AMBIENT AIR MONITORING REQUIREMENTS

FOR THE

AIR POLLUTION CONTROL DIVISION

OF THE

COLORADO DEPARTMENT OF HEALTH

January 1989

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Introduction

The Air Pollution Control Division (APCD) requires that applicants for Air Pollution Emission Permits provide information sufficient to evaluate a proposed source's impact on existing and future air quality. Air quality data is needed for indicating "baseline" conditions in the project area and as model input in the evaluation of compliance with the applicable State and Federal ambient air quality standards.

Air quality data is also used as a means of determining that the source's control methods are performing as designed, and that exceedances are not occurring. In the case of environmental cleanup actions, air quality data may be collected as part of baseline studies used to determine remedial actions. Data may also be collected during the remedial action itself, to ascertain that control measures are adequately limiting pollutant releases to the environment.

Meteorological data is used for model selection, as a model input, and in the selection of monitoring sites for post-construction monitoring. In areas of the state where little or no air quality or meteorological data is available, the applicant is required to collect it. It is imperative that valid data be collected. The following are the Air Pollution Control Division's requirements for collection and submission of this data. These requirements may be modified only with the approval of the Air Pollution Control Division.

Quality Control and Quality Assurance

The Air Pollution Control Division requires that air quality data meet strict quality control guidelines. In general, the EPA's Prevention of Significant Deterioration data quality guidelines will apply. Data will meet specified limits for percent data recovery, precision and accuracy. Monitoring must be conducted according to EPA reference or equivalent methods. In the case of non-criteria pollutants, the monitoring method is subject to Division approval. Monitors must be sited at locations which represent maximum air quality impacts and are approved by the APCD. Additional monitoring may be required at locations that reflect population exposure. Sites must meet EPA siting criteria.

As a minimum, each quality control program must have operational procedures for each of the following activities:

(1) selection of methods, analyzers, or samplers

(2) training

(3) installation of equipment

(4) selection and control of calibration standards

(5) calibrations

(6) zero and span checks and adjustments of automated analyzers

(7) control checks and their frequency

(8) control limits for zero, span, and other control checks, and respective corrective actions when such limits are surpassed

(9) calibration and zero/span checks for multiple range analyzers

(10) preventative and remedial maintenance

(11) recording and validating data

(12) data quality assessment (precision and accuracy);

(13) documentation of quality control information [1].

These activities must be explained in the monitoring plan.

Appendix D contains a copy of 40 CFR 58, Appendix B, Quality Assurance Requirements for PSD Air Monitoring. This document should serve as basic guidance for all quality control/quality assurance programs submitted to the APCD.

Sections 3.1, 3.3, 4.1, 5.1 of the PSD Quality Assurance Guidelines deal with precision assessments and may not necessarily be mandatory for monitoring required by the APCD.

1. above listing taken from 40 CFR 58, appendix B, March 19, 1986 update.

The calibration and quality assurance procedures for meteorological monitoring instruments that are recommended by the manufacturer and discussed in EPA's Quality Assurance Handbook for Air Pollution Measurement Systems: Volume IV, Meteorological Measurements must be followed. Calibrations and audits should be conducted on a six-month frequency.

Monitoring Plan

All monitoring projects installed as an APCD requirement must be outlined in a monitoring plan and are subject to the written approval of the APCD. The plan must be submitted and approved by the Division prior to the start-up of the monitoring project.

The monitoring plans should be similar to those produced as a PSD requirement. Table 1 is a modified description of the minimum contents for a PSD monitoring plan. This provides a good outline to follow in writing monitoring plans for APCD requirements.

Table I: Minimum Contents of a Monitoring Plan

I. Source Environment Description (within 2 Km of source)

- topographical description
- land-use description
- topographical map of source and environs (including location of existing stationary sources, roadways, and monitoring sites).
- climatological description
- description of site activity (new plant, environmental cleanup, mine, etc).
- nearby population

II. Sampling Program Description

- Time period for which the pollutant(s) will be measured
- rationale for location of monitors (including modeling results and analysis).

III. Monitor Site Description

- Universal transverse mercator (UTM) coordinates or other coordinate designations
- height of sampler (air intake) above ground
- height of meteorological tower, and parameters measured
- distance from obstructions and heights of obstructions
- distance from other sources (stationary and mobile).
- photographs of each site (five photos; one in each cardinal direction looking out from each existing sampler or where a future sampler will be located, and one closeup of each existing sampler or where a future sampler will be located. Ground cover should be included in the closeup photograph).

