adding excess air, get different percentages of CO_2 and O_2, based upon type of fuel and amount of excess air.

Point on graph

B. Definition of Excess Air:

L11-3

1. $$\% EA = \frac{\text{Volume Excess Air}}{\text{Theoretical Volume required for complete combustion}} \times 100$$

2. $$\% EA = \frac{\% O_2 - .5 (\% CO)}{.264(\% N_2) - [\% O_2 - .5(\% CO)]} \times 100$$

Refer to Appendix in Manual for derivations. Will not derive in class. Page D-1

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, $\% CO_2$, $\% O_2$ 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

L11-4

$$\bar{C}_{s_{50}} = \frac{\bar{C}_s (100 + \% EA)}{150}$$

4. 50% excess air correction from Orsat data

L11-5

$$\bar{C}_{s_{50}} = \frac{\overline{C_s}}{1 - \left[\frac{1.5(\% O_2) - .133(\% N_2) - .75(\% CO)}{21}\right]}$$

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 $\% O_2$, $\% N_2$, and $\% CO$, but are almost identical combustion sources.

CONTENT OUTLINE

Page 3 of 4

NOTES

Lecture 11

Course: 450

Lecture Title: CONCENTRATION CORRECTIONS AND PROBLEM SESSION

III. Correcting to 12%CO$_2$

L11-6

A. Used in NSPS for municipal incinerators and by some states for some other sources.

B. $\bar{C}_{s_{12}} = \bar{C}_s \dfrac{12}{\%CO_2}$

C. The correction may cause a significant error in the reported emission rate, due to errors in determining %CO$_2$ 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%CO$_2$, deviation jumped to almost 25%.

IV. Correcting concentration to 6% oxygen

L11-7

1. Some standards are written in terms of an oxygen correction instead of a CO$_2$ correction

2. $\bar{C}_{s_{6\%O_2}} = \dfrac{\bar{C}_s\,[20.9 - 6.0]}{20.9 - \%O_2}$

3. Some standards may be corrected to 3%O$_2$ instead of 6%. Change 6 to 3 in this case. 20.9 is the % O$_2$ in air.

V. Practice in performing concentration corrections.

Page 100 Workbook

A. Perform calculations page 100 of workbook - example given.

Allow 30 minutes for problem. Have students take a break after they have finished.

B. Answers - Problem I in workbook

Fill in answers in Table after most students have finished first problem. Help those who are having difficulty.

Test Number	% EA	Orsat Analysis				Q_s DSCF/min.	PMR gr./min.	C_s gr./DSCF	$C_{s_{12}}$	$C_{s_{50}}$	
		%CO$_2$	%O$_2$	%CO	%N$_2$					% EA	From Raw Orsat Data
1A	10	13.3	2.2	0	84.3	14,300	10,000	.699	.631	.513	.507
1B	46.9	9.7	7.1	0.2	83.0	19,400	10,000	.515	.637	.505	.502

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.

Test Number	% EA	Orsat Analysis				Q_s DSCF/min.	PMR gr./min.	C_s gr./DSCF	$C_{s_{12}}$	$C_{s_{50}}$	
		%CO_2	%O_2	%CO	%N_2					% EA	From Raw Orsat Data
2A	48.6	12.1	7.1	0.3	80.5	18,000	13,000	.722	.716	.715	.712
2B	100	9.1	10.6	0	80.3	24,000	13,000	.542	.714	.723	.721

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% CO_2 corresponding to approximately 6% O_2 at 50% EA.
Oil does not.

12/79 450 LESSON 11 7

[illegible] CONCENTRATION CORRECTIONS

[illegible]

1

2

3

50% Excess Air Correction for C_s

Given % EA

$C_s \frac{100 + \% EA}{150}$

4

5

[illegible]

6

CORRECTING CONCENTRATION TO 6% OXYGEN

$\% O_2 \quad C_s \frac{20.9 - 6.0}{20.9 - \% O_2}$

7

LESSON PLAN

AIR POLLUTION TRAINING INSTITUTE

TOPIC: LITERATURE SOURCES

COURSE: 450 Lecture 12
LESSON TIME: 30 minutes
PREPARED BY: DATE
J. A. Jahnke 9/21/78

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY

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

CONTENT OUTLINE

Page 1 of 3

NOTES

Course: 450 Lecture 12
Lecture Title: LITERATURE SOURCES

I. Books on Air Pollution Control, Sources, and Engineering L12-1

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 L12-2

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 L12-3

A. Many publications available - obtain through NTIS or EPA library

EPA Cumulative Bibliography 1970-1976 Parts 1 and 2 PB-265-920 and EPA Publications Bibliography Quarterly Abstracts Bulletin NTIS UB/D/042-01, 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 L12-4

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$_x$ Control Review

FGD Control Review, etc.

CONTENT OUTLINE

Course: 450 Lecture 12

Lecture Title: LITERATURE SOURCES

Page 3 *of* 3

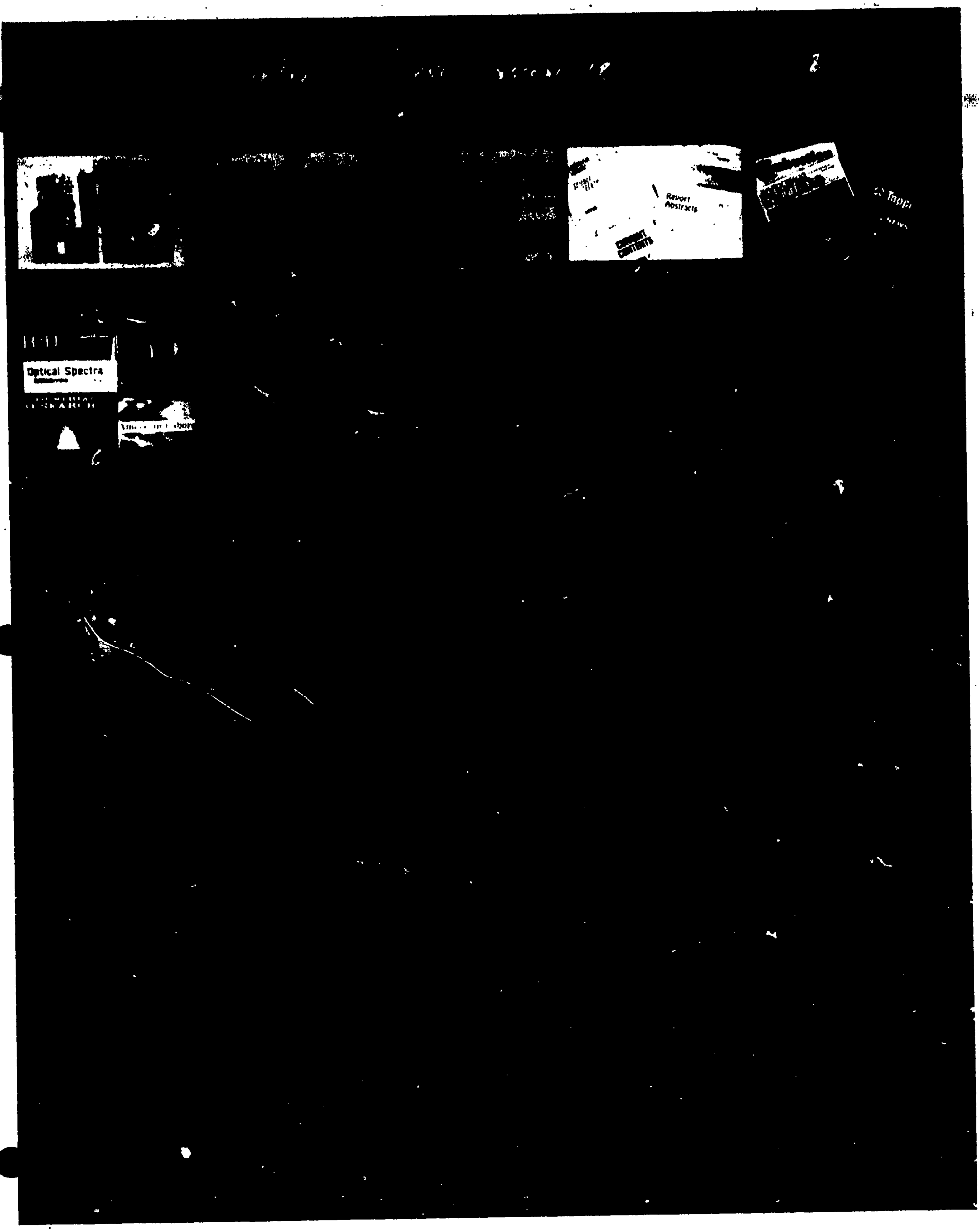
NOTES

V. Other Periodicals on Environmental Topics — L12-5

- A. Clean Air
- B. Environment
- C. Combustion
- D. etc. → Make your own list

VI. Freebees — L12-6

- A. For people who like to get something in the mail
- B. Industrial Research, American Laboratory, Laser Focus, etc.
- C. Pollution Equipment News


Optical Spectra
Report Abstracts
Current Contents
Tappi

LESSON PLAN

AIR POLLUTION TRAINING INSTITUTE

TOPIC: THE F-FACTOR METHOD

COURSE: 450 Lecture 13
LESSON TIME: 1 hour
PREPARED BY: DATE:
J. A. Jahnke 9/25/78

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY

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 Methd 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

Course: 450 Lecture 13
Lecture Title: THE F-FACTOR METHOD

I. Emission in terms of lbs/10^6Btu Heat Input

Page 108 Workbook

A. Previously expressed emissions in terms of

Write equation on board

$$E = \frac{pmr_s}{Q_H} = \frac{\bar{C}_s Q_s}{Q_H} = \frac{\frac{lbs}{\cancel{ft^3}} \; \frac{\cancel{ft^3}}{\cancel{hr}}}{10^6 Btu/\cancel{hr}}$$

$$= \frac{lbs}{10^6\ Btu}$$

Note: Did this the first day, but most people in class have forgotten it by now

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

write on board

$$E = \bar{C}_s F \begin{pmatrix} \text{dilution} \\ \text{correction} \\ \text{term} \end{pmatrix}.$$

B. Definition of the F_d factor

1. $$F_d = \frac{\text{volume of theoretical dry combustion products/lb}}{\text{heating value of fuel combusted } (10^6 \text{ Btu/lb})}$$

$$= \frac{ft^3}{10^6 Btu}$$

dimensionally, then

2. the emission rate from A, is then

$$E = \frac{\cancel{ft^3}}{10^6 \text{ Btu}} \quad \frac{lbs}{\cancel{ft^3}} = \frac{lbs}{10^6 \text{ Btu}}$$

dilution correction term is dimensionless

3. F-factors are relatively constant values for specific categories of fuels.

C. F_d factor method

L13-2

1. $E = \overline{C}_s F_d \left[\frac{20.9}{20.9-\%O_2}\right]$

uses $\%O_2$ for dilution correction.

2. This is the equation must use in EPA Method 5.

3. Examples of F-factors

L13-3

Note more extensive list in manual - numbers in parentheses, give % deviation from the mean of data sets for which the F-factors were calculated.

Turn to page 9-11 of manual.

Point out the small deviations.

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 Midgett - have two analysis agree to within .3%.

Turn to page 9-12 of manual.

Refer to page 9-15 of manual.

D. F_c factor method

L13-4

1. $F_c = \frac{\text{volume of theoretical } CO_2 \text{ generated by combustion/lb}}{\text{heating value of fuel combusted } (10^6 \text{ Btu/lb})}$

2. the F_c factor method

$$E = C_s F_c \left(\frac{100}{\%CO_2}\right)$$

This and following methods may be gone through quickly. They are important for continuous monitoring, but not for method 5 - Students, however, should know that they exist

L13-5

E. Using F_d factor to calculate E from data given on a wet basis

L13-6

Define $O_{2(w)}$ - Oxygen concentration on a wet basis

$$E = C_{ws} F_d \left[\frac{20.9}{20.9(1-B_{ws}) - \%O_{2(w)}} \right]$$

B_{ws} = fractional moisture content of stack gas

F. the wet F factor method F_w

L13-7

$$E = C_{ws} F_w \left[\frac{20.9}{20.9(1-B_{wa}) - \%O_{2(w)}} \right]$$

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

L13-8

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

$$F_{c(calc)} = \frac{Q_{ws}}{Q_H} \left(\frac{\%CO_{2(w)}}{100} \right)$$

H. F_o factor L13-9

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 L13-10

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

$$(\%\ CO_2)_{adj} = \%\ CO_2 + \%\ CO$$

$$(\%\ O_2)_{adj} = \%\ O_2 - .5(\%CO)$$

INSERT EMULSION SIDE DOWN

12/79 450 LESSON 13 FILE NO 9

KODAK SAFETY FILM 5060

[illegible] METHOD

$$E = C_s F_d \left[\frac{20.9}{20.9 - \%O_2}\right]$$

2

3

4

5

KODAK SAFETY FILM 5060

Alternate F Factor Method using wet basis data

$$E = C_{ws} F_d \left[\frac{20.9}{20.9(1-B_{ws}) - \%O_{2w}}\right]$$

B_{ws} = fractional moisture content of stack gas

6

Wet F Factor Method

F_w = [illegible]

$E = C_{ws} F_w$ [illegible]

B_{wa} = fractional moisture content in air

7

8

9

10

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LESSON PLAN

AIR POLLUTION TRAINING INSTITUTE

TOPIC: CALCULATIONS REVIEW;
CLEAN-UP PROCEDURES FOR THE
RM5TEST - CALCULATIONS AND PRE-
TEST REVIEW - DISCUSSION OF
LABORATORY RESULTS

COURSE: 450 Lecture 14
LESSON TIME: 1 hour 45 minutes
PREPARED BY: DATE
Giuseppe J. Aldina 10/2/78

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY

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.

CONTENT OUTLINE

Course: 450 Lecture 14
Lecture Title: CALCULATIONS REVIEW;
CLEAN-UP PROCEDURES FOR RM5 TEST
CALCULATIONS AND PRE-TEST REVIEW
DISCUSSION OF LABORATORY RESULTS

NOTES

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 113 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 similiarities and discrepancies in the laboratory results

  C. Introduce ERROR analysis topic

LESSON PLAN

AIR POLLUTION TRAINING INSTITUTE

TOPIC: ERROR ANALYSIS

COURSE: 450 Lecture 15
LESSON TIME: 30 minutes
PREPARED BY: DATE
J. A. Jahnke 9/22/78

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY

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 decribe 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 missapply 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
4. Handout - reprint of article - Midgett, M. Rodney. "How EPA Validates NSPS Methodology." Environmental Science and Technology 11:655-659; July 1977.

Special Instructions:

None

References:

Handout - reprint of article - Midgett, M. Rodney. "How EPA Validates NSPS Methodology." Environmental Science and Technology 11:655-659; July 1977.

CONTENT OUTLINE

Course: 450 Lecture 15
Lecture Title: ERROR ANALYSIS

Page 1 *of* 2

NOTES

I. The true value — L15-1

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 — L15-2

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 — L15-2

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 — Stress

III. Classification of errors — L15-3

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. %I 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 prescision for EPA reference methods

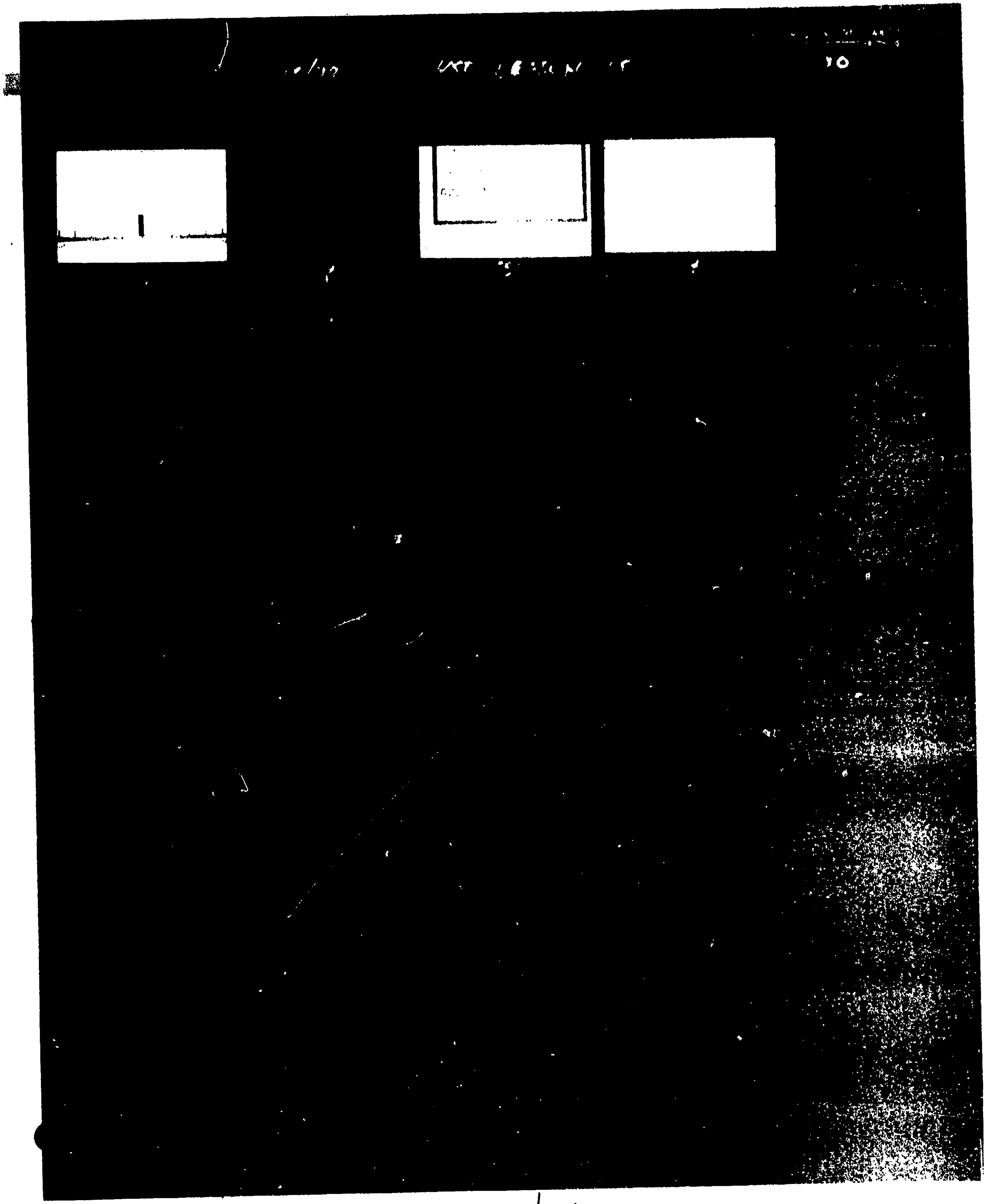
A. Refer to paper by R. Midgett-
11, #7, (1977) p.657 Table 2 - Within laboratory deviation of the reference methods

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.



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LESSON PLAN

AIR POLLUTION TRAINING INSTITUTE

TOPIC: SOURCE SAMPLING QUALITY ASSURANCE AND SAFETY ON THE SAMPLING SITE

COURSE: 450 Lecture 16
LESSON TIME: 1 hour 20 minutes
PREPARED BY: DATE:
Giuseppe J. Aldina 10/2/78

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY

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
4. Manual - page 5-15

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.

CONTENT OUTLINE

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY

Course: 450 Lecture 16

Lecture Title: SOURCE SAMPLING QUALITY ASSURANCE AND SAFETY ON THE SAMPLING SITE

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

L16-1

- 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 applys to attitudes about co-workers, supervisor, the job, or working conditions

J. Unpreditable 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

Ask the class to describe these. It is more useful than a simple listing.

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

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

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.

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 competancy of sampling team
    a. Experience
    b. Education
    c. Professionalims
7. Coordination with source operation
8. Parameter checks on stack gas
    a. Stack gas temperature
    b. Preliminary traverse for cyclonic gas flow and Δp
    c. Moisture content of the gas
9. Adherence to reference method procedures
10. System vacuum

CONTENT OUTLINE

Course: 450 Lecture 16
Lecture Title: SOURCE SAMPLING QUALITY ASSURANCE AND SAFETY ON THE SAMPLING SITE

Page 5 of 7

NOTES

11. Sampling system temperatures
    a. Filter
    b. Impingers
    c. Dry gas meter
12. ΔH calculation from Δp

C. Parameters the control agency observer 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 desicating
    a. Scale sensitivity within 0.5 mg
    b. Sensitivity checked routinely
    c. All tare weights carefully recorded
    d. Sample desicated 24 hours then weighed to nearest 0.5 mg
    e. Sample desicated 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 RM5 test. This concludes this lecture.

LESSON PLAN

AIR POLLUTION TRAINING INSTITUTE

TOPIC: PARTICLE SIZING USING A CASCADE IMPACTOR

COURSE 450 - Lecture 17
LESSON TIME 1 hour
PREPARED BY DATE
Giuseppe J. Aldina 10/2/78

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY

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.

CONTENT OUTLINE

Page 1 of 9

NOTES

Course 450 Lecture 17

Lecture Title Particle Sizing Using a Cascade Impactor

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

$$(d)Q = \propto d^N$$

d = diameter
$\propto$ = 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

Slide L17-1

a. The fluid is ideal - incompressible and non viscous

b. Flowing from P to Q

c. The mass flux at P is described L17-2

$$\frac{dm}{dt} = \rho_1 A_1 v_1$$

as t → 0

$$\Delta m_1 = \rho_1 A_1 v_1$$

d. We can describe the mass flux at Q as L17-3

$$\frac{dm_2}{dt} = \rho_2 A_2 v_2$$

as t → 0

$$\Delta m_2 = \rho_2 A_2 v_2$$

e. We stated before that our fluid is incompressible and non-viscous. This means ρ does not change and Δm at both points is equal.

1) $\frac{dm_1}{dt} = \frac{dm_2}{dt}$

as t → 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) L17-4

a. At Point I we have fluid moving toward the particle

1) Fluid pressure = P_T

2) Velocity = v_I

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

L17-5

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

It is not necessary to get too deeply into the fluid dynamics of this system

1) Some energy would be disipated 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.

L17-6

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 experession of fraction size for a collection stage is the D_{50}

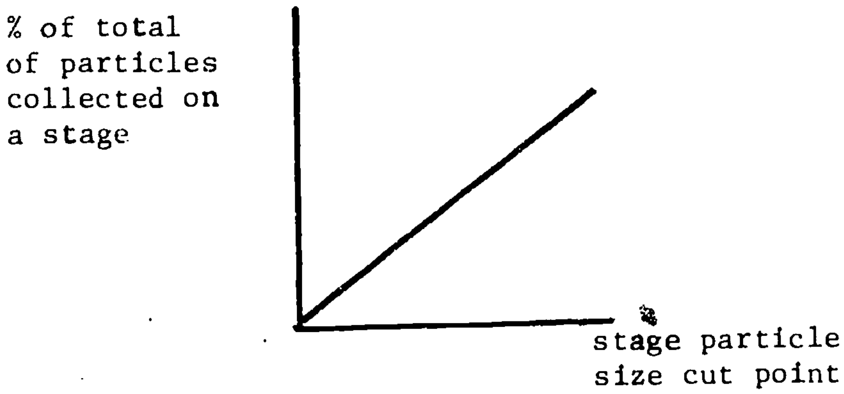
         1) The D_{50} is the particle size for which the stage has at least a 50% collection efficiency.

         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

2. The graph is plotted



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 RM5

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 RM5

2. The nomograph or calculator is used to determine the ΔH for the Δp 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

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

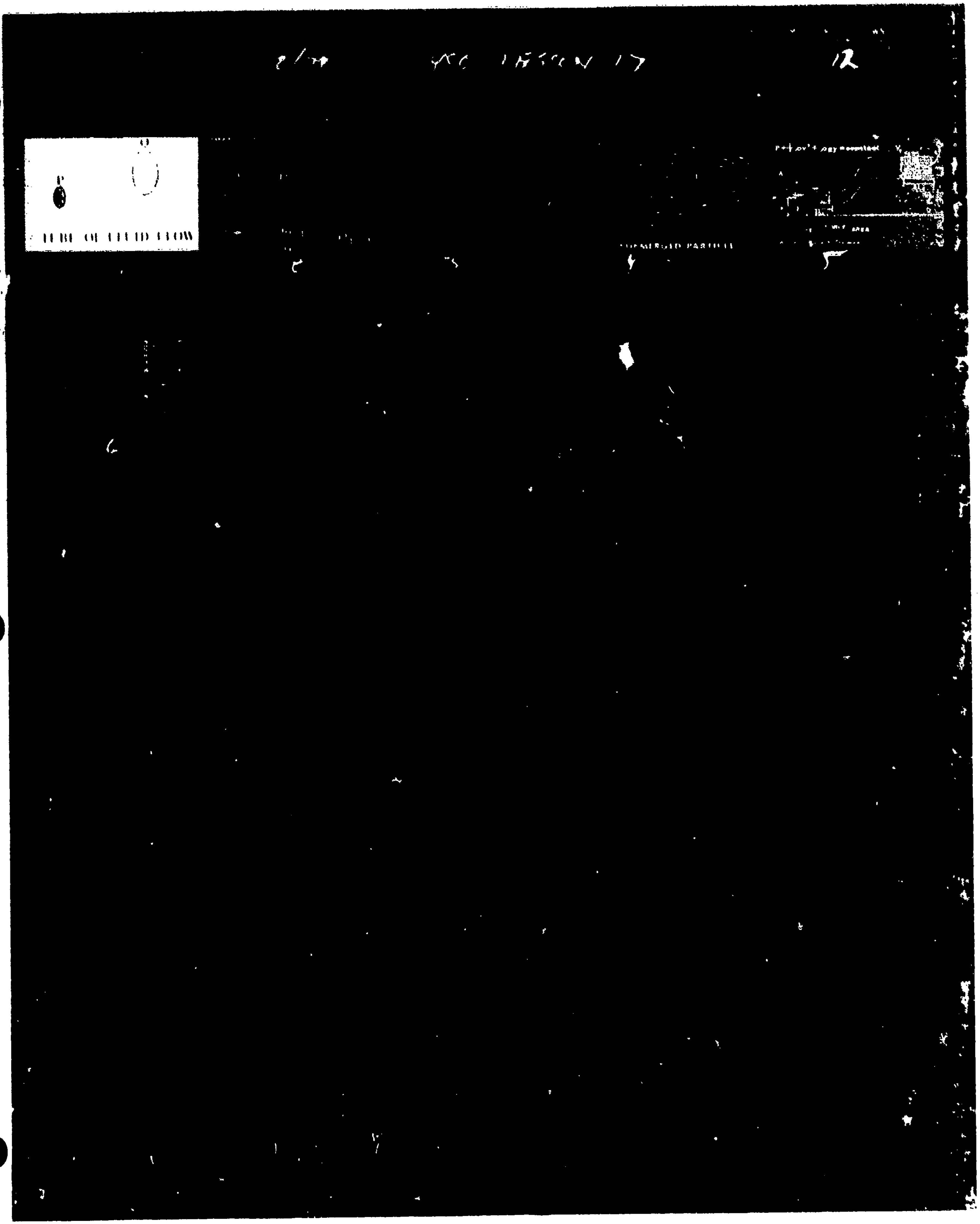
   c. These are uncertainties that are still being researched

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.


P
O
LINE OF FLUID FLOW
SUBMERGED PARTICLE

LESSON PLAN

AIR POLLUTION TRAINING INSTITUTE

TOPIC: TRANSMISSOMETERS

COURSE 450 - Lecture 18
LESSON TIME: 1 hour 15 minutes
PREPARED BY: J. Jahnke DATE 9/28/78

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY

18

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 Prequisite Skills:

Some concept of logarithms and exponential functions (note: students <u>do</u> 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:

Federal Register - Vol. 40, No. 194, October 6, 1975. "Emission Monitoring."

CONTENT OUTLINE

Page 1 of 4

NOTES

Course: 450 Lecture 18

Lecture Title: Transmissometers

I. Definition of opacity

L18-1
Intro. Slide

A. Opacity is the percentage of visible light attenuated due to the absorption and scattering of light by particulate matter in the flue gas.

L18-2

B. Relationship between % opacity and % transmittance
% opacity = 100% - % transmittance

C. Opacity monitor = transmissometer.

Transmissometer stands for transmission meter.

Give example -
using overhead
projector - look at
beam of projector
0% opacity 100% T,
put a book in front
of your eyes
100% opacity 0% T

II. Single-pass transmissometer

L18-3

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

L18-4

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

L18-5a
L18-5b

A. Many vendors - single pass and double pass

B. Vendors of double pass transmissometers - Lear-Siegler, RAC, Contravez-Goertz, Esterline Angus, Dynatron, Data test, Anderson-2000.

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

L18-6

A. Have two types of specifications for monitors required under NSPS and SIP's

1. Design specifications

2. Performance specifications

CONTENT OUTLINE

Course: 450 Lecture 18
Lecture Title: Transmissometers

Page 2 of 4

NOTES

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 $\leq$ 2% opacity
3. 24 hour calibration drift $\leq$ 2% opacity

VI. Photopic region – design specification L18-7

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 H_2O and CO_2 interference in IR region. H_2O not a pollutant.

C. Smaller particles attenuate light better at shorter wavelengths. Hence the light wavelengths are limited to the photopic region. L18-9

VII. Angle of projection and angle of view

A. Angle of projector – Angle of the cone of light projected by the lamp. L18-10

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. L18-11

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 L18-12

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 L18-13

A. Installation to satisfy EPA continuous monitoring requirements - 40 CFR 60.

B. Installation for process performance data - maintenance and repair indicator, process improvement combustion efficiency. L18-14

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 L18-15

A. The Beer-Lambert-Bougert relationship

$1 - O = T = e^{-naq\ell}$

T = transmittance
n = number of particles/unit volume
a = mean particle projected area
q = particle extinction coefficient
ℓ = effluent path-length

B. Optical density L18-16

1. $\text{O.D.} = \log_{10} \frac{1}{1 - \text{opacity}} = Kc\ell$

K = a constant
c = concentration
ℓ = pathlength

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 L18-17 L18-18 L18-19

   Examples: Lignite for boilers
   Cement kiln emissions
   Bituminous coal-fired boilers

XII. Examples of opacity monitoring installations

- A. Durag analyzer on power plant duct L18-20
- B. Durag analyzer on power plant duct L18-21
- C. Retro-reflector for Durag opacity monitor L18-23
- D. Transmissometer and blower assembly on EPA stationary source simulator facility L18-23
- E. Lear-Siegler Model #RM4 transmissometer on power plant stack L18-24
- F. Lear-Siegler Model #RM4 retroreflector assembly on power plant stack L18-25
- G. Protective shrouds on transmissometer located on stack L18-26
- H. Portable transmissometer, Lear-Siegler RM41P on EPA stationary source simulator L18-27

XIII. Course closing

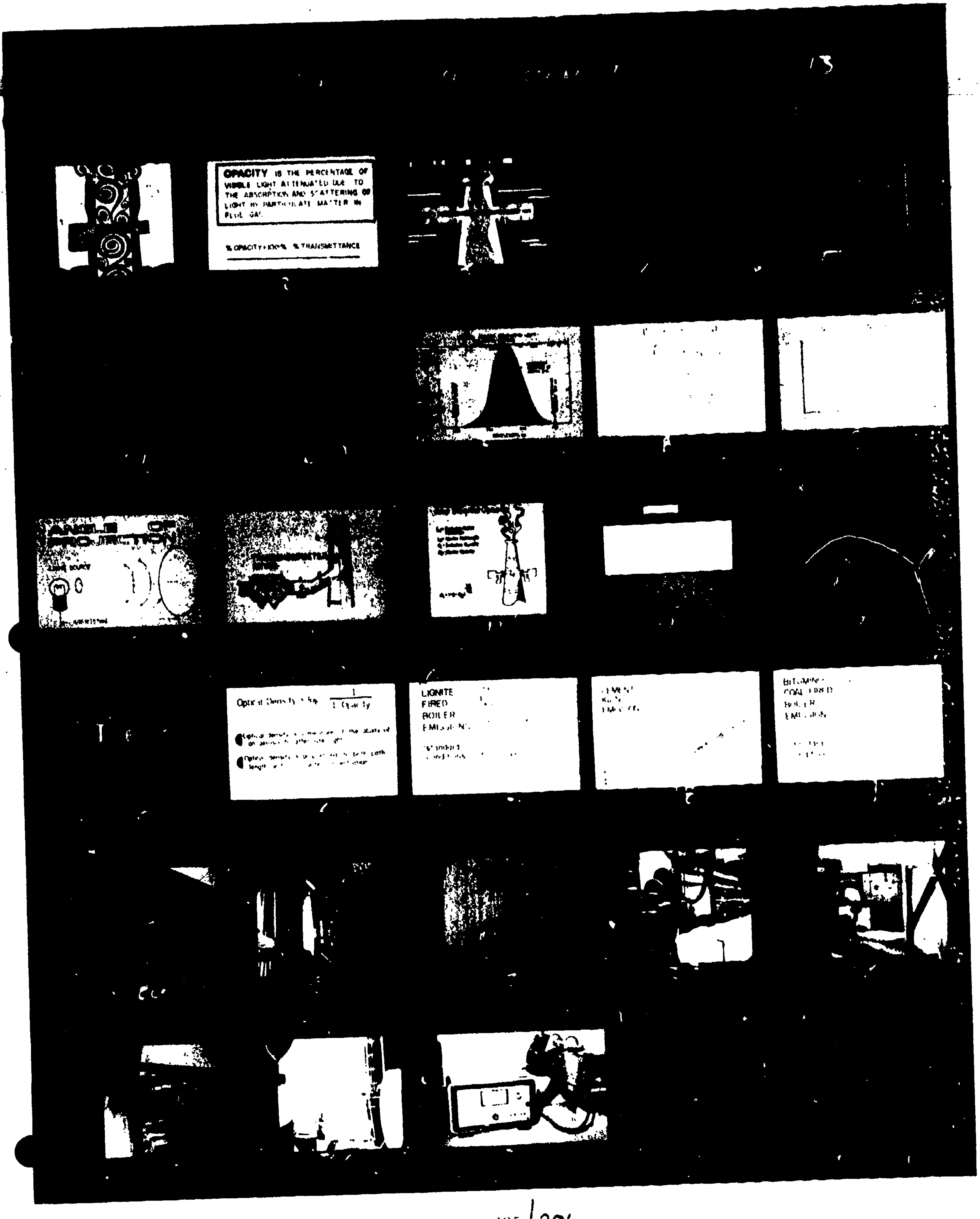
A. This is the last lecture in the course. Have the students take a break and then proceed with the post-test.

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



OPACITY IS THE PERCENTAGE OF VISIBLE LIGHT ATTENUATED DUE TO THE ABSORPTION AND SCATTERING OF LIGHT BY PARTICULATE MATTER IN FLUE GAS.

% OPACITY = 100% − % TRANSMITTANCE

Optical Density = log $\frac{1}{1-\text{Opacity}}$

LIGNITE
FIRED
BOILER
EMISSIONS

BITUMINOUS
COAL FIRED
BOILER
EMISSIONS

LESSON PLAN

AIR POLLUTION TRAINING INSTITUTE

TOPIC: MONDAY LABORATORY INSTRUCTIONS

COURSE 450 Laboratory 1
LESSON TIME: 2½ hours
PREPARED BY Giuseppe J. Aldina
DATE 10/2/78

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY

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_p 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 $\Delta H_@$ of 0.75 CFM at 29.92 in. Hg and 68 ^oF

Prerequisite Skills:

None

Level of Instruction:

College undergraduate science

Intended Student Professional Background:

General Science

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Support Materials and Equipment:

1. 450 Workbook
   - a. RM1 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 "S" type pitot and nozzle
   - e. Tubing
   - f. Thermometers
   - g. Cotton wicks and a beaker of H_2O
   - h. Stopwatches
   - i. Extension cords
   - j. Rulers
   - k. Tools
   - l. Duct tape
4. Calculators
5. Pencils

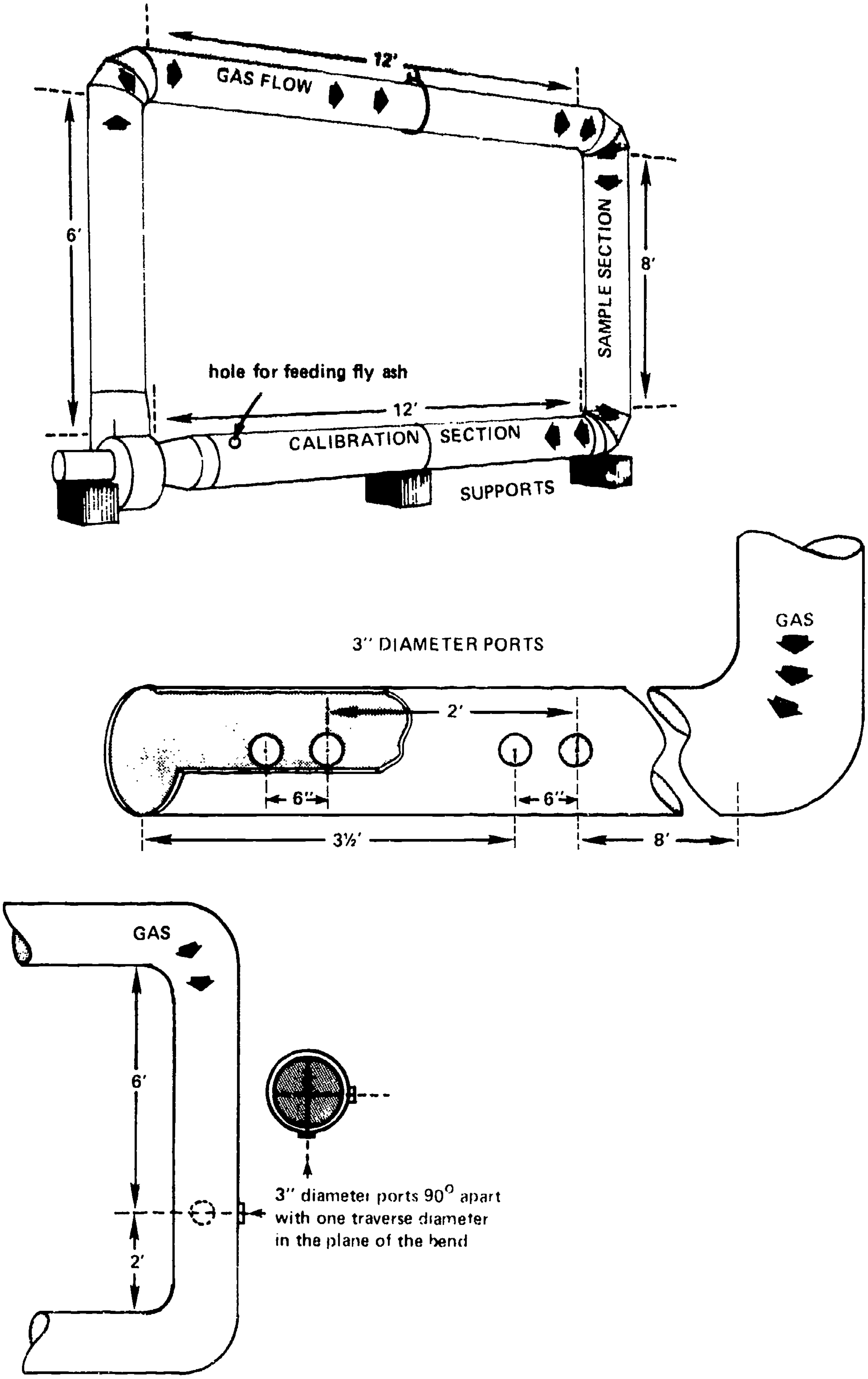


Figure 1. Laboratory Duct.

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. $\Delta H@$ should be 1.5-2.1 in. H_2O
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 DGMCF = 1.0.
7. Note: When the DGMCF is known the laboratory orifice meter calibration is accurate. APTD - 0576 should be the procedure used by the student as a standard practice unless DGMCF 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 H_2O 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 PLAN

AIR POLLUTION TRAINING INSTITUTE

TOPIC: OPERATION OF THE ORSAT ANALYZER

COURSE: 450 - Laboratory 2
LESSON TIME: 1½ hours
PREPARED BY: Giuseppe J. Aldina
DATE 10/2/78

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY

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 CO_2, O_2, 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 O_2 bubbler to show 20.9% O_2 in the air sample.

References:

FR 8/18/78

Instructor:

Demonstrate orsat operation and explain bubbler chemicals

1. Chemicals

   A. Burette solution — Na_2SO_4 saturated H_2O with methyl orange on red indicator and H_2SO_4 to keep it acidic. The burette solution is made this way to keep stack gases from dissolving in it

   B. CO_2 Bubbler — 42-46% KOH or NaOH

   C. O_2 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 CO_2 bubbler and bring it to the reference mark

      4. Repeat for O_2 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 CO_2 bubbler then bring it back to the burette
3. Proceed carefully -- do not mix the chemicals
4. After 3 passes read the CO_2 scrubbed by leveling the burette solution and leveling bottle.
5. Records the reading then confirm it by one more pass through CO_2 bubbler. Once is enough. If the reading is constant go on to O_2
6. O_2 -- analyze as for CO_2 but
   a. allow the gas to reside longer in the bubbler
   b. make 6-8 passes before the first reading
7. CO is analyzed as for CO_2.

C. Calculations

$M_d = \Sigma M_x B_x$ (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

217

LESSON PLAN

AIR POLLUTION TRAINING INSTITUTE

TOPIC: RM5 Testing

COURSE: 450 - Laboratory 3
LESSON TIME: 3 hours
PREPARED BY: G.J. Aldina DATE 10/2/78

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY

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:

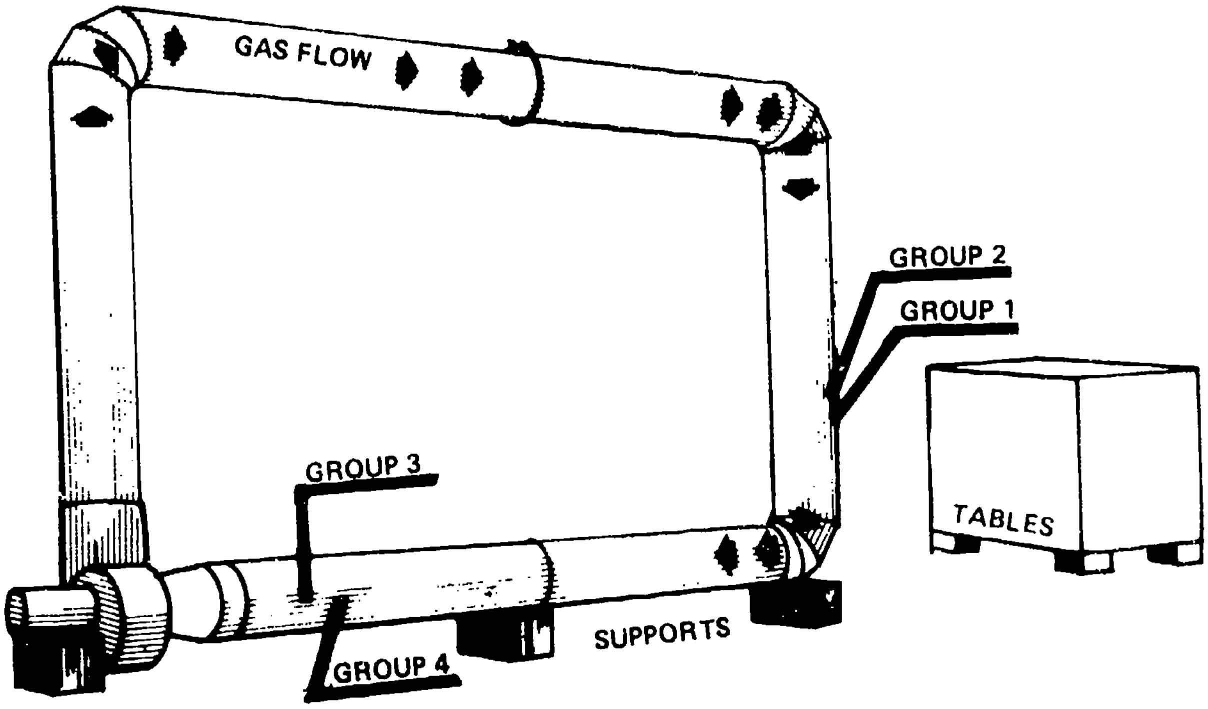
College undergraduate science

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.

   CO_2 = 12.5%
   O_2 = 6.2%
   CO = 0.1%
   Approximate H_2O = 5%

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 H_2O
   b. 100 ml H_2O
   c. Dry
   d. 200 gm silica gel

   but tell the students to assume that there is only 100 ml H_2O 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 H_2O 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

Federal Register - Vol. 42, No. 160, August 18, 1977. "Standards of Performance for New Stationary Sources - Revision to Reference Methods 1-8.

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 outrages. 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

I. Neccessary 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 (θ) _______ minutes

B. Reference Method #2
- Average stack temperature T_s _____ °F + 460 = ______ °R
- Stack absolute pressure ______ in. Hg.
- Barometric Pressure ______ in. Hg.
- $(\sqrt{\Delta p})_{ave}$ ______ $(\text{in. } H_2O)^{1/2}$

C. Reference Method #3
- $\%CO_2$ ______; $\%O_2$ ______; $\%CO$ ______; $\%N_2$ ______

D. Reference Method #4
- Water collected
  - Impinger H_2O _____ ml
  - Silica Gel _____ gm

E. Reference Method #5
- Area of nozzle ______ ft^2
- Average ΔH ______ in. H_2O
- 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 Y Dry Gas Meter calibration factor

$$V_{m(std)} = V_m Y \frac{T_{std}}{P_{std}} \left(\frac{P_b + \frac{\Delta H}{13.6}}{T_m} \right)$$

$$V_{m(std)} = (\qquad)(\text{CF}) \left(\frac{528\,°R}{29.92 \text{ in. Hg}} \right) \left(\frac{\_\_\_\_\_\_ \text{ in. Hg}}{°R} \right) = \_\_\_\_\_\_\_ \text{ dscf}$$

B. Moisture Content of Stack Gas

1. H_2O collected in impingers in standard cubic feet

$V_{wc(std)} = K\,(V_f - V_i)$

$V_{wc} = 0.04707\ \text{ft}^3/\text{ml}\ (\underline{\qquad}\ \text{ml}) = \underline{\qquad}\ \text{scf}$

2. H_2O collected in silica gel in standard cubic feet

$V_{wsg(std)} = K\,(W_f - W_i)$

$V_{wsg(std)} = 0.04715\ \text{ft}^3/\text{gm}\ (\underline{\qquad}\ \text{gm}) = \underline{\qquad}\ \text{scf}$

3. Moisture content of stack gas (B_{ws})

$$B_{ws} = \frac{V_{wc(std)} + V_{wsg(std)}}{V_{wc(std)} + V_{wsg(std)} + V_{m(std)}}$$

$$B_{ws} = \frac{(\underline{\qquad}\ \text{scf}) + (\underline{\qquad}\ \text{scf})}{(\underline{\qquad}\ \text{scf}) + (\underline{\qquad}\ \text{scf}) + (\underline{\qquad}\ \text{scf})} = \underline{\qquad}$$

C. Molecular Weight of Stack Gas (lb/lb-mole)

1. M_d (Dry molecular weight) $= \Sigma M_x B_x$

$M_d = (.44)\ \underline{\qquad}\ \%CO_2 + (.32)\ \underline{\qquad}\ \%O_2 +$

$(.28)\ \underline{\qquad}\ \%CO + (.28)\ \underline{\qquad}\ \%N_2 = \underline{\qquad}\ \text{lb/lb-mole}$

2. M_s (Wet Molecular Weight) $= M_d(1 - B_{ws}) + 18\ B_{ws}$

$M_s = \underline{\qquad}\ (1 - \underline{\qquad}) + 18(\underline{\qquad}) = \underline{\qquad}\ \text{lb/lb-mole}$

D. Average Stack Gas Velocity

$$\bar{v}_s = K_p C_p \sqrt{\frac{T_s}{P_s M_s}}\left(\sqrt{\Delta p}\right)_{ave}$$

$$\bar{v}_s = 85.49\ \text{ft/sec}\left(\frac{\text{lb/lb-mole (in. Hg)}}{{}^\circ\text{R(in.}H_2O)}\right)^{1/2} \underline{\qquad} \sqrt{\frac{(\underline{\qquad}\ )^\circ\text{R}}{(\underline{\qquad}\ \text{in. Hg})(\underline{\qquad}\ \text{lb/lb mole})}}\ \sqrt{\underline{\qquad}\ (\text{in. } H_2O)}\ \underline{\qquad}\ \text{ft/sec}$$

E. Average Stack Gas Volumetric Flow Rate

$$Q_s = (3600\ \text{sec/hr})(v_s)(A_s)(1 - B_{ws})\ \frac{T_{std}}{P_{std}}\ \frac{P_s}{T_s}$$

$$Q_s = (3600\ \text{sec/hr})(\underline{\qquad}\ \text{ft/sec})(\underline{\qquad}\ \text{ft}^2)(1\ \underline{\qquad})\ \frac{528\,^\circ\text{R}}{29.92\ \text{in. Hg}}\ \frac{\underline{\qquad}\ \text{in. Hg}}{\underline{\qquad}\ ^\circ\text{R}}$$

$Q_s = \underline{\qquad}\ \text{dscf/hr}$

F. Pollutant Mass Rate

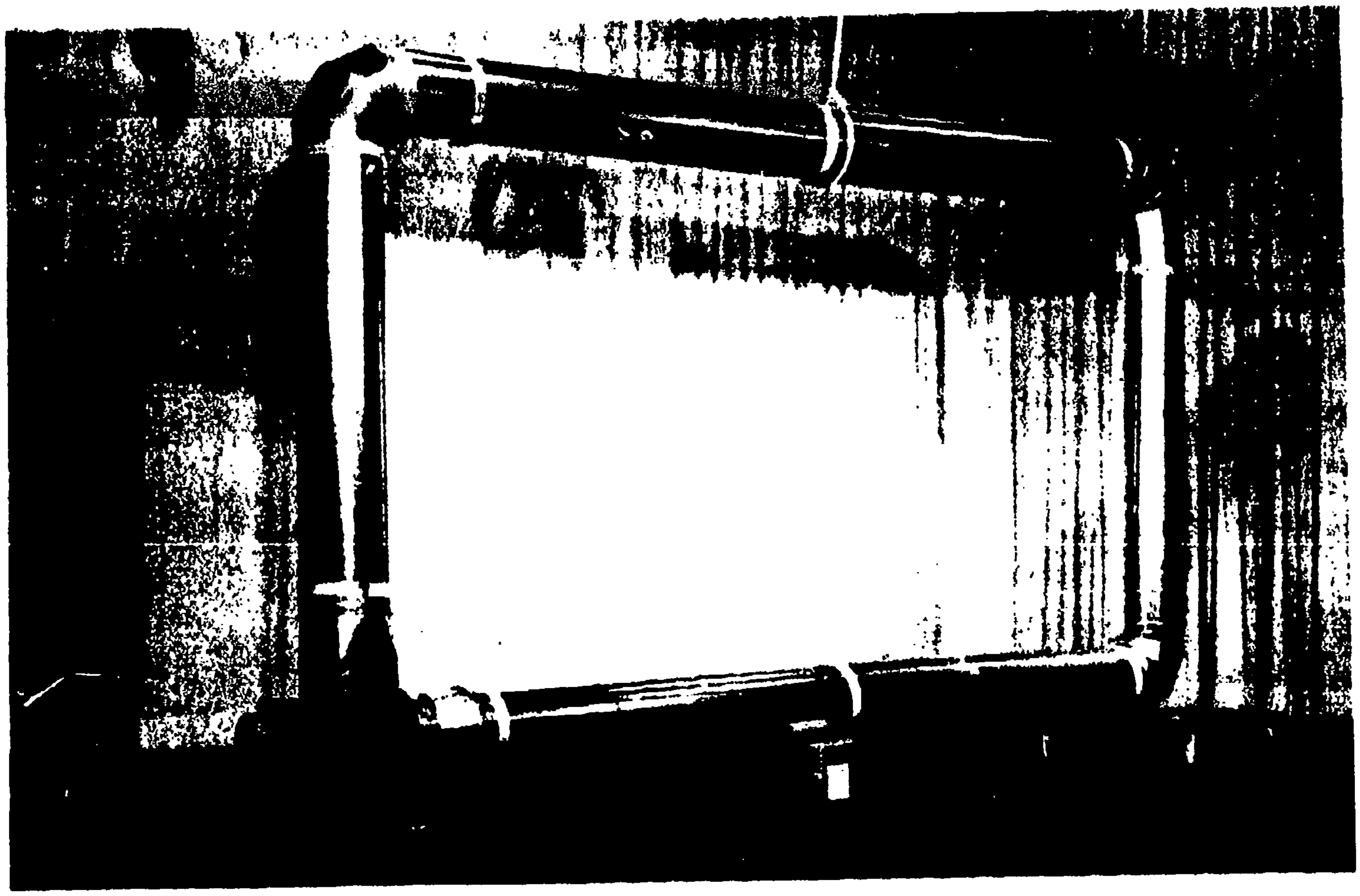
$$PMR = \frac{mass}{V_{m(std)}} \times Q_s$$

$$PMR = \frac{(\_\_\_\_\_\_)gm}{dscf} \times \_\_\_\_\_\_ dscf/hr \times \frac{1}{454\ gm/lb} = \_\_\_\_\_\_ lb/hr$$