IV. Methodology Description (also refers to meteorological equipment)

- name of monitor manufacturer
- description of calibration system to be used
- standard operating procedure for calibration
- description of audit system to be used
- standard operating procedure for audit
- type of flow control and flow recorder
- standard operating procedures for filter pad changes
- standard operating procedures for daily instrument checks
- maintenance schedule
- equations used for calculating particulate concentrations and correcting them to standard conditions.

- precision check - method and procedures
- zero-span check-method and procedures, control limits
- filter conditioning and analysis procedures
- calibration of laboratory equipment
- procedures for maintaining NBS traceability

V. Data Reporting

- description of data acquisition system
- type of strip chart recorder and calibration
- procedures for verifying that data is being correctly recorded
- format of data submission
- frequency of data reporting
- procedure for immediate reporting of an exceedance
- chain of custody
- storage of records

VI. Quality Assurance Program

- calibration frequency
- independent quarterly audit program
- internal quality control procedures
- data precision and accuracy calculation procedures
- goal for percentage data recovery
- acceptable audit performance limits
- action taken in response to a failed audit

VI. Personnel

- organizational chart
- division of responsibilities
- training

*Note: major portions of the above outline were taken from "Ambient Monitoring Guidelines for Prevention of Significant Deterioration (PSD) EPA - 450/4-80-012. November 1980.

Additions made by Colorado APCD.

MONITORING

Air Quality

Pollutants to be monitored may include any or all of the pollutants listed below, depending on the emissions and source type associated with the applicant's proposed activity:

1. Sulfur Dioxide, SO_2
2. Total Suspended Particulates, TSP
3. Particulate 10 microns or less in diameter, PM10
4. Nitrogen Dioxide, NO_2
5. Carbon Monoxide, CO
6. Ozone, O_3
7. Lead, Pb
8. Air Toxics and Hazardous Air Pollutants
9. Air Quality Related Values (acid precipitation, vegetation, visibility, etc).

Sources subject to Prevention of Significant Deterioration regulations may be required to monitor the pollutants that are "significant" according to PSD definition. These are basically the pollutants regulated in Regulation 8 (NESHAPS) and Regulation 6 (New Source Performance Standards). Requirements may depend on the availability of a monitoring method.

The Air Pollution Control Division will accept only the Federal Reference and Equivalent methods, for monitoring criteria air pollutants. These methods are approved by the U.S. Environmental Protection Agency and are published in the Federal Register. For cases where a reference method is not available, the monitoring method must be approved by the Division. In addition, quality assurance procedures, similar to those required for PSD monitoring, shall be performed as specified by EPA guidelines.

In the collection of continuous baseline data, the applicant shall collect valid air quality data over at least 75 percent (calibration time, if not unreasonable, counts toward the 75 percent) of each quarter in one full calendar year. All data will be collected in such a way that direct comparison with air quality standards is possible.

The following procedures for monitoring pollutants have been instituted by the State of Colorado in the interest of assuring that the air pollution data collected from all monitoring projects is of a consistent quality. These procedures are designed to supplement the Federal Reference Procedure only, and are in no way intended to alter the methods of sample collection specified in 40 CFR Part 50 appendix B, of the Federal Register.

1. The basic procedure to be followed is specified in the above listed reference. Only EPA - approved methods for the collection of particulates and gaseous data will be sanctioned unless prior written approval has been obtained from the Colorado Department of Health, Air Pollution Control Division.

2. All particulate sites shall be selected so that they are at least two meters, but not more than 15 meters, above ground. Sites shall be oriented in a manner that will minimize the influence of unpaved roads or other obvious point sources. (This is an operational suggestion only, since inappropriate site location with respect to specific sources can adversely affect your data). The sampler shall be free from obstructions in the near vicinity. Gaseous and particulate sites shall be selected so as to meet EPA siting criteria.

3. All particulate samples shall be collected from midnight, Mountain Standard (not daylight) Time, on a schedule that coincides with the State schedule. Monitoring frequency shall be as required by the APCD, and may range from a daily to a one-in-six day frequency. Schedules may be obtained from the Air Pollution Control Division.

4. Particulate sampler calibrations shall be performed: (1) after brush changes: (2) major motor maintenance: (3) change of flow measuring device, if it is subject to variations from unit to unit (rotometers): or (4) at a minimum of once per quarter. All calibrations shall be carried out as specified in the above listed Federal Register. Gaseous calibrations should be conducted after (1) major maintenance or repairs or (2) at a minimum of once per quarter.

   Certain PM10 units shall be calibrated at 40 cfm actual, rather than at a standard flowrate, in order to maintain the cutpoint.

5. The monitoring plan should include a sample of the calculations involved in determining the particulate concentrations (i.e., temperature and pressure corrections, time and flow calculations). It should also include descriptions of calibration and flowrate measurement procedures for both particulate and gaseous pollutants, as well as a description of any precision calculations and equipment used.

6. Evidence that the orifice used in calibration of the particulate sampler has received a primary calibration on an acceptable Roots meter must be submitted to the Air Pollution Control Division at the initiation of a sampling project. Calibration is available through Region VIII EPA, Surveillance and Analysis Section. The APCD requires that this EPA calibration be used, if possible. Gaseous standards must be NBS - traceable, and meet all current EPA traceability requirements.

7. Audit results shall accompany the data as it is submitted to the Air Pollution Control Division for review. An audit shall be conducted on all pollutant samplers, at least once per quarter. Precision results, if required, shall also be submitted.

8. The State may supply an annual quality assurance audit which may include any, or all, of the following, as requested by the contractor.

   a. field flow audit using the State's orifice
   b. laboratory practices review
   c. calibration review
   d. field calibration method review
   e. gaseous accuracy audits

Meteorology

In monitoring meteorology, the applicant shall collect valid data over at least 75 percent of each quarter. Appendix A discusses exposure and siting considerations for meteorological monitoring equipment. Parameters to be monitored may consist of any or all of the following, depending on the size and type of project:

1. Wind speed and Direction - Wind Speed and direction shall be collected at a minimum height of 10 meters above the ground for all proposed sources. For sources that will have emission releases from stacks higher than 10 meters, additional data shall be collected at the proposed stack height. For sources with physical stacks greater than 60 meters, a 60 meter meteorological tower supplemented with upper air data may be used. Data shall be recorded at no greater than 10 - minute intervals and vector averaged by hour.

2. Temperature and Humidity - Data shall be continuously recorded or measured once per hour. Monitor shall be located at "ground level".

3. Atmospheric Stability and Inversion Height
   Low level atmospheric stability may be determined by means of a tower equipped with temperature sensors at various heights, a tethered balloon, a bivane anemometer,or any other method approved by the Air Pollution Control Division.

   Upper air data, where required, shall be collected using a radiosonde for temperature and a theodolite or radio-theodolite for winds or other methods and equipment where applicable and approved by the APCD. The frequency of sampling for upper air data may be limited to 15 days per seasonal quarter, if supplemented with tower data. Upper air samples must be taken at a minimum of twice a day to obtain the maximum and minimum mixing heights.

Atmospheric stability can be measured in a number of ways. The preferred method is to use vertical sigma phi. In order of next preference are the modified sigma theta method, sigma theta, the Pasquill-Gifford method and the lapse rate method. The various methods acceptable to the APCD are explained in Appendix B.

4. <u>Tracer Studies</u> - Tracer studies may be required to determine flow characteristics over rough terrain. They will be required on a case-by-case basis and may be in conjunction with or in place of other monitoring techniques. (See Appendix C for Tracer Test Guidelines for Western Colorado).

Air Quality-Related Values

Any PSD "source which will have or is likely to have an impact on any designated Class I area may be required to conduct monitoring to establish the condition of and impact on air quality related values in such Class I area(s) both prior to completing an application for a permit to construct and during the construction and operation of such source."

(Colorado Air Quality Control Commission Regulation No. 3, Section XIV, Federal Class I Areas).

The Federal Land Manager of the Class I Area shall, together with the Division, determine the parameters to be monitored prior to permit application. Air quality related values of interest to the Division are acid precipitation, visibility, and vegetation. The monitoring methods used for these parameters are subject to Division approval. The maximum amount of AQRV monitoring that may be required is 3 parameters. The Federal Land Manager must also review and approve all monitoring methods.

The U.S. Department of Agriculture Forest Service has prepared a document "Guidelines for Measuring Physical, Chemical, and Biological Conditions of Wilderness Ecosystems" which describes monitoring techniques which may be required by the APCD.