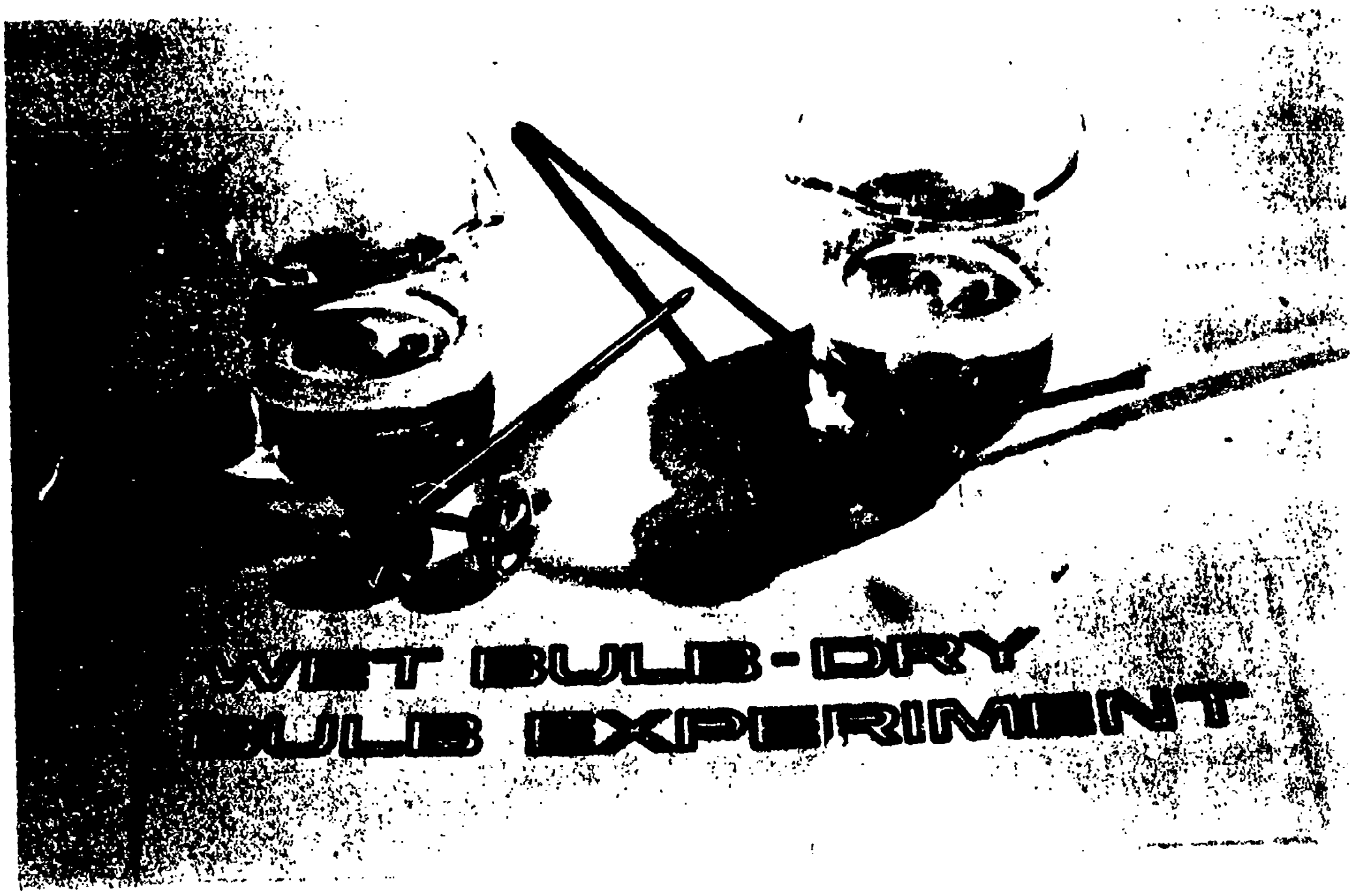
G. %Isokinetic Variation (Intermediate Data)

$$\%I = \frac{T_s V_{m(std)} P_{std} 100}{A_n \theta \bar{v}_s P_s T_{std} 60(1 - B_{ws})}$$

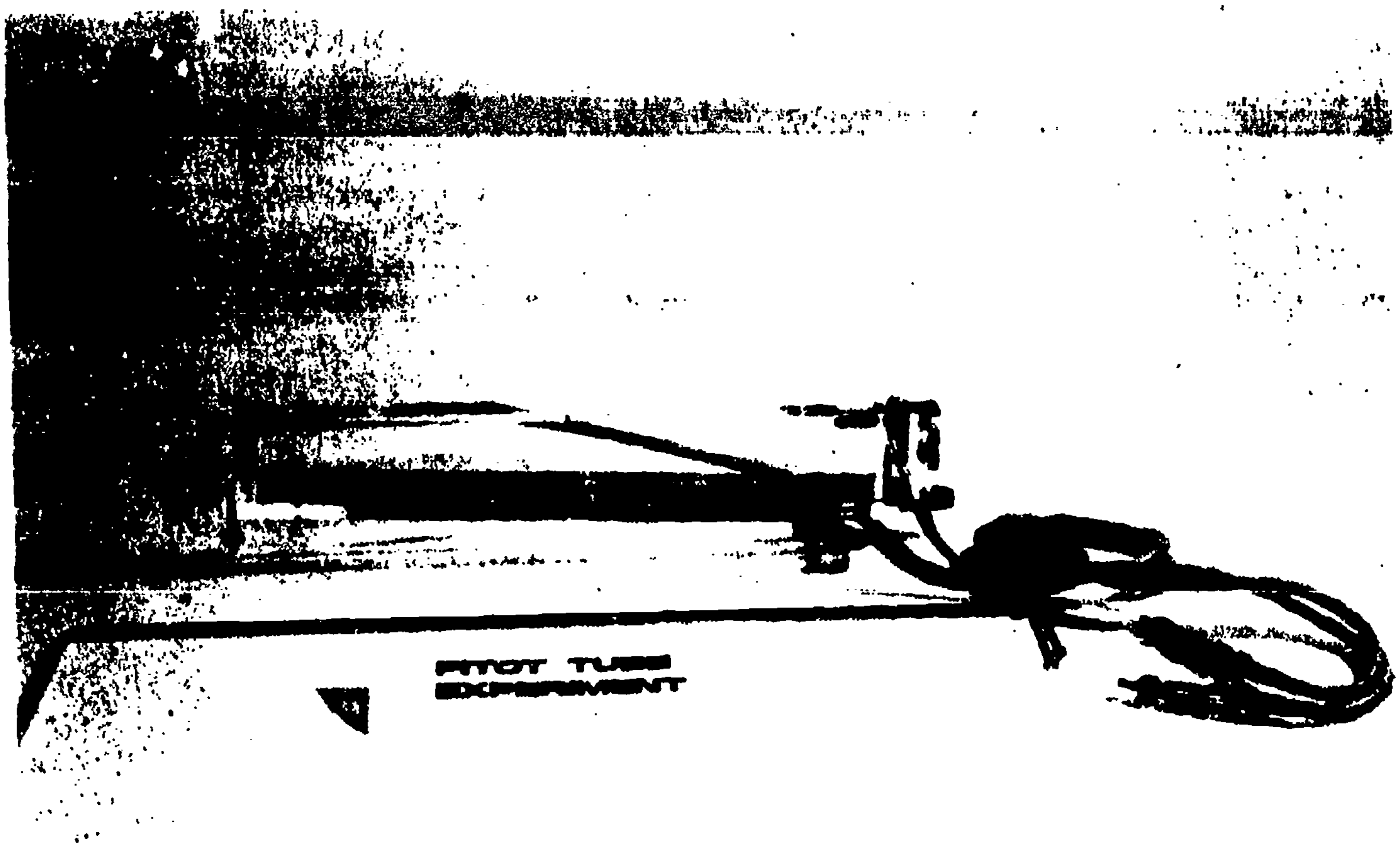
$$\% = \frac{(\_\_\_\_\_\_ °R)(\_\_\_\_\_\_ dscf)(29.92\ in.\ Hg)}{(\_\_\_\_\_\_ ft^2)(\_\_\_\_\_\_ min)(\_\_\_\_\_\_ ft/sec)(\_\_\_\_\_\_ in.\ Hg)(528°R)(60\ sec/min)(1 - \_\_\_\_\_\_)}$$



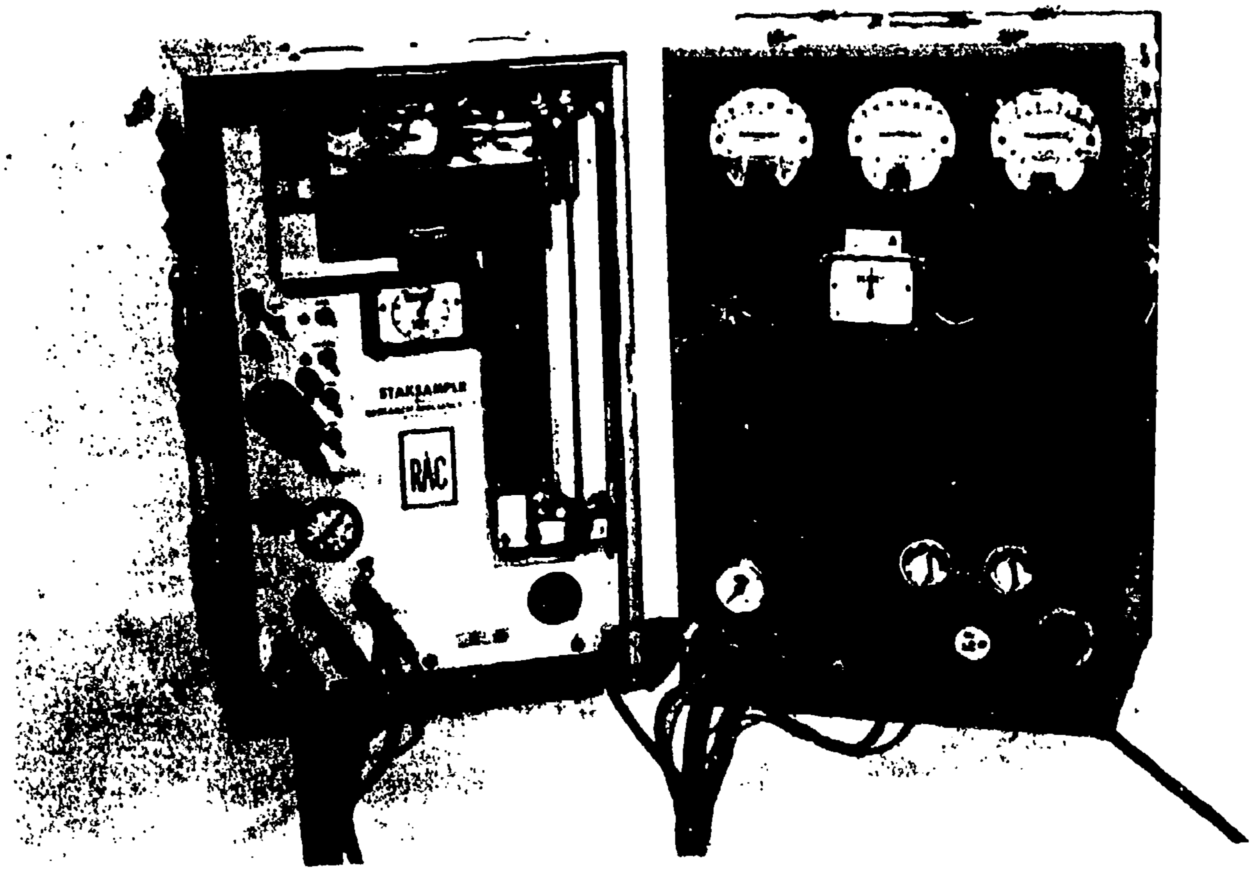
Assembled sampling duct constructed of 12 inch galvanized ductwork
Laboratories 1 and 3



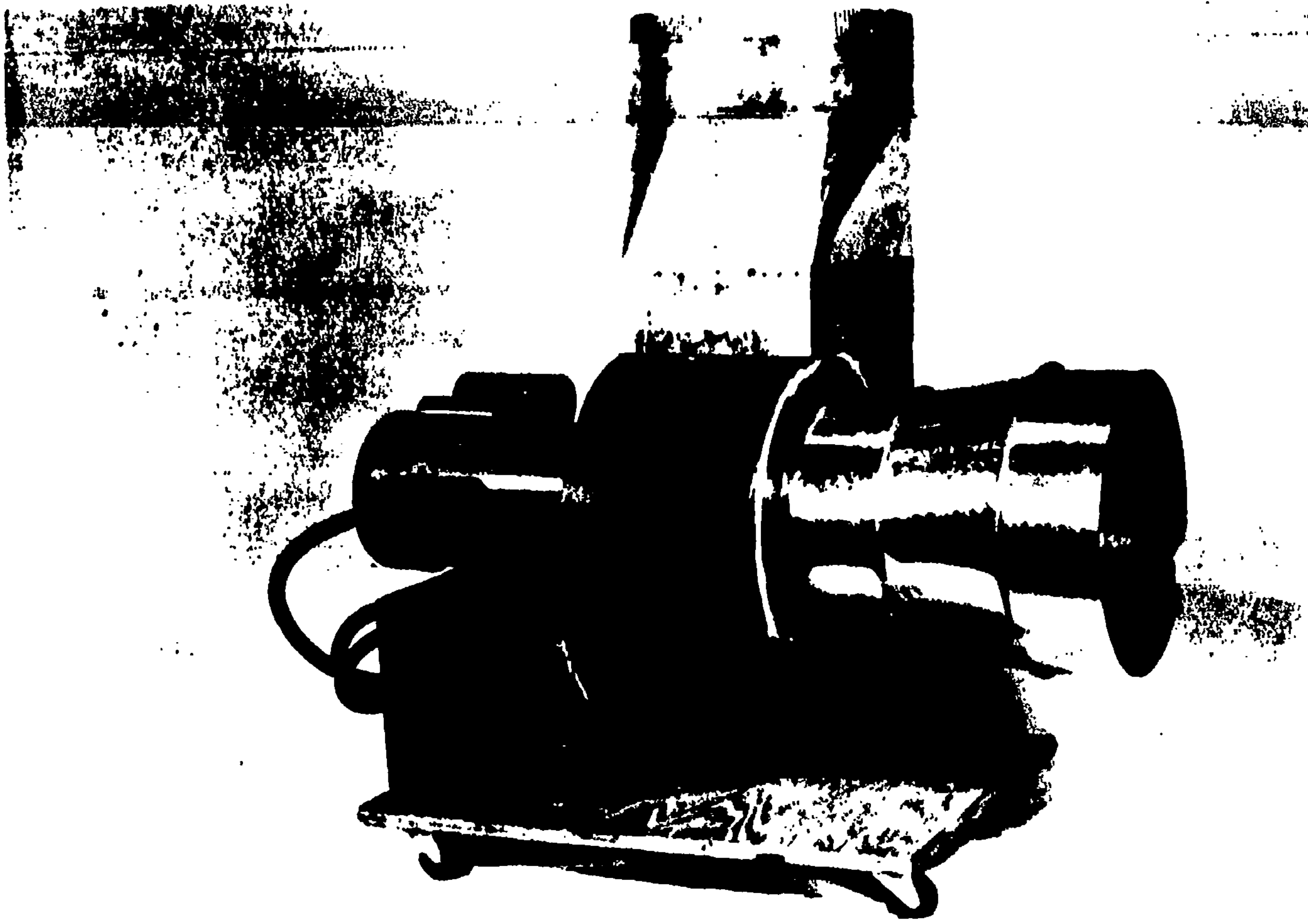
Apparatus for Wet Bulb-Dry Bulb moisture estimation experiment



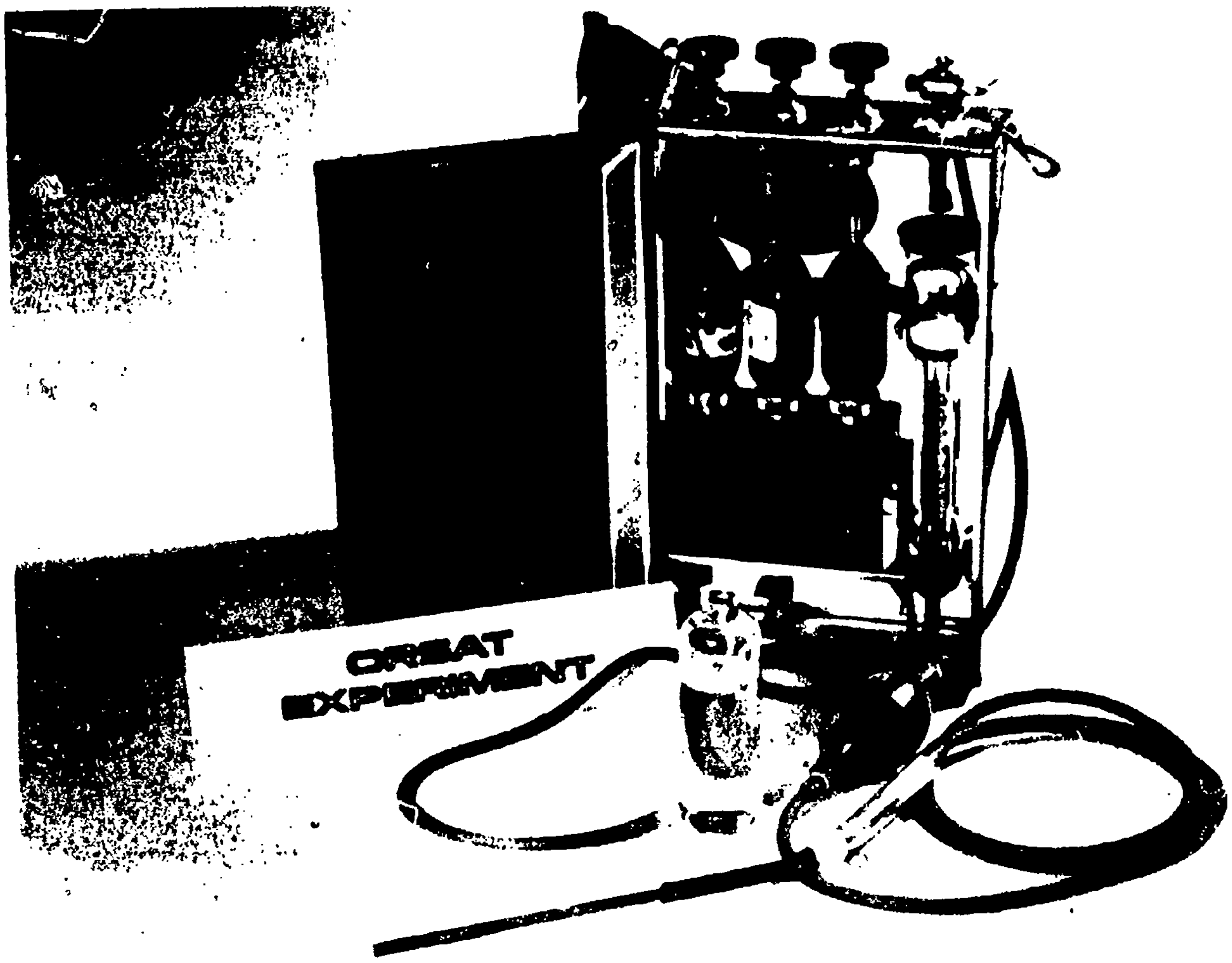
Inclined oil manometer and Prandtl tube for calibration of the Type S pitot tube



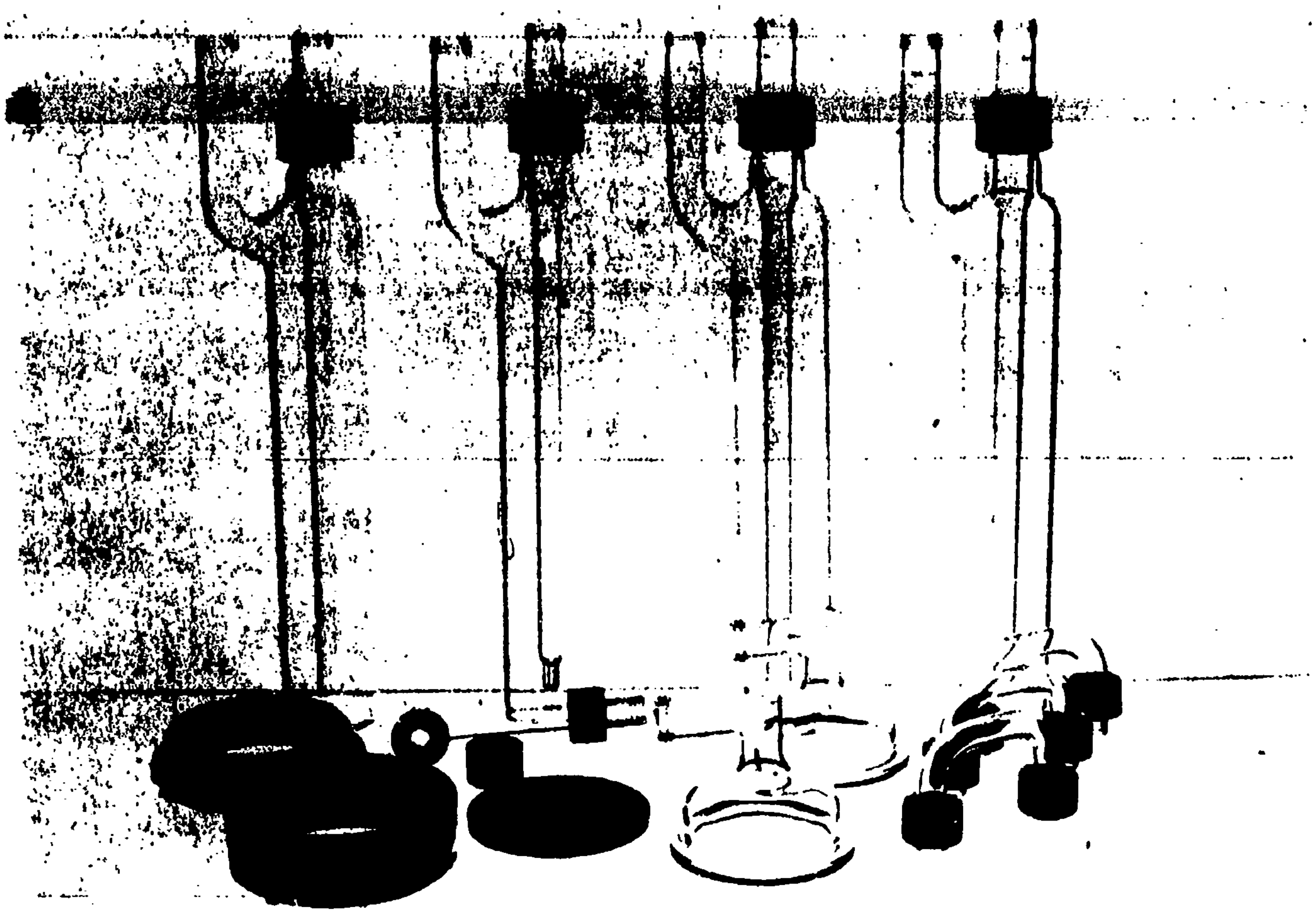
RAC (left) and Nutech (right) Meter Consoles



Blower section for sampling duct



Hayes Orsat



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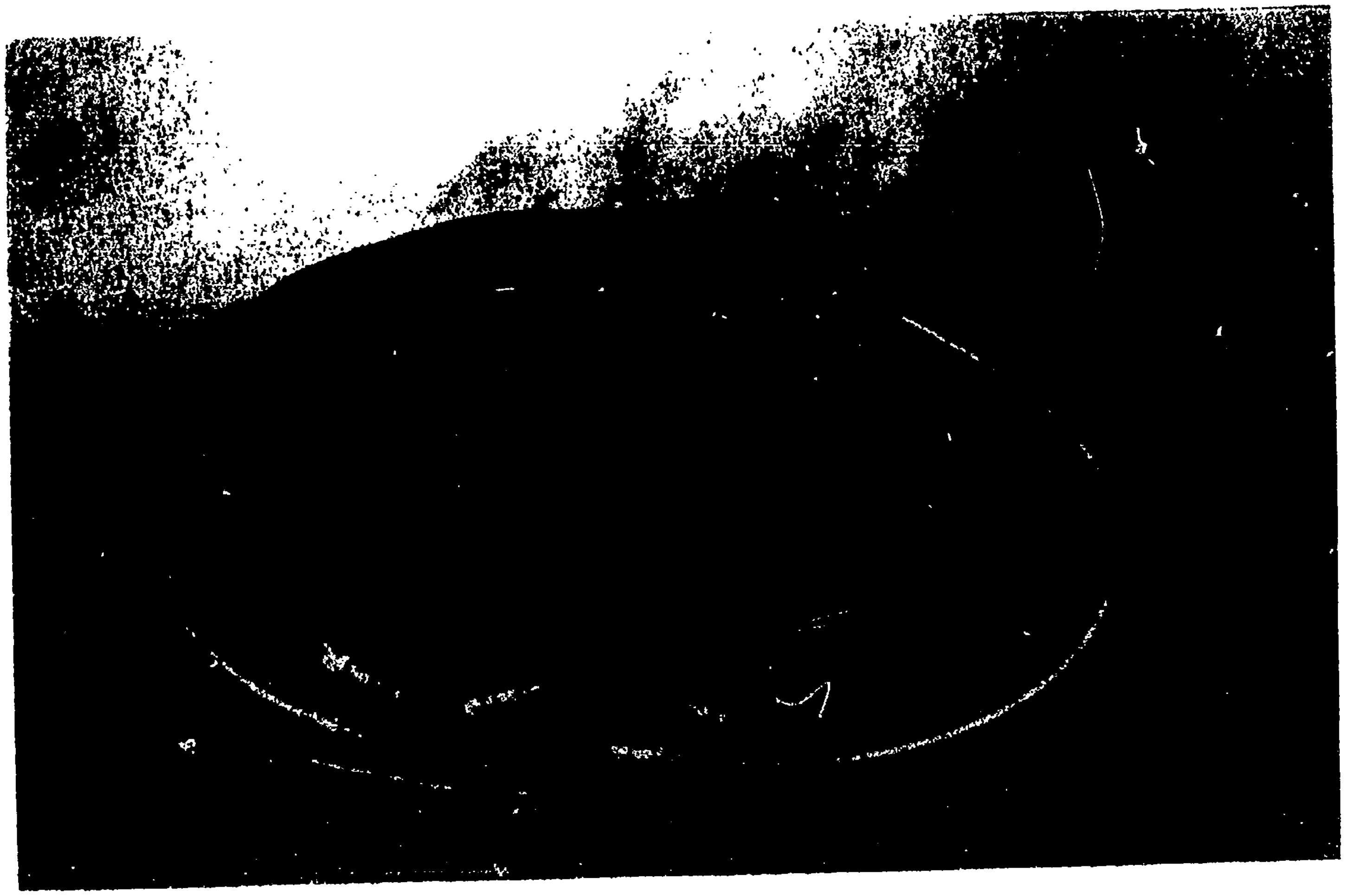

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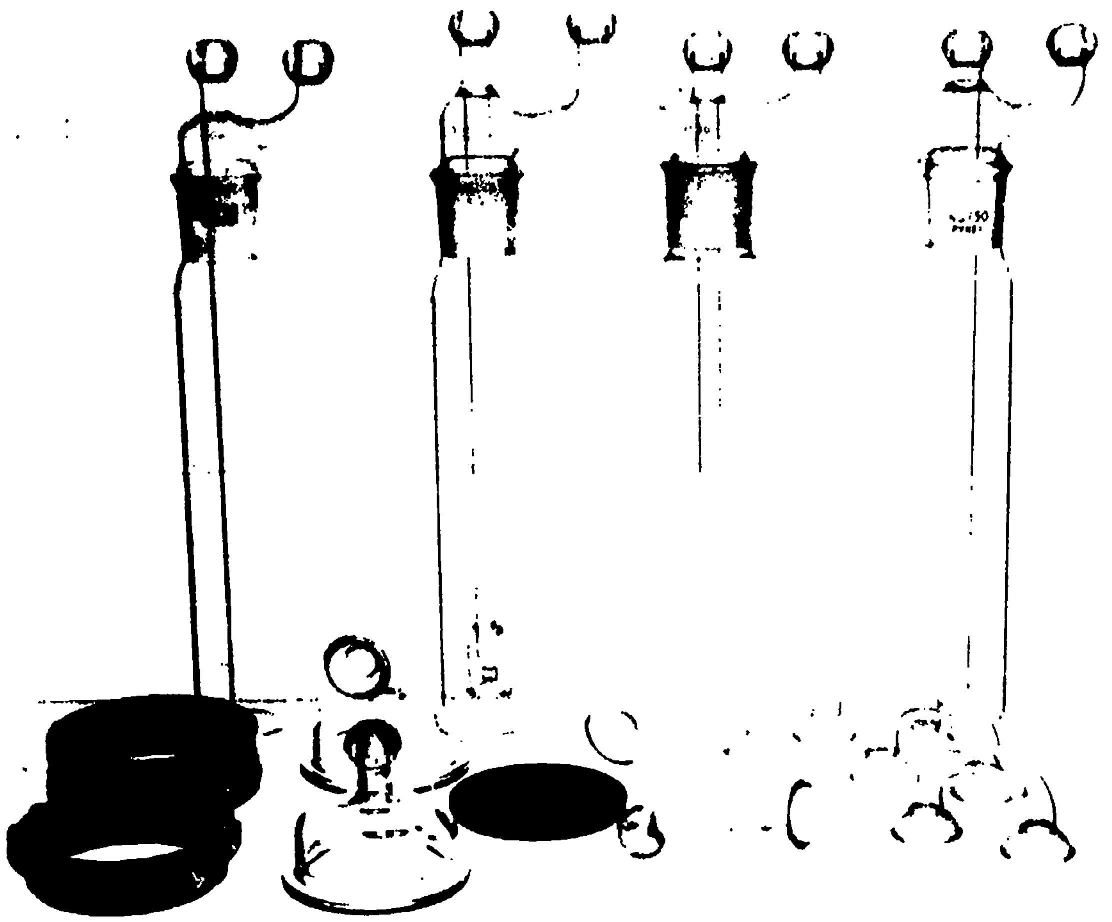
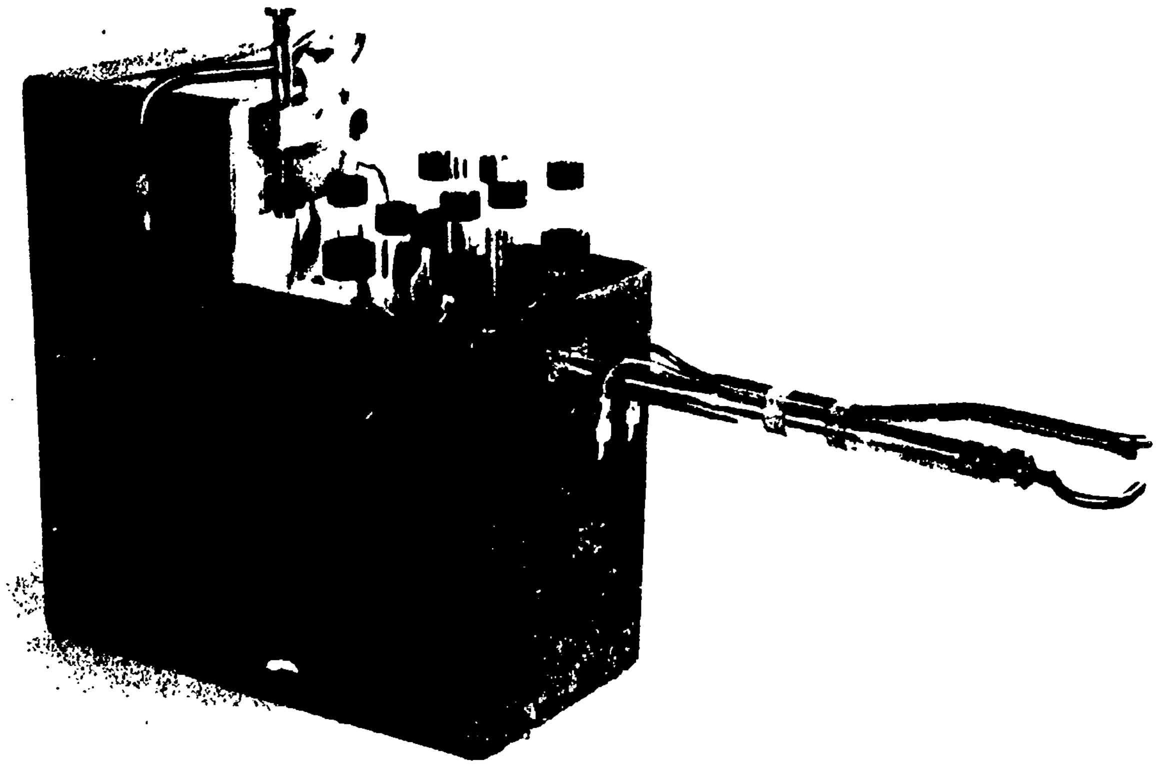
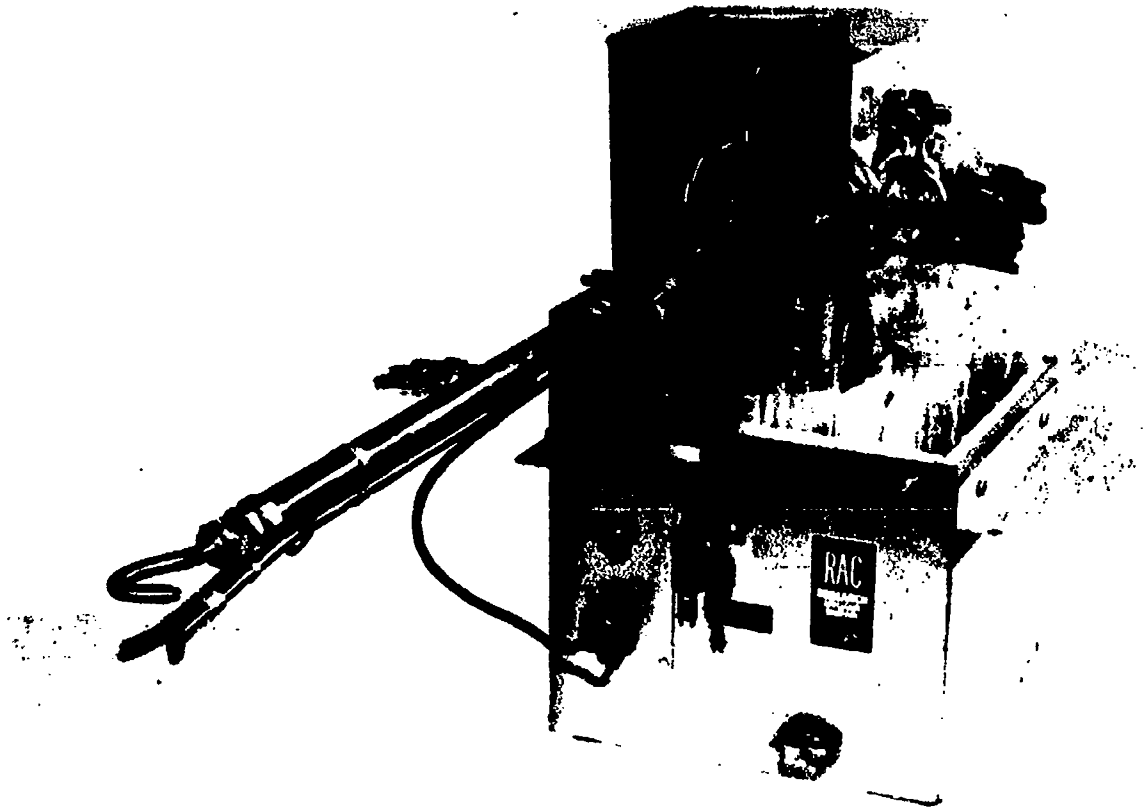


Ground glass ball-joint glassware



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

TECHNICAL REPORT DATA

(Please read Instructions on the reverse before completing)

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EPA 450/2-80-003

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Instructor's Guide

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EPA Project Officer for this manual is R. E. Townsend, EPA, ERC (MD-17), RTP, NC

16. ABSTRACT

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.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS		b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group
Measurement	Calibrating	Stack Sampling	14 B
Collection	Filtered Particle Sampling	Particle Measurement	14 D
Air Pollution			
Gas Sampling			
Dust			

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ENVIRONMENTAL PROTECTION AGENCY

■

KRAFT PULP MILLS

Standards of Performance for
New Stationary Sources and
Availability of Draft Guideline
Document

[6560-01]

Title 40—Protection of the Environment

CHAPTER I—ENVIRONMENTAL PROTECTION AGENCY

SUBCHAPTER C—AIR PROGRAMS

[FRL 833-1]

PART 60—STANDARDS OF PERFORMANCE FOR NEW STATIONARY SOURCES

Kraft Pulp Mills

AGENCY: Environmental Protection Agency.

ACTION: Final rule.

SUMMARY: The standards limit emissions of total reduced sulfur (TRS) and particulate matter from new, modified, and reconstructed kraft pulp mills. The standards implement the Clean Air Act and are based on the Administrator's determination that emissions from kraft pulp mills contribute significantly to air pollution. The intended effect of these standards is to require new, modified, and reconstructed kraft pulp mills to use the best demonstrated system of continuous emission reduction.

EFFECTIVE DATE: February 23, 1978.

ADDRESSES: The Standards Support and Environmental Impact Statement (SSEIS) may be obtained from the U.S. EPA Library (MD-35), Research Triangle, Park, N.C. 27711 (specify "Standards Support and Environmental Impact Statement, Volume 2: Promulgated Standards of Performance for Kraft Pulp Mills" (EPA-450/–-76-014b)). Copies of all comment letters received from interested persons participating in this rulemaking are available for inspection and copying during normal business hours at EPA's Public Information Reference Unit, Room 2922 (EPA Library), 401 M Street SW., Washington, D.C.

FOR FURTHER INFORMATION CONTACT:

Don R. Goodwin, Emission Standards and Engineering Division, Environmental Protection Agency, Research Triangle Park, N.C. 27711, telephone No. 919-541-5271.

SUPPLEMENTARY INFORMATION: On September 24, 1976 (41 FR 42012), standards of performance were proposed for new, modified, and reconstructed kraft pulp mills under section 111 of the Clean Air Act, as amended. The significant comments that were received during the public comment period have been carefully reviewed and considered and where determined by the Administrator to be appropriate, changes have been included in this notice of final rulemaking.

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, 0.10 gram per kilogram of black 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: 5 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; 5 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 at 8 percent oxygen from cross recovery furnaces, which are defined as furnaces burning at least 7 percent neutral sulfite semi-chemical (NSSC) 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 and opacity standards for the other facilities, however, are essentially the same as those proposed.

It should be noted that standards of performance for new sources 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. State implementation plans (SIP's) approved or promulgated under section 110 of the Act, on the other hand, must provide for the attainment and maintenance of national ambient air quality standards (NAAQS) designed to protect public health and welfare. For that purpose SIP's must in some cases require greater emission reductions than those required by standards of performance for new sources. Section 173(2) of the Clean Air Act, as amended in 1977, requires, among other things, that a new or modified source constructed in an area which exceeds the NAAQS must reduce emissions to the level which reflects the "lowest achievable emission rate" for such category of source, unless the owner or operator demonstrates that the source cannot achieve such an emission rate. In no event can the emission rate exceed any applicable standard of performance.

A similar situation may arise when a major emitting facility is to be constructed in a geographic area which falls under the prevention of significant deterioration of air quality provisions of the Act (Part C). These provisions require, among other things, that major emitting facilities to be constructed in such areas are to be subject to best available control technology. The term "best available control technology" (BACT) means "an emission limitation based on the maximum degree of reduction of each pollutant subject to regulation under this Act emitted from or which results from any major emitting facility, 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 or innovative fuel combustion techniques for control of each such pollutant. In no event shall application of 'best available control technology' result in emissions of any pollutants which will exceed the emissions allowed by any applicable standard established pursuant to section 111 or 112 of this Act."

Standards of performance should not be viewed as the ultimate in achievable emission control and should not preclude the imposition of a more stringent emission 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 locating in areas violating statutorily-mandated health and welfare standards. Although there may be emission control technology 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 in no way should preclude 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 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 energy 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 by 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 use of 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 was responsible for the lower TRS emissions observed at this lime kiln, and (c) the adequacy of the data base used in developing the TRS standard.

The effectiveness of caustic scrubbing is substantiated by comparison of TRS emissions during brief periods when caustic was not being added to the scrubber at lime kiln E, with 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 also substantiated by the experience at another kraft pulp mill which was able to reduce TRS emissions from its lime kiln from 40-50 ppm to about 20 ppm merely by adding caustic to the scrubber. These factors, coupled with the emission data showing higher TRS emissions from those lime kilns which employed only efficient mud washing and good lime kiln process control, clearly show that caustic scrubbing reduces TRS emissions.

The mud washing facilities at lime kiln E are larger than those at other kraft pulp mills of equivalent pulp 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 standards for lime kilns 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 "standards of performance reflect 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, while a system of emission reduction must be available for use to be considered adequately demonstrated, it does not have to be in routine use. However, in order 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 also 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 TRS 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 16 requiring determination of these losses during each source test and adjustment of the emission data obtained to take these losses into account.

With regard to the ability of 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 indicates 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 pulps since both TRS and particulate emissions from the smelt dissolving tanks are proportional to the tons of black liquor solids fed into the tanks. The 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 low-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 in recovery furnaces without facing a serious 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 within 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 expected 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 16, which is the performance test method to determine TRS emissions, is still under study. There is little doubt but that these TRS emission monitoring systems will be shown to be compatible with Reference Method 16, and that performance specifications for these systems will be developed. Consequently, the promulgated standards 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 60 is amended to provide that continuous monitoring systems need not be installed until performance specifications for these systems are promulgated under Appendix B to subpart 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. In general, these comments reflected a lack of understanding with regard to the concept of 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 performance test, under 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 inconvenient for routinely 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 an owner or operator and cannot be attributed to improper operation and maintenance. Similarly, excess emissions as a result of some inherent variability or fluctation within a process which influences emissions cannot be attributed to improper operation and maintenance, unless these fluctuations could be controlled by more carefully 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 contiguous 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 emissions 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 data generated by 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 emissions allowance for lime kilns, a reevaluation of the TRS emission data from lime kiln E led the Agency to the conclusion that, for a TRS emission limit of 5 ppm, an excess emission allowance of 6 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 promulgated standard for lime kilns contains no excess emission allowance. This does not represent a change in the basis of the standard. The standard will still require installation of the best system of emission reduction, considering costs (i.e., efficient mud washing, good lime kiln process operation, and caustic scrubbing; 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 normal 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 for direct recovery furnaces, 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 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

is based consists of efficient mud washing, good process operation of the lime kiln, and caustic scrubbing of the gases discharged from the lime kiln. As with the emission control system upon which the standard for recovery furnaces is based, the first two emission control techniques (i.e., mud washing and good process operation) are not particularly well suited to controlling fluctuations in the kraft pulping process. The third emission control technique, however, caustic scrubbing, is an "add-on" emission control technique that can be designed to accommodate fluctuations in TRS emissions and minimize or essentially eliminate these fluctuations.

EMISSION TESTING

A few comments were received which questioned the validity of the results obtained by Reference Method 16, due to sample losses and sulfur dioxide (SO_2) interference.

With regard to the validity of the results obtained by Reference Method 16, as mentioned earlier, during the emission testing program, it was not widely known that sample losses could occur within the TRS emission measurement system. Since proposal of the standards, however, 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 limits included in the proposed TRS emission standards, they have been considered in selecting the numerical emission limit included in the promulgated'standards. 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 16 requiring determination of these losses during each source test and adjustment of the emission data obtained to take these losses into account. This will ensure that the TRS emission data obtained during a performance test are accurate.

It has also been confirmed that high concentrations of SO_2 will interfere with the determination of TRS emissions to some extent. At this point, however, it is not known what SO_2 concentration levels will result in a significant loss of accuracy in determining TRS emissions. The ability of a citrate scrubber to selectively remove SO_2 prior to measurement of TRS emissions is now being tested. In addition, various chromatographic columns might exist which would effectively resolve this problem. As soon as an appropriate technique is developed to overcome this problem, Reference Method 16 will be amended.

This problem of SO_2 interference will not present major difficulties to the use of Reference Method 16. **Relatively high SO_2 concentration levels were observed in only one EPA emission** source test. Accordingly, high SO_2 concentration levels are probably not a frequent occurrence within kraft pulp mills. More importantly, however, high SO_2 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.

Miscellaneous: The effective date of this regulation is February 24, 1976. Section 111(b)(1)(B) of the Clean Air Act provides that standards of 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 as required under section 317 of the Act. This also satisfies the requirements of Executive Orders 11821 and OMB Circular A-107.

Dated: February 10, 1978.

BARBARA BLUM,
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 the 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 system under Appendix B to this part, unless:

(1) The continuous monitoring system is subject to the provisions of paragraphs (e)(2) and (e)(3) of this section, or

(2) otherwise specified in an applicable subpart or by the Administrator.

* * * * *

2. Part 60 is amended by adding subpart BB as follows:

Subpart BB—Standards of Performance for Kraft Pulp Mills

Sec.

AUTHORITY: Secs. 111, 301(a) of the Clean Air Act, as amended [42 U.S.C. 7411, 7601(a)], and additional authority as noted below.

Subpart BB—Standards of Performance for Kraft Pulp Mills

60.280 Applicability and designation of affected facility.

(a) The provisions of this subpart are applicable to the following affected facilities in kraft pulp mills: digester 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 pulping is combined with neutral sulfite semichemical pulping, the provisions of this subpart are applicable when any portion of the material charged to an affected facility is produced by the kraft pulping 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 pulping operation" means any operation in which pulp is produced from wood by cooking (digesting) wood chips in a solution of sodium sulfite and sodium bicarbonate, followed by mechanical defibrating (grinding).

(c) "Total reduced sulfur (TRS)" means the sum of the sulfur compounds hydrogen sulfide, methyl mercaptan, dimethyl sulfide, and dimethyl disulfide, that are released during the kraft pulping operation and measured by Reference Method 16.

(d) "Digester system" means each continuous digester or each batch digester used for the cooking of wood in white liquor, and associated flash tank(s), below tank(s), chip steamer(s), and condenser(s).

(e) "Brown stock washer system" means brown stock washers and associated knotters, vacuum pumps, and fil

trate tanks used to wash the pulp following the digester system.

(f) "Multiple-effect evaporator system" means the multiple-effect evaporators and associated condenser(s) and hotwell(s) used to concentrate the spent cooking liquid that is separated from the pulp (black liquor).

(g) "Black liquor oxidation system" means the vessels used to oxidize, with air or oxygen, the black liquor, and associated storage tank(s).

(h) "Recovery furnace" means either a straight kraft recovery furnace or a cross recovery furnace, and includes the direct-contact evaporator for a direct-contact furnace.

(i) "Straight kraft recovery furnace" means a furnace used to recover chemicals consisting primarily of sodium and sulfur compounds by burning black liquor which on a quarterly basis contains 7 weight percent or less of the total pulp solids from the neutral sulfite semichemical process or has green liquor sulfidity of 28 percent or less.

(j) "Cross recovery furnace" means a furnace used to recover chemicals consisting primarily of sodium and sulfur compounds by burning black liquor which on a quarterly basis contains more than 7 weight percent of the total pulp solids from the neutral sulfite semichemical process and has a green liquor sulfidity of more than 28 percent.

(k) "Black liquor solids" means the dry weight of the solids which enter the recovery furnace in the black liquor.

(l) "Green liquor sulfidity" means the sulfidity of the liquor which leaves the smelt dissolving tank.

(m) "Smelt dissolving tank" means a vessel used for dissolving the smelt collected from the recovery furnace.

(n) "Lime kiln" means a unit used to calcine lime mud, which consists primarily of calcium carbonate, into quicklime, which is calcium oxide.

(o) "Condensate stripper system" means a column, and associated condensers, used to strip, with air or steam, TRS compounds from condensate streams from various processes within a kraft pulp mill.

§ 60.282 Standard for particulate matter.

(a) On and after the date on which the performance test required to be conducted by § 60.8 is completed, no owner or operator subject to the provisions of this subpart shall cause to be discharged into the atmosphere:

(1) From any recovery furnace any gases which:

(i) Contain particulate matter in excess of 0.10 g/dscm (0.044 gr/dscf) corrected to 8 percent oxygen.

(ii) Exhibit 35 percent opacity or greater.

(2) From any smelt dissolving tank any gases which contain particulate matter in excess of 0.1 g/kg black **liquor solids (dry weight)[0.2 lb/ton black liquor solids (dry weight)].**

(3) From any lime kiln any gases which contain particulate matter in excess of:

(i) 0.15 g/dscm (0.067 gr/dscf) corrected to 10 percent oxygen, when gaseous fossil fuel is burned.

(ii) 0.30 g/dscm (0.13 gr/dscf) corrected to 10 percent oxygen, when liquid fossil fuel is burned.

§ 60.283 Standard for total reduced sulfur (TRS).

(a) On and after the date on which the performance test required to be conducted by § 60.8 is completed, no owner or operator subject to the provisions of this subpart shall cause to be discharged into the atmosphere:

(1) From any digester system, brown stock washer system, multiple-effect evaporator system, black liquor oxidation system, or condensate stripper system any gases which contain TRS in excess of 5 ppm by volume on a dry basis, corrected to 10 percent oxygen, unless the following conditions are met:

(i) The gases are combusted in a lime kiln subject to the provisions of paragraph (a)(5) of this section; or

(ii) The gases are combusted in a recovery furnace subject to the provisions of paragraphs (a)(2) or (a)(3) of this section; or

(iii) The gases are combusted with other waste gases in an incinerator or other device, or combusted in a lime kiln or recovery furnace not subject to the provisions of this subpart, and are subjected to a minimum temperature of 1200° F. for at least 0.5 second; or

(iv) It has been demonstrated to the Administrator's satisfaction by the owner or operator that incinerating the exhaust gases from a new, modified, or reconstructed black liquor oxidation system or brown stock washer system in an existing facility is technologically or economically not feasible. Any exempt system will become subject to the provisions of this subpart if the facility is changed so that the gases can be incinerated.

(2) From any straight kraft recovery furnace any gases which contain TRS in excess of 5 ppm by volume on a dry basis, corrected to 8 percent oxygen.

(3) From any cross recovery furnace any gases which contain TRS in excess of 25 ppm by volume on a dry basis, corrected to 8 percent oxygen.

(4) From any smelt dissolving tank any gases which contain TRS in excess of 0.0084 g/kg black liquor solids (dry weight) [0.0168 lb/ton liquor solids (dry weight)].

(5) From any lime kiln any gases which contain TRS in excess of 8 ppm by volume on a dry basis, corrected to 10 percent oxygen.

§ 60.284 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) (iii) or (iv) apply. These systems shall be located downstream of the control device(s) and the span(s) of these continuous monitoring system(s) shall be set:

(i) At a TRS concentration of 30 ppm for the TRS continuous monitoring system, except that for any cross recovery furnace the span shall be set at 50 ppm.

(ii) At 20 percent oxygen for the continuous oxygen monitoring system.

(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 which measures the combustion temperature at the point of incineration of effluent gases which are emitted from any digester system, brown stock washer system, multiple-effect evaporator system, black liquor oxidation system, or condensate stripper system where the provisions of § 60.283(a)(1)(iii) apply. The monitoring device is to 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 a gage pressure of ±500 pascals (ca. ±2 inches water gage pressure).

(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)(iv) or § 60.283(a)(4) apply.

(1) Calculate and record on a daily basis 12-hour average TRS concentrations for the two consecutive 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 for the recovery furnace and lime kiln. These 12 hour averages 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 oxygen, except that all 12-hour average TRS concentration from a recovery furnace shall be corrected to 8 volume percent using the following equation:

$$C_{corr} = C_{meas} \times (21 - X)/(21 - Y)$$

where

C_{corr} = the concentration corrected for oxygen.
C_{meas} = the concentration uncorrected for oxygen.
X = the volumetric oxygen concentration in percentage to be corrected to (8 percent for recovery furnaces and 10 percent for lime kilns, incinerators, or other devices).
Y = the measured 12-hour average volumetric oxygen concentration.

(d) For the purpose of reports required under § 60.7(c), any owner or operator subject to the provisions of this subpart shall report periods of excess emissions as follows:

(1) For emissions from any recovery furnace periods of excess emissions are:

(i) 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.

(ii) All 6-minute average opacities that exceed 35 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, **multiple-effect evaporator system, black liquor oxidation system, or condensate** stripper system periods of excess emissions are:

(i) All 12-hour average TRS concentrations above 5 ppm by volume unless the provisions of § 60.283(a)(1) (i), (ii), or (iv) apply; or

(ii) 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)(1)(ii) apply.

(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:

(i) One percent for TRS emissions from recovery furnaces.

(ii) 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 sample and velocity traverses.

(3) When determining compliance with § 60.282(a)(2), Method 2 for velocity and volumetric flow rate.

(4) Method 3 for gas analysis, and

(5) Method 9 for visible 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/min) except that shorter sampling times, when necessitated 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)(1)(i): *Provided*, That a constant value of 0.009 g/dscm (0.004 gr/dscf) is added to the results of Method 17 and the stack temperature is no greater than 205° C (ca. 400° **F). Water shall be used as the cleanup** solvent instead of acetone in the sample recovery procedure outlined in Method 17.

(d) For the purpose of determining compliance with § 60.283(a) (1), (2), (3), (4), and (5), the following reference methods shall be used:

(1) Method 16 for the concentration of TRS.

(2) Method 3 for gas analysis, and

(3) When determining compliance with § 60.283(a)(4), use the results of Method 2, Method 16, and the black liquor solids feed rate in the following equation to determine the TRS emission rate.

$$E = (C_{H_2S}F_{H_2S} + C_{MeSH}F_{MeSH} + C_{DMS}F_{DMS} + C_{DMDS}F_{DMDS})(Q_{sd})/BLS$$

Where:

E = mass of TRS emitted per unity of black liquor solids (g/kg) (lb/ton)
C_{H_2S} = average concentration of hydrogen sulfide (H_2S) during the test period, PPM.
C_{MeSH} = average concentration of methyl mercaptan (MeSH) during the test period, PPM.
C_{DMS} = average concentration of dimethyl sulfide (DMS) during the test period, PPM.
C_{DMDS} = average concentration of dimethyl disulfide (DMDS) during the test period, PPM.
F_{H_2S} = 0.001417 g/m^3 PPM for metric units = 0.08844 lb/ft^3 PPM for English units
F_{MeSH} = 0.00200 g/m^3 PPM for metric units = 0.1248 lb/ft^3 PPM for English units
F_{DMS} = 0.002583 g/m^3 PPM for metric units = 0.1612 lb/ft^3 PPM for English units
F_{DMDS} = 0.003917 g/m^3 PPM for metric units = 0.2445 lb/ft^3 PPM for English units
Q_{sd} = dry volumetric stack gas flow rate corrected to standard conditions, dscm/hr (dscf/hr)
BLS = black liquor solids feed rate, kg/hr (lb/hr)

(4) When determining whether a furnace is straight kraft recovery furnace or a cross recovery furnace, TAPPI Method T.624 shall be used to determine sodium sulfide, sodium hydroxide and sodium carbonate. These determinations shall be made three times daily from the green liquor and the daily average values shall be converted to sodium oxide (Na_2O) and substituted into the following equation to determine the green liquor sulfidity:

$$GLS = 100\, C_{Na_2S}/(C_{Na_2S} + C_{NaOH} + C_{Na_2CO_3})$$

Where:

GLS = percent green liquor sulfidity
C_{Na_2S} = average concentration of Na_2S expressed as Na_2O (mg/l)
C_{NaOH} = average concentration of $NaOH$ expressed as Na_2O (mg/l)
$C_{Na_2CO_3}$ = average concentration of Na_2CO_3 expressed as Na_2O (mg/l)

(e) All concentrations of particulate matter and TRS required to be measured by this section from lime kilns or incinerators shall be corrected 10 volume percent oxygen and those concentrations from recovery furnaces shall be corrected to 8 volume percent oxygen. These corrections shall be **made in the manner specified in § 60 284(c)(3).**

APPENDIX A REFERENCE METHODS

(3) Method 16 and Method 17 are added to Appendix A as follows.

* * * * *

METHOD 16. SEMICONTINUOUS DETERMINATION OF SULFUR EMISSIONS FROM STATIONARY SOURCES

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 with clean dry air. An aliquot of the diluted sample is then analyzed for hydrogen sulfide (H_2S), methyl mercaptan (MeSH), dimethyl sulfide (DMS) and dimethyl disulfide (DMDS) by gas chromatographic (GC) separation and flame photometric detection (FPD). These four compounds are known collectively as total reduced sulfur (TRS).

1.2 Applicability. This method is applicable for determination of TRS compounds from recovery furnaces, lime kilns, and smelt dissolving tanks at kraft pulp mills.

2. *Range and Sensitivity.*

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 ppm. This limit is expanded by dilution of the sample gas before analysis. Kraft mill gas samples are normally diluted tenfold (9:1), resulting in an upper limit of about 10 ppm for each compound.

For sources with emission levels between 10 and 100 ppm, the measuring range can be best 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, the analytical column, or the FPD burner block can 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 CO_2 have substantial desensitizing effect on the flame photometric detector even after 9:1 dilution. Acceptable systems must demonstrate that they have eliminated this interference by some procedure such as eluting these compounds before any of the compounds to be measured. Compliance with this requirement can be demonstrated by submitting chromatograms of calibration gases with and without CO_2 in the diluent gas. The CO_2 level should be approximately 10 percent for the case with CO_2 present. The two chromatographs should show agreement within the precision limits of Section 4.1.

3.3 Particulate Matter. Particulate matter in gas samples can cause interference by eventual clogging of the analytical system. This interference must be eliminated by use of a probe filter.

3.4 Sulfur Dioxide. SO_2 is not a specific interferent but may be present in such large amounts that it cannot be effectively separated from other compounds of interest. The procedure must be designed to eliminate this problem either by the choice of separation columns or by removal of SO_2 from the sample.

Compliance with this section can be demonstrated by submitting chromatographs of calibration gases with SO_2 present in the same quantities expected from the emission source to be tested. Acceptable systems shall show baseline separation with the amplifier attenuation set so that the reduced sulfur compound of concern is at least 50 percent of full scale. Base line separation is defined as a return to zero ± percent in the interval between peaks.

4. *Precision and Accuracy.*

4.1 GC/FPD and Dilution System Calibration Precision. A series of three consecutive injections of the same calibration gas, at any dilution, shall produce results which do not vary by more than ±3 percent from the mean of the three injections.

4.2 GC/FPD and Dilution System Calibration Drift. The calibration drift determined from the mean of three injections made at the beginning and end of any 8-hour period shall not exceed ± percent.

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* (See Figure 16-1).

5.1.1 Probe. The probe must be made of inert material such as stainless steel or glass. It should be designed to incorporate a filter and to allow calibration gas to enter the probe at or near the sample entry point. Any portion of the probe not exposed to the stack gas must be heated to prevent moisture condensation.

5.1.2 Sample Line. The sample line must be made of Teflon,[1] no greater than 1.3 cm (½) inside diameter. All parts from the probe to the dilution system must be thermostatically heated to 120

5.1.3 Sample Pump. The sample pump shall be a leakless Teflon-coated diaphragm type or equivalent. If the pump is upstream of the dilution system, the pump head must be heated to 120° C.

5.2 Dilution System. The dilution system must be constructed such 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 approximately a 9:1 dilution of the sample.

5.3 Gas Chromatograph. The gas chromatograph must have at least the following components:

5.3.1 Oven. Capable of maintaining the separation column at the proper operating temperature ±1° C.

5.3.2 Temperature Gauge. To monitor column oven, detector, and exhaust temperature ±1° C.

5.3.3 Flow System. Gas metering system to measure sample, fuel, combustion gas, and carrier gas flows.

5.3.4 Flame Photometric Det

5.3.4.1 Electrometer. Capable [illegible] scale **amplification of linear ranges of 10 [illegible] to 10 [illegible] amperes full scale.**

5.3.4.2 Power Supply. Capable of delivering up to 750 volts

5.3.4.3 Recorder. Compatible with the output voltage range of the electrometer.

5.4 Gas Chromatograph Columns. The column system must be demonstrated to be capble of resolving the four major reduced sulfur compounds: H_2S, MeSH, DMS, and DMDS. It must also demonstrate freedom from known interferences.

To demonstrate that adequate resolution has been achieved, the tester must submit a chromatograph of a calibration gas containing all four of the TRS compounds in the concentration range of the applicable standard. Adequate resolution will be defined as base line 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. Calibration System. The calibration 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 tester may elect to use the flow data that would yield the lowest flow measurement. Calibration with a wet test meter before a test is optional.

5.5.3 Constant 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 ±1° C.

6. *Reagents.*

6.1 Fuel. Hydrogen (H_2) prepurified grade or better.

6.2 Combustion Gas. Oxygen (O_2) or air, research purity or better.

6.3 Carrier Gas. Prepurified grade or better.

6.4 Diluent. Air containing less than 50 ppb 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 H_2S, MeSH, DMS, and DMDS, agravimetrically calibrated and certified at some convenient operating temperature. These tubes consist of hermetically sealed FEP Teflon tubing in which a liquified gaseous substance is enclosed. The enclosed gas permeates through the tubing wall at a constant rate. When the temperature is constant, calibration gases covering a wide range of known concentrations can be generated by varying and accurately measuring the flow rate of diluent gas passing over the tubes. These calibration gases are used to calibrate the GC/FPD system and the dilution system.

7. *Pretest Procedures.* The following procedures are optional but would be helpful in preventing any problem which might occur later and invalidate the entire test

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[1] Mention of trade names or specific products does not constitute endorsement by the Environmental Protection Agency

7.1 After the complete measurement system has been set up at the site and deemed to be operational, the following procedures should be completed before sampling is initiated.

7.1.1 Leak Test. Appropriate leak test procedures should be employed to verify the integrity of all components, sample lines, and connections. The following leak test procedure is suggested: For components upstream of the sample pump, attach the probe end of the sample line to a manometer or vacuum gauge, start the pump and pull greater than 50 mm (2 in.) Hg vacuum, close off the pump outlet, and then stop the pump and ascertain that there is no leak for 1 minute. For components after the pump, apply a slight positive pressure and check for leaks by applying a liquid (detergent in water, for example) at each joint. Bubbling indicates the presence of a leak.

7.1.2 System Performance. Since the complete system is calibrated following each test, the precise calibration of each component is not critical. However, these components should be verified to be operating properly. This verification can be performed by observing the response of flowmeters or of the GC output to changes in flow rates or calibration gas concentrations and ascertaining the response to be within predicted limits. In any component, or if the complete system fails to respond in a normal and predictable manner, the source of the discrepancy should be identified and corrected before proceeding.

8 *Calibration.* Prior to any sampling run, calibrate the system using the following procedures. (If more than one run is performed during any 24 hour period, a calibration need not be performed prior to the second and any subsequent runs. The calibration must, however, be verified as prescribed in Section 10, after the last run made within the 24 hour period.)

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 understanding of the individual system being used. Each system should include a written operating manual describing in detail the operating procedures associated with each component in the measurement system. In addition, the operator should be familiar with the operating principles of the components, particularly the GC/FPD. The citations in the Bibliography at the end of this method 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 injecting samples of calibration gas at 1 hour intervals. The permeation tubes can be assumed to have reached equilibrium when consecutive hourly samples agree within the precision limits of Section 4.1.

Vary the amount of air flowing over the tubes to produce the desired concentrations for calibrating the analytical and dilution systems. The air flow across the tubes must at all times exceed the flow requirement of the analytical systems. The concentration in parts per million generated by a tube containing a specific permeant can be calculated as follows:

[illegible]

Equation 16-1

where:

C = Concentration of permeant produced in ppm.

P, Permeation rate of the tube in μg/min.

M Molecular weight of the permeant (g/g-mole).

L Flow rate, l/min, of air over permeant @ 20° C, 760 mm Hg.

K Gas constant at 20° C and 760 mm Hg = 24.04 l/g mole.

8.3 Calibration of analysis system. Generate a series of three or more known concentrations spanning the linear range of the FPD (approximately 0.05 to 1.0 ppm) for each of the four major sulfur compounds. Bypassing the dilution system, inject these standards into the GC/FPD analyzers and monitor the responses. Three injects 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.

8.4 Calibration Curves. Plot the GC/FPD response in current (amperes) versus their causative concentrations in ppm on log-log coordinate graph paper for each sulfur compound. Alternatively, a least squares equation may be generated from the calibration data.

8.5 Calibration of Dilution System. Generate a known concentration of hydrogen sulfide using the permeation tube system. Adjust the flow rate of diluent air for the first dilution stage so that the desired level of dilution is approximated. Inject the diluted calibration gas into the GC/FPD system and monitor its response. Three injections for each dilution must yield the precision described in Section 4.1. Failure to attain this precision in this step 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 H_2S (developed under 8.3) determine the diluted calibration gas concentration in ppm. Then calculate the dilution factor as the ratio of the calibration gas concentration before dilution to the diluted 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 generating a series of three or more concentrations of each sulfur compound and diluting these samples before injecting them into the GC/FPD system. This data will then serve as the calibration data for the unknown samples and a separate determination of the dilution factor will not be necessary. However, the precision requirements of Section 4.1 are still applicable.

9 *Sampling and Analysis Procedure.*

9.1 Sampling. Insert the sampling probe into the test port making certain that no dilution air enters the stack through the port. Begin sampling and dilute the sample approximately 9:1 using the dilution system. Note that the precise dilution factor is that which is determined in paragraph 8.5. Condition the entire system with sample for a minimum of 15 minutes prior to commencing analysis.

9.2 Analysis. Aliquots of diluted sample are injected into the GC/FPD analyzer for analysis.

9.2.1 Sample Run. A sample run is composed of 16 individual analyses (injects) performed over a period of not less than 3 hours or more than 6 hours.

9.2.2 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 must be interrupted to determine if the sample probe is clogged with particulate matter. If the probe is found to be clogged, the test must be stopped and the results up to that point discarded. Testing may resume after cleaning the probe or replacing it with a clean one. After each run, the sample probe must be inspected and, if necessary, dismantled and cleaned.

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 at the opening of the probe in sufficient quantities to insure that there is an excess of sample which must be vented to the atmosphere. The sample must be transported through the entire sampling system to the measurement 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. Sampling losses of 0-20 percent must be corrected for by dividing the resulting sample concentration by the fraction of recovery. The known gas sample may be generated using permeation tubes. Alternatively, cylinders of hydrogen sulfide mixed in air may be used provided they are traceable to permeation tubes. The optional pretest procedures provide a good guideline for determining if there are leaks in the sampling system.

10.2 Recalibration. After each run, or after a series of runs made within a 24-hour period, perform a partial recalibration using the procedures in Section 8. Only H_2S (or other permeant) need be used to recalibrate the GC/FPD analysis system (8.3) and the dilution system (8.5).

10.3 Determination of Calibration Drift. Compare the calibration curves obtained prior to the runs, to the calibration curves obtained under paragraph 10.1. The calibration drift should not exceed the limits set forth in paragraph 4.2. If the drift exceeds this limit, the intervening run or runs should be considered not valid. The tester, however, may instead have the option of choosing the calibration data set which would give the highest sample values.

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.

11.2 Calculation of TRS. Total reduced sulfur will be determined for each anaylsis made by summing the concentrations of each reduced sulfur compound resolved during a given analysis.

$$TRS = \Sigma(H_2S, MeSH, DMS, 2DMDS)d$$

Equation 16-2

where

TRS = Total reduced sulfur in ppm, wet basis.

H_2S = Hydrogen sulfide, ppm.

MeSH = Methyl mercaptan, ppm.

DMS = Dimethyl sulfide, ppm.

DMDS = Dimethyl disulfide, ppm.

d = Dilution factor, dimensionless.

11.3 Average TRS. The average TRS will be determined as follows:

$$\text{Average TRS} = \frac{\sum_{i=1}^{N} TRS_i}{N(1-B_{wo})}$$

Average TRS = Average total reduced suflur in ppm, dry basis.
TRS_i = Total reduced sulfur in ppm as determined by Equation 16-2.
N = Number of samples.
B_{wo} = Fraction of volume of water vapor in the gas stream as determined by method 4—Determination of Moisture in Stack Gases (36 FR 24887).

11.4 Average concentration of individual reduced sulfur compounds.

$$C = \frac{\sum_{i=1}^{N} S_i}{N}$$

Equation 16-3

where:

S_i = Concentration of any reduced sulfur compound from the ith sample injection, ppm.
C = Average concentration of any one of the reduced sulfur compounds for the entire run, ppm.
N = Number of injections in any run period.

12. *Example System.* Described below is a system utilized by EPA in gathering 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 kilns and other sources where significant amounts of particulate matter are present, the probe is designed with the deflector shield placed between the sample and the gas inlet holes and the glass wool plugs to reduce clogging of the filter and possible adsorption of sample gas. The exposed portion of the probe between the sampling port and the sample line is heated with heating tape.

12.1.1.2 Sample Line ' inch inside diameter Teflon tubing, h to 120° C. This temperature is contr a thermostatic heater.

12.1.1.3 Sample ' eakless Teflon coated diaphragm . uivalent. The pump head is heatec 1: by enclosing it in the sample dilution b 12.2.4 below).

12.1.2 Dilution System. . chematic diagram of the dynamic dilution system is given in Figure 16-2. The dilution system is constructed such that all sample contacts are made of inert materials. The dilution system which is heated to 120 C must be capable of a minimum of 9:1 dilution of sample. Equipment used in the dilution system is listed below:

12.1.2.1 Dilution Pump. Model A-150 Kohmyhr Teflon positive displacement type, nonadjustable 150 cc/min. ±2.0 percent, or equivalent, per dilution stage. A 9:1 dilution of sample is accomplished by combining 150 cc of sample with 1,350 cc of clean dry air as shown in Figure 16-2.

12.1.2.2 Valves. Three-way Teflon solenoid or manual type.

12.1.2.3 Tubing. Teflon tubing and fittings are used throughout from the sample probe to the GC/FPD to present an inert surface for sample gas.

12.1.2.4 Box. Insulated box, heated and maintained at 120° C, of sufficient dimensions to house dilution apparatus.

12.1.2.5 Flowmeters. Rotameters or equivalent to measure flow from 0 to 1500 ml/min ±1 percent per dilution stage.

12.1.3 Gas Chromatograph Columns. Two types of columns are used for separation of low and high molecular weight sulfur compounds.

12.1.3.1 Low Molecular Weight Sulfur Compounds Column (GC/FPD-1).

12.1.3.1 Separation Column. 11 m by 2.16 mm (36 ft by 0.085 in) inside diameter Teflon tubing packed with 30/60 mesh Teflon coated with 5 percent polyphenyl ether and 0.05 percent orthophosphoric acid, or equivalent (see Figure 16-3).

12.1.3.1.2 Stripper or Precolumn. 0.6 m by 2.16 mm (2 ft by 0.085 in) inside diameter Teflon tubing packed as in 5.3.1.

12.1.3.1.3 Sample Valve. Teflon 10-port gas sampling valve, equipped with a 10 ml sample loop, actuated by compressed air (Figure 16-3).

12.1.3.1.4 Oven. For containing sample valve, stripper column and separation column. The oven should be capable of maintaining an elevated temperature ranging from ambient to 100° C, constant within ±1° C.

12.1.3.1.5 Temperature Monitor. Thermocouple pyrometer to measure column oven, detector, and exhaust temperature ±1° C.

12.1.3.1.6 Flow System. Gas metering system to measure sample flow, hydrogen flow, and oxygen flow (and nitrogen carrier gas flow).

12.1.3.1.7 Detector. Flame photometric detector.

12.1.3.1.8 Electrometer. Capable of full scale amplification of linear ranges of 10^{-9} to 10^{-4} amperes full scale.

12.1.3.1.9 Power Supply. Capable of delivering up to 750 volts.

12.1.3.1.10 Recorder. Compatible with the output voltage range of the electrometer.

12.1.3.2 High Molecular Weight Compounds Column (GC/FPD-11).

12.1.3.2.1. Separation Column. 3.05 m by 2.16 mm (10 ft by 0.085 in) inside diameter Teflon tubing packed with 30/60 mesh Teflon coated with 10 percent Triton X-305, or equivalent.

12.1.3.2.2 Sample Valve. Teflon 6-port gas sampling valve equipped with a 10 ml sample loop, actuated by compressed air (Figure 16-3).

12.1.3.2.3 Other Components. All components same as in 12.1.3.1.4 to 12.1.3.1.10.

12.1.4 Calibration. Permeation tube system (figure 16-4).

12.1.4.1 Tube Chamber. Glass chamber of sufficient dimensions to house permeation tubes.

12.1.4.2 Mass Flowmeters. Two mass flowmeters in the range 0-3 1/min and 0-10 1/min. to measure air flow over permeation tubes at ±2 percent. These flowmeters shall be cross-calibrated at the beginning of each test. Using a convenient flow rate in the measuring range of both flowmeters, set and monitor the flow rate of gas over the permeation tubes. Injection of calibration gas generated at this flow rate as measured by one flowmeter followed by injection of calibration gas at the same flow rate as measured by the other flowmeter should agree within the specified precision limits. If they do not, then there is a problem with the mass flow measurement. Each mass flowmeter shall be calibrated prior to the first test with a wet test meter and thereafter, at least once each year.

12.1.4.3 Constant Temperature Bath. Capable of maintaining permeation tubes at certification temperature of 30° C. within ±0.1° C.

12.2 Reagents

12.2.1 Fuel. Hydrogen (H_2) prepurified grade or better.

12.2.2. Combustion Gas. Oxygen (O_2) research purity or better.

12.2.3 Carrier Gas. Nitrogen (N_2) prepurified grade or better.

12.2.4 Diluent. Air containing less than 50 ppb total sulfur compounds and less than 10 ppm each of moisture and total hydrocarbons, and filtered using MSA filters 46727 and 79030, or equivalent. Removal of sulfur compounds can be verified by injecting dilution air only, described in Section 8.3.

12.2.5 Compressed Air. 60 psig for GC valve actuation.

12.2.6 Calibrated Gases. Permeation tubes gravimetrically calibrated and certified at 30.0° 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 50 cc/min, exhaust temperature of 110° C, detector temperature of 105° C, oven temperature of 40° C, hydrogen flow rate of 80 cc/min, oxygen flow rate of 20 cc/min, and sample flow rate between 20 and 80 cc/min.

12.3.2 High-Molecular Weight Sulfur Compounds. The operating parameters for the GC/FPD system for high molecular weight compounds are the same as in 12.3.1 except: oven temperature of 70° C, and nitrogen carrier gas flow of 100 cc/min.

12.4 Analysis Procedure.

12.4.1 Analysis. Aliquots of diluted sample are injected simultaneously into both GC/FPD analyzers for analysis. GC/FPD-I is used to measure the low-molecular weight reduced sulfur compounds. The low molecular weight compounds include hydrogen sulfide, methyl mercaptan, and dimethyl sulfide. GC/FPD-II is used to resolve the high-molecular weight compound. The high-molecular weight compound is dimethyl disulfide.

12.4.1.1 Analysis of Low-Molecular Weight Sulfur Compounds. The sample valve is actuated for 3 minutes in which time an aliquot of diluted sample is injected into the stripper column and analytical column. The valve is then deactivated for approximately 12 minutes in which time, the analytical column continues to be foreflushed, the stripper column is backflushed, and the sample loop is refilled. Monitor the responses. The elution time for each compound will be determined during calibration.

12.4.1.2 Analysis of High Molecular Weight Sulfur Compounds. The procedure is essentially the same as above except that no stripper column is needed.

13 *Bibliography*

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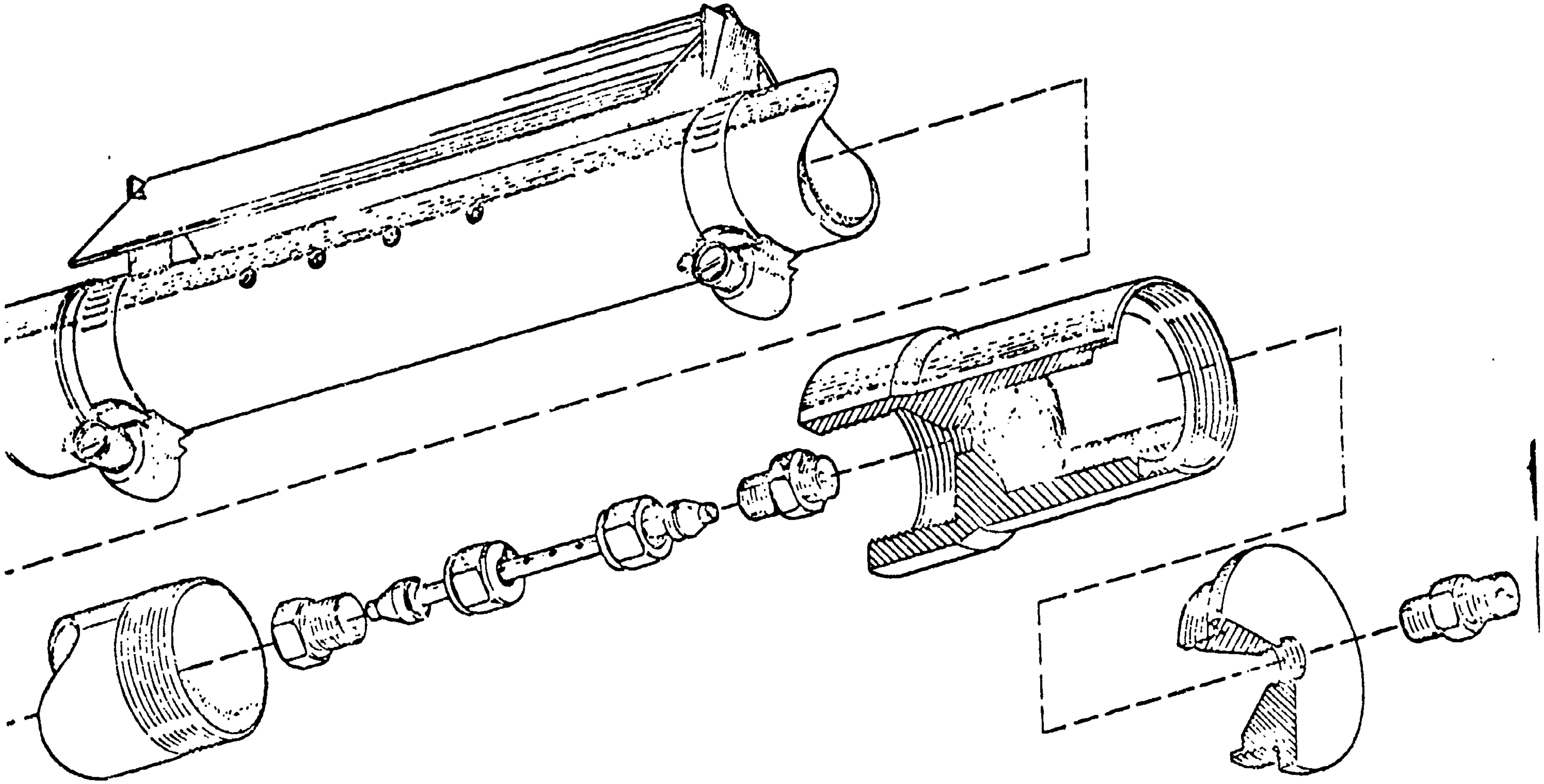

Figure 16-1. Probe used for sample gas containing high particulate loadings.

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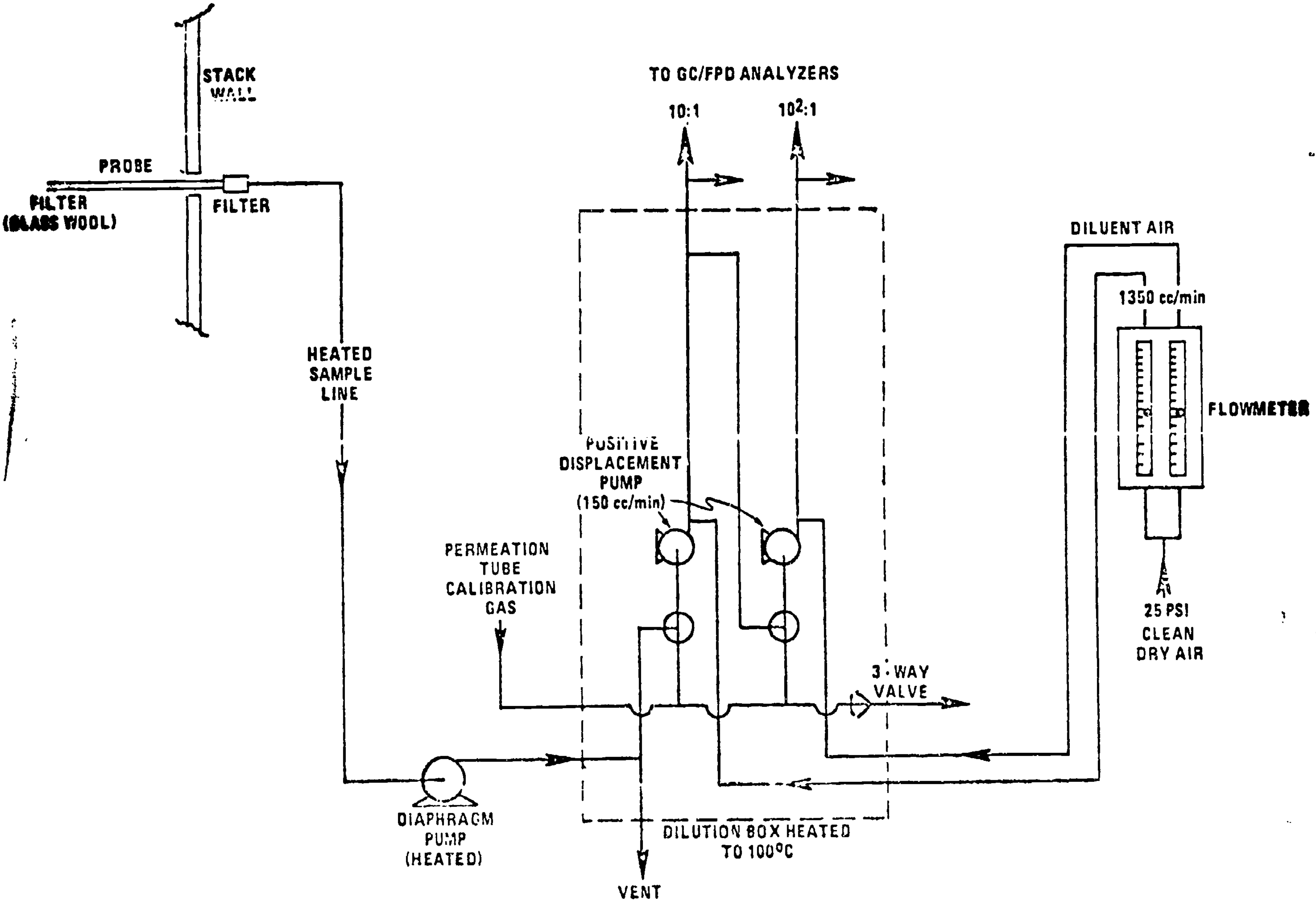


Figure 16-2. Sampling and dilution apparatus.

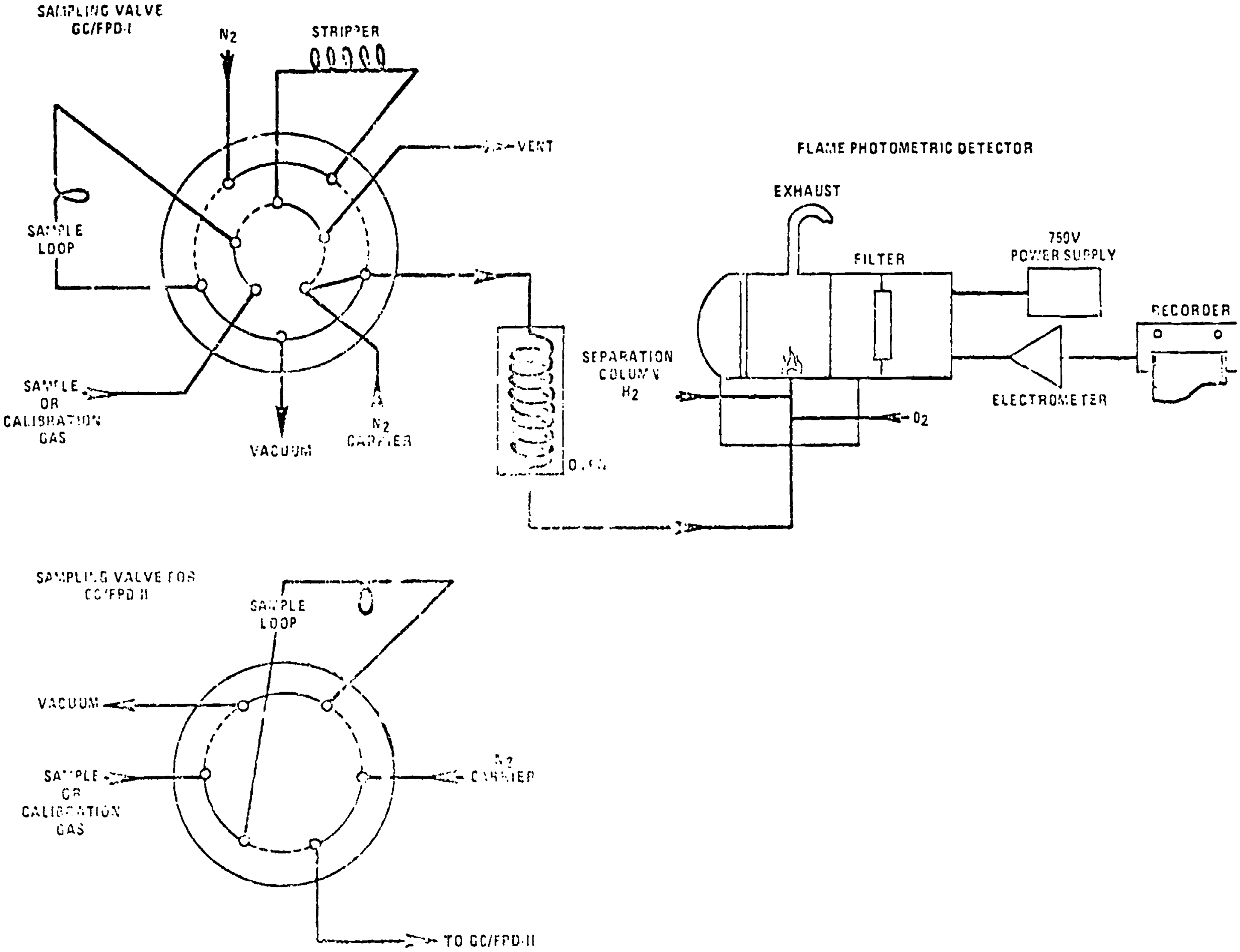


Figure 16-3. Gas chromatographic-flame photometric analyzers.

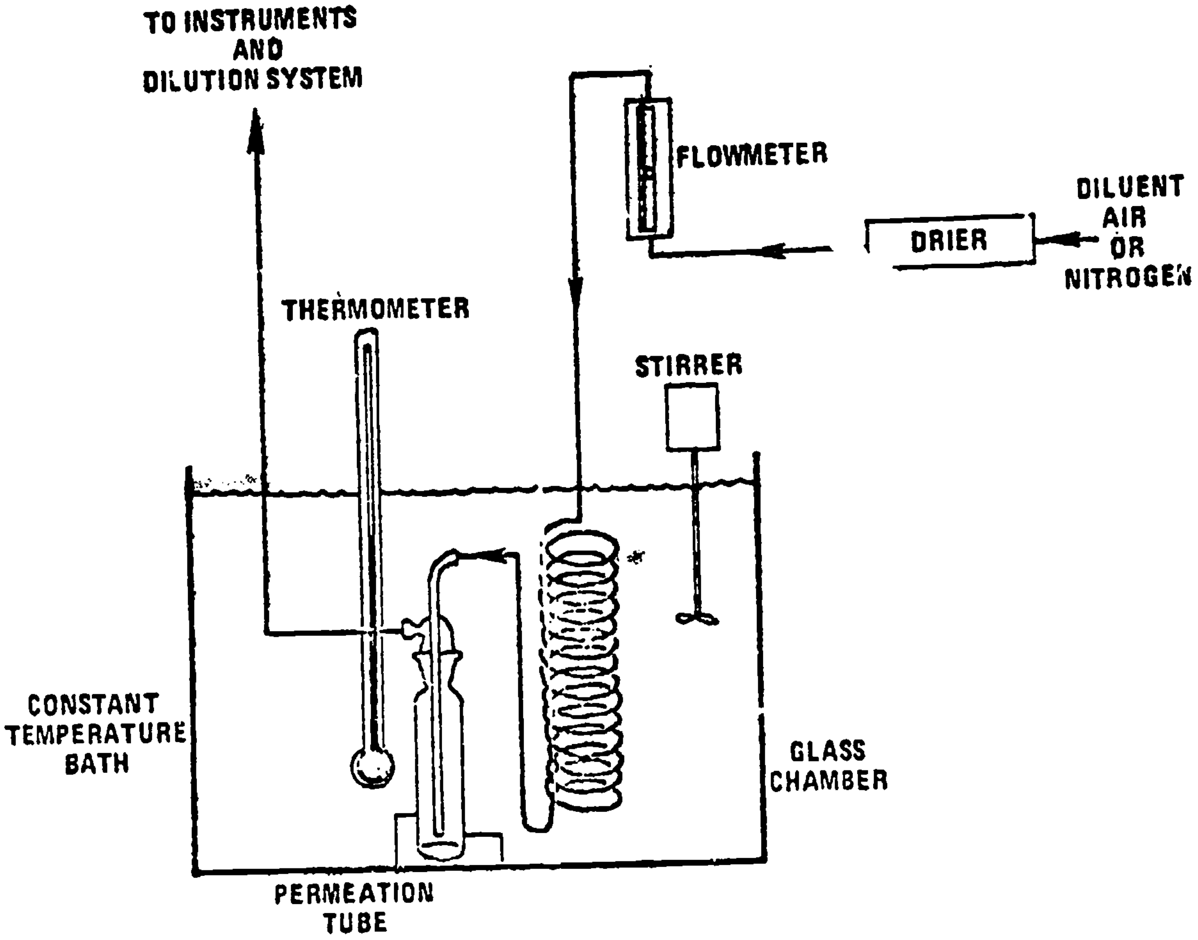


Figure 16-4. Apparatus for field calibration.

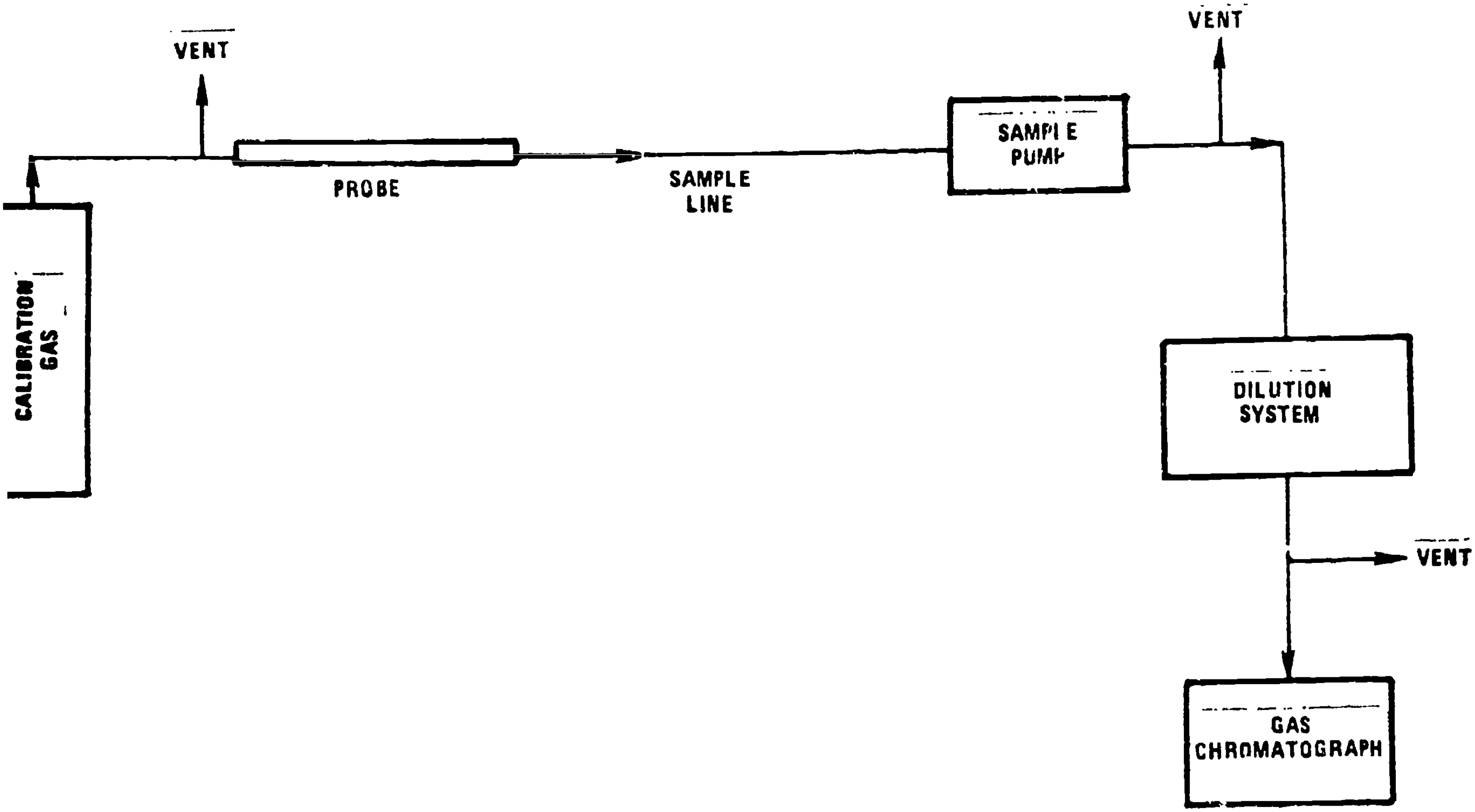


Figure 18-5. Determination of sample line loss.

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 (i.e., 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 care in its operation Therefore, where particulate matter concentrations (over 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 procedures 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 (if specified), or when otherwise approved by the Administrator

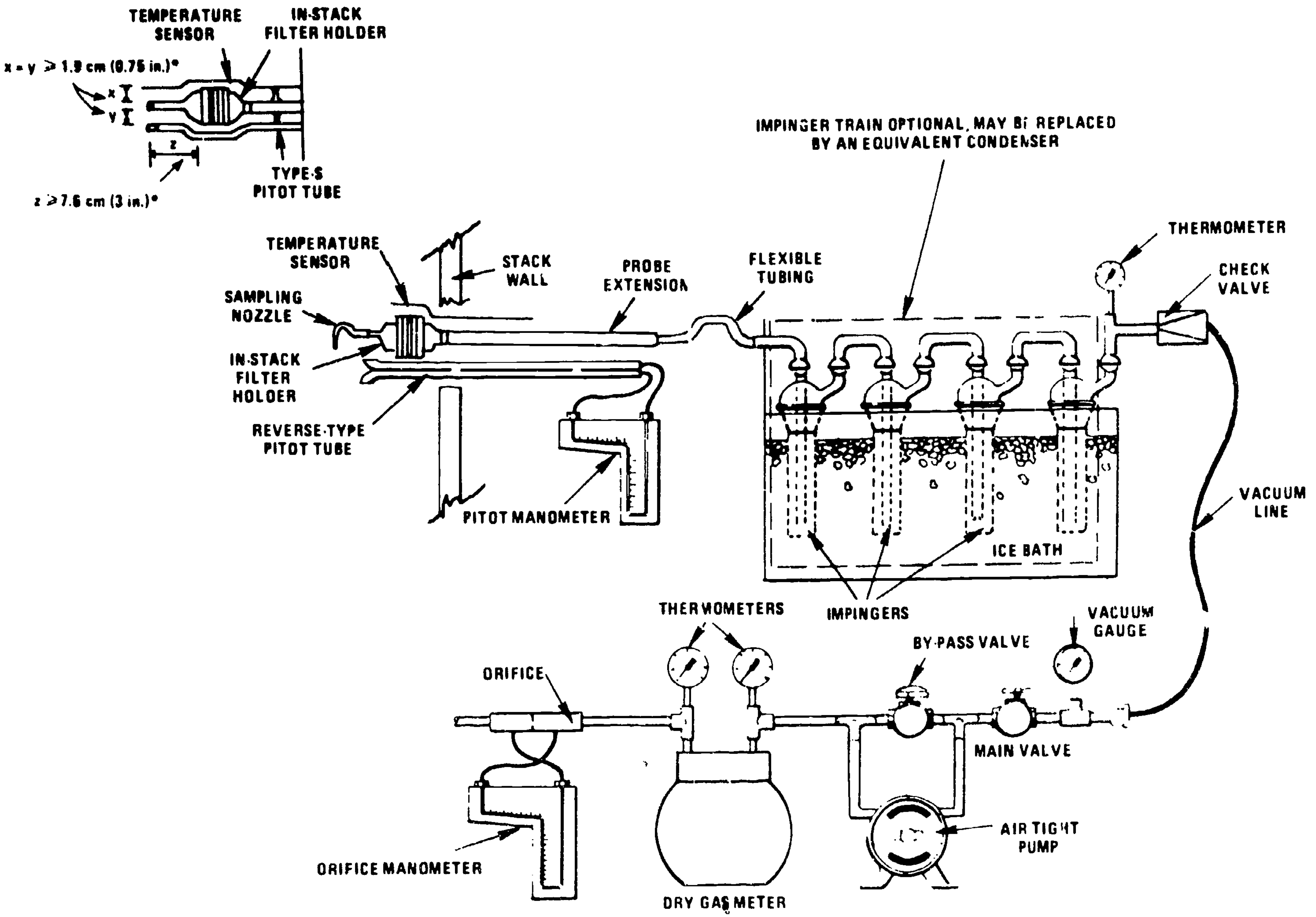
1 *Principle and Applicability*

1.1 Principle Particulate matter is withdrawn isokinetically from the source and collected on a glass fiber filter maintained at stack temperature The particulate mass 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 in an applicable subpart of the standards This method is not applicable to stacks that contain liquid droplets or are saturated with water vapor In addition this method shall not be used as written if the projected cross sectional area of the probe extension filter holder assembly covers more than 5 percent of the stack cross sectional area (see Section 4.1.2

2 *Apparatus*

2.1 Sampling Train A schematic of the sampling train used in this method is shown in Figure 17 1 Construction details for many but not all, of the train components are given in APTD 0581 (Citation 2 in Section 7), for changes from the APTD 0581 document and for allowable modifications to Figure 17 1 consult with the Administrator



* SUGGESTED (INTERFERENCE-FREE) SPACINGS

Figure 17-1. Particulate-Sampling Train, Equipped with In-Stack Filter.

The operating and maintenance procedures for many of the sampling train components are described in APTD-0576 (Citation 3 in Section 7). Since correct usage is important in obtaining valid results, all users should read the APTD-0576 document and adopt the operating and maintenance procedures outlined in it, unless otherwise specified herein. The sampling train consists of the following components:

2 1 1 Probe Nozzle Stainless steel (316) or glass, with sharp, tapered leading edge. The angle of taper shall be 030° and the taper shall be on the outside to preserve 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.

A range of sizes suitable for isokinetic sampling should be available, e.g., 0.32 to 1 27 cm (⅛ to ½ in)—or larger if higher volume sampling trains are used—inside diameter (ID) nozzles in increments of 0.16 cm (¹⁄₁₆ in). Each nozzle shall be calibrated according to the procedures outlined in Section 5 1

2 1 2 Filter Holder. The in-stack filter holder shall be constructed of borosilicate or quartz glass, or stainless steel; if a gasket is used, it shall be made of silicone rubber, Teflon, or stainless steel. Other holder and gasket 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 3 Probe Extension. Any suitable rigid probe extension may be used after the filter holder

2 1 4 Pitot Tube Type S as described in Section 2.1 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 even with or above the nozzle entry plane during sampling (see Method 2, Figure 2 6b) It is recommended: (1) that the pitot tube have a known baseline coefficient, determined as outlined in Section 4 of Method 2; and (2) that this known coefficient be preserved by placing the pitot tube in an interference-free arrangement with respect to the sampling nozzle, filter holder, and temperature sensor (see Figure 17 1). Note that the 1 9 cm (0.75 in) free-space between the nozzle and pitot tube shown in Figure 17 1, is based on a 1 3 cm (0.5 in) ID nozzle If the sampling train is designed for sampling at higher flow rates than that described in APTD 0581, thus necessitating the use of larger sized nozzles, the free-space shall be 1 9 cm (0 75 in) with the largest sized nozzle in place

Source sampling assemblies that do not meet the minimum spacing requirements of Figure 17 1 (or the equivalent of these requirements, e g , Figure 2 7 of Method 2) may be used, however, the pitot tube coefficients of such assemblies shall be determined by calibration, using methods subject to the approval of the Administrator

2 1 5 Differential Pressure Gauge Inclined manometer or equivalent device (two) as described in Section 2 2 of Method 2 One manometer shall be used for velocity head (Δp) readings and the other for orifice differential pressure readings

2.1.6 Condenser. It is recommended that the impinger system described in Method 5 be used to determine the moisture content of the stack gas. Alternatively, any system that allows measurement of both the water condensed and the moisture leaving the condenser, each to within 1 ml or 1 g, may be used. The moisture leaving the condenser can be measured either by: (1) monitoring the temperature and pressure at the exit of the condenser and using Dalton's law of partial pressures; or (2) passing the sample gas stream through a silica gel trap with exit gases kept below 20° C (68° F) and determining the weight gain.

Flexible tubing may be used between the probe extension and condenser. If means other than silica gel are used to determine the amount of moisture leaving the condenser, it is recommended that silica gel still be used between the condenser system and pump to prevent moisture condensation in the pump and metering devices and to avoid the need to make corrections for moisture in the metered volume.

2.1.7 Metering System. Vacuum gauge, leak-free pump, thermometers capable of measuring temperature to within 3° C (5.4° F), dry gas meter capable of measuring volume to within 2 percent, and related equipment, as shown in Figure 17 1. Other metering systems capable of maintaining sampling rates within 10 percent of isokinetic and of determining sample volumes to within 2 percent may be used, subject to the approval of the Administrator. When the metering system is used in conjunction with a pitot tube, the system shall enable checks of isokinetic rates.

Sampling trains utilizing metering systems designed for higher flow rates than that described in APTD-0581 or APTD-0576 may be used provided that the specifications of this method are met.

2.1.8 Barometer. Mercury, aneroid, or other barometer capable of measuring atmospheric pressure to within 2.5 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 and an adjustment for elevation differences between the weather station and sampling point shall be applied at a rate of minus 2.5 mm Hg (0.1 in. Hg) per 30 m (100 ft) elevation increase or vice versa for elevation decrease.

2.1.9 Gas Density Determination Equipment. Temperature sensor and pressure gauge, as described in Sections 2.3 and 2.4 of Method 2, and gas analyzer, if necessary, as described in Method 3.

The temperature sensor shall be attached to either the pitot tube or to the probe extension, in a fixed configuration If the temperature sensor is attached in the field, the sensor shall be placed in an interference-free arrangement with respect to the Type S pitot tube openings (as shown in Figure 17 1 or in Figure 2-7 of Method 2) Alternatively, the temperature sensor need not be attached to either the probe extension or pitot tube during sampling, provided that a difference of not more than 1 percent in the average velocity measurement is introduced This alternative is subject to the approval of the Administrator

2 2 Sample Recovery

2 2 1 Probe Nozzle Brush Nylon bristle brush with stainless steel wire handle The brush shall be properly sized and shaped to brush out the probe nozzle

2.2.2 Wash Bottles—Two. Glass wash bottles are recommended; polyethylene wash bottles may be used at the option of the tester. It is recommended that acetone not be stored in polyethylene bottles for longer than a month.

2.2.3 Glass Sample Storage Containers. Chemically resistant, borosilicate glass bottles, for acetone washes, 500 ml or 1000 ml. Screw cap liners shall either be rubber-backed Teflon or shall be constructed so as 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 1 g. Graduated cylinders shall have subdivisions no greater than 2 ml. Most laboratory balances are capable of weighing to the nearest 0.5 g or less. Any of these balances is suitable for use here and in Section 2.3.4.

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 container; not necessary if silica gel is weighed in the field

2.2.8 Funnel. Glass or polyethylene, 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 0.1 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 Gauge To measure the temperature of the laboratory environment.

3 *Reagents.*

3.1 Sampling

3.1 1 Filters The in-stack filters shall be glass mats or thimble fiber filters, without organic binders, and shall exhibit at least 99.95 percent efficiency (00.05 percent penetration) on 0 3 micron dioctyl phthalate smoke particles. The filter efficiency tests shall be conducted in accordance with ASTM standard method D 2986 71 Test data from the supplier's quality control program are sufficient for this purpose

3.1.2 Silica Gel. Indicating 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 desiccants (equivalent or better) may be used, subject to the approval of the Administrator.

3 1 3 Crushed Ice

3 1 4 Stopcock Grease Acetone insoluble, heat stable silicone grease This is not necessary if screw-on connectors 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 Recovery Acetone, reagent grade, 00 001 percent residue, in glass bottles Acetone from metal containers generally has a high residue blank and should not be used Sometimes, suppliers transfer acetone to glass bottles from metal containers Thus, acetone blanks shall be run prior to field use and only acetone with low blank

values (00.001 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.

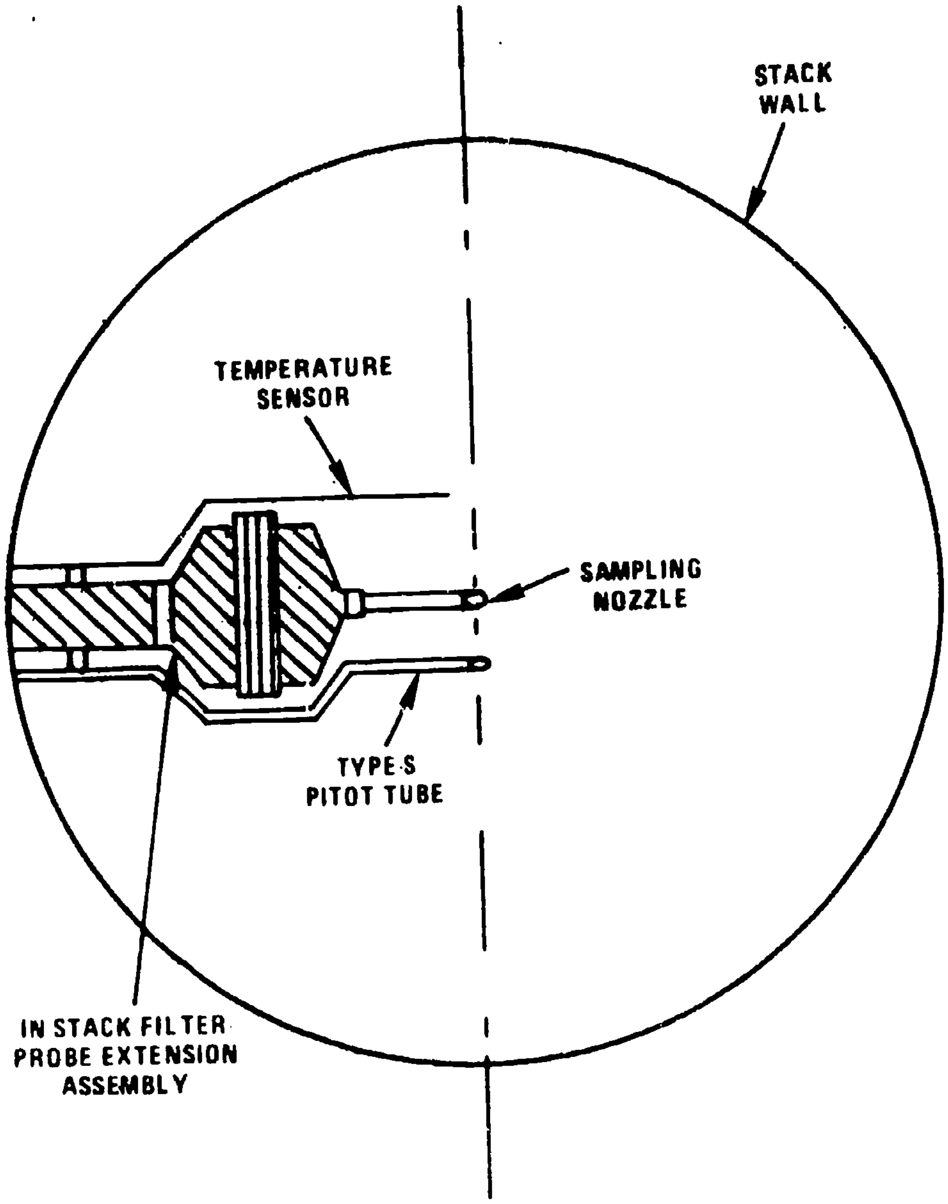
4.1.1 Pretest Preparation. All components shall be maintained and calibrated according to the procedure described in APTD 0576, unless otherwise specified herein.

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. As an alternative, the silica gel need not be preweighed, 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. As an alternative, label the shipping containers (glass or plastic petri dishes) and keep the filters in these containers at all times except during sampling and weighing.