Siting

Monitoring sites shall be located so as to show the actual background conditions or specific source impacts as indicated. A map showing topographic features of the area and the proposed monitoring locations shall be included in the monitoring plan. The specific locations of the equipment shall comply with guidelines as set forth below and in Appendix B.

It is advised that a meeting with APCD personnel be set-up to discuss the instrument siting before plans are finalized. Also, if possible a site visit by APCD personnel is recommended.

Once a secure and accessible area for locating the station has been established, attention must be given to the siting of the monitoring probe. Table 2 presents the recommended probe siting criteria for each of the pollutants of interest. The criteria were selected to standardize siting practice. In addition, it was desired to be as close as possible to the breathing zone without obstructing pedestrian traffic or subjecting the intake of the probe to vandalism. Further, vertical and horizontal distances above supporting structures were specified to minimize the effects of the air stream passing near surfaces where chemical reactions may take place and to avoid situations where unusual micro-meteorological conditions may exist.

Distances from influencing sources were also specified to standardize the effects these sources have on the measurement process. This is essential if a comparable data base is to be developed. Also, distances from vegetation were specified since they can serve as pollutant sinks.

It is important to note that the separation distances shown in Figure 2 are measured from the edge of the nearest traffic lane of the roadway presumed to have the most influence on the site. In general, this presumption is an oversimplification of the usual urban settings which normally have several streets that impact a given site. The effects of surrounding streets, wind speed, wind direction and topography should be considered along with Figure 2 before a final decision is made on the most appropriate spatial scale assigned to the sampling station.

8.4 *Other Considerations.* For those areas that are primarily influenced by stationary source emissions as opposed to roadway emissions, guidance in locating these areas may be found in the guideline document Optimum Network Design and Site Exposure Criteria for Particulate Matter.[29]

Stations should not be located in an unpaved area unless there is vegetative ground cover year round, so that the impact of wind blown dusts will be kept to a minimum.

e. Section 8 "Probe Material and Pollutant Sample Residence Time" is redesignated as section 9.

f. Section 9 "Waiver Provisions" is redesignated as section 10.

g. Section 10 "Discussion and Summary" is redesignated as section 11; the Table 5 therein is revised to read as follows:

11. Discussion and Summary.

* * * * *

TABLE 5.—SUMMARY OF PROBE SITING CRITERIA

Pollutant	Scale	Height above ground, meters	Distance from supporting structure, meters		Other spacing criteria
			Vertical	Horizontal[a]	
SO_2	All	3–15	>1	>1	1. Should be >20 meters from the dripline and must be 10 meters from the dripline when the tree(s) act as an obstruction. 2. Distance from inlet probe to obstacle, such as buildings, must be at least twice the height the obstacle protrudes above the inlet probe.[b] 3. Must have unrestricted airflow 270° around the inlet probe, or 180° if probe is on the side of a building. 4. No furnace or incinerator flues should be nearby.[c]
CO	Micro	3±½	>1	>1	1. Must be >10 meters from street intersection and should be at a midblock location. 2. Must be 2–10 meters from edge of nearest traffic lane. 3. Must have unrestricted airflow 180° around the inlet probe.
	Middle Neighborhood	3–15	>1	>1	1. Must have unrestricted airflow 270° around the inlet probe, or 180° if probe is on the side of a building. 2. Spacing from roads varies with traffic (see Table 1).
O_3	All	3–15	>1	>1	1. Should be >20 meters from the dripline and must be 10 meters from the dripline when the tree(s) act as an obstruction. 2. Distance from inlet probe to obstacle, such as buildings, must be at least twice the height the obstacle protrudes above the inlet probe.[b] 3. Must have unrestricted airflow 270° around the inlet probe, or 180° if probe is on the side of a building. 4. Spacing from roads varies with traffic (see Table 2).
NO_2	All	3–15	>1	>1	1. Should be >20 meters from the dripline and must be 10 meters from the dripline when the tree(s) act as an obstruction. 2. Distance from inlet probe to obstacle, such as buildings, must be at least twice the height the obstacle protrudes above the inlet probe.[b] 3. Must have unrestricted airflow 270° around the inlet probe, or 180° if probe is on the side of a building. 4. Spacing from roads varies with traffic (see Table 3).
Pb	Micro	2–7	—	>2	1. Should be >20 meters from the dripline and must be 10 meters from the dripline when the tree(s) act as an obstruction. 2. Distance from sampler to obstacle, such as buildings, must be at least twice the height the obstacle protrudes above the sampler.[b] 3. Must have unrestricted airflow 270° around the sampler except for street canyon sites. 4. No furnace or incineration flues should be nearby.[c] 5. Must be 5 to 15 meters from major roadway.