Desiccate the filters at 20 ± 5.6° C (68 ± 10° F) and ambient pressure for at least 24 hours and weigh at intervals of at least 6 hours to a constant weight, i.e., 0.5 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 (220° F) 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 pitot 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; or (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.



$$\text{ESTIMATED BLOCKAGE (\%)} = \left[\frac{\text{SHADED AREA}}{\text{DUCT AREA}}\right] \times 100$$

Figure 17 2. Projected area model of cross section blockage (approximate average for a sample traverse) caused by an in stack filter holder probe extension assembly.

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 isokinetic 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 encountered (see Section 2.2 of Method 2).

Select a probe extension length such that all traverse points can be sampled. For large stacks, consider sampling from opposite sides of the stack to reduce the length of probes.

Select a total sampling time greater than or equal to the minimum total sampling time specified in the test procedures for the specific industry such that (1) the sampling time per point is not less than 2 minutes (or some greater time interval if specified by the Administrator), and (2) the sample volume taken (corrected to standard conditions) will exceed the required minimum total gas sample volume. The latter is based on an approximate average sampling rate.

It is recommended that the number of minutes sampled at each point be an integer or an integer plus one-half minute, in order to avoid timekeeping errors.

In some circumstances, e.g., batch cycles, it may be necessary to sample for shorter times at the traverse points and to obtain smaller gas sample volumes. In these cases, the Administrator's approval must first be obtained.

4.1.3 Preparation of Collection Train. During preparation and assembly of the sampling train, keep all openings where contamination can occur covered until just prior to assembly or until sampling is about to begin.

If impingers are used to condense stack gas moisture, prepare them as follows: place 100 ml of water in each of the first two impingers, leave the third impinger empty, and transfer approximately 200 to 300 g of preweighed silica gel from its container to the fourth impinger. More silica gel may be used, but care should be taken to ensure that it is not entrained and carried out from the impinger during sampling. Place the container in a clean place for later use in the sample recovery. Alternatively, the weight of the silica gel plus impinger may be determined to the nearest 0.5 g and recorded.

If some means other than impingers is used to condense moisture, prepare the condenser (and, if appropriate, silica gel for condenser outlet) for use.

Using a tweezer or clean disposable surgical gloves, place a labeled (identified) and weighed filter in the filter holder. Be sure that the filter is properly centered and the gasket properly placed so as not to allow the sample gas stream to circumvent the filter. Check filter for tears after assembly is completed. Mark the probe extension with heat resistant tape or by some other method to denote the proper distance into the stack or duct for each sampling point.

Assemble the train as in Figure 17-1, using a very light coat of silicone grease on all ground glass joints and greasing only the outer portion (see APTD-0576) to avoid possibility of contamination by the silicone grease. Place crushed ice 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 380 mm Hg (15 in. Hg); 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 percent of the average sampling rate or 0.00057 m³/min (0.02 cfm), whichever is less, is unacceptable.

The following leak check instructions for the sampling train described in APTD-0576 and APTD-0581 may be helpful. Start the pump with by-pass valve fully open and coarse adjust valve completely closed. Partially open the coarse adjust valve and slowly close the by-pass valve until the desired vacuum is reached. Do not reverse direction of by-pass valve. If the desired vacuum is exceeded, either leak check at this higher vacuum or end the leak check as shown below and start over.

When the leak check is completed, first slowly remove the plug from the inlet to the probe nozzle and immediately turn off the vacuum pump. This prevents water from being forced backward and keeps silica gel from being entrained backward.

4.1.4.2 Leak Checks During Sample Run. If, during the sampling run, a component (e.g., filter assembly or impinger) change becomes necessary, a leak check shall be conducted immediately before the change is made. The leak check shall be done according to the procedure outlined in Section 4.1.4.1 above, except that it shall be done at a vacuum equal to or greater than the maximum value recorded up to that point in the test. 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 will need to be applied to the total volume of dry gas metered; if, however, a higher leakage rate is obtained, the tester shall either record the leakage rate and plan to correct 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 done in accordance with the procedures 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 dry gas metered. 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 such that sampling is within 10 percent of true isokinetic, 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 (20 percent variation in velocity head readings) necessitate additional adjustments in flow rate. Level and zero the manometer. Because the manometer level and zero may drift due to vibrations and temperature changes, make periodic checks during the traverse.

PLANT ______
LOCATION ______
OPERATOR ______
DATE ______
RUN NO. ______
SAMPLE BOX NO. ______
METER BOX NO. ______
METER ΔH@ ______
C FACTOR ______
PITOT TUBE COEFFICIENT, Cp ______

SCHEMATIC OF STACK CROSS SECTION

BAROMETRIC PRESSURE ______
ASSUMED MOISTURE, % ______
PROBE EXTENSION LENGTH, m(ft.) ______
NOZZLE IDENTIFICATION NO. ______
AVERAGE CALIBRATED NOZZLE DIAMETER cm(in.) ______
FILTER NO. ______
LEAK RATE, m^3/min,(cfm) ______
STATIC PRESSURE, mm Hg (in. Hg) ______

TRAVERSE POINT NUMBER	SAMPLING TIME (θ), min.	VACUUM mm Hg (in. Hg)	STACK TEMPERATURE (T_S), °C (°F)	VELOCITY HEAD (ΔP_S), mm H_2O (in. H_2O)	PRESSURE DIFFERENTIAL ACROSS ORIFICE METER, mm H_2O (in. H_2O)	GAS SAMPLE VOLUME, m^3 (ft^3)	GAS SAMPLE TEMPERATURE AT DRY GAS METER		TEMPERATURE OF GAS LEAVING CONDENSER OR LAST IMPINGER, °C (°F)
							INLET, °C (°F)	OUTLET, °C (°F)	
TOTAL							Avg	Avg	
AVERAGE							Avg		

Figure 17 3 Particulate field data

Clean the portholes prior to the test run to minimize the chance of sampling the deposited material. To begin sampling, remove the nozzle cap and verify that the pitot tube and probe extension are properly positioned. Position the nozzle at the first traverse point with the tip pointing directly into the gas stream. Immediately start the pump and adjust the flow to isokinetic conditions. Nomographs are available, which aid in the rapid adjustment to the isokinetic sampling rate without excessive computations. These nomographs are designed for use when the Type S pitot tube coefficient is 0.85 ± 0.02, and the stack gas equivalent density (dry molecular weight) is equal to 29 ± 4. APTD-0576 details the procedure for using the nomographs. If C_p and M_d are outside the above stated ranges, do not use the nomographs unless appropriate steps (see Citation 7 in Section 7) are taken to compensate for the deviations.

When the stack is under significant negative pressure (height of impinger stem), take care to close the coarse adjust valve before inserting the probe extension assembly into the stack to prevent water from being forced backward. If necessary, the pump may be turned on with the coarse adjust valve closed.

When the probe is in position, block off the openings around the probe and porthole to prevent unrepresentative dilution of the gas stream.

Traverse the stack cross section, as required by Method 1 or as specified by the Administrator, being careful not to bump the probe nozzle into the stack walls when sampling near the walls or when removing or inserting the probe extension through the portholes, to minimize chance of extracting deposited material.

During the test run, take appropriate steps (e.g., adding crushed ice to the impinger ice bath) to maintain a temperature of less than 20° C (68° F) at the condenser outlet; this will prevent excessive moisture losses. Also, periodically check the level and zero of the manometer.

If the pressure drop across the filter becomes too high, making isokinetic sampling difficult to maintain, the filter may be replaced in the midst of a sample run. It is recommended that another complete filter holder assembly be used rather than attempting to change the filter itself. Before a new filter holder is installed, conduct a leak check, as outlined in Section 4.1.4.2. The total particulate weight shall include the summation of all filter assembly catches.

A single train shall be used for the entire sample run, except in cases where simultaneous sampling is required in two or more separate ducts or at two or more different locations within the same duct, or, in cases where equipment failure necessitates a change of trains. In all other situations, the use of two or more trains will be subject to the approval of the Administrator. Note that when two or more trains are used, a separate analysis of the collected particulate from each train shall be performed, unless identical nozzle sizes were used on all trains, in which case the particulate catches from the individual trains may be combined and a single analysis performed.

At the end of the sample run, turn off the pump, remove the probe extension assembly from the stack, and record the final dry gas meter reading. Perform a leak check, as outlined in Section 4.1.4.3. Also, leak check the pitot lines as described in Section 3.1 of Method 2; the lines must pass this leak check, in order to validate the velocity head data.

4.1.6 Calculation of Percent Isokinetic. Calculate percent isokinetic (see Section 6.11) to determine whether another test run should be made. If there is difficulty in maintaining isokinetic rates due to source conditions, consult with the Administrator for possible variance on the isokinetic rates.

4.2 Sample Recovery. Proper cleanup procedure begins as soon as the probe extension assembly is removed from the stack at the end of the sampling period. Allow the assembly to cool.

When the assembly can be safely handled, wipe off all external particulate matter near the tip of the probe nozzle and place a cap over it to prevent losing or gaining particulate matter. Do not cap off the probe tip tightly while the sampling train is cooling down as this would create a vacuum in the filter holder, forcing condenser water backward.

Before moving the sample train to the cleanup site, disconnect the filter holder-probe nozzle assembly from the probe extension; cap the open inlet of the probe extension. Be careful not to lose any condensate, if present. Remove the umbilical cord from the condenser outlet and cap the outlet. If a flexible line is used between the first impinger (or condenser) and the probe extension, disconnect the line at the probe extension and let any condensed water or liquid drain into the impingers or condenser. Disconnect the probe extension from the condenser; cap the probe extension outlet. After wiping off the silicone grease, cap off the condenser inlet. Ground glass stoppers, plastic caps, or serum caps (whichever are appropriate) may be used to close these openings.

Transfer both the filter holder-probe nozzle assembly and the condenser to the cleanup area. This area should be clean and protected from the wind so that the chances of contaminating or losing the sample will be minimized.

Save a portion of the acetone used for cleanup as a blank. Take 200 ml of this acetone directly from the wash bottle being used and place it in a glass sample container labeled "acetone blank."

Inspect the train prior to and during disassembly and note any abnormal conditions. Treat the samples as follows:

Container No. 1. Carefully remove the filter from the filter holder and place it in its identified petri dish container. Use a pair of tweezers and/or clean disposable surgical gloves to handle the filter. If it is necessary to fold the filter, do so such that the particulate cake is inside the fold. Carefully transfer to the petri dish any particulate matter and/or filter fibers which adhere to the filter holder gasket, by using a dry Nylon bristle brush and/or a sharp-edged blade. Seal the container.

Container No. 2. Taking care to see that dust on the outside of the probe nozzle or other exterior surfaces does not get into the sample, quantitatively recover particulate matter or any condensate from the probe nozzle, fitting, and front half of the filter holder by washing these components with acetone and placing the wash in a glass container. Distilled water may be used instead of acetone when approved by the Administrator and shall be used when specified by the Administrator; in these cases, save a water blank and follow Administrator's directions on analysis. Perform the acetone rinses as follows:

Carefully remove the probe nozzle and clean the inside surface by rinsing with acetone from a wash bottle and brushing with a Nylon bristle brush. Brush until acetone rinse shows no visible particles, after which make a final rinse of the inside surface with acetone.

Brush and rinse with acetone the inside parts 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 bristle 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 sample container so that acetone will not leak out when it is shipped to the laboratory. Mark the height of the fluid level to determine whether or not leakage occurred during transport. Label the container to clearly identify its contents.

Container No. 3. If silica gel is used in the condenser system for mositure 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."

Condenser Water. Treat the condenser or impinger water as follows: make a notation of any color or film in the liquid catch. Measure the liquid volume to within ±1 ml by using a graduated cylinder or, if a balance is available, determine the liquid weight to within ±0.5 g. Record the total 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.

4.3 Analysis. Record the data required on the example sheet shown in Figure 17-4. Handle each sample container as follows:

Container No. 1. Leave the contents in the shipping container or transfer the filter and any loose particulate from the sample container to a tared glass weighing dish. Desiccate for 24 hours in a desiccator containing anhydrous calcium sulfate. Weigh to a constant weight and report the results to the nearest 0.1 mg. For purposes of this Section, 4.3, the term "constant weight" means a difference of no more than 0.5 mg or 1 percent of total weight less tare weight, whichever is greater, between two consecutive weighings with no less than 6 hours of desiccation time between weighings.

Alternatively, the sample may be oven dried at the average stack temperature or

105° C (220° F), whichever is less, for 2 to 3 hours, cooled in the desiccator, and weighed to a constant weight, unless otherwise specified by the Administrator. 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) ________________

CONTAINER NUMBER	WEIGHT OF PARTICULATE COLLECTED, mg		
	FINAL WEIGHT	TARE WEIGHT	WEIGHT GAIN
1			
2			
TOTAL	☒	☒	
Less acetone blank			
Weight of particulate matter			

	VOLUME OF LIQUID WATER COLLECTED	
	IMPINGER VOLUME ml	SILICA GEL WEIGHT g
FINAL		
INITIAL		
LIQUID COLLECTED		
TOTAL VOLUME COLLECTED		g* ml

* CONVERT WEIGHT OF WATER TO VOLUME BY DIVIDING TOTAL WEIGHT INCREASE BY DENSITY OF WATER (1g ml)

$$\frac{\text{INCREASE, g}}{\text{1 g/ml}} \quad \text{VOLUME WATER, ml}$$

Figure 17-4. Analytical data.

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 void 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 impinger) 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 "bumping," 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 numbers 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 leakages within the pump. For these cases the following leak-check procedure is suggested: make a 10-minute calibration run at 0.00057 m^3/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 m^3/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 metering system. 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 coefficient values obtained before and after a test series differ by more than 5 percent, the test series shall either be voided, or calculations 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 procedure in Section 4.3 of Method 2 to calibrate in-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 meter 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.

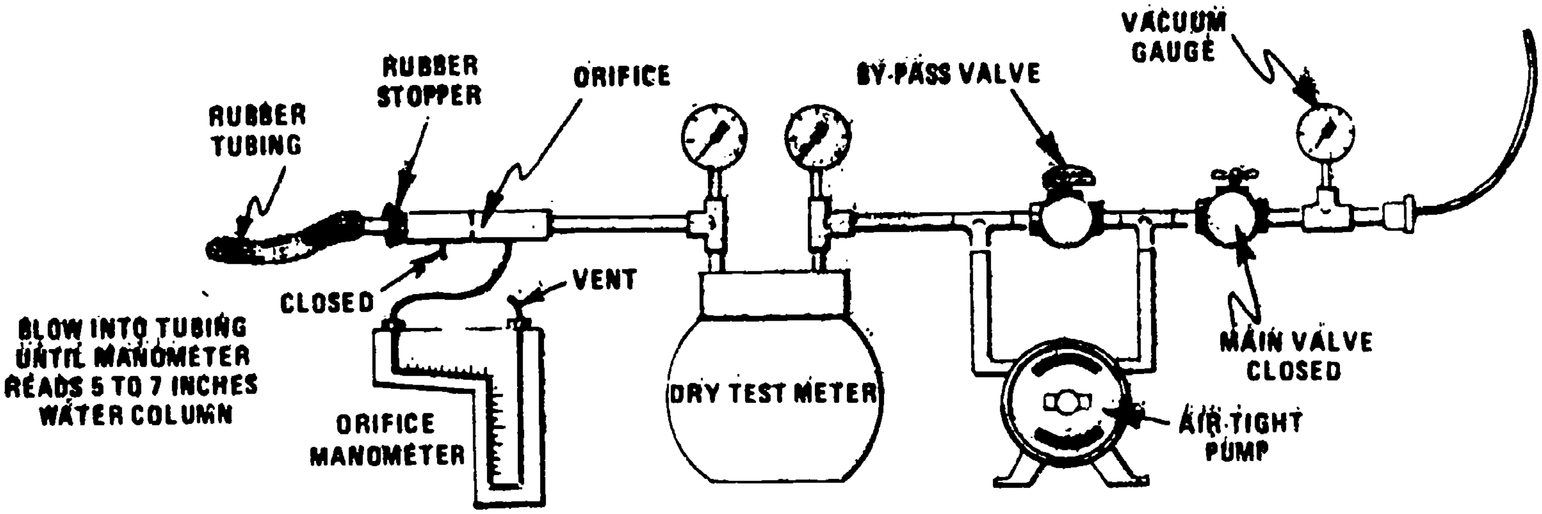


Figure 17-5. Leak check of meter box.

5.6 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_n = Cross-sectional area of nozzle, m² (ft²).
B_{ws} = Water vapor in the gas stream, proportion by volume.
C_a = Acetone blank residue concentration, mg/g
c_s = Concentration of particulate matter in stack gas, dry basis, corrected to standard conditions, g/dscm (g/dscf).
I = Percent of isokinetic sampling.
L_a = Maximum acceptable leakage rate for either a pretest leak check or for a leak check following a component change; equal to 0.00057 m³/min (0.02 cfm) or 4 percent of the average sampling rate, whichever is less.
L_i = Individual leakage rate observed during the leak check conducted prior to the "i^{th}" component change (i = 1, 2, 3 . . . n), m³/min (cfm).
L_p = Leakage rate observed during the post-test leak check, m³/min (cfm).
m_n = Total amount of particulate matter collected, mg.
M_w = Molecular weight of water, 18.0 g/g-mole (18.0 lb/lb-mole).
m_a = Mass of residue of acetone after evaporation, mg.
P_{bar} = Barometric pressure at the sampling site, mm Hg (in. Hg).
P_s = Absolute stack gas pressure, mm Hg (in. Hg).
P_{std} = Standard absolute pressure, 760 mm Hg (29.92 in. Hg).
R = Ideal gas constant, 0.06236 mm Hg-m³/°K-g-mole (21.85 in. Hg-ft³/°R-lb-mole).
T_m = Absolute average dry gas meter temperature (see Figure 17-3), °K (°R).
T_s = Absolute average stack gas temperature (see Figure 17-3), °K (°R).
T_{std} = Standard absolute temperature, 293°K (528°R).
V_a = Volume of acetone blank, ml.
V_{aw} = Volume of acetone used in wash, ml.
V_{lc} = Total volume of liquid collected in impingers and silica gel (see Figure 17-4), ml.
V_m = Volume of gas sample as measured by dry gas meter, dcm (dcf).
$V_{m(std)}$ = Volume of gas sample measured by the dry gas meter, corrected to standard conditions, dscm (dscf).
$V_{w(std)}$ = Volume of water vapor in the gas sample, corrected to standard conditions, scm (scf).
v_s = Stack gas velocity, calculated by Method 2, Equation 2-9, using data obtained from Method 17, m/sec (ft/sec).
W_a = Weight of residue in acetone wash, mg
Y = Dry gas meter calibration coefficient.
ΔH = Average pressure differential across the orifice meter (see Figure 17-3), mm H₂O (in. H₂O).
ρ_a = Density of acetone, mg/ml (see label on bottle)
ρ_w = Density of water, 0.9982 g/ml (0.002201 lb/ml)
θ = Total sampling time, min
θ_1 = Sampling time interval, from the beginning of a run until the first component change, min
θ_i = Sampling time interval, between two successive component changes, beginning with the interval between the first and second changes, min
θ_p = Sampling time interval, from the final (n^{th}) component change until the end of the sampling run, min.
13.6 = Specific gravity of mercury.
60 = Sec/min.
100 = Conversion to percent.

6.2 Average dry gas meter temperature and average orifice pressure drop. See data sheet (Figure 17-3).

6.3 Dry Gas Volume. Correct the sample volume measured by the dry gas meter to standard conditions (20° C, 760 mm Hg or 68° F, 29.92 in. Hg) by using Equation 17-1.

$$V_{m(std)} = V_m Y \left(\frac{T_{std}}{T_m}\right)\left[\frac{P_{bar} + \frac{\Delta H}{13.6}}{P_{std}}\right] = K_1 V_m Y \frac{P_{bar} + (\Delta H/13.6)}{T_m}$$

Equation 17-1

where,

K_1 = 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_a. If L_p or L_i exceeds L_a, Equation 17-1 must be modified as follows:

(a) Case I. No component changes made during sampling run. In this case, replace V_m in Equation 17-1 with the expression:

$$[V_m - (L_p - L_a)\theta]$$

(b) Case II. One or more component changes made during the sampling run. In this case, replace V_m in Equation 17-1 by the expression:

$$\left[V_m - (L_1 - L_a)\theta_1 - \sum_{i=2}^{n} (L_i - L_a)\theta_i - (L_p - L_a)\theta_p\right]$$

and substitute only for those leakage rates (L_i or L_p) which exceed L_a.

6.4 Volume of water vapor

$$V_{w(std)} = V_{lc}\left(\frac{\rho_w}{M_w}\right)\left(\frac{R T_{std}}{P_{std}}\right) = K_2 V_{lc}$$

Equation 17-2

where,

K_2 = 0.001333 m³/ml for metric units, 0.04707 ft³/ml for English units

6.5 Moisture Content

$$B_{ws} = \frac{V_{w(std)}}{V_{m(std)} + V_{w(std)}}$$

Equation 17-3

6.6 Acetone Blank Concentration.

$$C_a = \frac{m_a}{V_a \rho_a}$$

Equation 17-4

6.7 Acetone Wash Blank.

$$W_a = C_a V_{aw} \rho_a$$

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).

NOTE.—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.

$$c_s = (0.001\ g/mg)\,(m_n/V_{m(std)})$$

Equation 17-6

6.10 Conversion Factors:

From	To	Multiply by
scf	m³	0.02832
g/ft³	gr/ft³	15.43
g/ft³	lb/ft³	2.205×10^{-3}
g/ft³	g/m³	35.31

6.11 Isokinetic Variation.

6.11.1 Calculation from Raw Data.

$$I = \frac{100\, T_s\, [K_3 V_{lc} + (V_m Y/T_m)\,(P_{bar} + \Delta H/13.6)]}{60\, \theta\, v_s\, P_s\, A_n}$$

Equation 17-7

where:

K_3 = 0.003454 mm Hg-m³/ml-°K for metric units; 0.002669 in. Hg-ft³/ml-°R for English units.

6.11.2 Calculation from Intermediate Values.

$$I = \frac{T_s\, V_{m(std)}\, P_{std}\, 100}{T_{std}\, v_s\, \theta\, A_n\, P_s\, 60\, (1-B_{ws})} = K_4 \frac{T_s\, V_{m(std)}}{P_s\, v_s\, A_n\, \theta\, (1-B_{ws})}$$

Equation 17-8

where

K_4 = 4.320 for metric units, 0.09450 for English units

6.12 Acceptable Results. 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. Use Citation 4 in Section 7 to make judgments. Otherwise, reject the results and repeat the test.

7. *Bibliography.*

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8. Vollaro, R. F., A Survey of Commercially Available Instrumentation for the Measurement of Low-Range Gas Velocities. U.S. Environmental Protection Agency, Emission Measurement Branch. Research Triangle Park, N.C. November, 1976 (unpublished paper).

9. Annual Book of ASTM Standards. Part 26 Gaseous Fuels; Coal and Coke; Atmospheric Analysis. American Society for Testing and Materials. Philadelphia, Pa. 1974. pp. 617-622.

10. Vollaro, R. F., Recommended Procedure for Sample Traverses in Ducts Smaller than 12 Inches in Diameter. U.S. Environmental Protection Agency, Emission Measurement Branch, Research Triangle Park, N.C. November, 1976

[FR Doc. 78-4795 Filed 2-22-78; 8:45 am]

[6560-01]

ENVIRONMENTAL PROTECTION AGENCY

[FRL 828-6]

KRAFT PULP MILLS

Draft Guideline Document: Availability

AGENCY: Environmental Protection Agency.

ACTION: Notice of Availability of Draft Guideline Document.

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 draft 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 (specify "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 (EPA Library), Room 2922, 401 M Street SW., Washington, D.C.

FOR FURTHER INFORMATION CONTACT:

Don R. Goodwin, Emission Standards and Engineering Division, Environmental Protection Agency, Research Triangle Park, N.C. 27711, telephone 919-541-5271.

SUPPLEMENTARY INFORMATION: The Clean Air Act applies to three general categories of pollutants emitted from stationary sources. The first category consist of pollutants (often referred to as "criteria pollutants") for which air quality criteria national ambient air quality standards, and State implementation plans are established under sections 108-110 of the Act. The second category consist of pollutants listed and controlled as hazardous pollutants under section 112 of the Act.

The third 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 "designated pollutants," and existing facilities whose emissions of such pollutants must be controlled under section 111(d) are referred to as "designated 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 publish 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 or contribute to endangerment of public health (referred to as "health-related pollutants") and those for which adverse effects on public health have not been demonstrated (referred to as "welfare-related pollutants"). For health-related pollutants, emission standards and compliance schedules in State plans must ordinarily be at least as stringent as the corresponding emission guidelines and compliance times in EPA's guideline documents. 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 in the kraft pulping industry may cause or contribute to endangerment of the public welfare but that adverse effects on public health have not been demonstrated. As indicated above, this means that TRS emissions will be considered a welfare-related pollutant and the States will have greater flexibility in developing their plans than would be the case if public health might be affected.

EMISSION GUIDELINES: The emission guidelines and compliance times contained in the draft guideline document reflect the Administrator's judgment on the degree of control attainable with application of the best system of continuous emission reduction (considering the cost, nonair quality health, environmental impacts, and energy requirements of such reduction) that has been adequately demonstrated for existing facilities at kraft pulp mills, including the time within which these 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 TRS 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 cross recovery furnace systems, 20 ppm of TRS from lime kiln systems, and 5 ppm of TRS from condensate stripper systems. These concentration standards are all four hour averages. The recommended emission guideline for the smelt dissolving tank is 0.0084 gram of TRS per kilogram of black liquor solids (dry weight). The amount of time necessary to retrofit an existing kraft mill can vary widely depending upon such factors as space limitation, weather conditions, lack of available utilities, delays in equipment delivery, and time required to develop engineering data. Subject to these considerations, the approximate times necessary to retrofit existing facilities are 3-6 years for recovery furnaces; 2 years for digesters, multiple-effect evaporators, smelt dissolving tanks and condensate strippers; and 2-4 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 [illegible]

[illegible] S[illegible]

[illegible] section 111(d) of the [illegible] as amended. In accordance with [illegible] (a) of the Act, [illegible] guideline document has been preceded 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 [illegible] subpart B of 40 CFR Part 60.

AUTHORITY: This notice of proposed guideline is issued under the authority of sections 111, 114, and 301(a) of the Clean Air Act as amended (Pub. L. 91-604, 84 Stat. (42 U.S.C. 7411, 7414, 7601(a)).

Dated: February 10, 1978.

BARBARA BLUM,
Acting Administrator

[FR Doc. 78-4794 Filed 2-22-78; 8:45 am]

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MONDAY, AUGUST 7, 1978

THE NATIONAL ARCHIVES OF THE UNITED STATES
1934

AMENDMENTS TO KRAFT PULP MILLS

STANDARD AND REFERENCE METHOD 16

[6560-01]

Title 40—Protection of Environment

CHAPTER I—ENVIRONMENTAL PROTECTION AGENCY

SUBCHAPTER C—AIR PROGRAMS

[FRL 921 7]

PART 60—STANDARDS OF PERFORMANCE FOR NEW STATIONARY SOURCES

Amendments to Kraft Pulp Mills Standard and Reference Method 16

AGENCY: Environmental Protection Agency (EPA).

ACTION: Final rule.

SUMMARY: This action amends the standards of performance for Kraft pulp mills by adding a provision for determining compliance of affected facilities which use a control system incorporating a process other than combustion. This amendment is necessary because the standards would place control systems other than combustion at a disadvantage. The intent of this amendment is to remove any preclusion of new and improved control systems. This action also amends Reference Method 16 to insure that the testing procedure is consistent with the promulgated standards.

EFFECTIVE DATE: August 7, 1978

FOR FURTHER INFORMATION CONTACT:

Don R. Goodwin, Emission Standards and Engineering Division, Environmental Protection Agency, Research Triangle Park, N.C. 27711, telephone 919-541-5271.

SUPPLEMENTARY INFORMATION: Standards of performance for Kraft pulp mills were promulgated on February 23, 1978. On March 31, 1978, the National Council for Air and Stream Improvement (NCASI) requested two changes to these standards to prevent their interpretation in a manner which was inconsistent with their intent. The purpose of these amendments, therefore, is to clarify the intent of the standards.

OXYGEN CORRECTION FACTOR

In § 60.283(a)(1), the percent oxygen to which TRS emissions must be corrected was specified. The purpose of this specification was to provide a consistent basis for the determination of TRS emissions. Ten percent was selected because it reflected the observed oxygen concentrations at facilities controlled by the best system of emission reduction which was incineration. The NCASI pointed out, however, that the specification of a 10-percent oxygen level on sources which characteristically contain higher levels would effectively discourage the development of control technologies other than incineration.

The purpose of an emission standard is to reduce total emissions to the atmosphere. If an emission control technique should evolve which is capable of achieving the same mass rate of emissions from a given facility, use of that technique should be permitted. The standard, as written, could have inhibited the development of new technologies, if misinterpreted. Therefore, to remove this potential source of misinterpretation, § 60.283(a)(1)(v) has been added to the standard to provide for correction to untreated oxygen concentration in the case of brown stock washers, black liquor oxidation systems, or digester systems.

REFERENCE METHOD 16

The second point of concern to the NCASI was the correction factor to be applied for sampling system losses contained in the post-test procedures (paragraph 10.1) of method 16. The specific concern was the specification that a test gas be introduced at the beginning of the probe to determine sample loss in the sampling train. The data base for the promulgated standard considered only TRS losses in the sampling train, not the probe or probe filter. Consequently, the post-test procedures are amended to require the determination of sampling train losses by introducing the test gas after the probe filter consistent with the data base supporting the promulgated standards.

MISCELLANEOUS

The Administrator finds that good cause exists for omitting prior notice and public comment on these amendments and for making them immediately effective because they simply clarify the existing regulations and impose no additional substantive requirements.

Section 317 of the Clean Air Act requires the Administrator to prepare an economic impact assessment for revisions determined by the Administrator to be substantial. Since the costs associated with the proposed amendments would have a negligible impact on consumer costs, the Administrator has determined that the proposed amendments are not substantial and do not require preparation of an economic impact assessment.

Dated: August 1, 1978.

Douglas M. Costle,
Administrator.

Part 60 of Chapter I, Title 40 of the Code of Federal Regulations is amended as follows:

1. In § 60.283, paragraph (a)(1) is amended to read as follows:

§ 60.283 Standard for total reduced sulfur (TRS).

* * * * *

(a) * * *

(1) * * *

(v) The gases from the digester system, brown stock washer system, condensate stripper system, or black liquor oxidation system are controlled by a 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 untreated 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 quantities to insure that there is an excess of sample which must be vented to the atmosphere. The sample must be introduced immediately after the probe and filter and transported through the remainder of the sampling system to the measurement system in the normal manner. The resulting measured concentration should be compared to the known value to determine the sampling system loss.

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 gas sample may be generated using permeation tubes. Alternatively, cylinders of hydrogen sulfide mixed in air may be used provided they are traceable to permeation tubes. The optional pretest procedures provide a good guideline for determining if there are leaks in the sampling system.

* * * * *

(Sec. 111, 301(a) of the Clean Air Act as amended (42 U.S.C. 7411, 7601(a)).)

[FR Doc. 78-21801 Filed 8-4-78; 8:45 am]

federal register

THURSDAY, AUGUST 18, 1977

PART II

THE NATIONAL ARCHIVES OF THE UNITED STATES 1934

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

[FRL 754-5]

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.

EFFECTIVE DATE: September 19, 1977.

ADDRESSES: 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:

Don R. Goodwin, Emission Standards and Engineering Division, Environmental Protection Agency, Research Triangle Park, North Carolina 27711, telephone No. 919-541-5271.

SUPPLEMENTARY INFORMATION: The amendments were proposed on June 8, 1976 (40 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 Fluidyne (Particulate Sampling Strategies for Large Power Plants Including Nonuniform Flow, EPA-600/2-76-170, June 1976) and Entropy Environmentalists (Determination of the Optimum Number of Traverse Points: An Analysis of Method 1 Criteria (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 m^2 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. A 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_2, CO_2, CO, and N_2 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-600/2-76-170, 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_2 and O_2.

4. The equation for excess air has been revised to account for the presence of CO.

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 will span the length of time the pollutant emission rate is being determined or such time as specified 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_2 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 peroxide impurities that will cause erroneously low SO_2 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 (including acid mist) simultaneously with SO_2 and SO_3 has been allowed where applicable.

3. Since occassionally some commercially available quantities of isopropanol

have peroxide impurities that will cause erroneously high sulfuric acid mist measurements, a test for peroxides in isopropanol has been included in the method.

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 volumes of its content.

5. A closer correspondence has been made between similar parts of Methods 8 and 5.

MISCELLANEOUS

Several commenters questioned the meaning of the term "subject to the approval of the Administrator" in relation to using alternate test methods and procedures. As defined in § 60.2 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 60. These officials in consultation with other staff members familiar with technical aspects of source testing will render decisions regarding acceptable alternate 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.

(Secs. 111, 114 and 301(a) of the Clean Air Act, sec. 4(a) of Pub. L. No. 91-604, 84 Stat. 1683; sec. 4(a) of Pub. L. No. 91-604, 84 Stat. 1687; sec. 2 of Pub. L. No. 90-148, 81 Stat. 504 [42 U.S.C. 1857c-6, 1857c-9, 1857g(a)].)

NOTE.—The Environmental Protection Agency has determined that this document does not contain a major proposal requiring preparation of an Economic Impact Analysis under Executive Orders 11821 and 11949 and OMB Circular A-107.

Dated: August 10, 1977.

DOUGLAS M. COSTLE,
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:

APPENDIX A—REFERENCE METHODS

The reference methods in this appendix are referred to in § 60.8 (Performance Tests) and § 60.11 (Compliance With Standards and Maintenance Requirements) of 40 CFR Part 60, Subpart A (General Provisions). Specific uses of these reference methods are described in the standards of performance contained in the subparts, beginning with Subpart D.

Within each standard of performance, a section titled "Test Methods and Procedures" is provided to (1) identify the test methods applicable to the facility subject to the respective standard and (2) identify any special instructions or conditions to be followed when applying a method to the respective facility. Such instructions (for example, establish sampling rates, volumes, or temperatures) are to be used either in addition to, or as a substitute for procedures in a reference method. Similarly, for sources subject to emission monitoring requirements, specific instructions pertaining to any use of a reference method are provided in the subpart or in Appendix B.

Inclusion of methods in this appendix is not intended as an endorsement or denial of their applicability to sources that are not subject to standards of performance. The methods are potentially applicable to other sources; however, applicability should be confirmed by careful and appropriate evaluation of the conditions prevalent at such sources.

The approach followed in the formulation of the reference methods involves specifications for equipment, procedures, and performance. In concept, a performance specification approach would be preferable in all methods because this allows the greatest flexibility to the user. In practice, however, this approach is impractical in most cases because performance specifications cannot be established. Most of the methods described herein, therefore, involve specific equipment specifications and procedures, and only a few methods in this appendix rely on performance criteria.

Minor changes in the reference methods should not necessarily affect the validity of the results and it is recognized that alternative and equivalent methods exist. Section 60.8 provides authority for the Administrator to specify or approve (1) equivalent methods, (2) alternative methods, and (3) minor changes in the methodology of the reference methods. It should be clearly understood that unless otherwise identified all such methods and changes must have prior approval of the Administrator. An owner employing such methods or deviations from the reference methods without obtaining prior approval does so at the risk of subsequent disapproval and retesting with approved methods.

Within the reference methods, certain specific equipment or procedures are recognized as being acceptable or potentially acceptable and are specifically identified in the methods. The items identified as acceptable options may be used without approval but must be identified in the test report. The potentially approvable options are cited as "subject to the approval of the Administrator" or as "or equivalent." Such potentially approvable techniques or alternatives may be used at the discretion of the owner without prior approval. However, detailed descriptions for applying these potentially approvable techniques or alternatives are not provided in the reference methods. Also, the potentially approvable options are not necessarily acceptable in all applications. Therefore, an owner electing to use such potentially approvable techniques or alternatives is responsible for: (1) assuring that the techniques or alternatives are in fact applicable and are properly executed; (2) including a written description of the alternative method in the test report (the written method must be clear and must be capable of being performed without additional instruction, and the degree of detail should be similar to the detail contained in the reference methods); and (3) providing any rationale or supporting data necessary to show the validity of the alternative in the particular application. Failure to meet these requirements can result in the Administrator's disapproval of the alternative.

METHOD 1—SAMPLE AND VELOCITY TRAVERSES FOR STATIONARY SOURCES

1. *Principle and Applicability*

1.1 Principle. To aid in the representative measurement of pollutant emissions and/or total volumetric flow rate from a stationary source, a measurement site where the effluent stream is flowing in a known direction is selected, and the cross-section of the stack is divided into a number of equal areas. A traverse point is then located within each of these equal areas.

1.2 Applicability. This method is applicable to flowing gas streams in ducts, stacks, and flues. The method cannot be used when: (1) flow is cyclonic or swirling (see Section 2.4), (2) a stack is smaller than about 0.30 meter (12 in.) in diameter, or 0.071 m² (113 in.²) in cross-sectional area, or (3) the measurement site is less than two stack or duct diameters downstream or less than a half diameter upstream from a flow disturbance.

The requirements of this method must be considered before construction of a new facility from which emissions will be measured; failure to do so may require subsequent alterations to the stack or deviation from the standard procedure. Cases involving variants are subject to approval by the Administrator, U.S. Environmental Protection Agency.

2. *Procedure*

2.1 Selection of Measurement Site. Sampling or velocity measurement is performed at a site located at least eight stack or duct diameters downstream and two diameters upstream from any flow disturbance such as a bend, expansion, or contraction in the stack, or from a visible flame. If necessary, an alternative location may be selected, at a position at least two stack or duct diameters downstream and a half diameter upstream from any flow disturbance. For a rectangular cross section, an equivalent diameter (D_e) shall be calculated from the following equation, to determine the upstream and downstream distances:

$$D_e = \frac{2LW}{L+W}$$

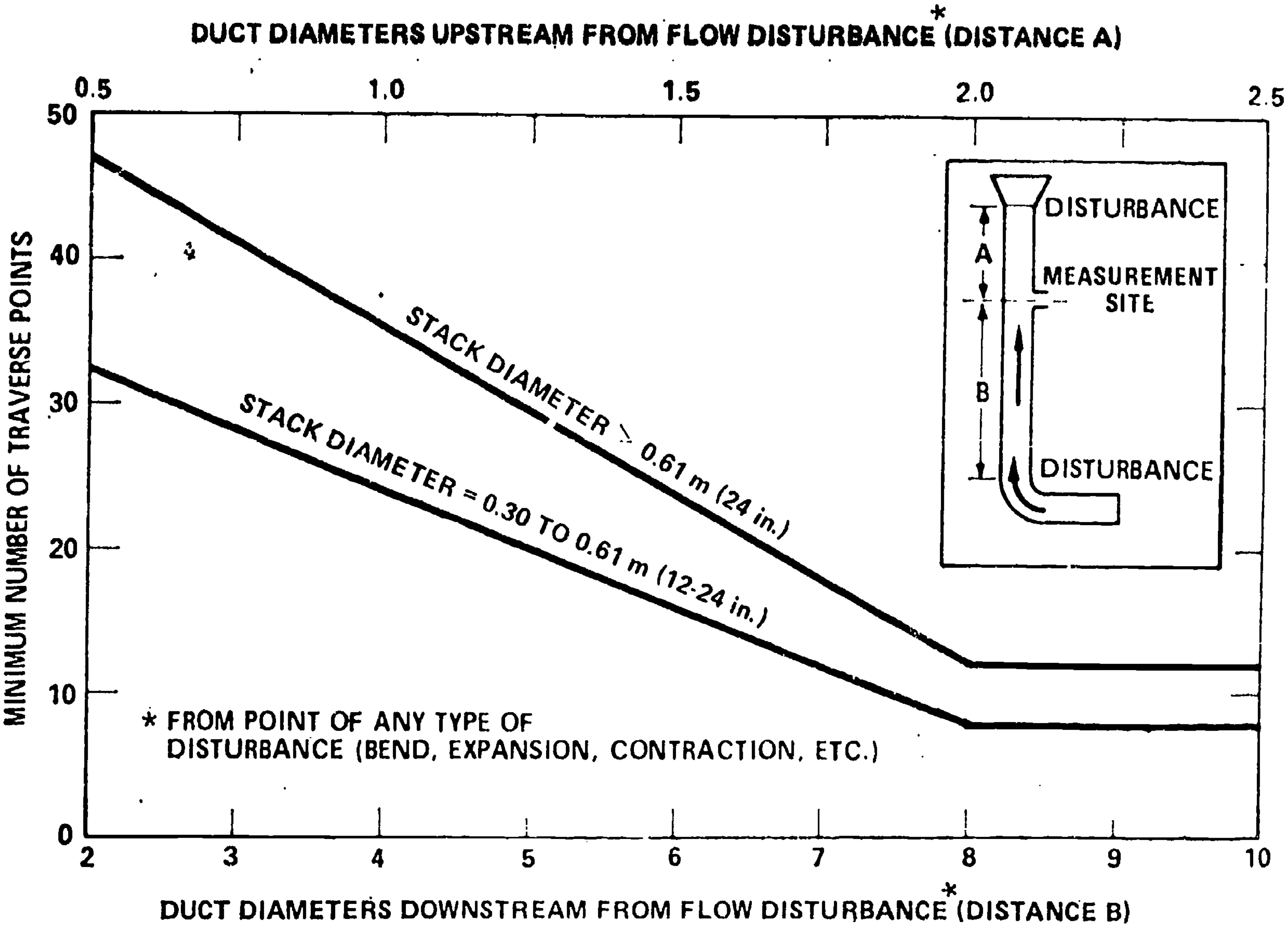

Figure 1-1. Minimum number of traverse points for particulate traverses.

where L = length and W = width.

2.2 Determining the Number of Traverse Points.

2.2.1 Particulate Traverses. When the eight- and two-diameter criterion can be met, the minimum number of traverse points shall be: (1) twelve, for circular or rectangular stacks with diameters (or equivalent diameters) greater than 0.61 meter (24 in.); (2) eight, for circular stacks with diameters between 0.30 and 0.61 meter (12-24 in.); (3) nine, for rectangular stacks with equivalent diameters between 0.30 and 0.61 meter (12-24 in.).

When the eight- and two-diameter criterion cannot be met, the minimum number of traverse points is determined from Figure 1-1. Before referring to the figure, however, determine the distances from the chosen measurement site to the nearest upstream and downstream disturbances, and divide each distance by the stack diameter or equivalent diameter, to determine the distance in terms of the number of duct diameters. Then, determine from Figure 1-1 the minimum number of traverse points that corresponds: (1) 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 a greater value, so that for circular stacks the number is a multiple of 4, and for rectangular stacks, the number is one of those shown in Table 1-1.

[illegible]

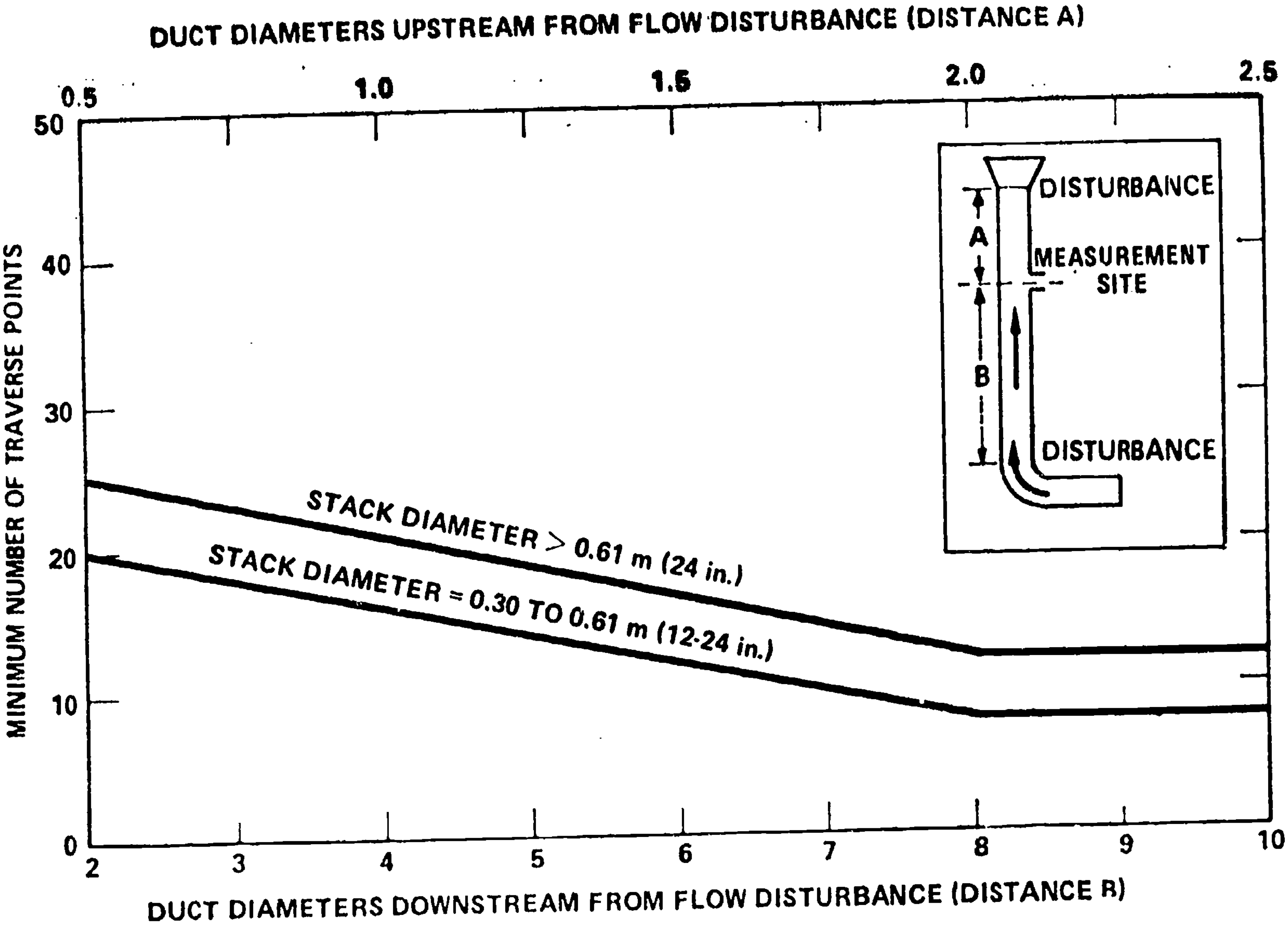

Figure 1-2. Minimum number of traverse points for velocity (nonparticulate) traverses.

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 may be used instead of Figure 1-1.

2.3 Cross Sectional Layout and Location of Traverse Points.

2.3.1 Circular Stacks. Locate the traverse points on two perpendicular diameters according to Table 1-2 and the example shown in Figure 1-3. Any equation (for examples, see Citations 2 and 3 in the Bibliography) that gives the same values as those in Table 1-2 may be used in lieu of Table 1-2.

For particulate traverses, one of the diameters must be in a plane containing the greatest expected concentration variation, e.g., after bends, one diameter shall be in the plane of the bend. This requirement becomes less critical as the distance from the disturbance increases; therefore, other diameter locations may be used, subject to approval of the Administrator.

In addition, for stacks having diameters greater than 0.61 m (24 in.) no traverse points shall be located within 2.5 centimeters (1.00 in.) of the stack walls; and for stack diameters equal to or less than 0.61 m (24 in.), no traverse points shall be located within 1.3 cm (0.50 in.) of the stack walls. To meet these criteria, observe the procedures given below.

2.3.1.1 Stacks With Diameters Greater Than 0.61 m (24 in.). [illegible]

TRAVERSE POINT	DISTANCE, % of diameter
1	4.4
2	14.7
3	29.5
4	70.5
5	85.3
6	95.6

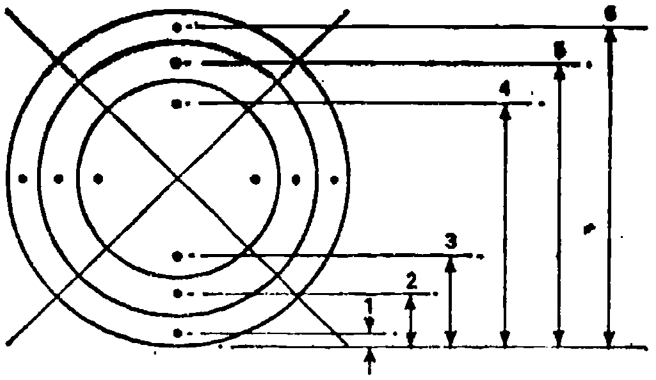

Figure 1-3. Example showing circular stack cross section divided into 12 equal areas, with location of traverse points indicated.

Table 1-2. LOCATION OF TRAVERSE POINTS IN CIRCULAR STACKS

(Percent of stack diameter from inside wall to traverse point)

Traverse point number on a diameter	Number of traverse points on a diameter											
	2	4	6	8	10	12	14	16	18	20	22	24
1	14.6	6.7	4.4	3.2	2.5	2.1	1.8	1.6	1.4	1.3	1.1	1.1
2	85.4	25.0	14.6	10.5	8.2	6.7	5.7	4.9	4.4	3.9	3.5	3.2
3		75.0	29.6	19.4	14.6	11.8	9.9	8.5	7.5	6.7	6.0	5.5
4		93.3	70.4	32.3	22.6	17.7	14.6	12.5	10.9	9.7	8.7	7.9
5			85.4	67.7	34.2	25.0	20.1	16.9	14.6	12.9	11.6	10.5
6			95.6	80.6	65.8	35.6	26.9	22.0	18.8	16.5	14.6	13.2
7				89.5	77.4	64.4	36.6	28.3	23.6	20.4	18.0	16.1
8				96.8	85.4	75.0	63.4	37.5	29.6	25.0	21.8	19.4
9					91.8	82.3	73.1	62.5	38.2	30.6	26.2	23.0
10					97.4	88.2	79.9	71.7	61.8	38.8	31.5	27.2
11						93.3	85.4	78.0	70.4	61.2	39.3	32.3
12						97.9	90.1	83.1	76.4	69.4	60.7	39.8
13							94.3	87.5	81.2	75.0	68.5	60.2
14							98.2	91.5	85.4	79.6	73.8	67.7
15								95.1	89.1	83.5	78.2	72.8
16								98.4	92.5	87.1	82.0	77.0
17									95.6	90.3	85.4	80.6
18									98.6	93.3	88.4	83.9
19										96.1	91.3	86.8
20										98.7	94.0	89.5
21											96.5	92.1
22											98.9	94.5
23												96.8
24												98.9

2.3.1.2 Stacks With Diameters Equal to or Less Than 0.61 m (24 in.). Follow the procedure in Section 2.3.1.1, noting only that any "adjusted" points should be relocated away from the stack walls to: (1) a distance of 1.3 cm (0.50 in.); or (2) a distance equal to the nozzle inside diameter, whichever is larger.

2.3.2 Rectangular Stacks. Determine the number of traverse points as explained in Sections 2.1 and 2.2 of this method. From Table 1-1, determine the grid configuration. Divide the stack cross section into as many equal rectangular elemental areas as traverse points, and then locate a traverse point at the centroid of each equal area according to the example in Figure 1-4.

The situation of traverse points being too close to the stack walls is not expected to arise with rectangular stacks. If this problem should ever arise, the Administrator must be contacted for resolution of the matter.

2.4 Verification of Absence of Cyclonic Flow. In most stationary sources, the direction of stack gas flow is essentially parallel to the stack walls. However, cyclonic flow may exist (1) after such devices as cyclones and inertial demisters following venturi scrubbers, or (2) in stacks having tangential inlets or other duct configurations which tend to induce swirling; in these instances, the presence or absence of cyclonic flow at the sampling location must be determined. The following techniques are acceptable for this determination.

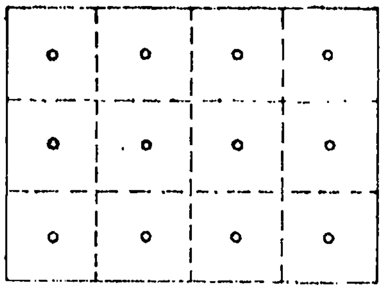

Figure 1-4. Example showing rectangular stack cross section divided into 12 equal areas, with a traverse point at centroid of each area.

Level and zero the manometer. Connect a Type S pitot tube to the manometer. Position the Type S pitot tube at each traverse point, in succession, so that the planes of the face openings of the pitot tube are perpendicular to the stack cross-sectional plane; when the Type S pitot tube is in this position, it is at "0° reference." Note the differential pressure (Δp) 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° yaw angle), until a null reading is obtained. Carefully determine and record the value of the rotation angle (α) to the nearest degree. After the null technique has been applied at each travrse point, calculate the average of the absolute values of α; assign α values of 0° to those points for which no rotation was required, and include these in the overall average. If the average value of α is greater than 10°, 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. *Bibliography*

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4. Standard Method for Sampling Stacks for Particulate Matter. In: 1971 Book of ASTM Standards, Part 23. ASTM Designation D-2928-71. Philadelphia, Pa. 1971.

5. Hanson, H. A., et al. Particulate Sampling Strategies for Large Power Plants Including Nonuniform Flow. USEPA, ORD, ESRL, Research Triangle Park, N.C. EPA-600/2-76-170. June 1976.

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METHOD 2—DETERMINATION OF STACK GAS VELOCITY AND VOLUMETRIC FLOW RATE (TYPE S PITOT TUBE)

1. *Principle and Applicability*

1.1 Principle. The average gas velocity in a stack is determined from the gas density and from measurement of the average velocity head with a Type S (Stausscheibe or reverse type) pitot tube.

1.2 Applicability. This method is applicable for measurement of the average velocity of a gas stream and for quantifying gas flow.

This procedure is not applicable at measurement sites which fail to meet the criteria of Method 1, Section 2.1. Also, the method cannot be used for direct measurement in cyclonic or swirling gas streams; Section 2.4 of Method 1 shows how to determine cyclonic or swirling flow conditions. When unacceptable conditions exist, alternative procedures, subject to the approval of the Administrator, U.S. Environmental Protection Agency, must be employed to make accurate flow rate determinations; examples of such alternative procedures are: (1) to install straightening vanes; (2) to calculate the total volumetric flow rate stoichiometrically, or (3) to move to another measurement site at which the flow is acceptable.

2. *Apparatus*

Specifications for the apparatus are given below. Any other apparatus that has been demonstrated (subject to approval of the Administrator) to be capable of meeting the specifications will be considered acceptable.