TABLE 5.—SUMMARY OF PROBE SITING CRITERIA—Continued

Pollutant	Scale	Height above ground, meters	Distance from supporting structure, meters		Other spacing criteria
			Vertical	Horizontal[d]	
	Middle, neighborhood, urban and regional.	2–15	—	>2	1. Should be >20 meters from the dripline and must be 10 meters from the dripline when the tree(s) act as an obstruction. 2. Distance from sampler to obstacle, such as buildings, must be at least twice the height the obstacle protrudes above the sampler.[b] 3. Must have unrestricted airflow 270° around the sampler. 4. No furnace or incineration flues should be nearby.[c] 5. Spacing from roads varies with traffic (see Table 4).
PM₁₀	Micro	2–7	—	>2	1. Should be >20 meters from the dripline and must be 10 meters from the dripline when the tree(s) acts as an obstruction. 2. Distance from sampler to obstacle, such as buildings, must be at least twice the height the obstacle protrudes above the sampler except for street canyon sites.[b] 3. Must have unrestricted airflow 270° around the sampler except for street canyon sites. 4. No furnace or incineration flues should be nearby 5. Spacing from roads varies with traffic (see Figure 2) except for street canyon sites which must be from 2 to 10 meters from the edge of the nearest traffic lane.
	Middle, neighborhood urban and regional scale.	2–15	—	>2	1. Should be >20 meters from the dripline and must be 10 meters from the dripline when the tree(s) act as an obstruction. 2. Distance from sampler to obstacle, such as buildings, must be at least twice the height the obstacle protrudes above the sampler.[b] 3. Must have unrestricted airflow 270° around the sampler. 4. No furnace or incineration flues should be nearby.[c] 5. Spacing from roads varies with traffic (see Figure 2).

[a] When probe is located on rooftop, this separation distance is in reference to walls, parapets, or penthouses located on the roof.
[b] Sites not meeting this criterion would be classified as middle scale (see text).
[c] Distance is dependent on height of furnace or incineration flues, type of fuel or waste burned, and quality of fuel (sulfur, ash or lead content). This is to avoid undue influences from minor pollutant sources.

h. Section 11, *References*, is redesignated as section 12, and the list of references is amended by adding references 29 and 30 as follows:

12. *References.*

* * * * *

29. Koch, R.C. and H.E. Rector. Optimum Network Design and Site Exposure Criteria for Particulate Matter, GEOMET Technologies, Inc., Rockville, MD. Prepared for U.S. Environmental Protection Agency, Research Triangle Park, NC. EPA Contract No. 68–02–3584. EPA 450/4–87–009. May 1987.

30. Burton, R.M. and J.C. Suggs. Philadelphia Roadway Study. Environmental Monitoring Systems Laboratory, U.S. Environmental Protection Agency, Research Triangle Park, N.C. EPA–600/4–84–070 September 1984.

Appendix F—[Amended]

SLAMS reports

14. Appendix F is amended as follows:

a. The following is added to the end of the table of contents:

2.7 Particulate Matter (PM_{10})
2.7.1 Site and Monitoring Information
2.7.2 Annual Summary Statistics

b. In section 2.2, the title is revised, subparagraph 2.2.2 is revised, and subparagraph 2.2.3 is added to read as follows:

2.2 *Total Suspended Particulates (TSP)*

* * * * *

2.2.2 *Annual Summary Statistics.* Annual arithmetic mean ($\mu g/m^3$) as specified in Appendix J of Part 50. Daily TSP values exceeding the level of the 24-hour PM_{10} NAAQS and dates of occurrence. If more than 10 occurrences, list only the 10 highest daily values. Sampling schedule used such as once every six days, once every three days, etc. Number of additional sampling days beyond sampling schedule used. Number of 24-hour average concentrations in ranges:

Range:	Number of values
0 to 50 ($\mu g/m^3$)	
51 to 100	
101 to 150	
151 to 200	
201 to 250	
251 to 300	
301 to 400	
Greater than 400	

2.2.3 *Episode and Other Unscheduled Sampling Data.* List episode measurements, other unscheduled sampling data, and dates of occurrence. List the regularly scheduled sample measurements and date of occurrence that preceded the episode or unscheduled measurement.

c. Section 2.7 is added to read as follows:

2.7 *Particulate Matter (PM_{10})*

2.7.1 *Site and Monitoring Information.* City name (when applicable), county name, and street address of site location. SAROAD site code. Number of daily observations.