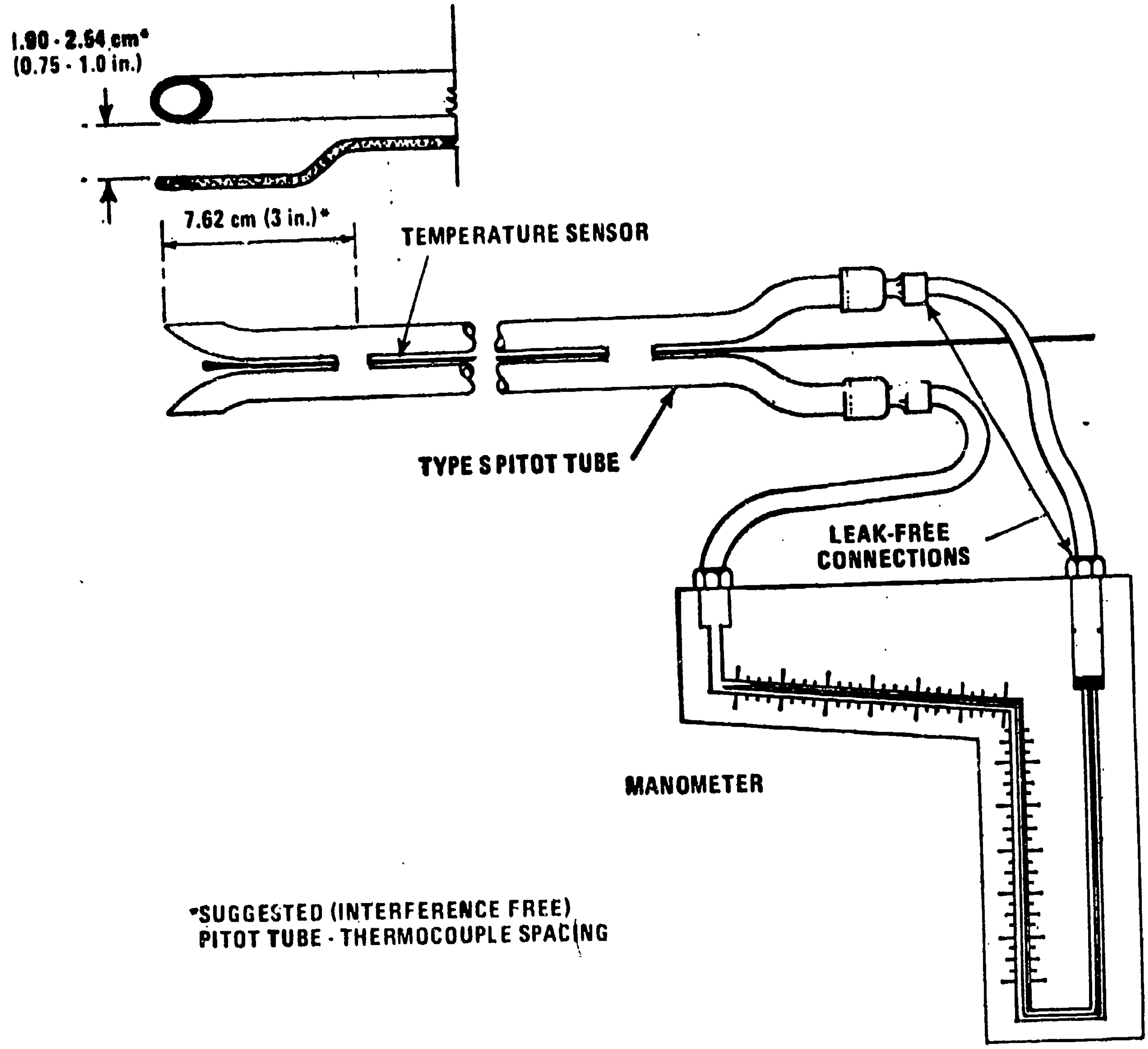


Figure 2-1. Type S pitot tube manometer assembly.

2.1 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 D_t, Figure 2-2b) be between 0.48 and 0.95 centimeters (3/16 and 3/8 inch). There shall be an equal distance from the base of each leg of the pitot tube to its face-opening plane (dimensions P_A and P_B, Figure 2-2b); it is recommended that this distance be between 1.05 and 1.50 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.

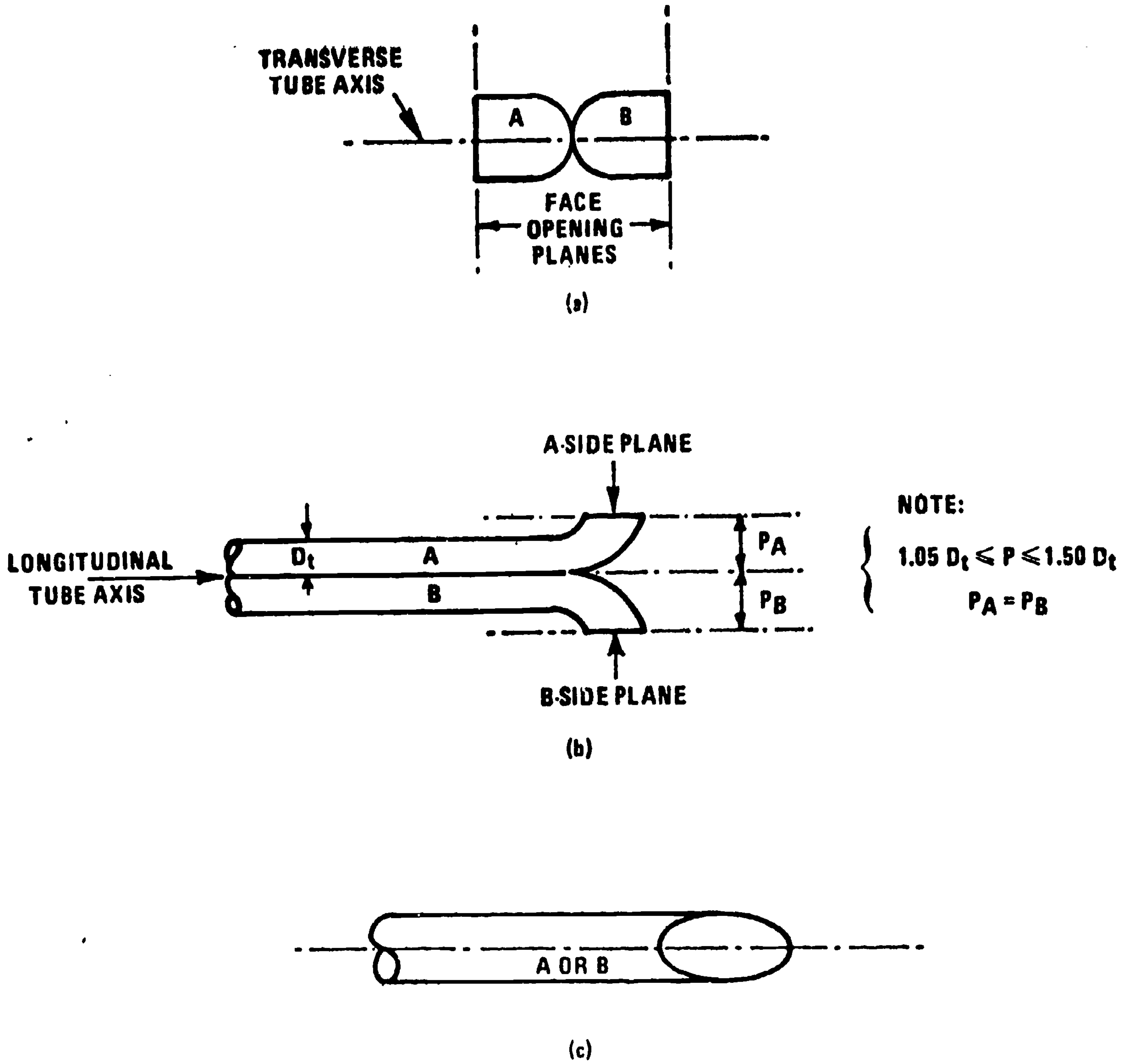


Figure 2-2. Properly constructed Type S pitot tube, shown in: (a) end view; face opening planes perpendicular to transverse axis; (b) top view; face opening planes parallel to longitudinal axis; (c) side view; both legs of equal length and centerlines coincident, when viewed from both sides. Baseline coefficient values of 0.84 may be assigned to pitot tubes constructed this way.

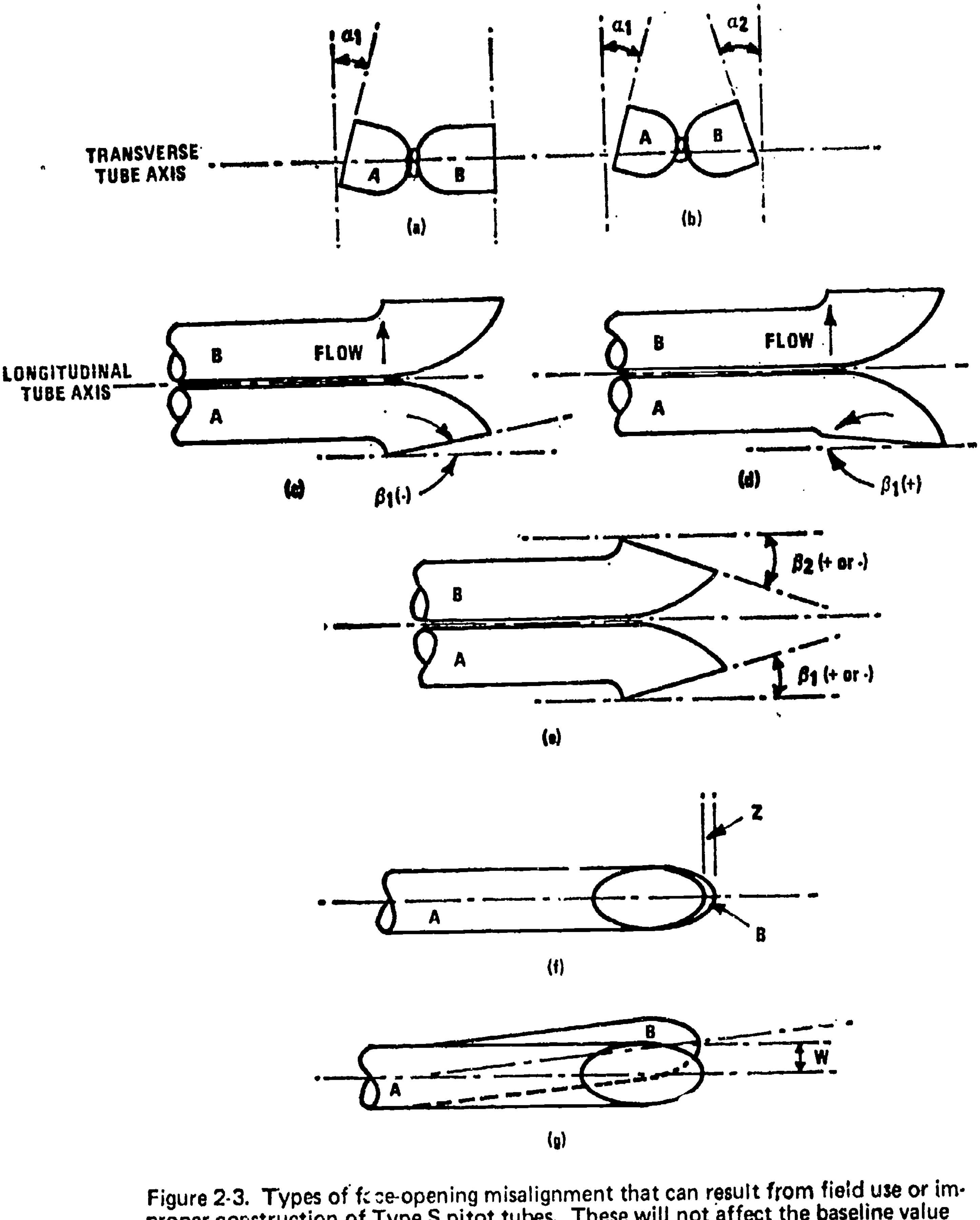


Figure 2-3. Types of face-opening misalignment that can result from field use or improper construction of Type S pitot tubes. These will not affect the baseline value of $\bar{C}p(s)$ so long as α_1 and $\alpha_2 < 10^\circ$, β_1 and $\beta_2 < 5^\circ$. $z < 0.32$ cm (1/8 in.) and $w < 0.08$ cm (1/32 in.) (citation 11 in Section 6).

A standard pitot tube may be used instead of a Type S, provided that it meets the specifications of Sections 2.7 and 4.2; note, however, that the static and impact pressure holes of standard pitot tubes are susceptible to plugging 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 plugged up during the traverse period; this can be done by taking a velocity head (Δp) reading at the final traverse point, cleaning out the impact and static holes of the standard pitot tube by "back-purging" with pressurized air, and then taking another Δp reading. If the Δp readings made before and after the air purge are the same (±5 percent), the traverse is acceptable. Otherwise, reject the run. Note that if Δp at the final traverse point is unsuitably low, another point may be selected. If "back-purging" at regular intervals is part of the procedure, then comparative Δp readings shall be taken, as above, for the last two back purges at which suitably high Δp readings are observed.

2.2 Differential Pressure Gauge. An inclined manometer or equivalent device is used. Most sampling trains are equipped with a 10-in. (water column) inclined-vertical manometer, having 0.01-in. H_2O divisions on the 0- to 1-in. inclined scale, and 0.1-in. H_2O divisions on the 1- to 10-in. vertical scale. This type of manometer (or other gauge of equivalent sensitivity) is satisfactory for the measurement of Δp values as low as 1.3 mm (0.05 in.) H_2O. However, a differential pressure gauge of greater sensitivity shall be used (subject to the approval of the Administrator), if any of the following is found to be true: (1) the arithmetic average of all Δp readings at the traverse points in the stack is less than 1.3 mm (0.05 in.) H_2O; (2) for traverses of 12 or more points, more than 10 percent of the individual Δp readings are below 1.3 mm (0.05 in.) H_2O; (3) for traverses of fewer than 12 points, more than one Δp reading is below 1.3 mm (0.05 in.) H_2O. Citation 18 in Section 6 describes commercially available instrumentation for the measurement of low-range gas velocities.

As an alternative to criteria (1) through (3) above, the following calculation may be performed to determine the necessity of using a more sensitive differential pressure gauge:

$$T = \frac{\sum_{i=1}^{n} \sqrt{\Delta p_i + K}}{\sum_{i=1}^{n} \sqrt{\Delta p_i}}$$

where:

Δp_i = Individual velocity head reading at a traverse point, mm H_2O (in. H_2O).

n = Total number of traverse points.

K = 0.13 mm H_2O when metric units are used and 0.005 in H_2O when English units are used.

If T is greater than 1.05, the velocity head data are unacceptable and a more sensitive differential pressure gauge must be used.

NOTE.—If differential pressure gauges other than inclined manometers are used (e.g., magnehelic gauges), their calibration must be checked after each test series. To check the calibration of a differential pressure gauge, compare Δp readings of the gauge with those of a gauge-oil manometer at a minimum of three points, approximately representing the range of Δp values in the stack. If, at each point, the values of Δp as read by the differential pressure gauge and gauge-oil manometer agree to within 5 percent, the differential pressure gauge shall be considered to be in proper calibration. Otherwise, the test series shall either be voided, or procedures to adjust the measured Δp values and final results shall be used, subject to the approval of the Administrator.

2.3 Temperature Gauge. A thermocouple, liquid-filled bulb thermometer, bimetallic thermometer, mercury-in-glass thermometer, or other gauge capable of measuring temperature to within 1.5 percent of the minimum absolute stack temperature shall be used. The temperature gauge shall be attached to the pitot tube such that the sensor tip does not touch any metal; the gauge shall be in an interference-free arrangement with respect to the pitot tube face openings (see Figure 2-1 and also Figure 2-7 in Section 4). Alternate positions may be used if the pitot tube-temperature gauge system is calibrated according to the procedure of Section 4. Provided that a difference of not more than 1 percent in the average velocity measurement is introduced, the temperature gauge need not be attached to the pitot tube; this alternative is subject to the approval of the Administrator.

2.4 Pressure Probe and Gauge. A piezometer tube and mercury- or water-filled U-tube manometer capable of measuring stack pressure to within 2.5 mm (0.1 in.) Hg is used. The static tap of a standard type pitot tube or one leg of a Type S pitot tube with the face opening planes positioned parallel to the gas flow may also be used as the pressure probe.

2.5 Barometer. A mercury, aneroid, or other barometer capable of measuring atmospheric pressure to within 2.5 mm Hg (0.1 in. Hg) may be used. 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 and an adjustment for elevation differences between the weather station and the sampling point shall be applied at a rate of minus 2.5 mm (0.1 in.) Hg per 30-meter (100 foot) elevation increase, or vice-versa for elevation decrease.

2.6 Gas Density Determination Equipment. Method 3 equipment, if needed (see Section 3.6), to determine the stack gas dry molecular weight, and Reference Method 4 or Method 5 equipment for moisture content determination; other methods may be used subject to approval of the Administrator.

2.7 Calibration Pitot Tube. When calibration of the Type S pitot tube is necessary (see Section 4), a standard pitot tube is used as a reference. The standard pitot tube shall, preferably, have a known coefficient, obtained either (1) directly from the National Bureau of Standards, Route 270, Quince Orchard Road, Gaithersburg, Maryland, or (2) by calibration against another standard pitot tube with an NBS-traceable coefficient. Alternatively, a standard pitot tube designed according to the criteria given in 2.7.1 through 2.7.5 below and illustrated in Figure 2-4 (see also Citations 7, 8, and 17 in Section 6) may be used. Pitot tubes designed according to these specifications will have baseline coefficients of about 0.99±0.01.

2.7.1 Hemispherical (shown in Figure 2-4), ellipsoidal, or conical tip.

2.7.2 A minimum of six diameters straight run (based upon D, the external diameter of the tube) between the tip and the static pressure holes.

2.7.3 A minimum of eight diameters straight run between the static pressure holes and the centerline of the external tube, following the 90 degree bend.

2.7.4 Static pressure holes of equal size (approximately 0.1 D), equally spaced in a piezometer ring configuration.

2.7.5 Ninety degree bend, with curved or mitered junction.

2.8 Differential Pressure Gauge for Type S Pitot Tube Calibration. An inclined manometer or equivalent is used. If the single-velocity calibration technique is employed (see Section 4.1.2.3), the calibration differential pressure gauge shall be readable to the nearest 0.13 mm H_2O (0.005 in. H_2O). For multivelocity calibrations, the gauge shall be readable to the nearest 0.13 mm H_2O (0.005 in H_2O) for Δp values between 1.3 and 25 mm H_2O (0.05 and 1.0 in. H_2O), and to the nearest 1.3 mm H_2O (0.05 in. H_2O) for Δp values above 25 mm H_2O (1.0 in. H_2O). A special, more sensitive gauge will be required to read Δp values below 1.3 mm H_2O [0.05 in. H_2O] (see Citation 18 in Section 6).

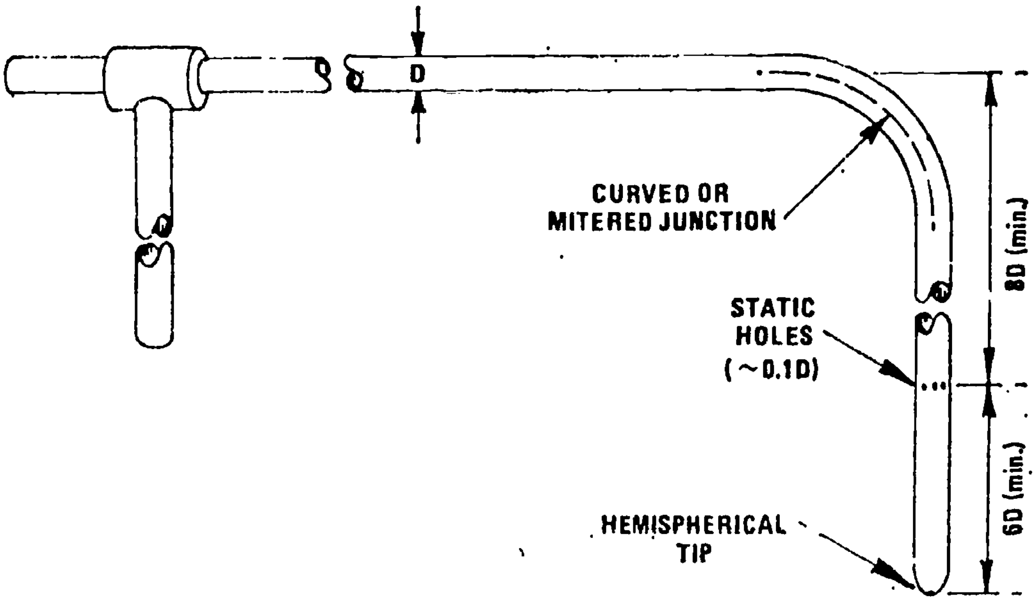


Figure 2-4. Standard pitot tube design specifications.

3. Procedure

3.1 Set up the apparatus as shown in Figure 2-1. Capillary tubing or surge tanks installed between the manometer and pitot tube may be used to dampen Δp fluctuations. It is recommended, but not required, that a pretest leak-check be conducted, as follows: (1) blow through the pitot impact opening until at least 7.6 cm (3 in.) H_2O velocity pressure registers on the manometer; then, close off the impact opening. The pressure shall remain stable for at least 15 seconds; (2) do the same for the static pressure side, except using suction to obtain the minimum of 7.6 cm (3 in.) H_2O. Other leak-check procedures, subject to the approval of the Administrator, may be used.

3.2 Level and zero the manometer. Because the manometer level and zero may drift due to vibrations and temperature changes, make periodic checks during the traverse. Record all necessary data as shown in the example data sheet (Figure 2-5).

3.3 Measure the velocity head and temperature at the traverse points specified by Method 1. Ensure that the proper differential pressure gauge is being used for the range of Δp values encountered (see Section 2.2). If it is necessary to change to a more sensitive gauge, do so, and remeasure the Δp and temperature readings at each traverse point. Conduct a post-test leak check (mandatory), as described in Section 3.1 above, to validate the traverse run.

3.4 Measure the static pressure in the stack. One reading is usually adequate.

3.5 Determine the atmospheric pressure.

PLANT ____________________

DATE __________ RUN NO. __________

STACK DIAMETER OR DIMENSIONS, m(in.) __________

BAROMETRIC PRESSURE, mm Hg (in. Hg) __________

CROSS SECTIONAL AREA, $m^2(ft^2)$ __________

OPERATORS __________

PITOT TUBE I.D. NO. __________

AVG. COEFFICIENT, C_p = __________

LAST DATE CALIBRATED __________

SCHEMATIC OF STACK CROSS SECTION

Traverse Pt. No.	Vel. Hd., Δp mm (in.) H_2O	Stack Temperature		P_g mm Hg (in.Hg)	$\sqrt{\Delta p}$
		t_s, °C (°F)	T_s, °K (°R)		
		Average			

Figure 2-5. Velocity traverse data.

3.6 Determine the stack gas dry molecular weight. For combustion processes or processes that emit essentially CO_2, O_2, CO, and N_2, 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 Obtain the moisture content from Reference Method 4 (or equivalent) or from Method 5.

3.8 Determine the cross-sectional area of the stack or duct at the sampling location. Wherever possible, physically measure the stack dimensions rather than using blueprints.

4 *Calibration*

4.1 Type S Pitot Tube. Before its initial use, carefully examine 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 2-2 or 2-3. The pitot tube shall not be used if it fails to meet these alignment specifications.

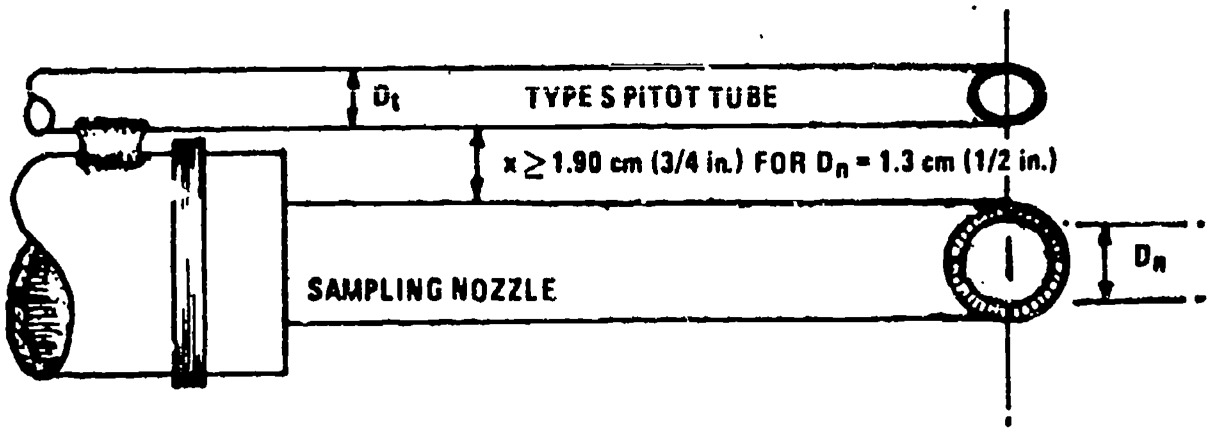
After verifying the face opening alignment, measure and record the following dimensions of the pitot tube: (a) the external tubing diameter (dimension D_t, Figure 2-2b); and (b) the base-to-opening plane distances (dimensions P_A and P_B, Figure 2-2b). If D_t is between 0.48 and 0.95 cm (3/16 and 3/8 in.) and if P_A and P_B are equal and between 1.05 and 1.50 D_t, 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 0.84 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 D_t, P_A, and P_B are outside the specified limits, the pitot tube must be calibrated as outlined in 4.1.2 through 4.1.5 below.

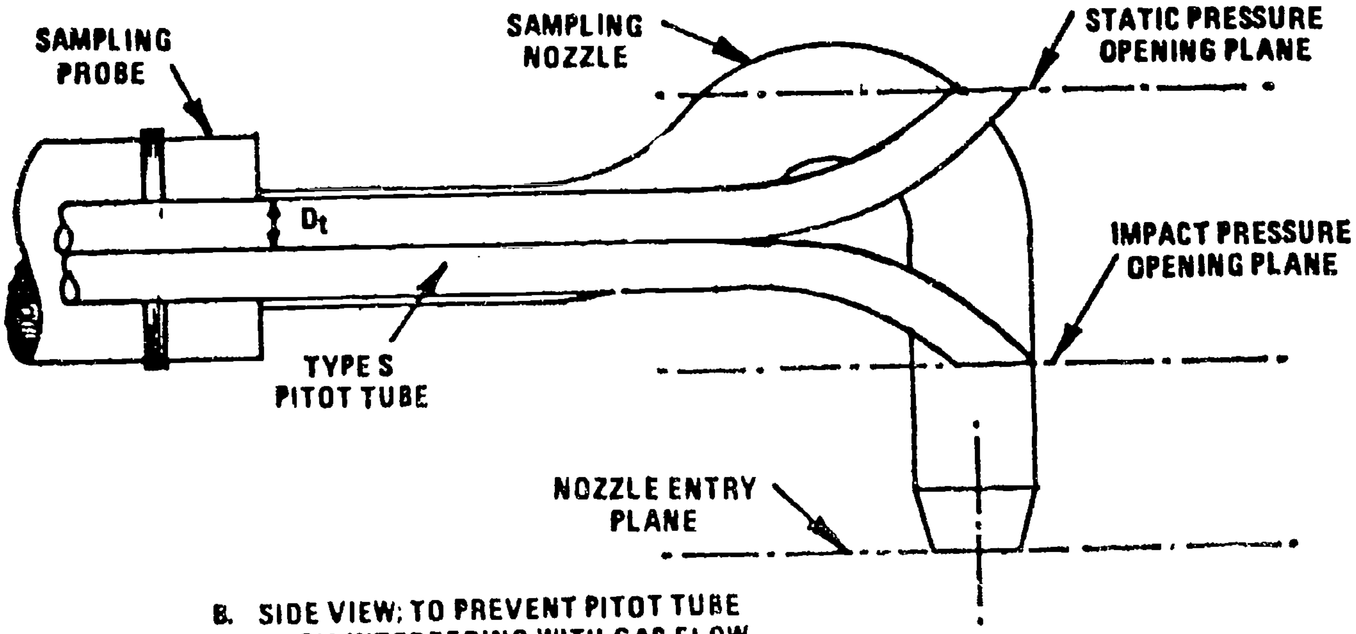
4.1.1 Type S Pitot Tube Assemblies. During sample and velocity traverses, the isolated Type S pitot tube is not always used; in many instances, the pitot tube is used in combination with other source-sampling components (thermocouple, sampling probe, nozzle) as part of an "assembly." The presence of other sampling components can sometimes affect the baseline value of the Type S pitot tube coefficient (Citation 9 in 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 identical only when the relative placement of the components in the assembly is such that aerodynamic interference effects are eliminated. 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 or all 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 spacings (pitot-nozzle, pitot-thermocouple, pitot-probe sheath) shall be measured and recorded.

NOTE.—Do not use any Type S pitot tube assembly which is constructed such that the impact pressure opening plane of the pitot tube is below the entry plane of the nozzle (see Figure 2-6b).

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. BOTTOM VIEW; SHOWING MINIMUM PITOT-NOZZLE SEPARATION.



B. SIDE VIEW; TO PREVENT PITOT TUBE FROM INTERFERING WITH GAS FLOW STREAMLINES APPROACHING THE NOZZLE, THE IMPACT PRESSURE OPENING PLANE OF THE PITOT TUBE SHALL BE EVEN WITH OR ABOVE THE NOZZLE ENTRY PLANE.

Figure 2-6. Proper pitot tube - sampling nozzle configuration to prevent aerodynamic interference; buttonhook - type nozzle; centers of nozzle and pitot opening aligned; D_t between 0.48 and 0.95 cm (3/16 and 3/8 in.).

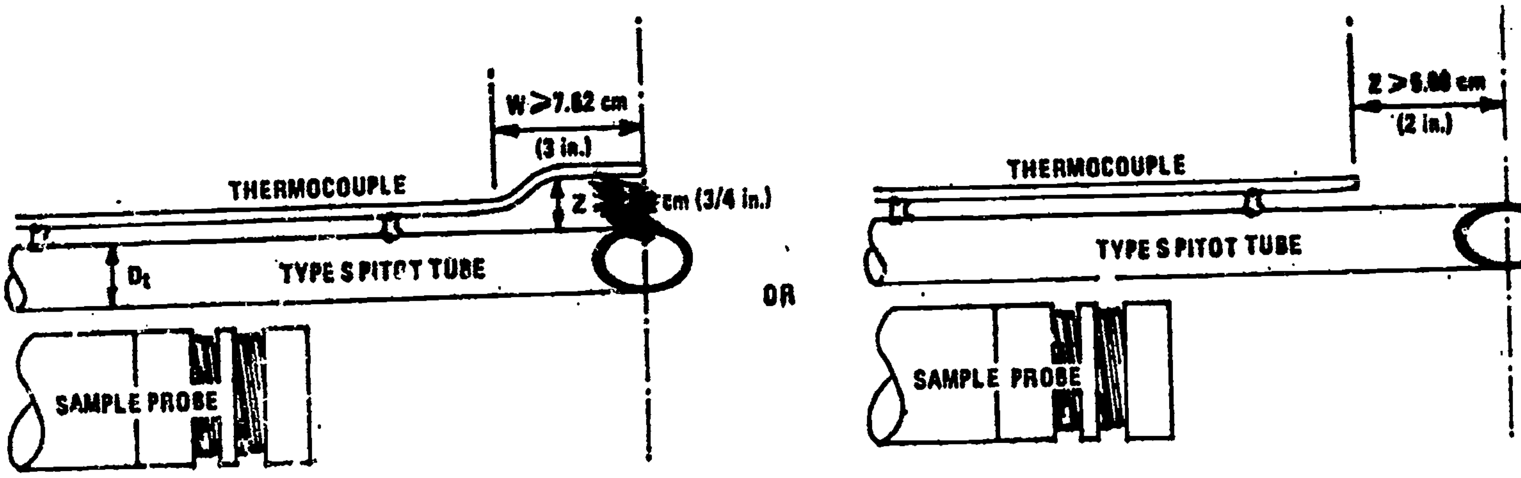


Figure 2-7. Proper thermocouple placement to prevent interference; D_t between 0.48 and 0.95 cm (3/16 and 3/8 in.).

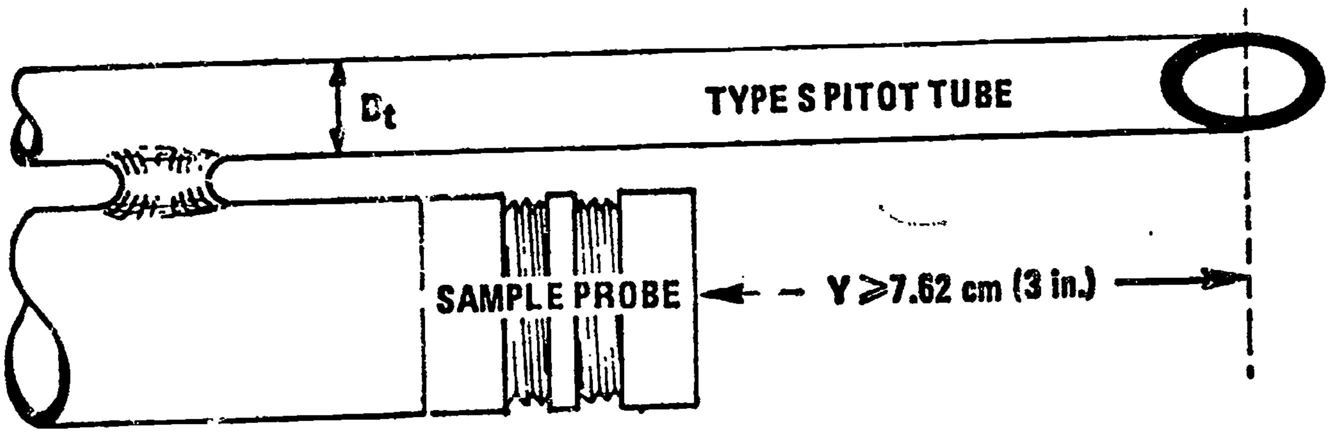


Figure 2-8. Minimum pitot-sample probe separation needed to prevent interference; D_t between 0.48 and 0.95 cm (3/16 and 3/8 in.).

4.1.2.1 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, use an equivalent diameter, calculated from the following equation, to determine the number of duct diameters:

$$D_e = \frac{2LW}{(L+W)}$$

Equation 2-1

where:

D_e = Equivalent diameter

L = Length

W = Width

To ensure the presence of stable, fully developed flow patterns at the calibration site, or "test section," the site must be located at least eight diameters downstream and two diameters upstream from the nearest disturbances.

NOTE – The eight- and two-diameter criteria are not absolute; other test section locations may be used (subject to approval of the Administrator), provided that the flow at the test site is stable and demonstrably parallel to the duct axis.

4.1.2.3 The flow system shall have the capacity to generate a test-section velocity around 915 m/min (3,000 ft/min). This velocity must be constant with time to guarantee steady flow during calibration. Note that Type S pitot tube coefficients obtained by single-velocity calibration at 915 m/min (3,000 ft/min) will generally be valid to within ±3 percent for the measurement of velocities above 305 m/min (1,000 ft/min) and to within ±5 to 6 percent for the measurement of velocities between 180 and 305 m/min (600 and 1,000 ft/min). If a more precise correlation between C_p and velocity is desired, the flow system shall have the capacity to generate at least four distinct, time-invariant test-section velocities covering the velocity range from 180 to 1,525 m/min (600 to 5,000 ft/min), and calibration data shall be taken at regular velocity intervals over this range (see Citations 9 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 impact openings will lie 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 plexiglas or some other transparent material.

4.1.3 Calibration Procedure. Note that this procedure is a general one and must not be used without first referring to the special considerations presented in Section 4.1.5. Note also that this procedure applies only to single-velocity calibration. To obtain calibration data for the A and B sides of the Type S pitot tube, proceed as follows:

4.1.3.1 Make sure that the manometer is properly filled and that the oil is free from contamination and is of the proper density. Inspect and leak check all pitot lines; repair or replace if necessary.

4.1.3.2 Level and zero the manometer. Turn on the fan and allow the flow to stabilize. Seal the Type S entry port.

4.1.3.3 Ensure that the manometer is level and zeroed. Position the standard pitot tube at the calibration point (determined as outlined in Section 4.1.5.1), and align the tube so that its tip is pointed directly into the flow. Particular care should be taken in aligning the tube to avoid yaw and pitch angles. Make sure that the entry port surrounding the tube is properly sealed.

4.1.3.4 Read Δp_{std} and record its value in a data table similar to the one shown in Figure 2-9. Remove the standard pitot tube from the duct and disconnect it from the manometer. Seal the standard entry port.

4.1.3.5 Connect the Type S pitot tube to the manometer. Open the Type S entry port. Check the manometer level and zero. Insert and align the Type S pitot tube so that its A side impact opening is at 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.

4.1.3.6 Read Δp_s and enter its value in the data table. Remove the Type S pitot tube from the duct and disconnect it from the manometer.

4.1.3.7 Repeat steps 4.1.3.3 through 4.1.3.6 above until three pairs of Δp readings have been obtained.

4.1.3.8 Repeat steps 4.1.3.3 through 4.1.3.7 above for the B side of the Type S pitot tube.

4.1.3.9 Perform calculations, as described in Section 4.1.4 below.

4.1.4 Calculations

4.1.4.1 For each of the six pairs of Δp readings (i.e., three from side A and three from side B) obtained in Section 4.1.3 above, calculate the value of the Type S pitot tube coefficient as follows:

PITOT TUBE IDENTIFICATION NUMBER: ______________ **DATE:** ______________

CALIBRATED BY: ____

	"A" SIDE CALIBRATION			
RUN NO.	Δp_{std} cm H_2O (in. H_2O)	$\Delta p_{(s)}$ cm H_2O (in. H_2O)	$C_{p(s)}$	DEVIATION $C_{p(s)} - \bar{C}_p(A)$
1				
2				
3				
		$\bar{C}_p$ (SIDE A)		

	"B" SIDE CALIBRATION			
RUN NO.	Δp_{std} cm H_2O (in. H_2O)	$\Delta p_{(s)}$ cm H_2O (in. H_2O)	$C_{p(s)}$	DEVIATION $C_{p(s)} - \bar{C}_p(B)$
1				
2				
3				
		$\bar{C}_p$ (SIDE B)		

$$\text{AVERAGE DEVIATION} = \sigma\,(\text{A OR B}) = \frac{\sum_{1}^{3} \left| C_{p(s)} - \bar{C}_p(\text{A OR B}) \right|}{3} \longleftarrow \text{MUST BE} \leq 0.01$$

$$\left| \bar{C}_p\,(\text{SIDE A}) - \bar{C}_p\,(\text{SIDE B}) \right| \longleftarrow \text{MUST BE} \leq 0.01$$

Figure 2-9. Pitot tube calibration data.

$$C_{p(s)} = C_{p(std)} \sqrt{\frac{\Delta p_{std}}{\Delta p_s}}$$

Equation 2-2

where:

$C_{p(s)}$ = Type S pitot tube coefficient

$C_{p(std)}$ = Standard pitot tube coefficient; use 0.99 if the coefficient is unknown and the tube is designed according to the criteria of Sections 2.7.1 to 2.7.5 of this method.

Δp_{std} = Velocity head measured by the standard pitot tube, cm H_2O (in. H_2O)

Δp_s = Velocity head measured by the Type S pitot tube, cm H_2O (in. H_2O)

4.1.4.2 Calculate $\bar{C}_p$ (side A), the mean A-side coefficient, and $\bar{C}_p$ (side B), the mean B-side coefficient; calculate the difference between these two average values.

4.1.4.3 Calculate the deviation of each of the three A-side values of $C_{p(s)}$ from $\bar{C}_p$ (side A), and the deviation of each B-side value of $C_{p(s)}$ from $\bar{C}_p$ (side B). Use the following equation:

$$\text{Deviation} = C_{p(s)} - \bar{C}_p(\text{A or B})$$

Equation 2-3

4.1.4.4 Calculate σ, the average deviation from the mean, for both the A and B sides of the pitot tube. Use the following equation:

$$\sigma\ (\text{side A or B}) = \frac{\sum_{1}^{3} \left| C_{p(s)} - \bar{C}_p(A \text{ or } B) \right|}{3}$$

Equation 2-4

4.1.4.5 Use the Type S pitot tube only if the values of σ (side A) and σ (side B) are less than or equal to 0.01 and if the absolute value of the difference between $\bar{C}_p$ (A) and $\bar{C}_p$ (B) is 0.01 or less.

4.1.5 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 so obtained, i.e., $\bar{C}_p$ (side A) and $\bar{C}_p$ (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 2-8).

4.1.5.1.2 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 and 2-8).

4.1.5.1.3 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 in Section 6). 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 a 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 3 percent or less for assemblies with external sheaths (Figure 2-10b).

4.1.5.2 For those probe assemblies in which pitot tube-nozzle interference is a factor (i.e., those in which the pitot-nozzel separation distance fails to meet the specification illustrated in Figure 2-6a), the value of $C_{p(s)}$ 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 larger nozzle sizes (>0.635 cm or ¼ in.) are not ordinarily used for isokinetic sampling at velocities around 915 m/min (3,000 ft/min), which is the calibration velocity; note also that it is not necessary to draw an isokinetic sample during calibration (see Citation 19 in Section 6).

4.1.5.3 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 (the side which will face the flow). The pitot tube must still meet the alignment specifications of Figure 2-2 or 2-3, however, and must have an average deviation (σ) value of 0.01 or less (see Section 4.1.4.4).

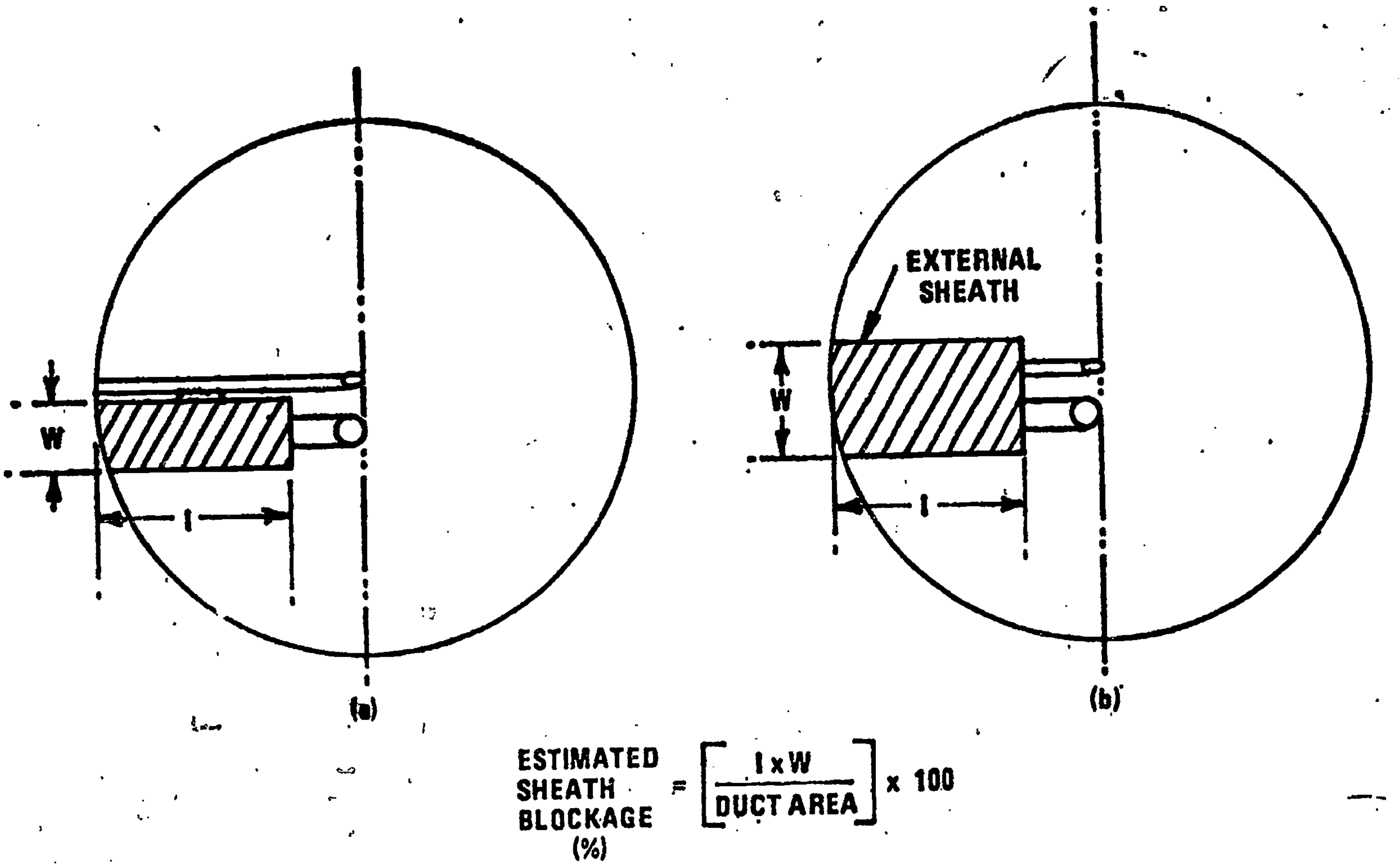


Figure 2-10. Projected-area models for typical pitot tube assemblies.

4.1.6 Field Use and Recalibration.

4.1.6.1 Field Use.

4.1.6.1.1 When a Type S pitot tube (isolated tube or assembly) is used in the field, the appropriate coefficient value (whether assigned or obtained by calibration) shall be used to perform velocity calculations. For calibrated Type S pitot tubes, the A side coefficient shall be used when the A side of the tube faces the flow, and the B side coefficient shall be used when the B side faces the flow; alternatively, the arithmetic average of the A and B side coefficient values may be used, irrespective of which side faces the flow.

4.1.6.1.2 When a probe assembly is used to sample a small duct (12 to 36 in. in diameter), the probe sheath sometimes blocks a significant part of the duct cross-section, causing a reduction in the effective value of $\overline{C}_{p(s)}$. Consult Citation 9 in Section 6 for details. Conventional pitot-sampling probe assemblies are not recommended for use in ducts having inside diameters smaller than 12 inches (Citation 16 in Section 6).

4.1.6.2 Recalibration.

4.1.6.2.1 Isolated Pitot Tubes. After each field use, the pitot tube shall be carefully reexamined in top, side, and end views. If the pitot face openings are still aligned within the specifications illustrated in Figure 2-2 or 2-3, it can be assumed that the baseline coefficient of the pitot tube has not changed. If, however, the tube has been damaged to the extent that it no longer meets the specifications of Figure 2-2 or 2-3, the damage shall either be repaired to restore proper alignment of the face openings or the tube shall be discarded.

4.1.6.2.2 Pitot Tube Assemblies. After each field use, check the face opening alignment of the pitot tube, as in Section 4.1.6.2.1; also, remeasure the intercomponent spacings of the assembly. If the intercomponent spacings have not changed and the face opening alignment is acceptable, it can be assumed that the coefficient of the assembly has not changed. If the face opening alignment is no longer within the specifications of Figures 2-2 or 2-3, either repair the damage or replace the pitot tube (recalibrating the new assembly, if necessary). If the intercomponent spacings have changed, restore the original spacings or recalibrate the assembly.

4.2 Standard pitot tube (if applicable). If a standard pitot tube is used for the velocity traverse, the tube shall be constructed according to the criteria of Section 2.7 and shall be assigned a baseline coefficient value of 0.99. If the standard pitot tube is used as part of an assembly, the tube shall be in an interference-free arrangement (subject to the approval of the Administrator).

4.3 Temperature Gauges. After each field use, calibrate dial thermometers, liquid-filled bulb thermometers, thermocouple-potentiometer systems, and other gauges at a temperature within 10 percent of the average absolute stack temperature. For temperatures up to 405° C (761° F), use an ASTM mercury-in-glass reference thermometer, or equivalent, as a reference; alternatively, either a reference thermocouple and potentiometer (calibrated by NBS) or thermometric fixed points, e.g., ice bath and boiling water (corrected for barometric pressure) may be used. For temperatures above 405° C (761° F), use an NBS-calibrated reference thermocouple-potentiometer system or an alternate reference, subject to the approval of the Administrator.

If, during calibration, the absolute temperatures measured with the gauge being calibrated and the reference gauge agree within 1.5 percent, the temperature data taken in the field shall be considered valid. Otherwise, the pollutant emission test shall either be considered invalid or adjustments (if appropriate) of the test results shall be made, subject to the approval of the Administrator.

4.4 Barometer. Calibrate the barometer used against a mercury barometer.

5. *Calculations*

Carry out calculations, retaining at least one extra decimal figure beyond that of the acquired data. Round off figures after final calculation.

5.1 Nomenclature

A = Cross-sectional area of stack, m² (ft²).

B_{ws} = Water vapor in the gas stream (from Method 5 or Reference Method 4), proportion by volume.

C_p = Pitot tube coefficient, dimensionless.

K_p = Pitot tube constant,

$$34.97 \frac{\text{m}}{\text{sec}} \left[\frac{(\text{g/g-mole})(\text{mm Hg})}{(°\text{K})(\text{mm H}_2\text{O})}\right]^{1/2}$$

for the metric system and

$$85.49 \frac{\text{ft}}{\text{sec}} \left[\frac{(\text{lb/lb-mole})(\text{in. Hg})}{(°\text{R})(\text{in. H}_2\text{O})}\right]^{1/2}$$

for the English system.

M_d = Molecular weight of stack gas, dry basis (see Section 3.6) g/g-mole (lb/lb-mole).

M_s = Molecular weight of stack gas, wet basis, g/g-mole (lb/lb-mole).

$= M_d (1-B_{ws})+18.0 B_{ws}$ Equation 2-5

P_{bar} = Barometric pressure at measurement site, mm Hg (in. Hg).

P_g = Stack static pressure, mm Hg (in. Hg).

P_s = Absolute stack gas pressure, mm Hg (in. Hg).

$= P_{bar}+P_g$ Equation 2-6

P_{std} = Standard absolute pressure, 760 mm Hg (29.92 in. Hg).

Q_{sd} = Dry volumetric stack gas flow rate corrected to standard conditions, dscm/hr (dscf/hr).

t_s = Stack temperature, °C (°F).

T_s = Absolute stack temperature, °K (°R).

$= 273+t_s$ for metric Equation 2-7

$= 460+t_s$ for English Equation 2-8

T_{std} = Standard absolute temperature, 293 °K (528° R)

v_s = Average stack gas velocity, m/sec (ft/sec).

Δp = Velocity head of stack gas, mm H₂O (in. H₂O).

3,600 = Conversion factor, sec/hr.

18.0 = Molecular weight of water, g/g-mole (lb/lb-mole).

5.2 Average stack gas velocity.

$$v_s = K_p C_p (\sqrt{\Delta p})_{avg} \sqrt{\frac{T_{s(avg)}}{P_s M_s}}$$

Equation 2-9

5.3 Average stack gas dry volumetric flow rate.

$$Q_{sd} = 3{,}600 (1-B_{ws}) v_s A \left(\frac{T_{std}}{T_{s(avg)}}\right) \left(\frac{P_s}{P_{std}}\right)$$

Equation 2-10

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METHOD 3—GAS 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: (1) single-point, grab sampling; (2) single-point, integrated sampling; or (3) multi-point, integrated sampling. The gas sample is analyzed for percent carbon dioxide (CO_2), percent oxygen (O_2), and, if necessary, percent carbon monoxide (CO). If a dry molecular weight determination is to be made, either an Orsat or a Fyrite[1] analyzer may be used for the analysis; for excess air or emission rate correction factor determination, an Orsat analyzer must be used.

1.2 Applicability. This method is applicable for determining CO_2 and O_2 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 processes where it has been determined that compounds other than CO_2, O_2, CO, and nitrogen (N_2) 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 Orsat analyzer to analyze individual grab samples obtained at each point; (2) a method using CO_2 or O_2 and stoichiometric calculations to determine dry molecular weight and excess air; (3) assigning a value of 30.0 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 Grab Sampling (Figure 3-1).

2.1.1 Probe. The probe should be made of stainless steel or borosilicate glass tubing and should be equipped with an in-stack or out-stack filter to remove particulate matter (a plug of glass wool is satisfactory for this purpose). Any other material inert to O_2, CO_2, CO, and N_2 and resistant to temperature at sampling conditions may be used for the probe; examples of such material are aluminum, copper, quartz glass and Teflon.

2.1.2 Pump. A one-way squeeze bulb, or equivalent, is used to transport the gas sample to the analyzer.

2.2 Integrated Sampling (Figure 3-2).

2.2.1 Probe. A probe such as that described in Section 2.1.1 is suitable.

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[1] Mention of trade names or specific products does not constitute endorsement by the Environmental Protection Agency.

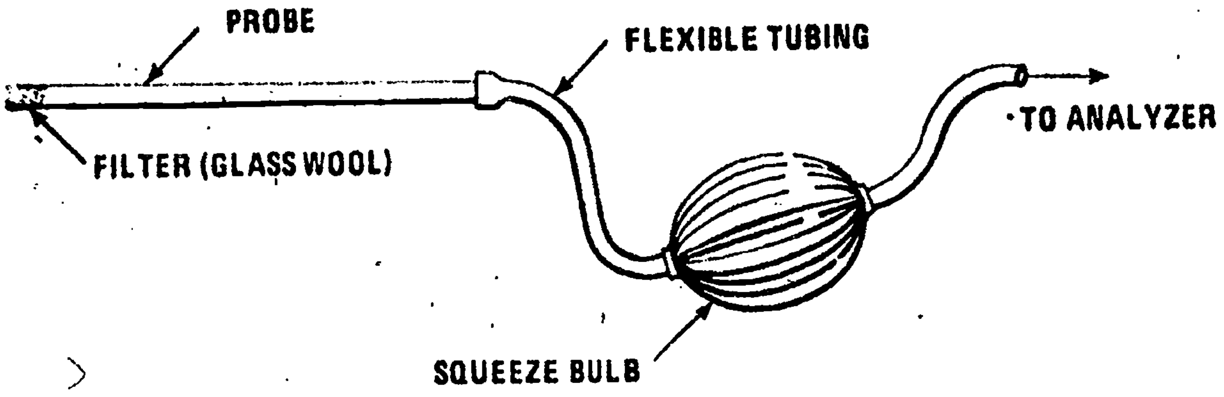

Figure 3-1. Grab-sampling train.