2.7.2 *Annual Summary Statistics.* Annual arithmetic mean ($\mu g/m^3$) as specified in Appendix K of Part 50. All daily PM_{10} values above the level of the 24-hour PM_{10} NAAQS and dates of occurrence. Sampling schedule used such as once every six days, once every three days, etc. Number of additional sampling days beyond sampling schedule used. Number of 24-hour average concentrations in ranges:

DATA REPORTING

Air quality data will be submitted to the APCD on a quarterly (seasonal) basis. All data reported will be presented in the formats shown in Figures 1 and 2, unless prior arrangements have been made with the APCD. All quarterly data will be submitted within forty-five (45) days of the end of the quarter. Each quarterly report should include audit results, calibration records and the reasons for excessive (greater than three(3) days) down time periods. Instrument testing information, as well as copies of instrument maintenance logs will be submitted upon request.

At the end of a year of monitoring, a summary report utilizing all valid air quality and meteorological data will be submitted to the APCD. This report will contain an evaluation of the data as well as a summary. Summary reports are due within 45 days of the end of the year or at the time a permit is applied for, whichever comes first. The air quality summary data should include:

a. Statistical evaluation indicating the first 5 maximums and percentile rankings.

b. Indicate any suspect data that cannot be discounted.

The format should follow the example in figure 3.

The annual meteorological data should include:

a. Joint frequency distribution by stability class (STAR program output).

b. List of the top five "worst case" days by hour giving the meteorological data for each hour. What meteorological data constitutes a "worst-case" day will vary according to the sources. Generally, persistent wind direction and low wind speeds lead to worst-case conditions. For low-level sources (ground-level to 10m) stabilities D thru F will cause the highest impacts. For elevated sources (above 30m), stabilities A thru D will generally cause the highest impacts, unless there is elevated terrain nearby. Dispersion modeling is the most reliable method of obtaining worst-case days. Contact APCD if assistance is needed in this determination.

AQCR: 003 AGENCY(F): STATE COLLECT METH: INSTRUMENTAL SLAMS/NAMS(3): OTHER/NOT CLASSIFIED
CNTY: 0080 PROJECT(01): POPULATION-ORIENTED SURV. ANALYSIS METH: ULTRAVIOLET ABSORPTION RPT AGNCY/SMSA: /
AREA: 0080 PARM(44201): OZONE SAMPLING INTR: 01 HOURS UTM ZONE:
SITE: 002 UNITS(07): PARTS PER MILLION (VOL/VOL) SAROAD KEY: 06/0080/002/F/01 UTM EASTING:
YEAR: 1987 MONTH(01): JANUARY MINIMUM DETEC: .01 UTM NORTHING:
LOCALE: 8100 S. UNIVERSITY HIGHLAND RES. ARAPAHOE TIME ZONE( ):

FEDERAL STANDARD PRIMARY 235 UG/M3 (25 C) 0.12 PPM 1 HR. MAX, 1 PER YR. SECONDARY 235 UG/M3 (25 C) 0.12 PPM 1 HR. MAX, 1 PER YR.