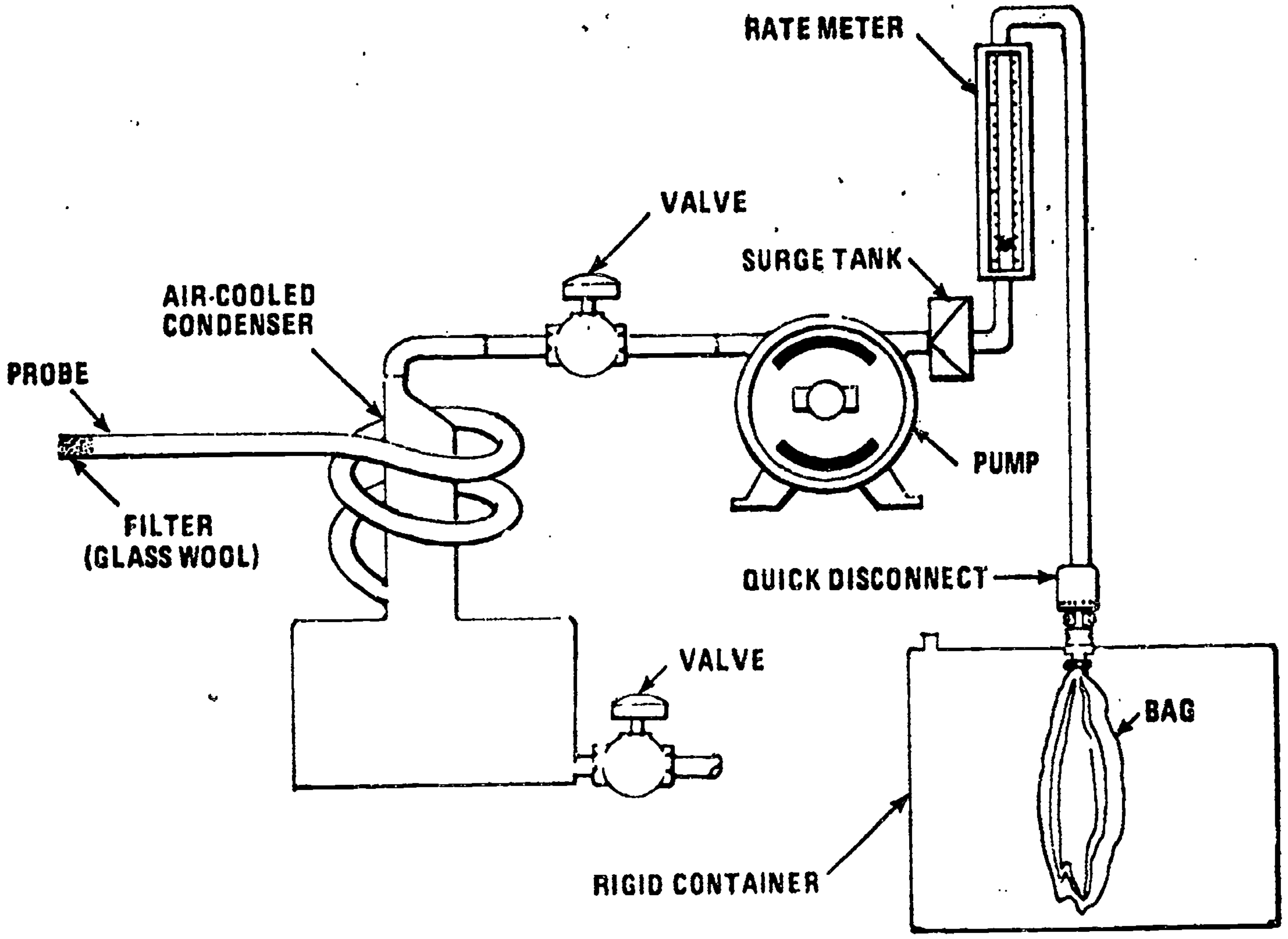

Figure 3-2. Integrated gas-sampling train.

2.2.2 Condenser. An air-cooled or water-cooled condenser, or other condenser that will not remove O_2, CO_2, CO, and N_2, may be used to remove excess moisture which would interfere with the operation of the pump and flow meter.

2.2.3 Valve. A needle valve is used to adjust sample gas flow rate.

2.2.4 Pump. A leak-free, diaphragm-type pump, or equivalent, is used to transport sample gas to the flexible bag. Install a small surge tank between the pump and rate meter to eliminate the pulsation effect of the diaphragm pump on the rotameter.

2.2.5 Rate Meter. The rotameter, or equivalent rate meter, used should be capable of measuring flow rate to within ±2 percent of the selected flow rate. A flow rate range of 500 to 1000 cm^3/min is suggested.

2.2.6 Flexible Bag. Any leak-free plastic (e.g., Tedlar, Mylar, Teflon) or plastic-coated aluminum (e.g., aluminized Mylar) bag, or equivalent, having a capacity consistent with the selected flow rate and time length of the test run, may be used. A capacity in the range of 55 to 90 liters is suggested.

To leak-check the bag, connect it to a water manometer and pressurize the bag to 5 to 10 cm H_2O (2 to 4 in. H_2O). Allow to stand for 10 minutes. Any displacement in the water manometer indicates a leak. An alternative leak-check method is to pressurize the bag to 5 to 10 cm H_2O (2 to 4 in. H_2O) and allow to stand overnight. A deflated bag indicates a leak.

2.2.7 Pressure Gauge. A water-filled U-tube manometer, or equivalent, of about 28 cm (12 in.) is used for the flexible bag leak-check.

2.2.8 Vacuum Gauge. A mercury manometer, or equivalent, of at least 760 mm Hg (30 in. Hg) is used for the sampling train leak-check.

2.3 Analysis. For Orsat and Fyrite analyzer maintenance and operation procedures, follow the instructions recommended by the manufacturer, unless otherwise specified herein.

2.3.1 Dry Molecular Weight Determination. An Orsat analyzer or Fyrite type combustion gas analyzer may be used.

2.3.2 Emission Rate Correction Factor or Excess Air Determination. An Orsat analyzer must be used. For low CO_2 (less than 4.0 percent) or high O_2 (greater than 15.0 percent) concentrations, the measuring burette of the Orsat must have at least 0.1 percent subdivisions.

3. *Dry Molecular Weight Determination*

Any of the three sampling and analytical procedures described below may be used for determining the dry molecular weight.

3.1 Single-Point, Grab Sampling and Analytical Procedure.

3.1.1 The sampling point in the duct shall either be at the centroid of the cross section or at a point no closer to the walls than 1.00 m (3.3 ft), unless otherwise specified by the Administrator.

3.1.2 Set up the equipment as shown in Figure 3-1, making sure all connections ahead of the analyzer are tight and leak-free. If an Orsat analyzer is used, it is recommended that the analyzer be leaked-checked by following the procedure in Section 5; however, the leak-check is optional.

3.1.3 Place the probe in the stack, with the tip of the probe positioned at the sampling point; purge the sampling line. Draw a sample into the analyzer and immediately analyze it for percent CO_2 and percent O_2. Determine the percentage of the gas that is N_2 and CO by subtracting the sum of the percent CO_2 and percent O_2 from 100 percent. Calculate the dry molecular weight as indicated in Section 6.3.

3.1.4 Repeat the sampling, analysis, and calculation procedures, until the dry molecular weights of any three grab samples differ from their mean by no more than 0.3 g/g-mole (0.3 lb/lb-mole). Average these three molecular weights, and report the results to the nearest 0.1 g/g-mole (lb/lb-mole).

3.2 Single-Point, Integrated Sampling and Analytical Procedure.

3.2.1 The sampling point in the duct shall be located as specified in Section 3.1.1.

3.2.2 Leak-check (optional) the flexible bag as in Section 2.2.6. Set up the equipment as shown in Figure 3-2. Just prior to sampling, leak-check (optional) the train by placing a vacuum gauge at the condenser inlet, pulling a vacuum of at least 250 mm Hg (10 in. Hg), plugging the outlet at the quick disconnect, and then turning off the pump. The vacuum should remain stable for at least 0.5 minute. Evacuate the flexible bag. Connect the probe and place it in the stack, with the tip of the probe positioned at the sampling point; purge the sampling line. Next, connect the bag and make sure that all connections are tight and leak free.

3.2.3 Sample at a constant rate. The sampling run should be simultaneous with, and for the same total length of time as, the pollutant emission rate determination. Collection of at least 30 liters (1.00 ft^3) of sample gas is recommended; however, smaller volumes may be collected, if desired.

3.2.4 Obtain one integrated flue gas sample during each pollutant emission rate determination. Within 8 hours after the sample is taken, analyze it for percent CO_2 and percent O_2 using either an Orsat analyzer or a Fyrite-type combustion gas analyzer. If an Orsat analyzer is used, it is recommended that the Orsat leak-check described in Section 5 be performed before this determination; however, the check is optional. Determine the percentage of the gas that is N_2 and CO by subtracting the sum of the percent CO and percent O_2 from 100 percent. Calculate the dry molecular weight as indicated in Section 6.3.

3.2.5 Repeat the analysis and calculation procedures until the individual dry molecular weights for any three analyses differ from their mean by no more than 0.3 g/g-mole (0.3 lb/lb-mole). Average these three molecular weights, and report the results to the nearest 0.1 g/g-mole (0.1 lb/lb-mole).

3.3 Multi-Point, Integrated Sampling and Analytical Procedure.

3.3.1 Unless otherwise specified by the Administrator, a minimum of eight traverse points shall be used for circular stacks having diameters less then 0.61 m (24 in.), a minimum of nine shall be used for rectangular stacks having equivalent diameters less than 0.61 m (24 in.), and a minimum of twelve traverse points shall be used for all other cases. The traverse points shall be located according to Method 1. The use of fewer points is subject to approval of the Administrator.

3.3.2 Follow the procedures outlined in Sections 3.2.2 through 3.2.5, except for the following: traverse all sampling points and sample at each point for an equal length of time. Record sampling data as shown in Figure 3-3.

4. *Emission Rate Correction Factor or Excess Air Determination*

NOTE.—A Fyrite-type combustion gas analyzer is not acceptable for excess air or emission rate correction factor determination, unless approved by the Administrator. If both percent CO_2 and percent O_2 are measured, the analytical results of any of the three procedures given below may also be used for calculating the dry molecular weight.

Each of the three procedures below shall be used only when specified in an applicable subpart of the standards. The use of these procedures for other purposes must have specific prior approval of the Administrator.

4.1 Single-Point, Grab Sampling and Analytical Procedure.

4.1.1 The sampling point in the duct shall either be at the centroid of the cross-section or at a point no closer to the walls than 1.00 m (3.3 ft), unless otherwise specified by the Administrator.

4.1.2 Set up the equipment as shown in Figure 3-1, making sure all connections ahead of the analyzer are tight and leak-free. Leak-check the Orsat analyzer according to the procedure described in Section 5. This leak-check is mandatory.

TIME	TRAVERSE PT.	Q lpm	% DEV.[a]
	AVERAGE		

$$^{a}\%\,\text{DEV} = \left(\frac{Q - Q_{avg}}{Q_{avg}}\right) 100 \qquad \text{(MUST BE} \leq 10\%\text{)}$$

Figure 3-3. Sampling rate data.

4.1.3 Place the probe in the stack, with the tip of the probe positioned at the sampling point; purge the sampling line. Draw a sample into the analyzer. For emission rate correction factor determination, immediately analyze the sample, as outlined in Sections 4.1.4 and 4.1.5, for percent CO_2 or percent O_2. If excess air is desired, proceed as follows: (1) immediately analyze the sample, as in Sections 4.1.4 and 4.1.5, for percent CO_2, O_2, and CO; (2) determine the percentage of the gas that is N_2 by subtracting the sum of the percent CO_2, percent O_2, and percent CO from 100 percent; and (3) calculate percent excess air as outlined in Section 6.2.

4.1.4 To ensure complete absorption of the CO_2, O_2, or if applicable, CO, make repeated passes through each absorbing solution until two consecutive readings are the same. Several passes (three or four) should be made between readings. (If constant readings cannot be obtained after three consecutive readings, replace the absorbing solution.)

4.1.5 After the analysis is completed, leak-check (mandatory) the Orsat analyzer once again, as described in Section 5. For the results of the analysis to be valid, the Orsat analyzer must pass this leak test before and after the analysis. NOTE.—Since this single-point, grab sampling and analytical procedure is normally conducted in conjunction with a single-point, grab sampling and analytical procedure for a pollutant, only one analysis is ordinarily conducted. Therefore, great care must be taken to obtain a valid sample and analysis. Although in most cases only CO_2 or O_2 is required, it is recommended that both CO_2 and O_2 be measured, and that Citation 5 in the Bibliography be used to validate the analytical data.

4.2 Single-Point, Integrated Sampling and Analytical Procedure.

4.2.1 The sampling point in the duct shall be located as specified in Section 4.1.1.

4.2.2 Leak-check (mandatory) the flexible bag as in Section 2.2.6. Set up the equipment as shown in Figure 3-2. Just prior to sampling, leak-check (mandatory) the train by placing a vacuum gauge at the condenser inlet, pulling a vacuum of at least 250 mm Hg (10 in. Hg), plugging the outlet at the quick disconnect, and then turning off the pump. The vacuum shall remain stable for at least 0.5 minute. Evacuate the flexible bag. Connect the probe and place it in the stack, with the tip of the probe positioned at the sampling point; purge the sampling line. Next, connect the bag and make sure that all connections are tight and leak free.

4.2.3 Sample at a constant rate, or as specified by the Administrator. The sampling run must be simultaneous with, and for the same total length of time as, the pollutant emission rate determination. Collect at least 30 liters (1.00 ft^3) of sample gas. Smaller volumes may be collected, subject to approval of the Administrator.

4.2.4 Obtain one integrated flue gas sample during each pollutant emission rate determination. For emission rate correction factor determination, analyze the sample within 4 hours after it is taken for percent CO_2 or percent O_2 (as outlined in Sections 4.2.5 through 4.2.7). The Orsat analyzer must be leak-checked (see Section 5) before the analysis. If excess air is desired, proceed as follows: (1) within 4 hours after the sample is taken, analyze it (as in Sections 4.2.5 through 4.2.7) for percent CO_2, O_2, and CO; (2) determine the percentage of the gas that is N_2 by subtracting the sum of the percent CO_2, percent O_2, and percent CO from 100 percent; (3) calculate percent excess air, as outlined in Section 6.2.

4.2.5 To ensure complete absorption of the CO_2, O_2, or if applicable, CO, make repeated passes through each absorbing solution until two consecutive readings are the same. Several passes (three or four) should be made between readings. (If constant readings cannot be obtained after three consecutive readings, replace the absorbing solution.)

4.2.6 Repeat the analysis until the following criteria are met:

4.2.6.1 For percent CO_2, repeat the analytical procedure until the results of any three analyses differ by no more than (a) 0.3 percent by volume when CO_2 is greater than 4.0 percent or (b) 0.2 percent by volume when CO_2 is less than or equal to 4.0 percent. Average the three acceptable values of percent CO_2 and report the results to the nearest 0.1 percent.

4.2.6.2 For percent O_2, repeat the analytical procedure until the results of any three analyses differ by no more than (a) 0.3 percent by volume when O_2 is less than 15.0 percent or (b) 0.2 percent by volume when O_2 is greater than 15.0 percent. Average the three acceptable values of percent O_2 and report the results to the nearest 0.1 percent.

4.2.6.3 For percent CO, repeat the analytical procedure until the results of any three analyses differ by no more than 0.3 percent. Average the three acceptable values of percent CO and report the results to the nearest 0.1 percent.

4.2.7 After the analysis is completed, leak-check (mandatory) the Orsat analyzer once again, as described in Section 5. For the results of the analysis to be valid, the Orsat analyzer must pass this leak test before and after the analysis. Note: Although in most instances only CO_2 or O_2 is required, it is recommended that both CO_2 and O_2 be measured, and that Citation 5 in the Bibliography be used to validate the analytical data.

4.3 Multi-Point, Integrated Sampling and Analytical Procedure.

4.3.1 Both the minimum number of sampling points and the sampling point location shall be as specified in Section 3.3.1 of this method. The use of fewer points than specified is subject to the approval of the Administrator.

4.3.2 Follow the procedures outlined in Sections 4.2.2 through 4.2.7, except for the following: Traverse all sampling points and sample at each point for an equal length of time. Record sampling data as shown in Figure 3-3.

5. *Leak-Check Procedure for Orsat Analyzers*

Moving an Orsat analyzer frequently causes it to leak. Therefore, an Orsat analyzer should be thoroughly leak-checked on site before the flue gas sample is introduced into it. The procedure for leak-checking an Orsat analyzer is:

5.1.1 Bring the liquid level in each pipette up to the reference mark on the capillary tubing and then close the pipette stopcock.

5.1.2 Raise the leveling bulb sufficiently to bring the confining liquid meniscus onto the graduated portion of the burette and then close the manifold stopcock.

5.1.3 Record the meniscus position.

5.1.4 Observe the meniscus in the burette and the liquid level in the pipette for movement over the next 4 minutes.

5.1.5 For the Orsat analyzer to pass the leak-check, two conditions must be met.

5.1.5.1 The liquid level in each pipette must not fall below the bottom of the capillary tubing during this 4-minute interval.

5.1.5.2 The meniscus in the burette must not change by more than 0.2 ml during this 4-minute interval.

5.1.6 If the analyzer fails the leak-check procedure, all rubber connections and stopcocks should be checked until the cause of the leak is identified. Leaking stopcocks must be disassembled, cleaned, and regreased. Leaking rubber connections must be replaced. After the analyzer is reassembled, the leak-check procedure must be repeated.

6. *Calculations*

6.1 Nomenclature.

M_d = Dry molecular weight, g/g-mole (lb/lb-mole).
%EA = Percent excess air.
$\%CO_2$ = Percent CO_2 by volume (dry basis).
$\%O_2$ = Percent O_2 by volume (dry basis).
%CO = Percent CO by volume (dry basis).
$\%N_2$ = Percent N_2 by volume (dry basis).
0.264 = Ratio of O_2 to N_2 in air, v/v.
0.280 = Molecular weight of N_2 or CO, divided by 100.
0.320 = Molecular weight of O_2 divided by 100.
0.440 = Molecular weight of CO_2 divided by 100.

6.2 Percent Excess Air. Calculate the percent excess air (if applicable), by substituting the appropriate values of percent O_2, CO, and N_2 (obtained from Section 4.1.3 or 4.2.4) into Equation 3-1.

$$\%EA = \left[\frac{\%O_2 - 0.5\%CO}{0.264\%N_2 - (\%O_2 - 0.5\%CO)}\right]100$$

Equation 3-1

Note: The equation above assumes that ambient air is used as the source of O_2 and that the fuel does not contain appreciable amounts of N_2 (as do coke oven or blast furnace gases). For those cases when appreciable amounts of N_2 are present (coal, oil, and natural gas do not contain appreciable amounts of N_2) or when oxygen enrichment is used, alternate methods, subject to approval of the Administrator, are required.

6.3 Dry Molecular Weight. Use Equation 3-2 to calculate the dry molecular weight of the stack gas.

$$M_d = 0.440(\%CO_2) + 0.320(\%O_2) + 0.280(\%N_2 + \%CO)$$

Equation 3-2

Note: The above equation does not consider argon in air (about 0.9 percent, molecular weight of 37.7). A negative error of about 0.4 percent is introduced. The tester may opt to include argon in the analysis using procedures subject to approval of the Administrator.

7. *Bibliography*

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METHOD 4—DETERMINATION OF MOISTURE CONTENT IN STACK GASES

1. *Principle and Applicability*

1.1 Principle. A gas sample is extracted at a constant rate from the source; moisture is removed from the sample stream and determined either volumetrically or gravimetrically.

1.2 Applicability. This method is applicable for determining the moisture content of stack gas.

Two procedures are given. The first is a reference method, for accurate determinations of moisture content (such as are needed to calculate emission data). The second is an approximation method, which provides estimates of percent moisture to aid in setting isokinetic sampling rates prior to a pollutant emission measurement run. The approximation method described herein is only a suggested approach; alternative means for approximating the moisture content, e.g., drying tubes, wet bulb-dry bulb techniques, condensation techniques, stoichiometric calculations, previous experience, etc., are also acceptable.

The reference method is often conducted simultaneously with a pollutant emission measurement run; when it is, calculation of percent isokinetic, pollutant emission rate, etc., for the run shall be based upon the results of the reference method or its equivalent; these calculations shall not be based upon the results of the approximation method, unless the approximation method is shown, to the satisfaction of the Administrator, U.S. Environmental Protection Agency, to be capable of yielding results within 1 percent H_2O of the reference method.

Note: The reference method may yield questionable results when applied to saturated gas streams or to streams that contain water droplets. Therefore, when these conditions exist or are suspected, a second determination of the moisture content shall be made simultaneously with the reference method, as follows: Assume that the gas stream is saturated. Attach a temperature sensor [capable of measuring to ±1° C (2° F)] to the reference method probe. Measure the stack gas temperature at each traverse point (see Section 2.2.1) during the reference method traverse; calculate the average stack gas temperature. Next, determine the moisture percentage, either by: (1) using a psychrometric chart and making appropriate corrections if stack pressure is different from that of the chart, or (2) using saturation vapor pressure tables. In cases where the psychrometric chart or the saturation vapor pressure tables are not applicable (based on evaluation of the process), alternate methods, subject to the approval of the Administrator, shall be used.

2. *Reference Method*

The procedure described in Method 5 for determining moisture content is acceptable as a reference method.

2.1 Apparatus. A schematic of the sampling train used in this reference method is shown in Figure 4-1. All components shall be maintained and calibrated according to the procedure outlined in Method 5.

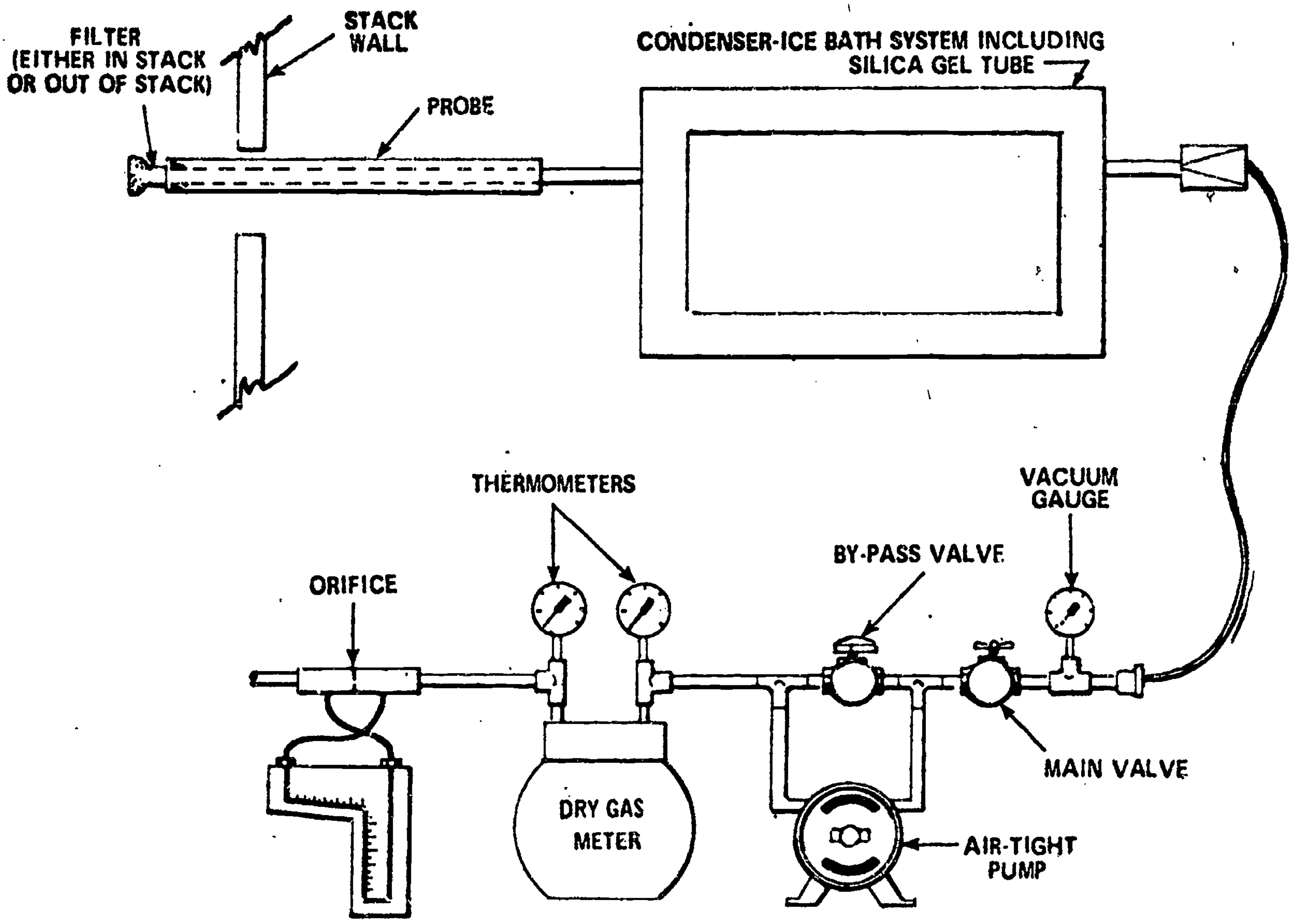

Figure 4-1. Moisture sampling train-reference method.

2.1.1 Probe. The probe is constructed of stainless steel or glass tubing, sufficiently heated to prevent water condensation, and is equipped with a filter, either in-stack (e.g., a plug of glass wool inserted into the end of the probe) or heated out-stack (e.g., as described in Method 5), to remove 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 any similarly leak-free non-contaminating fittings. The first, third, and fourth impingers shall be of the Greenburg-Smith design, modified by replacing the tip with a 1.3 centimeter (½ in.) ID glass tube extending to about 1.3 cm (½ in.) from the bottom of the flask. The second impinger shall be of the Greenburg-Smith design with the standard tip. Modifications (e.g., using flexible connections between the impingers, using materials other than glass, or using flexible vacuum lines to connect the filter 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 empty, and the fourth shall contain a known weight of 6- to 16-mesh indicating type silica gel, or equivalent desiccant. If the silica gel has been previously used, dry at 175° C (350° F) for 2 hours. New silica gel may be used as received. A thermometer, capable of measuring temperature to within 1° C (2° F), shall be placed at the outlet of the fourth impinger, for monitoring purposes.

Alternatively, any system may be used (subject to the approval of the Administrator) that cools the sample gas stream and allows measurement of both the water that has been condensed and the moisture leaving the condenser, each to within 1 ml or 1 g. Acceptable means are to measure the condensed water, either gravimetrically or volumetrically and to measure the moisture leaving the condenser by: (1) monitoring the temperature and pressure at the exit of the condenser and using Dalton's law of partial pressures, or (2) passing the sample gas stream through a tared silica gel (or equivalent desiccant) trap, with exit gases kept below 20° C (68° F), and determining the weight gain.

If means other than silica gel are used to determine the amount of moisture leaving the condenser, it is recommended that silica gel (or equivalent) still be used between the condenser system and pump, to prevent moisture condensation in the pump and metering devices and to avoid the need to make corrections for moisture in the metered volume.

2.1.3 Cooling System. An ice bath container and crushed ice (or equivalent) are used to aid in condensing moisture.

2.1.4 Metering System. This system includes a vacuum gauge, leak-free pump, thermometers capable of measuring temperature to within 3° C (5.4° 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 Barometer. Mercury, aneroid, or other barometer capable of measuring atmospheric pressure to within 2.5 mm Hg (0.1 in. Hg) may be used. 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 and an adjustment for elevation differences between the weather station and the sampling point shall be applied at a rate of minus 2.5 mm Hg (0.1 in. Hg) per 30 m (100 ft) elevation increase or vice versa for elevation decrease.

2.1.6 Graduated Cylinder and/or Balance. These items are used to measure condensed water and moisture caught in the silica gel to within 1 ml or 0.5 g. Graduated cylinders shall have subdivisions no greater than 2 ml. Most laboratory balances are capable of weighing to the nearest 0.5 g or less. These balances are suitable for use here.

2.2 Procedure. The following procedure is written for a condenser system (such as the impinger 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.), a minimum of nine points shall be used for rectangular stacks having equivalent diameters less than 0.61 m (24 in.), and a minimum of twelve travers points shall be used in all other cases. The traverse points shall be located according to Method 1. The use of fewer points is subject to the approval of the Administrator. Select a suitable probe and probe length such that all traverse points can be sampled. Consider sampling from opposite sides of the stack (four total sampling ports) for large stacks, to permit use of shorter probe lengths. Mark the probe with heat resistant tape or by some other method to denote the proper distance into the stack or duct for each sampling point. Place known volumes of water in the first two impingers. Weigh and record the weight of the silica gel to the nearest 0.5 g, and transfer the silica gel to the fourth impinger; alternatively, the silica gel may first be transferred to the impinger, and the weight of the silica gel plus impinger recorded.

2.2.2 Select a total sampling time such that a minimum total gas volume of 0.60 scm (21 scf) will be collected, at a rate no greater than 0.021 m³/min (0.75 cfm). 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 emission rate run, unless otherwise specified in an applicable subpart of the standards.

2.2.3 Set up the sampling train as shown in Figure 4-1. Turn on the probe heater and (if applicable) the filter heating system to temperatures of about 120° C (248° F), to prevent water condensation ahead of the condenser; allow time for the temperatures to stabilize. Place crushed ice in the ice bath container. It is recommended, but not required, that a leak check be done, as follows: Disconnect the probe from the first impinger or (if applicable) from the filter holder. Plug the inlet to the first impinger (or filter holder) and pull a 380 mm (15 in.) Hg vacuum; a lower vacuum may be used, provided that it is not exceeded during the test. A leakage rate in excess of 4 percent of the average sampling rate or 0.00057 m³/min (0.02 cfm), whichever is less, is unacceptable. Following the leak check, reconnect the probe to the sampling train.

2.2.4 During the sampling run, maintain a sampling rate within 10 percent of constant rate, or as specified by the Administrator. For each run, record the data required on the example data sheet shown in Figure 4-2. Be sure to record the dry gas meter reading at the beginning and end of each sampling time increment and whenever sampling is halted. Take other appropriate readings at each sample point, at least once during each time increment.

2.2.5 To begin sampling, position the probe tip at the first traverse point. Immediately start the pump and adjust the flow to the desired rate. Traverse the cross section, sampling at each traverse point for an equal length of time. Add more ice and, if necessary, salt to maintain a temperature of less than 20° C (68° F) at the silica gel outlet.

2.2.6 After collecting the sample, disconnect the probe from the filter holder (or from the first impinger) and conduct a leak check (mandatory) as described in Section 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 8.3 of Method 5. Next, measure the volume of the moisture condensed to the nearest ml. Determine the increase in weight of the silica gel (or silica gel plus impinger) to the nearest 0.5 g. Record this information (see example data sheet, Figure 4-3) and calculate the moisture percentage, as described in 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 calculation.

PLANT____________________
LOCATION____________________
OPERATOR____________________
DATE____________________
RUN NO.____________________
AMBIENT TEMPERATURE____________________
BAROMETRIC PRESSURE____________________
PROBE LENGTH m(ft)____________________

SCHEMATIC OF STACK CROSS SECTION

TRAVERSE POINT NUMBER	SAMPLING TIME (θ), min.	STACK TEMPERATURE °C (°F)	PRESSURE DIFFERENTIAL ACROSS ORIFICE METER (ΔH), mm(in.) H_2O	METER READING GAS SAMPLE VOLUME m^3 (ft^3)	ΔV_m m^3 (ft^3)	GAS SAMPLE TEMPERATURE AT DRY GAS METER		TEMPERATURE OF GAS LEAVING CONDENSER OR LAST IMPINGER, °C (°F)
						INLET ($T_{m_{in}}$), °C (°F)	OUTLET ($T_{m_{out}}$), °C (°F)	
TOTAL						Avg.	Avg.	
AVERAGE						Avg.		

Figure 4-2. Field moisture determination reference method.

	IMPINGER VOLUME, ml	SILICA GEL WEIGHT, g
FINAL		
INITIAL		
DIFFERENCE		

Figure 4-3. Analytical data - reference method.

2.3.1 Nomenclature.

B_{ws} = Proportion of water vapor, by volume, in the gas stream.

M_w = Molecular weight of water, 18.0 g/g-mole (18.0 lb/lb-mole).

P_m = Absolute pressure (for this method, same as barometric pressure) at the dry gas meter, mm Hg (in. Hg).

P_{std} = Standard absolute pressure, 760 mm Hg (29.92 in. Hg).

R = Ideal gas constant, 0.06236 (mm Hg) (m³)/(g-mole) (°K) for metric units and 21.85 (in. Hg) (ft³)/(lb-mole) (°R) for English units.

T_m = Absolute temperature at meter, °K (°R).

T_{std} = Standard absolute temperature, 293° K (528° R).

V_m = Dry gas volume measured by dry gas meter, dcm (dcf).

ΔV_m = Incremental dry gas volume measured by dry gas meter at each traverse point, dcm (dcf).

$V_{m(std)}$ = Dry gas volume measured by the dry gas meter, corrected to standard conditions, dscm (dscf).

$V_{wc(std)}$ = Volume of water vapor condensed corrected to standard conditions, scm (scf).

$V_{wsg(std)}$ = Volume of water vapor collected in silica gel corrected to standard conditions, scm (scf).

V_f = Final volume of condenser water, ml.

V_i = Initial volume, if any, of condenser water, ml.

W_f = Final weight of silica gel or silica gel plus impinger, g.

W_i = Initial weight of silica gel or silica gel plus impinger, g.

Y = Dry gas meter calibration factor.

ρ_w = Density of water, 0.9982 g/ml (0.002201 lb/ml).

2.3.2 Volume of water vapor condensed.

$$V_{wc(std)} = \frac{(V_f - V_i)\rho_w R T_{std}}{P_{std} M_w} = K_1 (V_f - V_i)$$

Equation 4-1

where:

K_1 = 0.001333 m³/ml for metric units
= 0.04707 ft³/ml for English units

2.3.3 Volume of water vapor collected in silica gel.

$$V_{wsg(std)} = \frac{(W_f - W_i) R T_{std}}{P_{std} M_w} = K_2 (W_f - W_i)$$

Equation 4-2

where:

K_2 = 0.001335 m³/g for metric units
= 0.04715 ft³/g for English units

2.3.4 Sample gas volume.

$$V_{m(std)} = V_m Y \frac{(P_m)(T_{std})}{(P_{std})(T_m)} = K_3 Y \frac{V_m P_m}{T_m}$$

Equation 4-3

where:

K_3 = 0.3858 °K/mm Hg for metric units
= 17.64 °R/in. Hg for English units

NOTE.—If the post-test leak rate (Section 2.2.6) exceeds the allowable rate, correct the value of V_m in Equation 4-3, as described in Section 6.3 of Method 5.

2.3.5 Moisture Content.

$$B_{ws} = \frac{V_{wc(std)} + V_{wsg(std)}}{V_{wc(std)} + V_{wsg(std)} + V_{m(std)}}$$

Equation 4-4

NOTE.—In saturated or moisture droplet-laden gas streams, two calculations of the moisture content of the stack gas shall be made, one using a value based upon the saturated conditions (see Section 1.2), and another based upon the results of the impinger analysis. The lower of these two values of B_{ws} shall be considered correct.

2.3.6 Verification of constant sampling rate. For each time increment, determine the ΔV_m. Calculate the average. If the value for any time increment differs from the average by more than 10 percent, reject the results and repeat the run.

3. *Approximation Method*

The approximation method described below is presented only as a suggested method (see Section 1.2).

3.1 Apparatus.

3.1.1 Probe. Stainless steel or glass tubing, sufficiently heated to prevent water condensation and equipped with a filter (either in-stack or heated out-stack) to remove particulate matter. A plug of glass wool, inserted into the end of the probe, is a satisfactory filter.

3.1.2 Impingers. Two midget impingers, each with 30 ml capacity, or equivalent.

3.1.3 Ice Bath. Container and ice, to aid in condensing moisture in impingers.

3.1.4 Drying Tube. Tube packed with new or regenerated 6- to 16-mesh indicating-type silica gel (or equivalent desiccant), to dry the sample gas and to protect the meter and pump.

3.1.5 Valve. Needle valve, to regulate the sample gas flow rate.

3.1.6 Pump. Leak-free, diaphragm type, or equivalent, to pull the gas sample through the train.

3.1.7 Volume meter. Dry gas meter, sufficiently accurate to measure the sample volume within 2%, and calibrated over the range of flow rates and conditions actually encountered during sampling.

3.1.8 Rate Meter. Rotameter, to measure the flow range from 0 to 3 lpm (0 to 0.11 cfm).

3.1.9 Graduated Cylinder. 25 ml.

3.1.10 Barometer. Mercury, aneroid, or other barometer, as described in Section 2.1.5 above.

3.1.11 Vacuum Gauge. At least 760 mm Hg (30 in. Hg) gauge, to be used for the sampling leak check.

3.2 Procedure.

3.2.1 Place exactly 5 ml distilled water in each impinger. Assemble the apparatus without the probe as shown in Figure 4-4. Leak check the train by placing a vacuum gauge at the inlet to the first impinger and drawing a vacuum of at least 250 mm Hg (10 in. Hg), plugging the outlet of the rotameter, and then turning off the pump. The vacuum shall remain constant for at least one minute. Carefully release the vacuum gauge before unplugging the rotameter end.

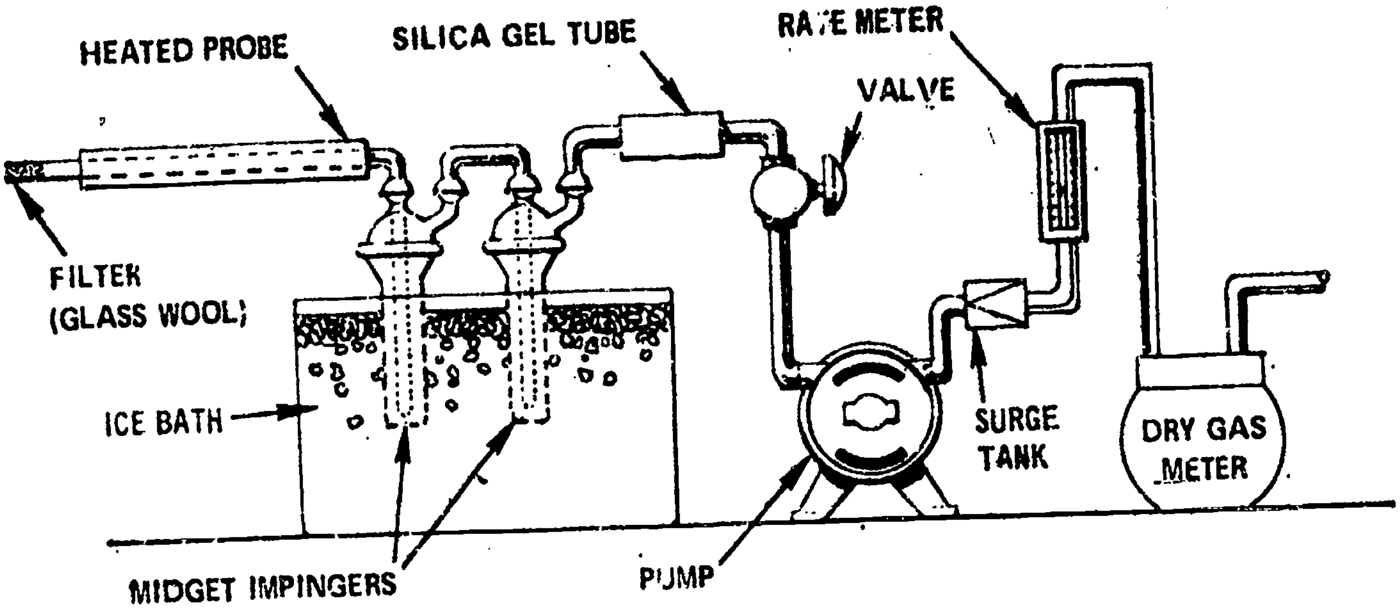

Figure 4-4. Moisture sampling train - approximation method.

LOCATION ________________________ COMMENTS

TEST ________________________

DATE ________________________

OPERATOR ________________________

BAROMETRIC PRESSURE ________________________

CLOCK TIME	GAS VOLUME THROUGH METER, (Vm), m^3 (ft^3)	RATE METER SETTING m^3/min. (ft^3/min.)	METER TEMPERATURE, °C (°F)

Figure 4-5. Field moisture determination - approximation method.

3.2.2 Connect the probe, insert it into the stack, and sample at a constant rate of 2 lpm (0.071 cfm). Continue sampling until the dry gas meter registers about 30 liters (1.1 ft³) 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.

3.2.3 After collecting the sample, combine the contents of the two impingers and measure the volume to the nearest 0.5 ml.

3.3 Calculations. The calculation method presented is designed to estimate the moisture in the stack gas; therefore, other data, which are only necessary for accurate moisture determinations, are not collected. The following equations adequately estimate the moisture content, for the purpose of determining isokinetic sampling rate settings.

3.3.1 Nomenclature.

B_{wm} = Approximate proportion, by volume, of water vapor in the gas stream leaving the second impinger, 0.025.
B_{ws} = Water vapor in the gas stream, proportion by volume.
M_w = Molecular weight of water, 18.0 g/g-mole (18.0 lb/lb-mole)
P_m = Absolute pressure (for this method, same as barometric pressure) at the dry gas meter.
P_{std} = Standard absolute pressure, 760 mm Hg (29.92 in. Hg).
R = Ideal gas constant, 0.06236 (mm Hg) (m³)/(g-mole) (°K) for metric units and 21.85 (in. Hg) (ft³)/lb-mole) (°R) for English units.
T_m = Absolute temperature at meter, °K (°R)
T_{std} = Standard absolute temperature, 293° K (528° R)
V_f = Final volume of impinger contents, ml.
V_i = Initial volume of impinger contents, ml.
V_m = Dry gas volume measured by dry gas meter, dcm (dcf).
$V_{m(std)}$ = Dry gas volume measured by dry gas meter, corrected to standard conditions, dscm (dscf).
$V_{wc(std)}$ = Volume of water vapor condensed, corrected to standard conditions, scm (scf).
ρ_w = Density of water, 0.9982 g/ml (0.002201 lb/ml).

3.3.2 Volume of water vapor collected.

$$V_{wc}=\frac{(V_f-V_i)\rho_w RT_{std}}{P_{std}M_w}=K_1(V_f-V_i)$$

Equation 4-5

where:
K_1 = 0.001333 m³/ml for metric units
= 0.04707 ft³/ml for English units.

3.3.3 Gas volume.

$$V_{m(std)}=V_m\left(\frac{P_m}{P_{std}}\right)\left(\frac{T_{std}}{T_m}\right)=K_2\frac{V_mP_m}{T_m}$$

Equation 4-6

where:
K_2 = 0.3858 °K/mm Hg for metric units
= 17.64 °R/in. Hg for English units

3.3.4 Approximate moisture content.

$$B_{ws}=\frac{V_{wc}}{V_{wc}+V_{m(std)}}+B_{wm}=\frac{V_{wc}}{V_{wc}+V_{m(std)}}+(0.025)$$

Equation 4-7

4. *Calibration*

4.1 For the reference method, calibrate equipment as specified in the following sections of Method 5: Section 5.3 (metering system); Section 5.5 (temperature gauges); and Section 5.7 (barometer). The recommended leak check of the metering system (Section 5.6 of Method 5) also applies to the reference method. For the approximation method, use the procedures outlined in Section 5.1.1 of Method 6 to calibrate the metering system, and the procedure of Method 5, Section 5.7 to calibrate the barometer.

5. *Bibliography*

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METHOD 5—DETERMINATION OF PARTICULATE EMISSIONS FROM STATIONARY SOURCES

1. *Principle and Applicability*

1.1 Principle. Particulate matter is withdrawn isokinetically from the source and collected on a glass fiber filter maintained at a temperature in the range of 120±14° C (248±25° F) or such other temperature as specified by an applicable subpart of the standards or approved by the Administrator, U.S. Environmental Protection Agency, for a particular application. The particulate mass, which includes any material that condenses at or above the filtration temperature, is determined gravimetrically after removal of uncombined water.

1.2 Applicability. This method is applicable for the determination of particulate emissions from stationary sources.

2. *Apparatus*

2.1 Sampling Train. A schematic of the sampling train used in this method is shown in Figure 5-1. Complete construction details are given in APTD-0581 (Citation 2 in Section 7); commercial models of this train are also available. For changes from APTD-0581 and for allowable modifications of the train shown in Figure 5-1, see the following subsections.

The operating and maintenance procedures for the sampling train are described in APTD-0576 (Citation 3 in Section 7). Since correct usage is important in obtaining valid results, all users should read APTD-0576 and adopt the operating and maintenance procedures outlined in it, unless otherwise specified herein. The sampling train consists of the following components:

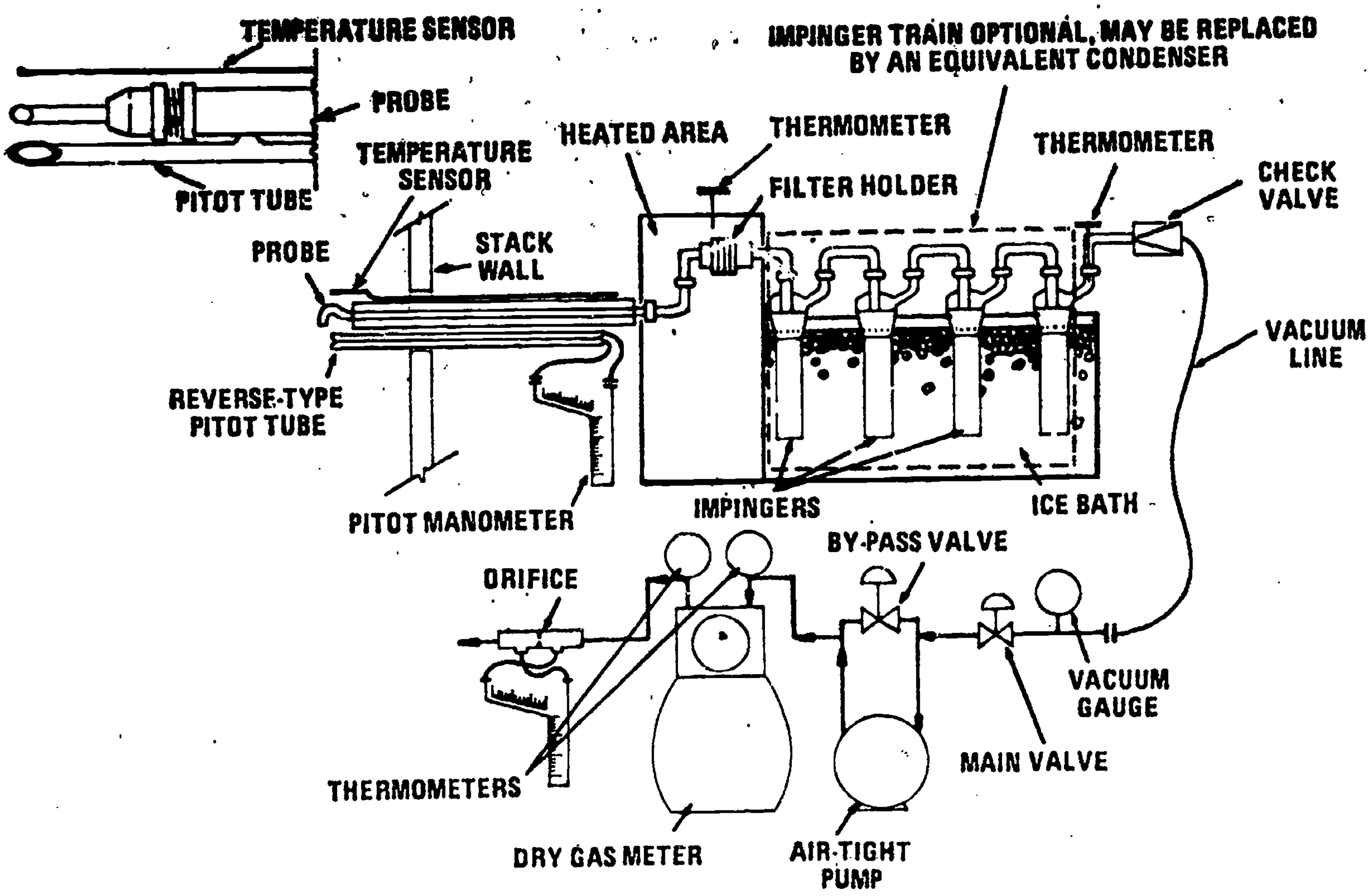

Figure 5-1. Particulate-sampling train.

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 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.

A range of nozzle sizes suitable for isokinetic sampling should be available, e.g., 0.32 to 1.27 cm (¼ to ½ in.)—or larger if higher volume sampling trains are used—inside diameter (ID) nozzles in increments of 0.16 cm (1/16 in.). Each nozzle shall be calibrated according to the procedures outlined in Section 5.

2.1.2 Probe Liner. Borosilicate or quartz glass tubing with a heating system capable of maintaining a gas temperature at the exit end during sampling of 120±14° C (248±25° F), or such other temperature as specified by an applicable subpart of the standards or approved by the Administrator for a particular application. (The tester may opt to operate the equipment at a temperature lower than that specified.) Since the actual temperature at the outlet of the probe is not usually monitored during sampling, probes constructed according to APTD-0581 and utilizing the calibration curves of APTD-0576 (or calibrated according to the procedure outlined in APTD-0576) will be considered acceptable.

Either borosilicate or quartz glass probe liners may be used for stack temperatures up to about 480° C (900° F); quartz liners shall be used for temperatures between 480 and 900° C (900 and 1,650° 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 softening temperature for borosilicate is 820° C (1,508° F), and for quartz it is 1,500° C (2,732° F).

Whenever practical, every effort should be made to use borosilicate or quartz glass probe liners. Alternatively, metal liners (e.g., 316 stainless steel, Incoloy 825,[2] or other corrosion resistant metals) made of seamless tubing may be used, subject to the approval of the Administrator.

2.1.3 Pitot Tube. Type S, as described in Section 2.1 of Method 2, or other device approved by the Administrator. The pitot tube shall be attached to the probe (as shown in Figure 5-1) to allow constant monitoring of the stack gas velocity. The impact (high pressure) opening plane of the pitot tube shall be even with or above the nozzle entry plane (see Method 2, Figure 2-6b) during sampling. The Type S pitot tube assembly shall have a known coefficient, determined as outlined in Section 4 of Method 2.

2.1.4 Differential Pressure Gauge. Inclined manometer or equivalent devices (two), as described in Section 2.2 of Method 2. One manometer shall be used for velocity head (Δp) readings, and the other, for orifice differential pressure readings.

2.1.5 Filter Holder. Borosilicate glass, with a glass frit filter support and a silicone rubber gasket. Other materials of construction (e.g., stainless steel, Teflon, Viton) may be used, subject to 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 cyclone, if used).

2.1.6 Filter Heating System. Any heating system capable of maintaining a temperature around the filter holder during sampling of 120±14° C (248±25° 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 tester may opt to operate the equipment at a temperature lower than that specified. A temperature gauge capable of measuring temperature to within 3° C (5.4° F) shall be installed so that the temperature around the filter holder can be regulated and monitored during sampling. Heating systems other than the one shown in APTD-0581 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 leak-free ground glass fittings or any similar leak-free non-contaminating fittings. The first, third, and fourth impingers shall be of the Greenburg-Smith design, modified by replacing the tip with 1.3 cm (½ in.) ID glass tube extending to about 1.3 cm (½ in.) from the bottom of the flask. The second impinger shall be of the Greenburg-Smith design with the standard tip. Modifications (e.g., using flexible connections between the impingers, using materials other than glass, or using flexible vacuum lines to connect the filter holder to the condenser) may be used, subject to the approval of the Administrator. The first and second impingers shall contain known quantities of water (Section 4.1.3), the third shall be empty, and the fourth shall contain a known weight of silica gel, or equivalent desiccant. A thermometer, capable of measuring temperature to within 1° C (2° F) shall be placed at the outlet of the fourth impinger for monitoring purposes.

Alternatively, any system that cools the sample gas stream and allows measurement of the water condensed and moisture leaving the condenser, each to within 1 ml or 1 g may be used subject to the approval of the Administrator. Acceptable means are to measure the condensed water either gravimetrically or volumetrically and to measure the moisture leaving the condenser by: (1) monitoring the temperature and pressure at the exit of the condenser and using Dalton's law of partial pressures; or (2) passing the sample gas stream through a tared silica gel (or equivalent desiccant) trap with exit gases kept below 20° C (68° F) and determining the weight gain.

If means other than silica gel are used to determine the amount of moisture leaving the condenser, it is recommended that silica gel (or equivalent) still be used between the condenser system and pump to prevent moisture condensation in the pump and metering devices and to avoid the need to make corrections for moisture in the metered volume.

NOTE.—If a determination of the particulate matter collected in the impingers is desired in addition to moisture content, the impinger system described above shall be used, without modification. Individual States or control agencies requiring this information shall be contacted as to the sample recovery and analysis of the impinger contents.

2.1.8 Metering System. Vacuum gauge, leak-free pump, thermometers capable of measuring temperature to within 3° C (5.4° F), dry gas meter capable of measuring volume to within 2 percent, and related equipment, as shown in Figure 5-1. Other metering systems capable of maintaining sampling rates within 10 percent of isokinetic and of determining sample volumes to within 2 percent may be used, subject to the approval of the Administrator. When the metering system is used in conjunction with a pitot tube, the system shall enable checks of isokinetic rates.

Sampling trains utilizing metering systems designed for higher flow rates than that described in APTD-0581 or APTD-0576 may be used provided that the specifications of this method are met.

2.1.9 Barometer. Mercury, aneroid, or other barometer capable of measuring atmospheric pressure to within 2.5 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

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[2] Mention of trade names or specific products does not constitute endorsement by the Environmental Protection Agency.

the absolute barometric pressure) shall be requested and an adjustment for elevation differences between the weather station and sampling point shall be applied at a rate of minus 2.5 mm Hg (0.1 in. Hg) per 30 m (100 ft) elevation increase or vice versa for elevation decrease.

2.1.10 Gas Density Determination Equipment. Temperature sensor and pressure gauge, as described in Sections 2.3 and 2.4 of Method 2, and gas analyzer, if necessary, as described in Method 3. The temperature sensor shall, preferably, be permanently attached to the pitot tube or sampling probe in a fixed configuration, such that the tip of the sensor extends beyond the leading edge of the probe sheath and does not touch any metal. Alternatively, the sensor may be attached just prior to use in the field. Note, however, that if the temperature sensor is attached in the field, the sensor must be placed in an interference-free arrangement with respect to the Type S pitot tube openings (see Method 2, Figure 2-7). As a second alternative, if a difference of not more than 1 percent in the average velocity measurement is to be introduced, the temperature gauge need not be attached to the probe or pitot tube. (This alternative is subject to the approval of the Administrator.)

2.2 Sample Recovery. The following items are needed.

2.2.1 Probe-Liner and Probe-Nozzle Brushes. Nylon bristle brushes with stainless steel wire handles. The probe brush shall have extensions (at least as long as the probe) of stainless steel, Nylon, Teflon, or similarly inert material. The brushes shall be properly sized and shaped to brush out the probe liner and nozzle.

2.2.2 Wash Bottles—Two. Glass wash bottles are recommended; polyethylene wash bottles may be used at the option of the tester. It is recommended that acetone not be stored in polyethylene bottles for longer than a month.

2.2.3 Glass Sample Storage Containers. Chemically resistant, borosilicate glass bottles, for acetone washes, 500 ml or 1000 ml. Screw cap liners shall either be rubber-backed Teflon or shall be constructed so as 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 1 g. Graduated cylinders shall have subdivisions no greater than 2 ml. Most laboratory balances are capable of weighing to the nearest 0.5 g or less. Any of these balances is suitable for use here and in Section 2.3.4.

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 container; not necessary if silica gel is weighed in the field.

2.2.8 Funnel. Glass or polyethylene, to aid in sample recovery.

2.3 Analysis. For analysis, the following equipment is needed.

2.3.1 Glass Weighing Dishes.

2.3.2 Desiccator.

2.3.3 Analytical Balance. To measure to within 0.1 mg.

2.3.4 Balance. To measure to within 0.5 g.

2.3.5 Beakers. 250 ml.

2.3.6 Hygrometer. To measure the relative humidity of the laboratory environment.

2.3.7 Temperature Gauge. To measure the temperature of the laboratory environment.

3. *Reagents*

3.1 Sampling. The reagents used in sampling are as follows:

3.1.1 Filters. Glass fiber filters, without organic binder, exhibiting at least 99.95 percent efficiency (<0.05 percent penetration) on 0.3-micron dioctyl phthalate smoke particles. The filter efficiency test shall be conducted in accordance with ASTM standard method D 2986-71. Test data from the supplier's quality control program are sufficient for this purpose.

3.1.2 Silica Gel. [illegible]

[illegible]

3.3 Analysis. Two reagents are required for the 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 the 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. As an alternative, the silica gel need not be preweighed, 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 diameter on the back side near the edge using numbering machine ink. As an alternative, label the shipping containers (glass or plastic petri dishes) and keep the filters in these containers at all times except during sampling and weighing.

Desiccate the filters at 20±5.6° C (68±10° F) and ambient pressure for at least 24 hours and weigh at intervals of at least 6 hours to a constant weight, i.e., <0.5 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 (220° F) 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. 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 particulate sample run.

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 isokinetic 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 encountered (see Section 2.2 of Method 2).

Select a suitable probe liner and probe length such that all traverse points can be sampled. For large stacks, consider sampling from opposite sides of the stack to reduce the length of probes.

Select a total sampling time greater than or equal to the minimum total sampling time specified in the test procedures for the specific industry such that (1) the sampling time per point is not less than 2 min (or some greater time interval as specified by the Administrator), and (2) the sample volume taken (corrected to standard conditions) will exceed the required minimum total gas sample volume. The latter is based on an approximate average sampling rate.

It is recommended that the number of minutes sampled at each point be an integer or an integer plus one-half minute, in order to avoid timekeeping errors.

[illegible]

details. Other connecting systems using either 316 stainless steel or Teflon ferrules may be used. When metal liners are used, install the nozzle as above or by a leak-free direct mechanical connection. Mark the probe with heat resistant tape or by some other method to denote the proper distance into the stack or duct for each sampling point.

Set up the train as in Figure 5-1, using (if necessary) a very light coat of silicone grease on all ground glass joints, greasing only the outer portion (see APTD-0576) to avoid possibility of contamination by the silicone grease. Subject to the approval of the Administrator, a glass cyclone may be used between the probe and filter holder when the total particulate catch is expected to exceed 100 mg or when water droplets are present in the stack gas.

Place crushed ice 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, turn on and set the filter and probe heating systems at the desired operating temperatures. Allow time for the temperatures to stabilize. If a Viton A O-ring or other leak-free connection is used in assembling the probe nozzle to the probe liner, leak-check the train at the sampling site by plugging the nozzle and pulling a 380 mm Hg (15 in. Hg) vacuum.

NOTE.—A lower vacuum may be used, provided that it is not exceeded during the test.

If an asbestos string is used, do not connect the probe to the train during the leak-check. Instead, leak-check the train by first plugging the inlet to the filter holder (cyclone, if applicable) and pulling a 380 mm Hg (15 in. Hg) vacuum (see Note immediately above). Then connect the probe to the train and leak-check at about 25 mm Hg (1 in. Hg) vacuum; alternatively, the probe may be leak-checked with the rest of the sampling train, in one step, at 380 mm Hg (15 in. Hg) vacuum. Leakage rates in excess of 4 percent of the average sampling rate or 0.00057 m³/min (0.02 cfm), whichever is less, are unacceptable.

The following leak-check instructions for the sampling train described in APTD-0576 and APTD-0581 may be helpful. Start the pump with bypass valve fully open and coarse adjust valve completely closed. Partially open the coarse adjust valve and slowly close the bypass valve until the desired vacuum is reached. Do not reverse direction of bypass valve; this will cause water to back up into the filter holder. If the desired vacuum is exceeded, either leak-check at this higher vacuum or end the leak-check as shown below and start over.

When the leak-check is completed, first slowly remove the plug from the inlet to the probe, filter holder, or cyclone (if applicable) and immediately turn off the vacuum pump. This prevents the water in the impingers from being forced backward into the filter holder and silica gel from being entrained backward into the third impinger.

4.1.4.2 Leak-Checks During Sample Run. If, during the sampling run, a component (e.g., filter assembly or impinger) change becomes necessary, a leak-check shall be conducted immediately before the change is made. The leak-check shall be done according to the procedure outlined in Section 4.1.4.1 above, except that it shall be done at a vacuum equal to or greater than the maximum value recorded up to that point in the test. 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 will need to be applied to the total volume of dry gas metered; if, however, a higher leakage rate is obtained, the tester shall either record the leakage rate and plan to correct 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 should be used.

[illegible]

Take other readings required by Figure 5-2 at least once at each sample point during each time increment and additional readings when significant changes (20 percent variation in velocity head readings) necessitate additional adjustments in flow rate. Level and zero the manometer. Because the manometer level and zero may drift due to vibrations and temperature changes, make periodic checks during the traverse.

Clean the portholes prior to the test run to minimize the chance of sampling deposited material. To begin sampling, remove the nozzle cap, verify that the filter and probe heating systems are up to temperature, and that the pitot tube and probe are properly positioned. Position the nozzle at the first traverse point with the tip pointing directly into the gas stream. Immediately start the pump and adjust the flow to isokinetic conditions. Nomographs are available, which aid in the rapid adjustment of the isokinetic sampling rate without excessive computations. These nomographs are designed for use when the Type S pitot tube coefficient is 0.85±0.02, and the stack gas equivalent density (dry molecular weight) is equal to 29±4. APTD-0576 details the procedure for using the nomographs. If C_p and M_d are outside the above stated ranges do not use the nomographs unless appropriate steps (see Citation 7 in Section 7) are taken to compensate for the deviations.

PLANT __________
LOCATION __________
OPERATOR __________
DATE __________
RUN NO. __________
SAMPLE BOX NO. __________
METER BOX NO. __________
METER ΔH@ __________
C FACTOR __________
PITOT TUBE COEFFICIENT, C_p __________

SCHEMATIC OF STACK CROSS SECTION

AMBIENT TEMPERATURE __________
BAROMETRIC PRESSURE __________
ASSUMED MOISTURE, % __________
PROBE LENGTH, m (ft) __________
NOZZLE IDENTIFICATION NO. __________
AVERAGE CALIBRATED NOZZLE DIAMETER, cm (in.) __________
PROBE HEATER SETTING __________
LEAK RATE, m^3/min, (cfm) __________
PROBE LINER MATERIAL __________
STATIC PRESSURE, mm Hg (in. Hg) __________
FILTER NO. __________

TRAVERSE POINT NUMBER	SAMPLING TIME (θ), min.	VACUUM mm Hg (in. Hg)	STACK TEMPERATURE (T_S) °C (°F)	VELOCITY HEAD (ΔP_S), mm (in.) H_2O	PRESSURE DIFFERENTIAL ACROSS ORIFICE METER mm H_2O (in. H_2O)	GAS SAMPLE VOLUME m^3 (ft^3)	GAS SAMPLE TEMPERATURE AT DRY GAS METER		FILTER HOLDER TEMPERATURE, °C (°F)	TEMPERATURE OF GAS LEAVING CONDENSER OR LAST IMPINGER, °C (°F)
							INLET °C (°F)	OUTLET °C (°F)		
TOTAL							Avg.	Avg.		
AVERAGE							Avg.			

Figure 5-2. Particulate field data.

When the stack is under significant negative pressure (height of impinger stem), take care to close the course adjust valve before inserting the probe into the stack to prevent water from backing into the filter holder. If necessary, the pump may be turned on with the coarse adjust valve closed.

When the probe is in position, block off the openings around the probe and porthole to prevent unrepresentative dilution of the gas stream.

Traverse the stack cross-section, as required by Method 1 or as specified by the Administrator, being careful not to bump the probe nozzle into the stack walls when sampling near the walls or when removing or inserting the probe through the portholes; this minimizes the chance of extracting deposited material.

During the test run, make periodic adjustments to keep the temperature around the filter holder at the proper level; add more ice and, if necessary, salt to maintain a temperature of less than 20° C (68° F) at the condenser/silica gel outlet. Also, periodically check the level and zero of the manometer.

If the pressure drop across the filter becomes too high, making isokinetic sampling difficult to maintain, the filter may be replaced in the midst of a sample run. It is recommended that another complete filter assembly be used rather than attempting to change the filter itself. Before a new filter assembly is installed, conduct a leak-check (see Section 4.1.4.2). The total particulate weight shall include the summation of all filter assembly catches.

A single train shall be used for the entire sample run, except in cases where simultaneous sampling is required in two or more separate ducts or at two or more different locations within the same duct, or, in cases where equipment failure necessitates a change of trains. In all other situations, the use of two or more trains will be subject to the approval of the Administrator.

Note that when two or more trains are used, separate analyses of the front-half and (if applicable) impinger catches from each train shall be performed, unless identical nozzle sizes were used on all trains, in which case, the front-half catches from the individual trains may be combined (as may the impinger catches) and one analysis of front-half catch and one analysis of impinger catch may be performed. Consult with the Administrator for details concerning the calculation of results when two or more trains are used.

At the end of the sample run, turn off the coarse adjust valve, remove the probe and nozzle from the stack, turn off the pump, record the final dry gas meter reading, and conduct a post-test leak-check, as outlined in Section 4.1.4.3. Also, leak-check the pitot lines as described in Method 2, Section 3.1; the lines must pass this leak-check, in order to validate the velocity head data.

4.1.6 Calculation of Percent Isokinetic. Calculate percent isokinetic (see Calculations, Section 6) to determine whether the run was valid or another test run should be made. If there was difficulty in maintaining isokinetic rates due to source conditions, consult with the Administrator for possible variance on the isokinetic rates.

4.2 Sample Recovery. Proper cleanup procedure begins as soon as the probe is removed from the stack at the end of the sampling period. Allow the probe to cool.

When the probe can be safely handled, wipe off all external particulate matter near the tip of the probe nozzle and place a cap over it to prevent losing or gaining particulate matter. Do not cap off the probe tip tightly while the sampling train is cooling down as this would create a vacuum in the filter holder, thus drawing water from the impingers into the filter holder.

Before moving the sample train to the cleanup site, remove the probe from the sample train, wipe off the silicone grease, and cap the open outlet of the probe. Be careful not to lose any condensate that might be present. Wipe off the silicone grease from the filter inlet where the probe was fastened and cap it. Remove the umbilical cord from the last impinger and cap the impinger. If a flexible line is used between the first impinger or condenser and the filter holder, disconnect the line at the filter holder and let any condensed water or liquid drain into the impingers or condenser. After wiping off the silicone grease, cap off the filter holder outlet and impinger inlet. Either ground-glass stoppers, plastic caps, or serum caps may be used to close these openings.

Transfer the probe and filter-impinger assembly to the cleanup area. This area should be clean and protected from the wind so that the chances of contaminating or losing the sample will be minimized.

Save a portion of the acetone used for cleanup as a blank. Take 200 ml of this acetone directly from the wash bottle being used and place it in a glass sample container labeled "acetone blank."

Inspect the train prior to and during disassembly and note any abnormal conditions. Treat the samples as follows:

Container No. 1. Carefully remove the filter from the filter holder and place it in its identified petri dish container. Use a pair of tweezers and/or clean disposable surgical gloves to handle the filter. If it is necessary to fold the filter, do so such that the particulate cake is inside the fold. Carefully transfer to the petri dish any particulate matter and/or filter fibers which adhere to the filter holder gasket, by using a dry nylon bristle brush and/or a sharp-edged blade. Seal the container.

Container No. 2. Taking care to see that dust on the outside of the probe or other exterior surfaces does not get into the sample, quantitatively recover particulate matter or any condensate from the probe nozzle, probe fitting, probe liner, and front half of the filter holder by washing these components with acetone and placing the wash in a glass container. Distilled water may be used instead of acetone when approved by the Administrator and shall be used when specified by the Administrator; in these cases, save a water blank and follow the Administrator's directions on analysis. Perform the acetone rinses as follows:

Carefully remove the probe nozzle and clean the inside surface by rinsing with acetone from a wash bottle and brushing with a nylon bristle brush. Brush until the acetone rinse shows no visible particles, after which make a final rinse of the inside surface with acetone.

Brush and rinse the inside parts of the Swagelok fitting with acetone in a similar way until no visible particles remain.

Rinse the probe liner with acetone by tilting and rotating the probe while squirting acetone into its upper end so that all inside surfaces will be wetted with acetone. Let the acetone drain from the lower end into the sample container. A funnel (glass or polyethylene) may be used to aid in transferring liquid washes to the container. Follow the acetone rinse with a probe brush. Hold the probe in an inclined position, squirt acetone into the upper end as the probe brush is being pushed with a twisting action through the probe; hold a sample container underneath the lower end of the probe, and catch any acetone and particulate matter which is brushed from the probe. Run the brush through the probe three times or more until no visible particulate matter is carried out with the acetone or until none remains in the probe liner on visual inspection. With stainless steel or other metal probes, run the brush through in the above prescribed manner at least six times since metal probes have small crevices in which particulate matter can be entrapped. Rinse the brush with acetone, and quantitatively collect these washings in the sample container. After the brushing, make a final acetone rinse of the probe as described above.

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 rubbing the surfaces with a nylon bristle brush and rinsing with acetone. Rinse each surface three times or more if needed to remove visible particulate. Make a final rinse of the brush and filter holder. Carefully rinse out the glass cyclone, also (if applicable). After all acetone washings and particulate matter have been collected in the sample container, tighten the lid on the sample container so that acetone will not leak out when it is shipped to the laboratory. Mark the height of the fluid level to determine whether or not leakage 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 make it easier to pour the silica gel without spilling. A rubber policeman may be used as an aid in removing the silica gel from the impinger. It is not necessary to remove the small amount of dust particles that may adhere to the impinger wall 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 in Section 4.3.

Impinger Water. Treat the impingers as follows: Make a notation of any color or film in the liquid catch. Measure 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 g 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.

Whenever possible, containers should be shipped in such a way that they remain upright at all times.

4.3 Analysis. Record the data required on a sheet such as the one shown in Figure 5-3. Handle each sample container as follows:

Container No. 1. Leave the contents in the shipping container or transfer the filter and any loose particulate from the sample container to a tared glass weighing dish. Desiccate for 24 hours in a desiccator containing anhydrous calcium sulfate. Weigh to a constant weight and report the results to the nearest 0.1 mg. For purposes of this Section, 4.3, the term "constant weight" means a difference of no more than 0.5 mg or 1 percent of total weight less tare weight, whichever is greater, between two consecutive weighings, with no less than 6 hours of desiccation time between weighings.

Plant ____________________

Date ____________________

Run No. ____________________

Filter No. ____________________

Amount liquid lost during transport ____________________

Acetone blank volume, ml ____________________

Acetone wash volume, ml ____________________

Acetone blank concentration, mg/mg (equation 5-4) ____________________

Acetone wash blank, mg (equation 5-5) ____________________

CONTAINER NUMBER	WEIGHT OF PARTICULATE COLLECTED, mg		
	FINAL WEIGHT	TARE WEIGHT	WEIGHT GAIN
1			
2			
TOTAL			
	Less acetone blank		
	Weight of particulate matter		

	VOLUME OF LIQUID WATER COLLECTED	
	IMPINGER VOLUME, ml.	SILICA GEL WEIGHT, g
FINAL		
INITIAL		
LIQUID COLLECTED		
TOTAL VOLUME COLLECTED		g* ml

* CONVERT WEIGHT OF WATER TO VOLUME BY DIVIDING TOTAL WEIGHT INCREASE BY DENSITY OF WATER (1g/ml):

$$\frac{\text{INCREASE, g}}{1\text{ g/ml}} = \text{VOLUME WATER, ml}$$

Figure 5-3. Analytical data.

Alternatively, the sample may be oven dried at 105° C (220° F) for 2 to 3 hours, cooled in the desiccator, and weighed to a constant weight, unless otherwise specified by the Administrator. The tester may also opt to oven dry the sample at 105 ° C (220 ° F) for 2 to 3 hours, weigh the sample, and use this weight as a final weight.

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 void 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. Weigh the spent silica gel (or silica gel plus impinger) to the nearest 0.5 g using a balance. This step may be conducted in the field.

"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 contsant 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 "bumping," 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 numbers 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. The Type S pitot tube assembly shall be calibrated according to the procedure outlined in Section 4 of Method 2.

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 leakages within the pump. For these cases the following leak-check procedure is suggested: make a 10-minute calibration run at 0.00057 m ³/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 m ³/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 metering system. 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 coefficient values obtained before and after a test series differ by more than 5 percent, the test series shall either be voided, or calculations 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 Probe Heater Calibration. The probe heating system shall be calibrated before its initial use in the field according to the procedure outlined in APTD-0576. Probes constructed according to APTD-0581 need not be calibrated if the calibration curves in APTD-0576 are used.

5.5 Temperature Gauges. Use the procedure in Section 4.3 of Method 2 to calibrate in-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.

5.6 Leak Check of Metering System Shown in Figure 5-1. That portion of the sampling train from the pump to the orifice meter 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 5-4): 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.

5.7 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.

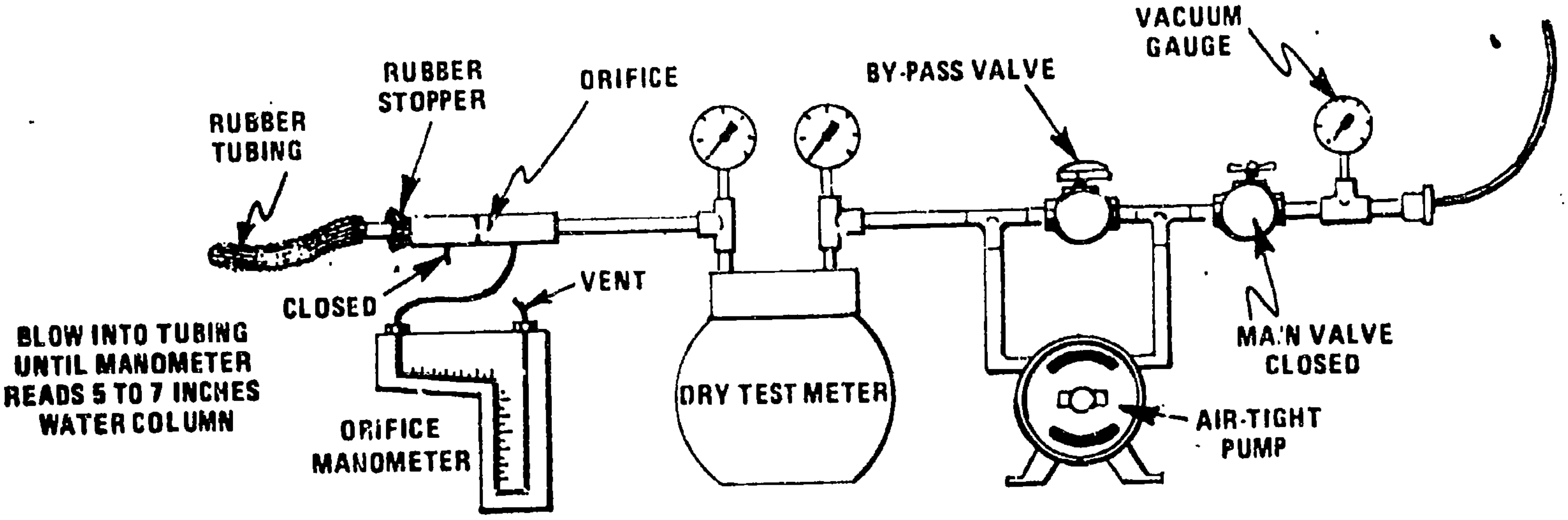

Figure 5-4. Leak check of meter box.

6.1 Nomenclature

A_n = Cross-sectional area of nozzle, m² (ft²).

B_{ws} = Water vapor in the gas stream, proportion by volume.

C_a = Acetone blank residue concentrations, mg/g.

c_s = Concentration of particulate matter in stack gas, dry basis, corrected to standard conditions, g/dscm (g/dscf).

I = Percent of isokinetic sampling.

L_a = Maximum acceptable leakage rate for either a pretest leak check or for a leak check following a component change; equal to 0.00057 m³/min (0.02 cfm) or 4 percent of the average sampling rate, whichever is less.

L_i = Individual leakage rate observed during the leak check conducted prior to the "i^{th}" component change (i = 1, 2, 3 . . . . n), m³/min (cfm).

L_p = Leakage rate observed during the post-test leak check, m³/min (cfm).

m_n = Total amount of particulate matter collected, mg.

M_w = Molecular weight of water, 18.0 g/g-mole (18.0 lb/lb-mole).

m_a = Mass of residue of acetone after evaporation, mg.

P_{bar} = Barometric pressure at the sampling site, mm Hg (in. Hg).

P_s = Absolute stack gas pressure, mm Hg (in. Hg).

P_{std} = Standard absolute pressure, 760 mm Hg (29.92 in. Hg).

R = Ideal gas constant, 0.06236 mm Hg-m³/°K-g-mole (21.85 in. Hg-ft³/°R-lb-mole).

T_m = Absolute average dry gas meter temperature (see Figure 5-2), °K (°R).

T_s = Absolute average stack gas temperature (see Figure 5-2), °K (°R).

T_{std} = Standard absolute temperature, 293° K (528° R).

V_a = Volume of acetone blank, ml.

V_{aw} = Volume of acetone used in wash, ml.

V_{lc} = Total volume of liquid collected in impingers and silica gel (see Figure 5-3), ml.

V_m = Volume of gas sample as measured by dry gas meter, dcm (dcf).

$V_{m(std)}$ = Volume of gas sample measured by the dry gas meter, corrected to standard conditions, dscm (dscf).

$V_{w(std)}$ = Volume of water vapor in the gas sample, corrected to standard conditions, scm (scf).

V_s Stack gas velocity, calculated by Method 2, Equation 2-9, using data obtained from Method 5, m/sec (ft/sec).

W_a Weight of residue in acetone wash, mg.

Y Dry gas meter calibration factor.

ΔH Average pressure differential across the orifice meter (see Figure 5-2), mm H_2O (in. H_2O).

ρ_a Density of acetone, mg/ml (see label on bottle).

ρ_w Density of water, 0.9982 g/ml (0.002201 lb/ml).

θ Total sampling time, min.

θ_1 Sampling time interval, from the beginning of a run until the first component change, min.

θ_i Sampling time interval, between two successive component changes, beginning with the interval between the first and second changes, min.

θ_p Sampling time interval, from the final (n^{th}) component change until the end of the sampling run, min.

13.6 Specific gravity of mercury.

60 Sec/min.

100 Conversion to percent.

6.2 Average dry gas meter temperature and average orifice pressure drop. See data sheet (Figure 5-2).

6.3 Dry Gas Volume. Correct the sample volume measured by the dry gas meter to standard conditions (20° C, 760 mm Hg or 68° F, 29.92 in. Hg) by using Equation 5-1.

$$V_{m(std)} = V_m Y \left(\frac{T_{std}}{T_m}\right)\left[\frac{P_{bar} + \frac{\Delta H}{13.6}}{P_{std}}\right] = K_1 V_m Y \frac{P_{bar} + (\Delta H/13.6)}{T_m}$$

Equation 5-1

where;
m_1=0.3858 °K/mm Hg for metric units
=17.64 °R/in. Hg for English units

NOTE.—Equation 5-1 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_a. If L_p or L_i exceeds L_a, Equation 5-1 must be modified as follows;

(a) Case I. No component changes made during sampling run. In this case, replace V_m in Equation 5-1 with the expression;

$$V_m-(L_p-L_a)\theta]$$

(b) Case II. One or more component changes made during the sampling run. In this case, replace V_m in Equation 5-1 by the expression:

$$\left[V_m-(L_1-L_a)\theta_1-\sum_{i=2}^{n}(L_i-L_a)\theta_i-(L_p-L_a)\theta_p\right]$$

and substitute only for those leakage rates (L_i or L_p) which exceed L_a.

6.4 Volume of water vapor.

Equation 5-2

$$V_{w(\mathrm{std})}=V_{1c}\left(\frac{\rho_w}{M_w}\right)\left(\frac{RT_{\mathrm{std}}}{P_{\mathrm{std}}}\right)=K_2V_{1c}$$

where:
K_2=0.001333 m³/ml for metric units
=0.04707 ft³/ml for English units.

6.5 Moisture Content.

$$B_{ws}=\frac{V_{w(\mathrm{std})}}{V_{m(\mathrm{std})}+V_{w(\mathrm{std})}}$$

Equation 5-3

NOTE.—In saturated or water droplet-laden gas streams, two calculations of the moisture content of the stack gas shall be made, one from the impinger analysis (Equation 5-3), and a second from the assumption of saturated conditions. The lower of the two values of B_{ws} shall be considered correct. The procedure for determining the moisture content based upon assumption of saturated conditions is given in the Note of Section 1.2 of Method 4. For the purposes of this method, the average stack gas temperature from Figure 5-2 may be used to make this determination, provided that the accuracy of the in-stack temperature sensor is ± 1° C (2° F).

6.6 Acetone Blank Concentration.

$$C_a=\frac{m_a}{V_a\rho_a}$$

Equation 5-4

6.7 Acetone Wash Blank.

$$W_a=C_aV_{aw}\rho_a$$

Equation 5-5

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 5-3). NOTE.—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.

$$c_s=(0.001\ g/mg)\ (m_n/V_{m(\mathrm{std})})$$

Equation 5-6

6.10 Conversion Factors:

From	To	Multiply by
scf	m³	0.02832
g/ft³	gr/ft³	15.43
g/ft³	lb/ft³	2.205×10⁻³
g/ft³	g/m³	35.31

6.11 Isokinetic Variation.

6.11.1 Calculation From Raw Data.

$$I=\frac{100\,T_s[K_3V_{1c}+(V_m/T_m)\,(P_{\mathrm{bar}}+\Delta H/13.6)]}{60\,\theta v_sP_sA_n}$$

Equation 5-7

where:
K_3=0.003454 mm Hg−m³/ml−°K for metric units.
=0.002669 in. Hg−ft³/ml−°R for English units.

6.11.2 Calculation From Intermediate Values.

$$I=\frac{T_sV_{m(\mathrm{std})}P_{\mathrm{std}}100}{T_{\mathrm{std}}v_s\theta A_nP_s60(1-B_{ws})}$$

$$=K_4\frac{T_sV_{m(\mathrm{std})}}{P_sV_sA_n\theta(1-B_{ws})}$$

Equation 5-8

where:
K_4=4.320 for metric units
=0.09450 for English units.

6.12 Acceptable Results. If 90 percent $\leq I \leq 110$ 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. Use Citation 4 to make judgments. Otherwise, reject the results and repeat the test.

7. *Bibliography*

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METHOD 6—DETERMINATION OF SULFUR DIOXIDE 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 sulfur trioxide) and the sulfur dioxide are separated. The sulfur dioxide fraction is measured by the barium-thorin titration method.

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 3.4 milligrams (mg) of SO_2/m³ (2.12×10⁻⁷ lb/ft³). Although no upper limit has been established, tests have shown that concentrations as high as 80,000 mg/m³ of SO_2 can be collected efficiently in two midget impingers, each containing 15 milliliters of 3 percent hydrogen peroxide, at a rate of 1.0 lpm for 20 minutes. Based on theoretical calculations, the upper concentration limit in a 20-liter sample is about 93,300 mg/m³.

Possible interferents are free ammonia, water-soluble cations, and fluorides. The cations and fluorides are removed by glass wool filters and an isopropanol bubbler, and hence do not affect the SO_2 analysis. When samples are being taken from a gas stream with high concentrations of very fine metallic fumes (such as in inlets to control devices), a high-efficiency glass fiber filter must be used in place of the glass wool plug (i.e., the one in the probe) to remove the cation interferents.

Free ammonia interferes by reacting with SO_2 to form particulate sulfite and by reacting with the indicator. If free ammonia is present (this can be determined by knowledge of the process and noticing white particulate matter in the probe and isopropanol bubbler), alternative methods, subject to the approval of the Administrator, U.S. Environmental Protection Agency, are required.

2. *Apparatus*

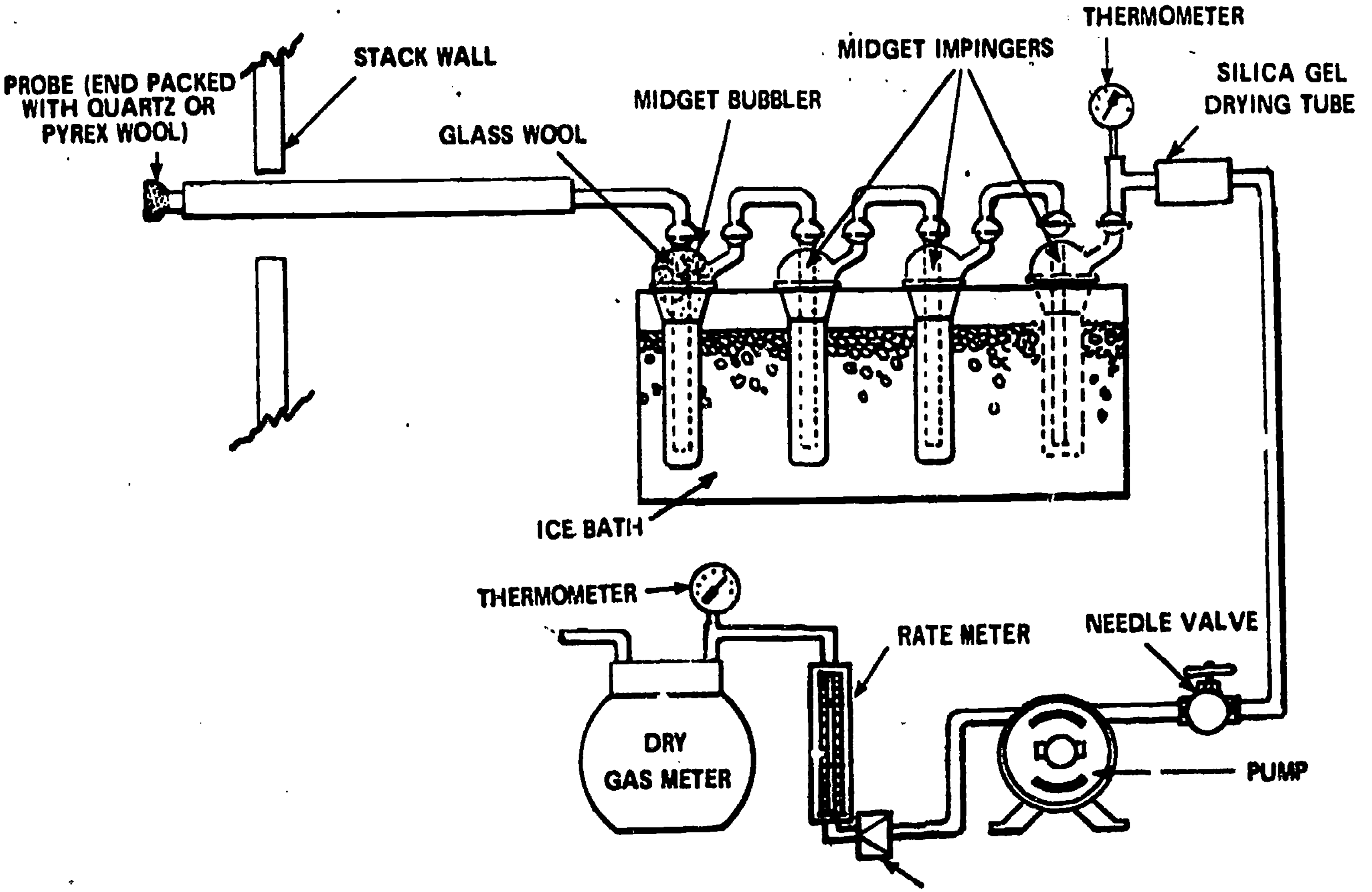

Figure 6-1. SO_2 sampling train.

2.1 Sampling. The sampling train is shown in Figure 6-1, and component parts are discussed below. The tester has the option of substituting sampling equipment described in Method 8 in place of the midget impinger equipment of Method 6. However, the Method 8 train must be modified to include a heated filter between the probe and isopropanol impinger, and the operation of the sampling train and sample analysis must be at the flow rates and solution volumes defined in Method 8.

The tester also has the option of determining SO_2 simultaneously with particulate matter and moisture determinations by (1) replacing the water in a Method 5 impinger system with 3 percent perioxide solution, or (2) by replacing the Method 5 water impinger system with a Method 8 isopropanol-filter-peroxide system. The analysis for SO_2 must be consistent with the procedure in Method 8.

2.1.1 Probe. Borosilicate glass, or stainless steel (other materials of construction may be used, subject to the approval of the Administrator), approximately 6-mm inside diameter, with a heating system to prevent water condensation and a filter (either in-stack or heated out-stack) to remove particulate matter, including sulfuric acid mist. A plug of glass wool is a satisfactory filter.

2.1.2 Bubbler and Impingers. One midget bubbler, with medium-coarse glass frit and borosilicate or quartz glass wool packed in top (see Figure 6-1) to prevent sulfuric acid mist carryover, and three 30-ml midget impingers. The bubbler and midget impingers must be connected in series with leak-free glass connectors. Silicone grease may be used, if necessary, to prevent leakage.

At the option of the tester, a midget impinger may be used in place of the midget bubbler.

Other collection absorbers and flow rates may be used, but are subject to the approval of the Administrator. Also, collection efficiency must be shown to be at least 99 percent for each test run and must be documented in the report. If the efficiency is found to be acceptable after a series of three tests, further documentation is not required. To conduct the efficiency test, an extra absorber must be added and analyzed separately. This extra absorber must not contain more than 1 percent of the total SO_2.

2.1.3 Glass Wool. Borosilicate or quartz.

2.1.4 Stopcock Grease. Acetone insoluble, heat-stable silicone grease may be used, if necessary.

2.1.5 Temperature Gauge. Dial thermometer, or equivalent, to measure temperature of gas leaving impinger train to within 1° C (2° F.)

2.1.6 Drying Tube. Tube packed with 6- to 16-mesh indicating type silica gel, or equivalent, to dry the gas sample and to protect the meter and pump. If the silica gel has been used previously, dry at 175° C (350° F) for 2 hours. New silica gel may be used as received. Alternatively, other types of desiccants (equivalent or better) may be used, subject to approval of the Administrator.

2.1.7 Valve. Needle valve, to regulate sample gas flow rate.

2.1.8 Pump. Leak-free diaphragm pump, or equivalent, to pull gas through the train. Install a small tank between the pump and rate meter to eliminate the pulsation effect of the diaphragm pump on the rotameter.

2.1.9 Rate Meter. Rotameter, or equivalent, capable of measuring flow rate to within 2 percent of the selected flow rate of about 1000 cc/min.

2.1.10 Volume Meter. Dry gas meter, sufficiently accurate to measure the sample volume within 2 percent, calibrated at the selected flow rate and conditions actually encountered during sampling, and equipped with a temperature gauge (dial thermometer, or equivalent) capable of measuring temperature to within 3°C (5.4°F).

2.1.11 Barometer. Mercury, aneroid, or other barometer capable of measuring atmospheric pressure to within 2.5 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 and an adjustment for elevation differences between the weather station and sampling point shall be applied at a rate of minus 2.5 mm Hg (0.1 in. Hg) per 30 m (100 ft) elevation increase or vice versa for elevation decrease.

2.1.12 Vacuum Gauge. At least 760 mm Hg (30 in. Hg) gauge, to be used for leak check of the sampling train.

2.2 Sample Recovery.

2.2.1 Wash bottles. Polyethylene or glass, 500 ml, two.

2.2.2 Storage Bottles. Polyethylene, 100 ml, to store impinger samples (one per sample).

2.3 Analysis.

2.3.1 Pipettes. Volumetric type, 5-ml, 20-ml (one per sample), and 25-ml sizes.

2.3.2 Volumetric Flasks. 100-ml size (one per sample) and 100-ml size.

2.3.3 Burettes. 5- and 50-ml sizes.

2.3.4 Erlenmeyer Flasks. 250 ml-size (one for each sample, blank, and standard).

2.3.5 Dropping Bottle. 125-ml size, to add indicator.

2.3.6 Graduated Cylinder. 100-ml size.

2.3.7 Spectrophotometer. To measure absorbance at 352 nanometers.

3. *Reagents*

Unless otherwise indicated, all reagents must conform to the specifications established by the Committee on Analytical Reagents of the American Chemical Society. Where such specifications are not available, use the best available grade.

3.1 Sampling.

3.1.1 Water. Deionized, distilled to conform to ASTM specification D1193-74, Type 3. At the option of the analyst, the $KMnO_4$ test for oxidizable organic matter may be omitted when high concentrations of organic matter are not expected to be present.

3.1.2 Isopropanol, 80 percent. Mix 80 ml of isopropanol with 20 ml of deionized, distilled water. Check each lot of isopropanol for peroxide impurities as follows: shake 10 ml of isopropanol with 10 ml of freshly prepared 10 percent potassium iodide solution. Prepare a blank by similarly treating 10 ml of distilled water. After 1 minute, read the absorbance at 352 nanometers on a spectrophotometer. If absorbance exceeds 0.1, reject alcohol for use.

Peroxides may be removed from isopropanol by redistilling or by passage through a column of activated alumina; however, reagent grade isopropanol with suitably low peroxide levels may be obtained from commercial sources. Rejection of contaminated lots may, therefore, be a more efficient procedure.

3.1.3 Hydrogen Peroxide, 3 Percent. Dilute 30 percent hydrogen peroxide 1:9 (v/v) with deionized, distilled water (30 ml is needed per sample). Prepare fresh daily.

3.1.4 Potassium Iodide Solution, 10 Percent. Dissolve 10.0 grams KI in deionized, distilled water and dilute to 100 ml. Prepare when needed.

3.2 Sample Recovery.

3.2.1 Water. Deionized, distilled, as in 3.1.1.

3.2.2 Isopropanol, 80 Percent. Mix 80 ml of isopropanol with 20 ml of deionized, distilled water.

3.3 Analysis.

3.3.1 Water. Deionized, distilled, as in 3.1.1.

3.3.2 Isopropanol, 100 percent.

3.3.3 Thorin Indicator. 1-(o-arsonophenylazo)-2-naphthol-3,6-disulfonic acid, disodium salt, or equivalent. Dissolve 0.20 g in 100 ml of deionized, distilled water.

3.3.4 Barium Perchlorate Solution, 0.0100 N. Dissolve 1.95 g of barium perchlorate trihydrate $[Ba(ClO_4)_2 \cdot 3H_2O]$ in 200 ml distilled water and dilute to 1 liter with isopropanol. Alternatively, 1.22 g of $[BaCl_2 \cdot 2H_2O]$ may be used instead of the perchlorate. Standardize as in Section 5.5.

3.3.5 Sulfuric Acid Standard, 0.0100 N. Purchase or standardize to ±0.0002 N against 0.0100 N NaOH which has previously 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 percent hydrogen peroxide into each of the first two midget impingers. Leave the final midget impinger dry. Assemble the train as shown in Figure 6–1. Adjust probe heater to a temperature sufficient 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 optional; however, a leak check after the sampling run is mandatory. The leak-check procedure is as follows:

With the probe disconnected, place a vacuum gauge at the inlet to the bubbler and pull a vacuum of 250 mm (10 in.) Hg; plug or pinch off the outlet of the flow meter, and then turn off 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 back flow of the impinger fluid.

Other leak-check procedures may be used, subject to the approval of the Administrator, U.S. Environmental Protection Agency. The procedure used in Method 5 is not suitable for diaphragm pumps.

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 1.0 liter/min as indicated by the rotameter. Maintain this constant rate (±10 percent) during the entire sampling run. Take readings (dry gas meter, temperatures at dry gas meter and at impinger outlet and rate meter) at least every 5 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 stack, and record the final readings. 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 purge 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 H_2O_2. The tester may opt to simply use ambient air, without purification.

4.2 Sample Recovery. Disconnect the impingers after purging. Discard the contents of the midget bubbler. Pour the contents of the midget impingers into a leak-free polyethylene bottle for shipment. Rinse the three midget impingers and the connecting tubes with deionized, distilled water, and add the washings to the same storage container. Mark the fluid level. Seal and identify the sample container.

4.3 Sample Analysis. Note level of liquid in container, and confirm whether any sample was lost during shipment; note this on analytical data sheet. If a noticeable amount of leakage has occurred, either void the sample or use methods, subject to the approval of the Administrator, to correct the final results.

Transfer the contents of the storage container to a 100-ml volumetric flask and dilute to exactly 100 ml with deionized, distilled water. Pipette a 20-ml aliquot of this solution into a 250-ml Erlenmeyer flask, add 80 ml of 100 percent isopropanol and two to four drops of thorin indicator, and titrate to a pink endpoint using 0.0100 N barium perchlorate. Repeat and average the titration volumes. Run a blank with each series of samples. Replicate titrations must agree within 1 percent or 0.2 ml, whichever is larger.

(NOTE.—Protect the 0.0100 N barium perchlorate solution from evaporation at all times.)

5. *Calibration*

5.1 Metering System.

5.1.1 Initial Calibration. Before its initial use in the field, first leak check the metering system (drying tube, needle valve, pump, rotameter, and dry gas meter) as follows: place a vacuum gauge at the inlet to the drying tube and pull a vacuum of 250 mm (10 in.) Hg, plug or pinch off the outlet or the flow meter, and then turn off the pump. The vacuum shall remain stable for at least 30 seconds. Carefully release the vacuum gauge before releasing the flow meter end.

Next, calibrate the metering system (at the sampling flow rate specified by the method) as follows: connect an appropriately sized wet test meter (e.g., 1 liter per revolution) to the inlet of the drying tube. Make three independent calibration runs, using at least five revolutions of the dry gas meter per run. Calculate the calibration factor, *Y* (wet test meter calibration volume divided by the dry gas meter volume, both volumes adjusted to the same reference temperature and pressure), for each run, and average the results. If any *Y* value deviates by more than 2 percent from the average, the metering system is unacceptable for use. Otherwise, use the average as the calibration factor for subsequent test runs.

5.1.2 Post-Test Calibration Check. After each field test series, conduct a calibration check as in Section 5.1.1 above, except for the following variations: (a) the leak check is not to be conducted, (b) three, or more revolutions of the dry gas meter may be used, and (c) only two independent runs need be made. If the calibration factor does not deviate by more than 5 percent from the initial calibration factor (determined in Section 5.1.1), then the dry gas meter volumes obtained during the test series are acceptable. If the calibration factor deviates by more than 5 percent, recalibrate the metering system as in Section 5.1.1, and for the calculations, use the calibration factor (initial or recalibration) that yields the lower gas volume for each test run.

5.2 Thermometers. Calibrate against mercury-in-glass thermometers.

5.3 Rotameter. The rotameter need not be calibrated but should be cleaned and maintained according to the manufacturer's instruction.

5.4 Barometer. Calibrate against a mercury barometer.

5.5 Barium Perchlorate Solution. Standardize the barium perchlorate solution against 25 ml of standard sulfuric acid to which 100 ml of 100 percent isopropanol has been added.

6. *Calculations*

Carry out calculations, retaining at least one extra decimal figure beyond that of the acquired data. Round off figures after final calculation.

6.1 Nomenclature.

C_{SO_2} = Concentration of sulfur dioxide, dry basis corrected to standard conditions, mg/dscm (lb/dscf).
N = Normality of barium perchlorate titrant, milliequivalents/ml.
P_{bar} = Barometric pressure at the exit orifice of the dry gas meter, mm Hg (in. Hg).
P_{std} = Standard absolute pressure, 760 mm Hg (29.92 in. Hg).
T_m = Average dry gas meter absolute temperature, °K (°R).
T_{std} = Standard absolute temperature, 293° K (528° R).
V_a = Volume of sample aliquot titrated, ml.
V_m = Dry gas volume as measured by the dry gas meter, dcm (dcf).
$V_{m(std)}$ = Dry gas volume measured by the dry gas meter, corrected to standard conditions, dscm (dscf).
V_{soln} = Total volume of solution in which the sulfur dioxide sample is contained, 100 ml.
V_t = Volume of barium perchlorate titrant used for the sample, ml (average of replicate titrations).
V_{tb} = Volume of barium perchlorate titrant used for the blank, ml.
Y = Dry gas meter calibration factor.
32.03 = Equivalent weight of sulfur dioxide.

6.2 Dry sample gas volume, corrected to standard conditions.

$$V_{m(std)} = V_m Y \left(\frac{T_{std}}{T_m}\right)\left(\frac{P_{bar}}{P_{std}}\right) = K_1 Y \frac{V_m P_{bar}}{T_m}$$

Equation 6-1

where:

K_1 = 0.3858 °K/mm Hg for metric units.
= 17.64 °R/in. Hg for English units.

6.3 Sulfur dioxide concentration.

$$C_{SO_2} = K_3 \frac{(V_t - V_{tb})\, N\left(\frac{V_{soln}}{V_a}\right)}{V_{m(std)}}$$

Equation 6-2

where:

K_3 = 32.03 mg/meq. for metric units.
= 7.061 × 10^{-5} lb/meq. for English units.

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METHOD 7—DETERMINATION OF NITROGEN OXIDE EMISSIONS FROM STATIONARY SOURCES

1. *Principle and Applicability*

1.1 Principle. A grab sample is collected in an evacuated flask containing a dilute sulfuric acid-hydrogen peroxide absorbing solution, and the nitrogen oxides, except nitrous oxide, are measured colorimetrically using the phenoldisulfonic acid (PDS) procedure.

1.2 Applicability. This method is applicable to the measurement of nitrogen oxides emitted from stationary sources. The range of the method has been determined to be 2 to 400 milligrams NO_x (as NO_2) per dry standard cubic meter, without having to dilute the sample.

2. *Apparatus*

2.1 Sampling (see Figure 7-1). Other grab sampling systems or equipment, capable of measuring sample volume to within ±2.0 percent and collecting a sufficient sample volume to allow analytical reproducibility to within ±5 percent, will be considered acceptable alternatives, subject to approval of the Administrator, U.S. Environmental Protection Agency. The following equipment is used in sampling:

2.1.1 Probe. Borosilicate glass tubing, sufficiently heated to prevent water condensation and equipped with an in-stack or out-stack filter to remove particulate matter (a plug of glass wool is satisfactory for this purpose). Stainless steel or Teflon[1] tubing may also be used for the probe. Heating is not necessary if the probe remains dry during the purging period.

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[1] Mention of trade names or specific products does not constitute endorsement by the Environmental Protection Agency.

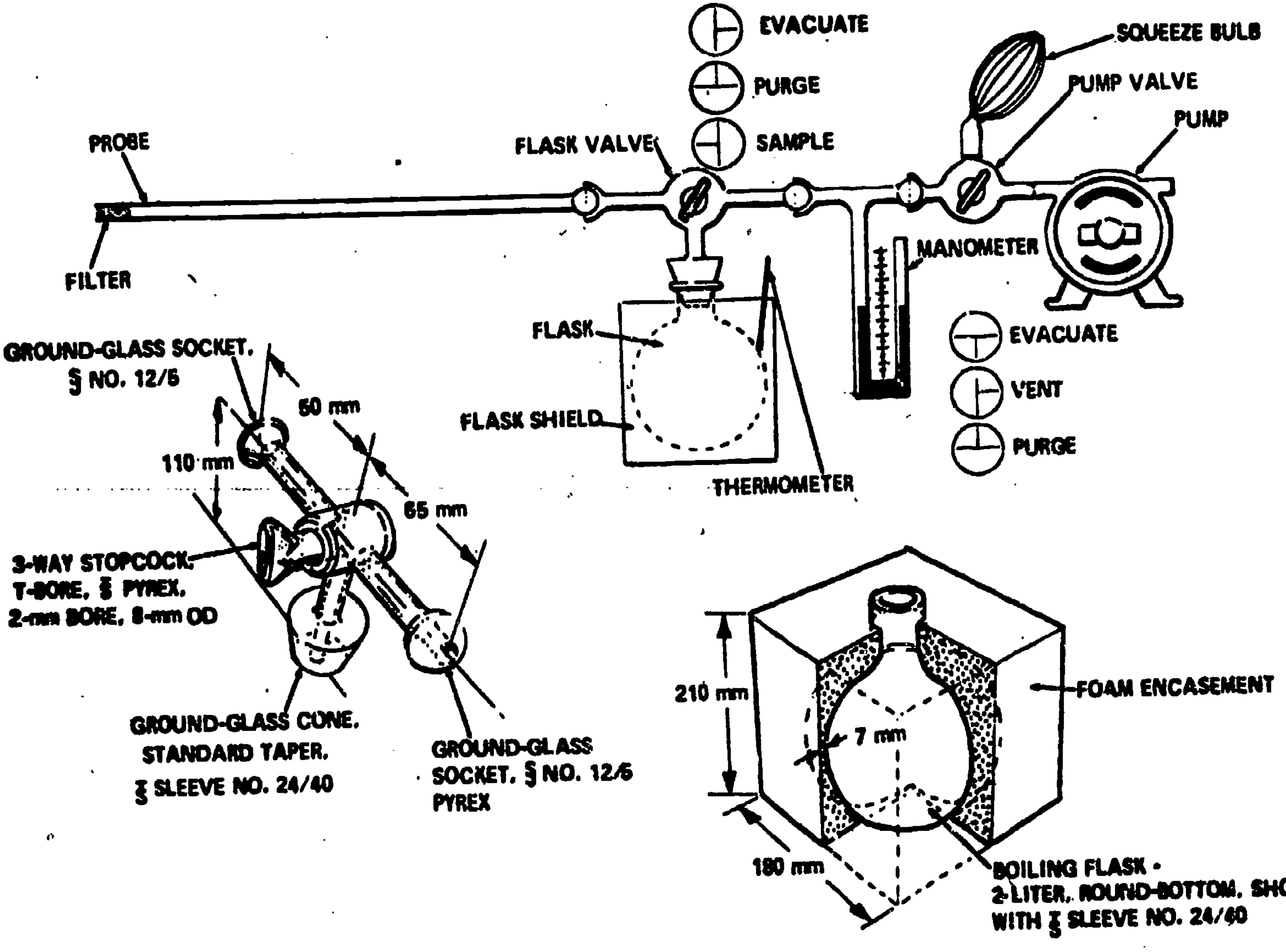

Figure 7-1. Sampling train, flask valve, and flask.

2.1.2 Collection Flask. Two-liter borosilicate, round bottom flask, with short neck and 24/40 standard taper opening, protected against implosion or breakage.

2.1.3 Flask Valve. T-bore stopcock connected to a 24/40 standard taper joint.

2.1.4 Temperature Gauge. Dial-type thermometer, or other temperature gauge, capable of measuring 1° C (2° F) intervals from −5 to 50° C (25 to 125° F).

2.1.5 Vacuum Line. Tubing capable of withstanding a vacuum of 75 mm Hg (3 in. Hg) absolute pressure, with "T" connection and T-bore stopcock.

2.1.6 Vacuum Gauge. U-tube manometer, 1 meter (36 in.), with 1-mm (0.1-in.) divisions, or other gauge capable of measuring pressure to within ±2.5 mm Hg (0.10 in. Hg).

2.1.7 Pump. Capable of evacuating the collection flask to a pressure equal to or less than 75 mm Hg (3 in. Hg) absolute.

2.1.8 Squeeze Bulb. One-way.

2.1.9 Volumetric Pipette. 25 ml.

2.1.10 Stopcock and Ground Joint Grease. A high-vacuum, high-temperature chlorofluorocarbon grease is required. Halocarbon 25-5S has been found to be effective.

2.1.11 Barometer. Mercury, aneroid, or other barometer capable of measuring atmospheric pressure to within 2.5 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 and an adjustment for elevation differences between the weather station and sampling point shall be applied at a rate of minus 2.5 mm Hg (0.1 in. Hg) per 30 m (100 ft) elevation increase, or vice versa for elevation decrease.

2.2 Sample Recovery. The following equipment is required for sample recovery:

2.2.1 Graduated Cylinder. 50 ml with 1-ml divisions.

2.2.2 Storage Containers. Leak-free polyethylene bottles.

2.2.3 Wash Bottle. Polyethylene or glass.

2.2.4 Glass Stirring Rod.

2.2.5 Test Paper for Indicating pH. To cover the pH range of 7 to 14.

2.3 Analysis. For the analysis, the following equipment is needed:

2.3.1 Volumetric Pipettes. Two 1 ml, two 2 ml, one 3 ml, one 4 ml, two 10 ml, and one 25 ml for each sample and standard.

2.3.2 Porcelain Evaporating Dishes. 175- to 250-ml capacity with lip for pouring, one for each sample and each standard. The Coors No. 45006 (shallow-form, 195 ml) has been found to be satisfactory. Alternatively, polymethyl pentene beakers (Nalge No. 1203, 150 ml), or glass beakers (150 ml) may be used. When glass beakers are used, etching of the beakers may cause solid matter to be present in the analytical step. the solids should be removed by filtration (see Section 4.3).

2.3.3 Steam Bath. Low-temperature ovens or thermostatically controlled hot plates kept below 70° C (160° F) are acceptable alternatives.

2.3.4 Dropping Pipette or Dropper. Three required.

2.3.5 Polyethylene Policeman. One for each sample and each standard.

2.3.6 Graduated Cylinder. 100 ml with 1-ml divisions.

2.3.7 Volumetric Flasks. 50 ml (one for each sample), 100 ml (one for each sample and each standard, and one for the working standard KNO_3 solution), and 1000 ml (one).

2.3.8 Spectrophotometer. To measure absorbance at 410 nm.

2.3.9 Graduated Pipette. 10 ml with 0.1-ml divisions.

2.3.10 Test Paper for Indicating pH. To cover the pH range of 7 to 14.

2.3.11 Analytical Balance. To measure to within 0.1 mg.

3. *Reagents*

Unless otherwise indicated, it is intended that all reagents conform to the specifications established by the Committee on Analytical Reagents of the American Chemical Society, where such specifications are available; otherwise, use the best available grade.

3.1 Sampling. To prepare the absorbing solution, cautiously add 2.8 ml concentrated H_2SO_4 to 1 liter of deionized, distilled water. Mix well and add 6 ml of 3 percent hydrogen peroxide, freshly prepared from 30 percent hydrogen peroxide solution. The absorbing solution should be used within 1 week of its preparation. Do not expose to extreme heat or direct sunlight.

3.2 Sample Recovery. Two reagents are required for sample recovery:

3.2.1 Sodium Hydroxide (1N). Dissolve 40 g NaOH in deionized, distilled water and dilute to 1 liter.

3.2.2 Water. Deionized, distilled to conform to ASTM specification D1193-74, Type 3. At the option of the analyst, the $KMnO_4$ test for oxidizable organic matter may be omitted when high concentrations of organic matter are not expected to be present.

3.3 Analysis. For the analysis, the following reagents are required:

3.3.1 Fuming Sulfuric Acid. 15 to 18 percent by weight free sulfur trioxide. HANDLE WITH CAUTION.

3.3.2 Phenol. White solid.

3.3.3 Sulfuric Acid. Concentrated, 95 percent minimum assay. HANDLE WITH CAUTION.

3.3.4 Potassium Nitrate. Dried at 105 to 110° C (220 to 230° F) for a minimum of 2 hours just prior to preparation of standard solution.

3.3.5 Standard KNO_3 Solution. Dissolve exactly 2.198 g of dried potassium nitrate (KNO_3) in deionized, distilled water and dilute to 1 liter with deionized, distilled water in a 1,000-ml volumetric flask.

3.3.6 Working Standard KNO_3 Solution. Dilute 10 ml of the standard solution to 100 ml with deionized distilled water. One milliliter of the working standard solution is equivalent to 100 μg nitrogen dioxide (NO_2).

3.3.7 Water. Deionized, distilled as in Section 3.2.2.

3.3.8 Phenoldisulfonic Acid Solution. Dissolve 25 g of pure white phenol in 150 ml concentrated sulfuric acid on a steam bath. Cool, add 75 ml fuming sulfuric acid, and heat at 100° C (212° F) for 2 hours. Store in a dark, stoppered bottle.

4. *Procedures*

4.1 Sampling.

4.1.1 Pipette 25 ml of absorbing solution into a sample flask, retaining a sufficient quantity for use in preparing the calibration standards. Insert the flask valve stopper into the flask with the valve in the "purge" position. Assemble the sampling train as shown in Figure 7-1 and place the probe at the sampling point. Make sure that all fittings are tight and leak-free, and that all ground glass joints have been properly greased with a high-vacuum, high-temperature chlorofluorocarbon-based stopcock grease. Turn the flask valve and the pump valve to their "evacuate" positions. Evacuate the flask to 75 mm Hg (3 in. Hg) absolute pressure, or less. Evacuation to a pressure approaching the vapor pressure of water at the existing temperature is desirable. Turn the pump valve to its "vent" position and turn off the pump. Check for leakage by observing the manometer for any pressure fluctuation. (Any variation greater than 10 mm Hg (0.4 in. Hg) over a period of 1 minute is not acceptable, and the flask is not to be used until the leakage problem is corrected. Pressure in the flask is not to exceed 75 mm Hg (3 in. Hg) absolute at the time sampling is commenced.) Record the volume of the flask and valve (V_f), the flask temperature (T_i), and the barometric pressure. Turn the flask valve counterclockwise to its "purge" position and do the same with the pump valve. Purge the probe and the vacuum tube using the squeeze bulb. If condensation occurs in the probe and the flask valve area, heat the probe and purge until the condensation disappears. Next, turn the pump valve to its "vent" position. Turn the flask valve clockwise to its "evacuate" position and record the difference in the mercury levels in the manometer. The absolute internal pressure in the flask (P_i) is equal to the barometric pressure less the manometer reading. Immediately turn the flask valve to the "sample" position and permit the gas to enter the flask until pressures in the flask and sample line (i.e., duct, stack) are equal. This will usually require about 15 seconds; a longer period indicates a "plug" in the probe, which must be corrected before sampling is continued. After collecting the sample, turn the flask valve to its "purge" position and disconnect the flask from the sampling train. Shake the flask for at least 5 minutes.

4.1.2 If the gas being sampled contains insufficient oxygen for the conversion of NO to NO_2 (e.g., an applicable subpart of the standard may require taking a sample of a calibration gas mixture of NO in N_2), then oxygen shall be introduced into the flask to permit this conversion. Oxygen may be introduced into the flask by one of three methods; (1) Before evacuating the sampling flask, flush with pure cylinder oxygen, then evacuate flask to 75 mm Hg (3 in. Hg) absolute pressure or less; or (2) inject oxygen into the flask after sampling; or (3) terminate sampling with a minimum of 50 mm Hg (2 in. Hg) vacuum remaining in the flask, record this final pressure, and then vent the flask to the atmosphere until the flask pressure is almost equal to atmospheric pressure.

4.2 Sample Recovery. Let the flask set for a minimum of 16 hours and then shake the contents for 2 minutes. Connect the flask to a mercury filled U-tube manometer. Open the valve from the flask to the manometer and record the flask temperature (T_f), the barometric pressure, and the difference between the mercury levels in the manometer. The absolute internal pressure in the flask (P_f) is the barometric pressure less the manometer reading. Transfer the contents of the flask to a leak-free polyethylene bottle. Rinse the flask twice with 5-ml portions of deionized, distilled water and add the rinse water to the bottle. Adjust the pH to between 9 and 12 by adding sodium hydroxide (1 N), dropwise (about 25 to 35 drops). Check the pH by dipping a stirring rod into the solution and then touching the rod to the pH test paper. Remove as little material as possible during this step. Mark the height of the liquid level so that the container can be checked for leakage after transport. Label the container to clearly identify its contents. Seal the container for shipping.

4.3 Analysis. Note the level of the liquid in container and confirm whether or not any sample was lost during shipment; note this on the analytical data sheet. If a noticeable amount of leakage has occurred, either void the sample or use methods, subject to the approval of the Administrator, to correct the final results. Immediately prior to analysis, transfer the contents of the shipping container to a 50-ml volumetric flask, and rinse the container twice with 5-ml portions of deionized, distilled water. Add the rinse water to the flask and dilute to the mark with deionized, distilled water; mix thoroughly. Pipette a 25-ml aliquot into the procelain evaporating dish. Return any unused portion of the sample to the polyethylene storage bottle. Evaporate the 25-ml aliquot to dryness on a steam bath and allow to cool. Add 2 ml phenoldisulfonic acid solution to the dried residue and triturate thoroughly with a poylethylene policeman. Make sure the solution contacts all the residue. Add 1 ml deionized, distilled water and four drops of concentrated sulfuric acid. Heat the solution on a steam bath for 3 minutes with occasional stirring. Allow the solution to cool, add 20 ml deionized, distilled water, mix well by stirring, and add concentrated ammonium hydroxide, dropwise, with constant stirring, until the pH is 10 (as determined by pH paper). If the sample contains solids, these must be removed by filtration (centrifugation is an acceptable alternative, subject to the approval of the Administrator), as follows: filter through Whatman No. 41 filter paper into a 100-ml volumetric flask; rinse the evaporating dish with three 5-ml portions of deionized, distilled water; filter these three rinses. Wash the filter with at least three 15-ml portions of deionized, distilled water. Add the filter washings to the contents of the volumetric flask and dilute to the mark with deionized, distilled water. If solids are absent, the solution can be transferred directly to the 100-ml volumetric flask and diluted to the mark with deionized, distilled water. Mix the contents of the flask thoroughly, and measure the absorbance at the optimum wavelength used for the standards (Section 5.2.1), using the blank solution as a zero reference. Dilute the sample and the blank with equal volumes of deionized, distilled water if the absorbance exceeds A_4, the absorbance of the 400 μg NO_2 standard (see Section 5.2.2).

5. *Calibration*

5.1 Flask Volume. The volume of the collection flask-flask valve combination must be known prior to sampling. Assemble the flask and flask valve and fill with water, to the stopcock. Measure the volume of water to ±10 ml. Record this volume on the flask.

5.2 Spectrophotometer Calibration.

5.2.1 Optimum Wavelength Determination. For both fixed and variable wavelength spectrophotometers, calibrate against standard certified wavelength of 410 nm, every 6 months. Alternatively, for variable wave length spectrophotometers, scan the spectrum between 400 and 415 nm using a 200 μg NO_2 standard solution (see Section 5.2.2). If a peak does not occur, the spectrophotometer is probably malfunctioning, and should be repaired. When a peak is obtained within the 400 to 415 nm range, the wavelength at which this peak occurs shall be the optimum wavelength for the measurement of absorbance for both the standards and samples.

5.2.2 Determination of Spectrophotometer Calibration Factor K_c. Add 0.0, 1.0, 2.0, 3.0, and 4.0 ml of the KNO_3 working standard solution (1 ml = 100 μg NO_2) to a series of five porcelain evaporating dishes. To each, add 25 ml of absorbing solution, 10 ml deionized, distilled water, and sodium hydroxide (1N), dropwise, until the pH is between 9 and 12 (about 25 to 35 drops each). Beginning with the evaporation step, follow the analysis procedure of Section 4.3, until the solution has been transferred to the 100 ml volumetric flask and diluted to the mark. Measure the absorbance of each solution, at 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:

$$K_c = 100 \frac{A_1 + 2A_2 + 3A_3 + 4A_4}{A_1^2 + A_2^2 + A_3^2 + A_4^2}$$

Equation 7-1

where:

K_c = Calibration factor

A_1 = Absorbance of the 100-μg NO_2 standard

A_2 = Absorbance of the 200-μg NO_2 standard

A_3 = Absorbance of the 300-μg NO_2 standard

A_4 = Absorbance of the 400-μg NO_2 standard

5.3 Barometer. Calibrate against a mercury barometer.

5.4 Temperature Gauge. Calibrate dial thermometers against mercury-in-glass thermometers.

5.5 Vacuum Gauge. Calibrate mechanical gauges, if used, against a mercury manometer such as that specified in 2.1.6.

5.6 Analytical Balance. Calibrate against standard weights.

6. *Calculations*

Carry out the calculations, retaining at least one extra decimal figure beyond that of the acquired data. Round off figures after final calculations.

6.1 Nomenclature.

A = Absorbance of sample.

C = Concentration of NO_x as NO_2, dry basis, corrected to standard conditions, mg/dscm (lb/dscf).

F = Dilution factor (i.e., 25/5, 25/10, etc., required only if sample dilution was needed to reduce the absorbance into the range of calibration).

K_c = Spectrophotometer calibration factor.

m = Mass of NO_x as NO_2 in gas sample, μg.

P_f = Final absolute pressure of flask, mm Hg (in. Hg).

P_i = Initial absolute pressure of flask, mm Hg (in. Hg)

P_{std} = Standard absolute pressure, 760 mm Hg (29.92 in. Hg).

T_f = Final absolute temperature of flask, °K (°R).

T_i = Initial absolute temperature of flask, °K (°R).

T_{std} = Standard absolute temperature, 293° K (528° R)

V_{sc} = Sample volume at standard conditions (dry basis), ml.

V_f = Volume of flask and valve, ml.

V_a = Volume of absorbing solution, 25 ml.

2 = 50/25, the aliquot factor. (If other than a 25-ml aliquot was used for analysis, the corresponding factor must be substituted).

6.2 Sample volume, dry basis, corrected to standard conditions.

$$V_{sc} = \frac{T_{std}}{P_{std}} (V_f - V_a) \left[\frac{P_f}{T_f} - \frac{P_i}{T_i}\right]$$

$$= K_1 (V_f - 25 \text{ ml}) \left[\frac{P_f}{T_f} - \frac{P_i}{T_i}\right]$$

Equation 7-2

where

$$K_1 = 0.3858 \frac{°K}{\text{mm Hg}} \text{ for metric units}$$

$$= 17.64 \frac{°R}{\text{in. Hg}} \text{ for English units}$$

6.3 Total μg NO_2 per sample.

$$m = 2 K_c A F$$

Equation 7-3

NOTE.—If other than a 25-ml aliquot is used for analysis, the factor 2 must be replaced by a corresponding factor.

6.4 Sample concentration, dry basis, corrected to standard conditions.

$$C = K_2 \frac{m}{V_{sc}}$$

Equation 7-4

where:

$$K_2 = 10^3 \frac{\text{mg/m}^3}{\mu\text{g/ml}} \text{ for metric units}$$

$$= 6.243 \times 10^{-5} \frac{\text{lb/scf}}{\mu\text{g/ml}} \text{ for English units}$$

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METHOD 8—DETERMINATION OF SULFURIC ACID MIST AND SULFUR DIOXIDE EMISSIONS FROM STATIONARY SOURCES

1. *Principle and Applicability*

1.1 Principle. A gas sample is extracted isokinetically from the stack. The sulfuric acid mist (including sulfur trioxide) and the sulfur dioxide are separated, and both fractions are measured separately by the barium-thorin titration method.

1.2 Applicability. This method is applicable for the determination of sulfuric acid mist (including sulfur trioxide, and in the absence of other particulate matter) and sulfur dioxide emissions from stationary sources. Collaborative tests have shown that the minimum detectable limits of the method are 0.05 milligrams/cubic meter (0.03×10^{-7} pounds/cubic foot) for sulfur trioxide and 1.2 mg/m³ (0.74×10^{-7} lb/ft³) for sulfur dioxide. No upper limits have been established. Based on theoretical calculations for 200 milliliters of 3 percent hydrogen peroxide solution, the upper concentration limit for sulfur dioxide in a 1.0 m³ (35.3 ft³) gas sample is about 12,500 mg/m³ (7.7×10^{-4} lb/ft³). The upper limit can be extended by increasing the quantity of peroxide solution in the impingers.

Possible interfering agents of this method are fluorides, free ammonia, and dimethyl aniline. If any of these interfering agents are present (this can be determined by knowledge of the process), alternative methods, subject to the approval of the Administrator, are required.

Filterable particulate matter may be determined along with SO_3 and SO_2 (subject to the approval of the Administrator); however, the procedure used for particulate matter must be consistent with the specifications and procedures given in Method 5.

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 different and the filter holder does not have to be heated. Commercial models of this train are available. For those who desire to build their own, however, complete construction details are described in APTD-0581. Changes from the APTD-0581 document and allowable modifications to Figure 8-1 are discussed in the following subsections.

The operating and maintenance procedures for the sampling train are described in APTD-0576. Since correct usage is important in obtaining valid results, all users should read the APTD-0576 document and adopt the operating and maintenance procedures outlined in it, unless otherwise specified herein. Further details and guidelines on operation and maintenance are given in Method 5 and should be read and followed whenever they are applicable.

2.1.1 Probe Nozzle. Same as Method 5, Section 2.1.1.

2.1.2 Probe Liner. Borosilicate or quartz glass, with a heating system to prevent visible condensation during sampling. Do not use metal probe liners.

2.1.3 Pitot Tube. Same as Method 5, Section 2.1.3.

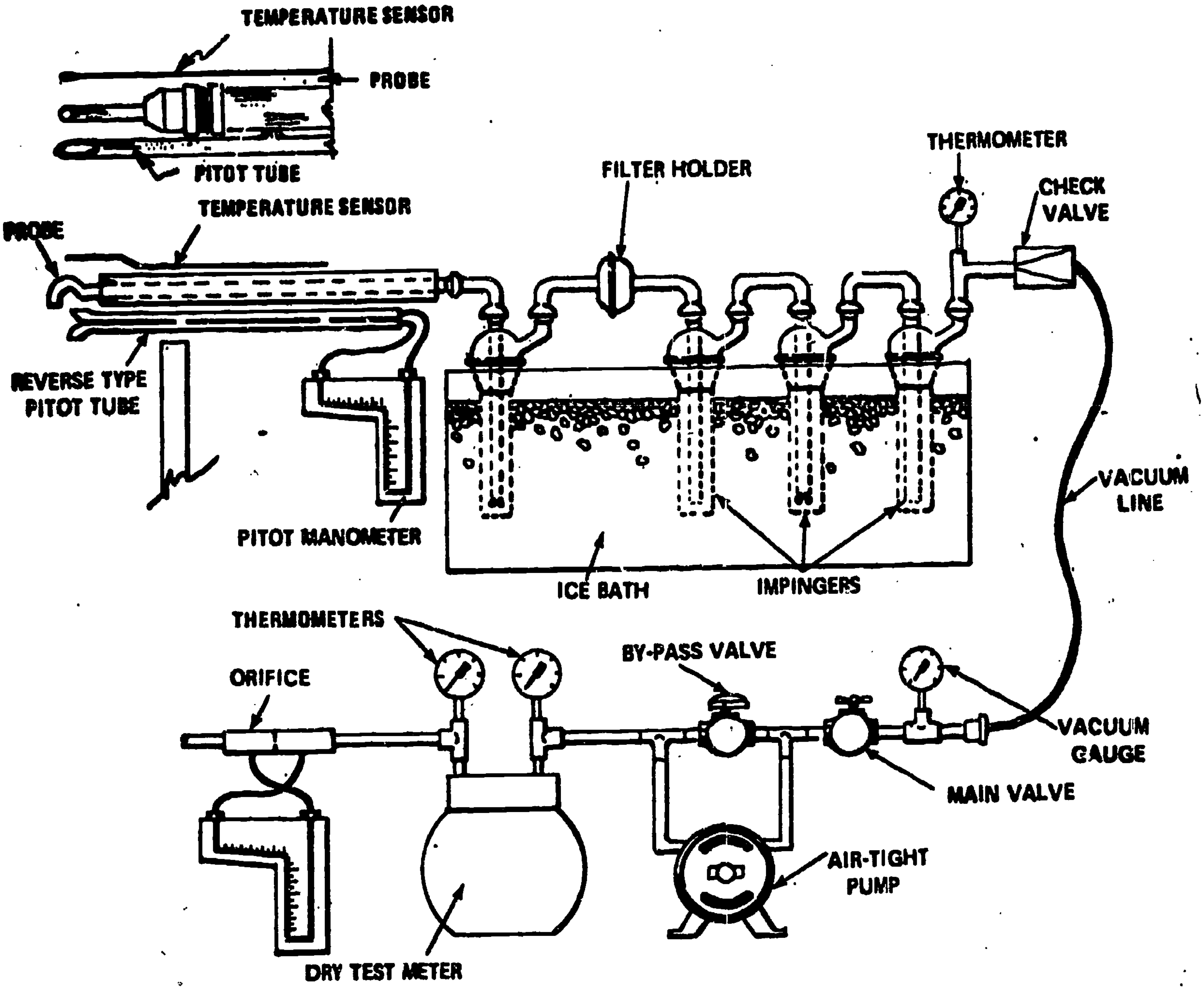

Figure 8-1. Sulfuric acid mist sampling train.

2.1.4 Differential Pressure Gauge. Same as Method 5, Section 2.1.4.

2.1.5 Filter Holder. Borosilicate glass, with a glass frit filter support and a silicone rubber gasket. Other gasket materials, e.g., Teflon or Viton, 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 filter holder shall be placed between the first and second impingers. Note: Do not heat the filter holder.

2.1.6 Impingers—Four, as shown in Figure 8-1. The first and third shall be of the Greenburg-Smith design with standard tips. The second and fourth shall be of the Greenburg-Smith design, modified by replacing the insert with an approximately 13 millimeter (0.5 in.) ID glass tube, having an unconstricted tip located 13 mm (0.5 in.) from the bottom of the flask. Similar collection systems, which have been approved by the Administrator, may be used.

2.1.7 Metering System. Same as Method 5, Section 2.1.8.

2.1.8 Barometer. Same as Method 5, Section 2.1.9.

2.1.9 Gas Density Determination Equipment. Same as Method 5, Section 2.1.10.

2.1.10 Temperature Gauge. Thermometer, or equivalent, to measure the temperature of the gas leaving the impinger train to within 1° C (2° F).

2.2 Sample Recovery.

2.2.1 Wash Bottles. Polyethylene or glass, 500 ml. (two).

2.2.2 Graduated Cylinders. 250 ml, 1 liter. (Volumetric flasks may also be used.)

2.2.3 Storage Bottles. Leak-free polyethylene bottles, 1000 ml size (two for each sampling run).

2.2.4 Trip Balance. 500-gram capacity, to measure to ±0.5 g (necessary only if a moisture content analysis is to be done).

2.3 Analysis.

2.3.1 Pipettes. Volumetric 25 ml, 100 ml.

2.3.2 Burrette. 50 ml.

2.3.3 Erlenmeyer Flask. 250 ml. (one for each sample blank and standard).

2.3.4 Graduated Cylinder. 100 ml.

2.3.5 Trip Balance. 500 g capacity, to measure to ±0.5 g.

2.3.6 Dropping Bottle. To add indicator solution, 125-ml size

3. *Reagents*

Unless otherwise indicated, all reagents are to conform to the specifications established by the Committee on Analytical Reagents of the American Chemical Society, where such specifications are available. Otherwise, use the best available grade.

3.1 Sampling.

3.1.1 Filters. Same as Method 5, Section 3.1.1.

3.1.2 Silica Gel. Same as Method 5, Section 3.1.2.

3.1.3 Water. Deionized, distilled to conform to ASTM specification D1193-74, Type 3. At the option of the analyst, the $KMnO_4$ test for oxidizable organic matter may be omitted when high concentrations of organic matter are not expected to be present.

3.1.4 Isopropanol, 80 Percent. Mix 800 ml of isopropanol with 200 ml of deionized, distilled water.

NOTE.—Experience has shown that only A.C.S. grade isopropanol is satisfactory. Tests have shown that isopropanol obtained from commercial sources occasionally has peroxide impurities that will cause erroneously high sulfuric acid mist measurement. Use the following test for detecting peroxides in each lot of isopropanol: Shake 10 ml of the isopropanol with 10 ml of freshly prepared 10 percent potassium iodide solution. Prepare a blank by similarly treating 10 ml of distilled water. After 1 minute, read the absorbance on a spectrophotometer at 352 nanometers. If the absorbance exceeds 0.1, the isopropanol shall not be used. Peroxides may be removed from isopropanol by redistilling, or by passage through a column of activated alumina. However, reagent-grade isopropanol with suitably low peroxide levels is readily available from commercial sources; therefore, rejection of contaminated lots may be more efficient than following the peroxide removal procedure.

3.1.5 Hydrogen Peroxide, 3 Percent. Dilute 100 ml of 30 percent hydrogen peroxide to 1 liter with deionized, distilled water. Prepare fresh daily.

3.1.6 Crushed Ice.

3.2 Sample Recovery.

3.2.1 Water. Same as 3.1.3.

3.2.2 Isopropanol, 80 Percent. Same as 3.1.4.

3.3 Analysis.

3.3.1 Water. Same as 3.1.3.

3.3.2 Isopropanol, 100 Percent.

3.3.3 Thorin Indicator. 1-(o-arsonophenylazo)-2-naphthol-3, 6-disulfonic acid, disodium salt, or equivalent. Dissolve 0.20 g in 100 ml of deionized, distilled water.

3.3.4 Barium Perchlorate (0.0100 Normal). Dissolve 1.95 g of barium perchlorate trihydrate ($Ba(ClO_4)_2 \cdot 3H_2O$) in 200 ml deionized, distilled water, and dilute to 1 liter with isopropanol; 1.22 g of barium chloride dihydrate ($BaCl_2 \cdot 2H_2O$) may be used instead of the barium perchlorate. Standardize with sulfuric acid as in Section 5.2. This solution must be protected against evaporation at all times.

3.3.5 Sulfuric Acid Standard (0.0100 N). Purchase or standardize to ±0.0002 N against 0.0100 N NaOH that has previously been standardized against primary standard potassium acid phthalate.

4. *Procedure*

4.1 Sampling.

4.1.1 Pretest Preparation. Follow the procedure outlined in Method 5, Section 4.1.1; filters should be inspected, but need not be desiccated, 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 4.1.2.

4.1.3 Preparation of Collection Train. Follow the procedure outlined in Method 5, Section 4.1.3 (except for the second paragraph and other obviously inapplicable parts) and use Figure 8-1 instead of Figure 5-1. Replace the second paragraph with: Place 100 ml of 80 percent isopropanol in the first impinger, 100 ml of 3 percent hydrogen peroxide in both the second and third impingers; retain a portion of each reagent for use as a blank solution. Place about 200 g of silica gel in the fourth impinger.

NOTE.—If moisture content is to be determined by impinger analysis, weigh each of the first three impingers (plus absorbing solution) to the nearest 0.5 g and record these weights. The weight of the silica gel (or silica gel plus container) must also be determined to the nearest 0.5 g and recorded.

4.1.4 Pretest 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 verbage such as, "* * * plugging the inlet to the filter holder * * *," shall be replaced by, "* * * plugging the inlet to the first impinger * * *." The pretest leak-check is optional.

4.1.5 Train Operation. Follow the basic procedures outlined in Method 5, Section 4.1.5, 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 m³/min (1.0 cfm) 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 4.1.4.2 of Method 5 (with appropriate modifications, as mentioned in Section 4.1.4 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 6.3 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.

PLANT ____________

LOCATION ____________

OPERATOR ____________

DATE ____________

RUN NO. ____________

SAMPLE BOX NO. ____________

METER BOX NO. ____________

METER ΔH@ ____________

C FACTOR ____________

PITOT TUBE COEFFICIENT, Cp ____________

SCHEMATIC OF STACK CROSS SECTION

STATIC PRESSURE, mm Hg (in. Hg) ____________

AMBIENT TEMPERATURE ____________

BAROMETRIC PRESSURE ____________

ASSUMED MOISTURE, % ____________

PROBE LENGTH, m (ft) ____________

NOZZLE IDENTIFICATION NO. ____________

AVERAGE CALIBRATED NOZZLE DIAMETER, cm (in.) ____________

PROBE HEATER SETTING ____________

LEAK RATE, m³/min, (cfm) ____________

PROBE LINER MATERIAL ____________

FILTER NO. ____________

TRAVERSE POINT NUMBER	SAMPLING TIME (θ), min.	VACUUM mm Hg (in. Hg)	STACK TEMPERATURE (Ts), °C (°F)	VELOCITY HEAD (ΔPs), mm H2O (in. H2O)	PRESSURE DIFFERENTIAL ACROSS ORIFICE METER, mm H2O (in. H2O)	GAS SAMPLE VOLUME, m³ (ft³)	GAS SAMPLE TEMPERATURE AT DRY GAS METER		TEMPERATURE OF GAS LEAVING CONDENSER OR LAST IMPINGER, °C (°F)
							INLET, °C (°F)	OUTLET, °C (°F)	
TOTAL							Avg	Avg	
AVERAGE							Avg		

Figure 8-2. Field data.

After turning off the pump and recording the final readings at the conclusion of each run, remove the probe from the stack. Conduct a post-test (mandatory) leak-check as in Section 4.1.4.3 of Method 5 (with appropriate modification) and record the leak rate. If the post-test leakage rate exceeds the specified acceptable rate, the tester shall either correct the sample volume, as outlined in Section 6.3 of Method 5, or shall void the run.

Drain the ice bath and, with the probe disconnected, purge the remaining part of the train, by drawing clean ambient air through the system for 15 minutes at the average flow rate used for sampling.

NOTE.—Clean ambient air can be provided by passing air through a charcoal filter. At the option of the tester, ambient air (without cleaning) may be used.

4.1.6 Calculation of Percent Isokinetic. Follow the procedure outlined in Method 5, Section 4.1.6.

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 0.5 g and record this weight.

Transfer the contents of the first impinger to a 250-ml graduated cylinder. Rinse the probe, first impinger, all connecting glassware before the filter, and the front half of the filter holder with 80 percent isopropanol. Add the rinse solution to the cylinder. Dilute to 250 ml with 80 percent isopropanol. Add the filter to the solution, mix, and transfer to the storage container. Protect the solution against evaporation. Mark the level of liquid on the container and identify the sample container.

4.2.2 Container No. 2. If a moisture content analysis is to be done, weigh the second and third impingers (plus contents) to the nearest 0.5 g and record these weights. Also, weigh the spent silica gel (or silica gel plus impinger) to the nearest 0.5 g.

Transfer the solutions from the second and third impingers to a 1000-ml 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 this rinse water to the cylinder. Dilute to a volume of 1000 ml with deionized, distilled water. Transfer the solution to a storage container. Mark the level of liquid on the container. Seal and identify the sample container.

4.3 Analysis.

Note the level of liquid in containers 1 and 2 and confirm whether or not any sample was lost during shipment; note this on the analytical data sheet. If a noticeable amount of leakage has occurred, either void the sample or use methods, subject to the approval of the Administrator, to correct the final results.

4.3.1 Container No. 1. Shake the container holding the isopropanol solution and the filter. If the filter breaks up, allow the fragments to settle for a few minutes before removing a sample. Pipette a 100-ml aliquot of this solution into a 250-ml Erlenmeyer flask, add 2 to 4 drops of thorin indicator, and titrate to a pink endpoint using 0.0100 N barium perchlorate. Repeat the titration with a second aliquot of sample and average the titration values. Replicate titrations must agree within 1 percent or 0.2 ml, whichever is greater.

4.3.2 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 250-ml Erlenmeyer flask. Add ml of isopropanol, 2 to 4 drops of thorin indicator, and titrate to a pink endpoint using 0.0100 N barium perchlorate. Repeat the titration with a second aliquot of sample and average the titration values. Replicate titrations must agree within 1 percent or 0.2 ml, whichever is greater.

4.3.3 Blanks. Prepare blanks by adding 2 to 4 drops of thorin indicator to 100 ml of 80 percent isopropanol. Titrate 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 5.3 (metering system); Section 5.5 (temperature gauges); Section 5.7 (barometer). Note that the recommended leak-check of the metering system, described in Section 5.6 of Method 5, also applies to this method.

5.2 Standardize the barium perchlorate solution with 25 ml of standard sulfuric acid, to which 100 ml of 100 percent isopropanol has been added.

6. *Calculations*

NOTE.—Carry out calculations retaining at least one extra decimal figure beyond that of the acquired data. Round off figures after final calculation.

6.1 Nomenclature.

A_n = Cross-sectional area of nozzle, m² (ft²).
B_{ws} = Water vapor in the gas stream, proportion by volume.
$C_{H_2SO_4}$ = Sulfuric acid (including SO_3) concentration, g/dscm (lb/dscf).
C_{SO_2} = Sulfur dioxide concentration, g/dscm (lb/dscf).
I = Percent of isokinetic sampling.
N = Normality of barium perchlorate titrant, g equivalents/liter.
P_{bar} = Barometric pressure at the sampling site, mm Hg (in. Hg).
P_s = Absolute stack gas pressure, mm Hg (in. Hg).
P_{std} = Standard absolute pressure, 760 mm Hg (29.92 in. Hg).
T_m = Average absolute dry gas meter temperature (see Figure 8–2), °K (°R).
T_s = Average absolute stack gas temperature (see Figure 8–2), °K (°R).
T_{std} = Standard absolute temperature, 293° K (528° R).
V_a = Volume of sample aliquot titrated, 100 ml for H_2SO_4 and 10 ml for SO_2.
V_{lc} = Total volume of liquid collected in impingers and silica gel, ml.
V_m = Volume of gas sample as measured by dry gas meter, dcm (dcf).
$V_{m(std)}$ = Volume of gas sample measured by the dry gas meter corrected to standard conditions, dscm (dscf).
v_s = Average stack gas velocity, calculated by Method 2, Equation 2–9, using data obtained from Method 8, m/sec (ft/sec).
V_{soln} = Total volume of solution in which the sulfuric acid or sulfur dioxide sample is contained, 250 ml or 1,000 ml, respectively.
V_t = Volume of barium perchlorate titrant used for the sample, ml.
V_{tb} = Volume of barium perchlorate titrant used for the blank, ml.
Y = Dry gas meter calibration factor.
ΔH = Average pressure drop across orifice meter, mm (in.) H_2O.
θ = Total sampling time, min.
13.6 = Specific gravity of mercury.
60 = sec/min.
100 = Conversion to percent.

6.2 Average dry gas meter temperature and average orifice 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.

$$V_{m(std)} = V_m Y \left(\frac{T_{std}}{T_m}\right) \frac{P_{bar} + \left(\frac{\Delta H}{13.6}\right)}{P_{std}}$$

$$= K_1 V_m Y \frac{P_{bar} + (\Delta H/13.6)}{T_m}$$

Equation 8-1

where:
K_1 = 0.3858 °K/mm Hg for metric units.
= 17.64 °R/in. Hg for English units.

NOTE.—If the leak rate observed during any mandatory leak-checks exceeds the specified acceptable rate, the tester shall either correct the value of V_m in Equation 8-1 (as described in Section 6.3 of Method 5), or shall invalidate the test run.

6.4 Volume of Water Vapor and Moisture Content. Calculate the volume of water vapor using Equation 5-2 of Method 5; the weight of water collected in the impingers and silica gel can be directly converted to milliliters (the specific gravity of water is 1 g/ml). Calculate the moisture content of the stack gas, using Equation 5-3 of Method 5. The "Note" in Section 6.5 of Method 5 also applies to this method. Note that if the effluent gas stream can be considered dry, the volume of water vapor and moisture content need not be calculated.

6.5 Sulfuric acid mist (including SO_3) concentration.

$$C_{H_2SO_4} = K_2 \frac{N(V_t - V_{tb})\left(\frac{V_{soln}}{V_a}\right)}{V_{m(std)}}$$

Equation 8–2

where:
K_2 = 0.04904 g/milliequivalent for metric units.
= 1.081×10^{-4} lb/meq for English units.

6.6 Sulfur dioxide concentration.

$$C_{SO_2} = K_3 \frac{N(V_t - V_{tb})\left(\frac{V_{soln}}{V_a}\right)}{V_{m(std)}}$$

Equation 8–3

where:
K_3 = 0.03203 g/meq for metric units.
= 7.061×10^{-5} lb/meq for English units.

6.7 Isokinetic Variation.

6.7.1 Calculation from raw data.

$$I = \frac{100\, T_s [K_4 V_{lc} + (V_m/T_m)\, P_{bar} + \Delta H/13.6)]}{60\, \theta\, V_s\, P_s\, A_n}$$

Equation 8–4

where:
K_4 = 0.003464 mm Hg-m³/ml-°K for metric units.
= 0.002676 in. Hg-ft³/ml-°R for English units.

6.7.2 Calculation from intermediate values.

$$I = \frac{T_s V_{m(std)} P_{std}\, 100}{T_{std}\, v_s\, \theta\, A_n\, P_s\, 60\, (1 - B_{ws})}$$

$$= K_5 \frac{T_s V_{m(std)}}{P_s\, v_s\, A_n\, \theta\, (1 - B_{ws})}$$

Equation 8–5

where:
K_5 = 4.320 for metric units.
= 0.09450 for English units.

6.8 Acceptable Results. If 90 percent ≤I ≤110 percent, the results are acceptable. If the results are low in comparison to the standards and I is beyond the acceptable range, the Administrator may opt to accept the results. Use Citation 4 in the Bibliography of Method 5 to make judgments. Otherwise, reject the results and repeat the test.

7. *Bibliography*

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7. Annual Book of ASTM Standards. Part 31; Water, Atmospheric Analysis. pp. 40–42. American Society for Testing and Materials. Philadelphia, Pa. 1974.

* * * * *

(Secs. 111, 114, 301(a), Clean Air Act, sec. 4(a) of Pub. L. 91-604, 84 Stat. 1683; sec. 4(a) of Pub. L. 91-604, 84 Stat. 1687; sec. 2 of Pub. L. 90-148, 81 Stat. 504 [42 U.S.C. 1857c-6, 1857c-9, 1857g(a)].)

[FR Doc.77-13608 Filed 8-17-77;8:45 am]

Method 5 Particulate Test
Calculation Form

I. Neccessary 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 (θ) ______ minutes

B. Reference Method #2
- Average stack temperature T_s ____ °F + 460 = ____ °R
- Stack absolute pressure ____ in. Hg.
- Barometric Pressure ____ in. Hg.
- $\left(\sqrt{\Delta p}\right)_{ave}$ ____ $(\text{in. } H_2O)^{1/2}$

C. Reference Method #3
- $\%CO_2$ ____; $\%O_2$ ____; $\%CO$ ____; $\%N_2$ ____

D. Reference Method #4
- Water collected

  Impinger H_2O ____ ml

  Silica Gel ____ gm

E. Reference Method #5
- Area of nozzle ____ ft^2
- Average ΔH ____ in. H_2O
- 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 Y = Dry Gas Meter calibration factor

$$V_{m(std)} = V_m Y \frac{T_{std}}{P_{std}} \left(\frac{P_b + \frac{\Delta H}{13.6}}{T_m} \right)$$

$$V_{m(std)} = (\underline{\qquad\qquad} \text{ CF}) \left(\frac{528\,°R}{29.92 \text{ in. Hg}} \right) \left(\frac{\underline{\qquad\qquad} \text{ in. Hg}}{°R} \right) = \underline{\qquad\qquad} \text{ dscf}$$

B. Moisture Content of Stack Gas

1. H_2O collected in impingers in standard cubic feet

$$V_{wc(std)} = K\,(V_f - V_i)$$

$$V_{wc} = 0.04707\ \text{ft}^3/\text{ml}\ (\underline{\qquad}\ \text{ml}) = \underline{\qquad}\ \text{scf}$$

2. H_2O collected in silica gel in standard cubic feet

$$V_{wsg(std)} = K\,(W_f - W_i)$$

$$V_{wsg(std)} = 0.04715\ \text{ft}^3/\text{gm}\ (\underline{\qquad}\ \text{gm})\quad \underline{\qquad}\ \text{scf}$$

3. Moisture content of stack gas (B_{ws})

$$B_{ws} = \frac{V_{wc(std)} + V_{wsg(std)}}{V_{wc(std)} + V_{wsg(std)} + V_{m(std)}}$$

$$B_{ws} = \frac{(\underline{\qquad}\ \text{scf}) + (\underline{\qquad}\ \text{scf})}{(\underline{\qquad}\ \text{scf}) + (\underline{\qquad}\ \text{scf}) + (\underline{\qquad}\ \text{scf})} = \underline{\qquad}$$

C. Molecular Weight of Stack Gas (lb/lb-mole)

1. M_d (Dry molecular weight) = $\Sigma M_x B_x$

$$M_d = (.44)\ \underline{\qquad}\ \%CO_2 + (.32)\ \underline{\qquad}\ \%O_2\ +$$

$$(.28)\ \underline{\qquad}\ \%CO + (.28)\ \underline{\qquad}\ \%N_2 = \underline{\qquad}\ \text{lb/lb-mole}$$

2. M_s (Wet Molecular Weight) = $M_d(1 - B_{ws}) + 18\ B_{ws}$

$$M_s = \underline{\qquad}\ (1 - \underline{\qquad}) + 18(\underline{\qquad}) = \underline{\qquad}\ \text{lb/lb-mole}$$

D. Average Stack Gas Velocity

$$\bar{v}_s = K_p C_p \sqrt{\frac{T_s}{P_s M_s}}\left(\sqrt{\Delta p}\right)_{\text{ave}}$$

$$\bar{v}_s = 85.49\ \text{ft/sec}\left(\frac{\text{lb/lb-mole (in. Hg)}}{{}^\circ\text{R(in.}H_2O)}\right)^{1/2} \underline{\qquad} \sqrt{\frac{(\qquad)\,{}^\circ\text{R}}{(\qquad \text{in. Hg})(\qquad \text{lb/lb-mole})}}$$

$$\sqrt{\underline{\qquad}\ (\text{in. } H_2O)} = \underline{\qquad}\ \text{ft/sec}$$

E. Average Stack Gas Volumetric Flow Rate

$$Q_s = (3600\ \text{sec/hr})(v_s)(A_s)(1 - B_{ws})\ \frac{T_{std}}{P_{std}}\ \frac{P_s}{T_s}$$

$$Q_s = (3600\ \text{sec/hr})(\underline{\qquad}\ \text{ft/sec})(\underline{\qquad}\ \text{ft}^2)(1 - \underline{\qquad})\ \frac{528\,{}^\circ\text{R}}{29.92\ \text{in. Hg}}\ \frac{\underline{\qquad}\ \text{in. Hg}}{\underline{\qquad}\ {}^\circ\text{R}}$$

$$Q_s = \underline{\qquad}\ \text{dscf/hr}$$

F. Pollutant Mass Rate

$$\text{PMR} \quad \frac{\text{mass}}{V_{m(std)}} \times Q_s$$

$$\text{PMR} = \frac{(\underline{\qquad\qquad})\text{gm}}{\text{dscf}} \times \underline{\qquad\qquad}\ \text{dscf/hr} \times \frac{1}{454\ \text{gm/lb}} = \underline{\qquad\qquad}\ \text{lb/hr}$$

G. %Isokinetic Variation (Intermediate Data)

$$\%I = \frac{T_s V_{m(std)} P_{std} 100}{A_n \theta v_s P_s T_{std} 60(1 - B_{ws})}$$

$$\% = \frac{(\underline{\qquad\quad}\,^\circ\text{R})(\underline{\qquad\quad}\,\text{dscf})(29.92\ \text{in. Hg})}{(\underline{\qquad}\,\text{ft}^2)(\underline{\qquad\quad}\,\text{min})(\underline{\qquad}\,\text{ft/sec})(\underline{\qquad\quad}\,\text{in. Hg})(528\,^\circ\text{R})(60\ \text{sec/min})(1 - \underline{\qquad\quad})}$$

A GUIDELINE FOR EVALUATING COMPLIANCE TEST RESULTS

(Isokinetic Sampling Rate Criterion)

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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 5[1] states, "If 90 percent $\leq$ I $\leq$ 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.[2] 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. <u>Case 1 - I is between 90 and 110 percent</u>. The concentration c_s must be considered acceptable. A variation of ± 10 percent from 100 percent isokinetic is permitted by Method 5.

b. <u>Case 2 - I is less than 90 percent</u>.

(1) 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 definintely 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

Case	I	Category	Decision
1	90 - 110		Accept
2	< 90	$E \leq$ Em. Std.	Accept
		$c_s(I/100) \rightarrow E_{adj} >$ Em. Std.	Accept
		$c_s(I/100) \rightarrow E_{adj} \leq$ Em. Std.	Retest
3	> 110	$E >$ Em. Std.	Accept
		$c_s(I/100) \rightarrow E_{adj} \leq$ Em. Std.	Accept
		$c_s(I/100) \rightarrow E_{adj} >$ Em. Std.	Retest

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

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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.

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 $C_p = .79$?

   a. Take $C^{corr}_{nomog} = 0.85/0.79 C_{nomog}$

   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_s, 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% 0_2, 14.2% $C0_2$, 0% C0, 79.6%N_2 and the % H_20 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 $\Delta H_{@}$ 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) x 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 Δp.
b. Orient the pitot tube parallel to the sides of the stack and the Δp 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 (Δp).
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 $\leq 40^{\circ}$
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 = stack gas velocity
A_s = stack cross-sectional area
A_n = nozzle cross-sectional area
θ = sampling time (minutes)
V_m = standard volume metered at the dry gas meter
V_n = volume at stack conditions passing through the nozzle

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

a. $\% \text{ isokinetic} = \dfrac{A_s}{A_n} \times 100$

b. $\% \text{ isokinetic} = \dfrac{V_n}{v_s \ A_s \theta}$

c. $\% \text{ isokinetic} = \dfrac{V_n}{\theta A_n \ v_s} \times 100$

d. $\% \text{ isokinetic} = \dfrac{V_m}{\theta A_s \ v_s} \times 100$

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 $\leq 400^{\circ}$F

24. An Orsat analyzer is commonly used to determine the composition of a combustion effluent where N_2, 0_2, CO, and CO_2 are the principal constituents of the gas stream. It directly measures:

a. 0_2, N_2, CO, and CO_2

b. CO, CO_2, 0_2

c. CO_2, 0_2, N_2

d. N_2, 0_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, 0_2, CO

b. 0_2, CO_2, CO, N_2

c. CO, 0_2, CO_2

d. N_2, 0_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 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. $$C_p = \frac{Q_s / A_s}{K_p \sqrt{\frac{T_s \Delta p}{P_s \ M_s}}}$$

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

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

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

A_s = stack cross-sectional area

C_p = pitot tube calibration coefficient

$C_{p(std)}$ = standard pitot-static tube calibration coefficient

K_p = dimensional constant

M_s = wet molecular weight of the gas

P_s = absolute pressure o the gas

Δp = pitot tube velocity pressure

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

$\Delta p(std)$ = standard pitot static tube velocity pressure

Q_s = volumetric flow rate

T_s = absolute temperature 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. $M_d = \Sigma \; M_x B_x$

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} = 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})

a. $$B_{ws} = \frac{V_{wc}}{V_{wc} + V_m} + 0.02$$

b. $$B_{ws} = \frac{V_{wc(std)} + V_{wsg(std)}}{V_{wc(std)} + V_{sg(std)} + V_{m(std)}}$$

c. $$B_{ws} = \frac{1}{V_{wc} + V_m}$$

d. $$B_{ws} = 1\left[-\frac{V_{wc}}{V_m}\right]$$

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

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 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 Δp is known, is:

$\Delta H = K \Delta p$.

ANSWER SHEET

Name ______________________ Date ______________________

1. a b c d
2. a b c d
3. a b c d
4. a b c d
5. a b c d
6. a b c d
7. a b c d
8. a b c d
9. a b c d
10. a b c d
11. a b c d
12. a b c d
13. a b c d
14. a b c d
15. a b c d
16. a b c d
17. a b c d
18. a b c d
19. a b c d
20. a b c d
21. a b c d
22. a b c d
23. a b c d
24. a b c d
25. a b c d
26. a b c d
27. a b c d
28. a b c d
29. a b c d
30. a b c d
31. a b c d
32. a b c d
33. a b c d
34. a b c d
35. a b c d
36. a b c d
37. a b c d
38. a b c d
39. a b c d
40. a b c d
41. T F
42. T F
43. T F
44. T F
45. T F
46. T F
47. T F
48. T F
49. T F
50. T F

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.

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_2O. 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. $0.998\ (0.7)^2$
   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% H_2O and traveled up the stack at 30 ft./sec. The stack had a cross-sectiona 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 different components using the Orsat. Orsat analysis makes possible the calculation of:

   a. Mole fraction of CO_2, O_2, and CO, dry gas molecular weight and percent excess air in the duct
   b. Percent excess air, CO_2, and volumetric flow rate (dry)
   c. Percent CO_2, O_2, 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. $D_e = \dfrac{(L)(W)}{(L)^2}$

b. $D_e = \dfrac{(L)(W)}{(W)^2}$

c. $D_e = \dfrac{2(L)(W)}{L + W}$

d. $D_e = \dfrac{4(L)(W)}{W + L}$

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 H_2O in a stack gas as calculated by the Reference Method, is determined using the equation

a. $B_{ws} = \dfrac{V_{wc}}{V_{wc} + V_m} + 0.02$

b. $B_{ws} = \dfrac{V_{wc(std)} + V_{wsg(std)}}{V_{wc(std)} + V_{wsg(std)} + V_{m(std)}}$

c. $B_{ws} = \dfrac{V_{wc}}{V_{wc} + V_m}$

d. $B_{ws} = \dfrac{1}{V_{wc} + V_m}$

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 sensors.
   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 Δp for the chosen sampling train. size.
- 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 ΔH from the observed Δp.
- d. It is a type of slide rule used to determine a Δp from the observed ΔH.

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. $\Delta H_{@} = 0$
- 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 H_2O and CO_2
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 onl[illegible]
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% CO_2 in the stack gas. What is the emission rate connected to 12% CO_2?

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. $M_d = \Sigma M_x B_x$
   b. $M_s = M_d(1-B_{ws}) + 18(B_{ws})$
   c. $M_s = M_d(1-B_{ws}) + 0.025$
   d. $M_s = M_d(1-B_{ws}) + B_{ws}$

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 Δp
   b. Orient the pitot tube parallel to the sides of the stack. The Δp 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 (Δp)
   d. Install 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 lbs/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:

   a. Would be rejected by EPA since it is not within ± 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 <u>false</u>.

   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 = $\log_{10} \frac{1}{(1\text{-opacity})}$
b. transmittance/opacity = – naql
c. % opacity = 100% - % transmittance
d. % opacity = % transmittance – naql

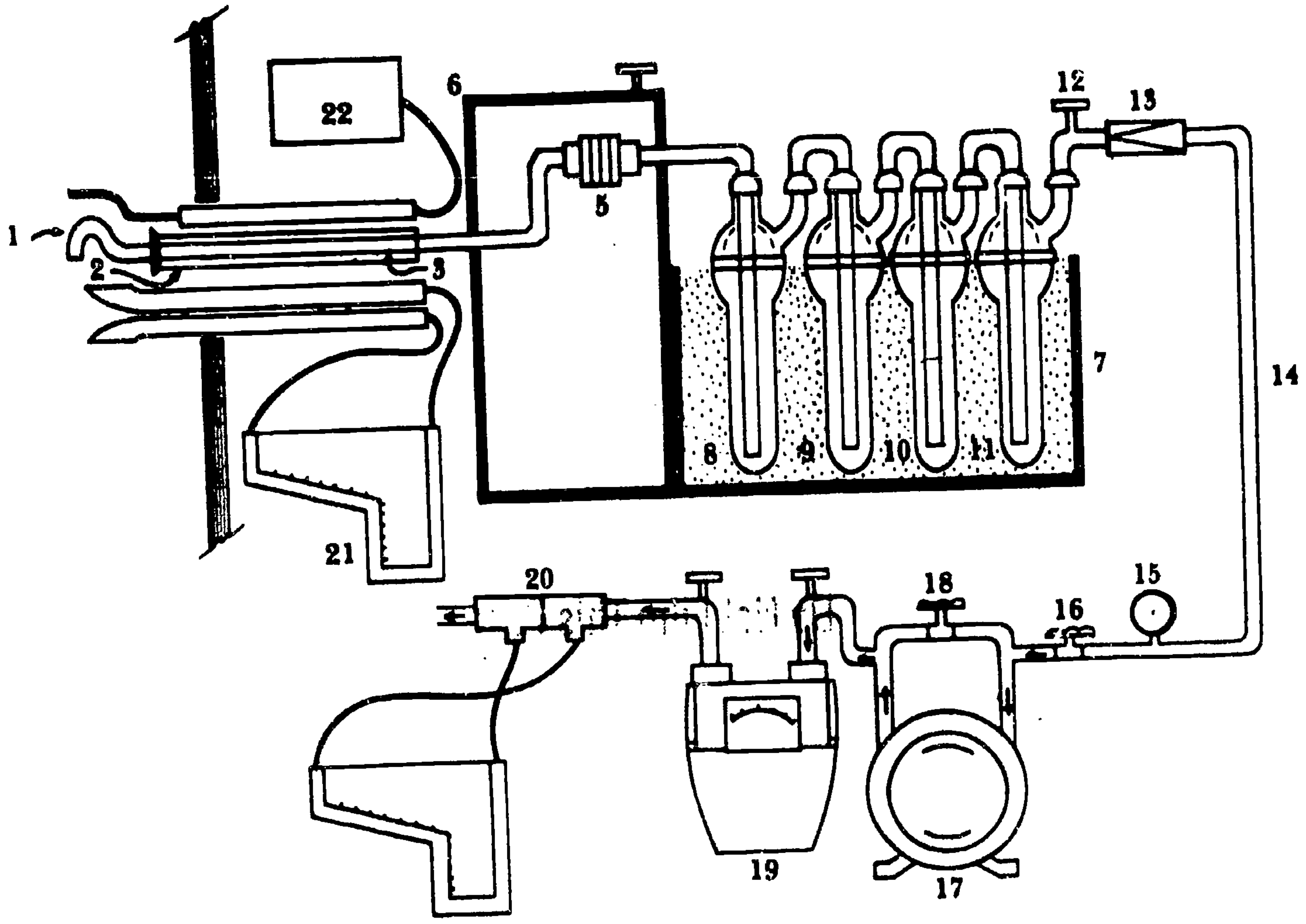
36. A transmissometer will provide information on mass emissions from a pollutant source for a given time period if:

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 .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 H_2O, 2 – Dry, 3 – 100cc H_2O, 4 – Silica Gel (100g)
b. 1 – 100cc H_2O, 2 – 200cc H_2O, 3 – Dry, 4 – Silica Gel (200g)
c. 1 – 100cc H_2O, 2 – 100cc H_2O, 3 – Dry, 4 – Silica Gel (200g)
d. 1 – 200cc H_2O, 2 – 200cc H_2O, 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 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°F
b. $\geq$ 250°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

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 $\Delta H_@$. Solving the orifice meter flow rate equation for a $\Delta H_@$ that meets the stated conditions we find:

a. $\Delta H_@ = \dfrac{Q_m^{\ 2}}{K_m^{\ 2}}$

b. $\Delta H_@ = \dfrac{1}{K_m^{\ 2}}$

c. $\Delta H_@ = \dfrac{0.9244}{K_m^{\ 2}}$

d. $\Delta H_@ = \dfrac{Q_m}{K_m}\left[\dfrac{P_m}{T_m}\right]^2$

ANSWER SHEET

Name ______________________________ **Date** ______________________________

1. a b c d
2. a b c d
3. a b c d
4. a b c d
5. a b c d
6. a b c d
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47. a b c d
48. a b c d