HOUR

DAY	12	13	14	15	16	17	18	19	20	21	22	23	NO.	MEAN	MAX
01	0.033	0.038	0.033	0.028	0.017	0.018	0.023	0.016	0.011	0.015	0.004	0.008	24	.0225	0.039
02	0.009	0.012	0.010	0.016	0.017	0.015	0.014	0.015	0.010	0.003	0.008	0.013	24	.0117	0.029
03	0.031	0.030	0.022	0.024	0.024	0.025	0.028	0.033	0.036	0.035	0.029	0.033	24	.027	0.037
04	0.036	0.035	0.034	0.032	0.025	0.030	0.030	0.029	0.031	0.034	0.035	0.037	24	.0339	0.040
05	0.029	0.029	0.027	0.022	0.013	0.000	0.000	0.000	0.016	0.020	0.017	0.013	24	.0274	0.067
06	0.024	0.025	0.025	0.024	0.022	0.014	0.006	0.009	0.014	0.014	0.012	0.012	24	.0151	0.025
07	0.016	0.013	0.006	0.003	0.005	0.012	0.003	0.000	0.000	0.000	0.000	0.000	24	.0062	0.016
08	0.013	0.020	0.025	0.017	0.011	0.007	0.014	0.004	0.002	0.002	0.003	0.002	24	.0071	0.025
09	0.005	0.009	0.015	0.014	0.006	0.000	0.000	0.000	0.000	0.000	0.000	0.000	23	.0183	0.088
10	0.004	0.005	0.006	0.004	0.004	0.001	0.007	0.012	0.014	0.014	0.016	0.016	24	.0102	0.017
11	0.009	0.008	0.008	0.007	0.006	0.000	0.000	0.001	0.004	0.006	0.007	0.008	24	.011	0.020
12	0.006	0.005	0.005	0.005	0.006	0.000	0.000	0.000	0.000	0.001	0.003	0.006	24	.0057	0.011
13	0.005	0.005	0.003	0.004	0.004	0.000	0.000	0.000	0.000	0.000	0.000	0.000	24	.0048	0.011
14	0.012	0.014	0.013	0.012	0.011	0.003	0.001	0.000	0.000	0.000	0.002	0.006	24	.0044	0.014
15	0.000	0.004	0.005	0.005	0.005	0.000	0.000	0.000	0.000	0.000	0.000	0.000	24	.0041	0.011
16	0.005	0.000	0.006	0.006	0.006	0.002	0.002	0.002	0.002	0.002	0.002	0.002	24	.0027	0.006
17	0.007	0.009	0.009	0.009	0.004	0.000	0.000	0.001	0.006	0.009	0.010	0.011	24	.0043	0.011
18	0.009	0.006	0.006	0.006	0.006	0.000	0.000	0.000	0.000	0.000	0.000	0.002	24	.0097	0.020
19	0.010	0.010	0.012	0.011	0.010	0.002	0.001	0.000	0.000	0.000	0.000	0.000	24	.0061	0.012
20	0.012	0.011	0.009	0.005	0.004	0.000	0.000	0.000	0.005	0.008	0.010	0.009	24	.0065	0.012
21	0.013	0.017	0.015	0.016	0.014	0.003	0.000	0.000	0.000	0.000	0.000	0.001	24	.0063	0.017
22	0.009	0.011	0.012	0.007	0.010	0.001	0.005	0.011	0.006	0.003	0.001	0.005	24	.008	0.013
23	0.005	0.005	0.005	0.005	0.005	0.000	0.000	0.000	0.000	0.000	0.000	0.000	24	.0032	0.006
24	0.013	0.017	0.012	0.009	0.012	0.001	0.000	0.000	0.000	0.000	0.000	0.000	24	.0043	0.017
25	0.008	0.012	0.015	0.011	0.015	0.010	0.007	0.003	0.000	0.000	0.000	0.000	24	.0102	0.018
26	0.011	0.011	0.012	0.014	0.018	0.010	0.007	0.006	0.005	0.002	0.002	0.002	24	.0063	0.018
27	0.004	0.005	0.007	0.009	0.010	0.003	0.007	0.010	0.011	0.010	0.008	0.009	24	.0062	0.011
28	0.006	0.006	0.007	0.010	0.008	0.002	0.003	0.009	0.014	0.023	0.023	0.022	24	.0123	0.023
29	0.015	0.021	0.017	0.014	0.009	0.000	0.003	0.006	0.007	0.007	0.005	0.000	24	.0105	0.024
30	0.005	0.006	0.007	0.008	0.004	0.000	0.000	0.000	0.000	0.000	0.000	0.000	24	.0045	0.013
31	0.004	0.008	0.013	0.010	0.008	0.001	0.002	0.000	0.000	0.000	0.000	0.000	24	.0047	0.013
NO	31	31	31	31	31	31	31	31	31	31	31	31	743		
MEAN	.0118	.0131	.0129	.0118	.0102	.0051	.0052	.0053	.0062	.0067	.0063	.007		.0102	
MAX	0.036	0.038	0.034	0.032	0.025	0.030	0.030	0.033	0.036	0.035	0.035	0.037			0.088

AQCR: 003 AGENCY(F): STATE
CNTY: 0080 PROJECT(01): POPULATION-ORIENTED SURV.
AREA: 0080 PARM(44201): OZONE
SITE: 002 UNITS(07): PARTS PER MILLION (VOL/VOL)
YEAR: 1987 MONTH(01): JANUARY

COLLECT METH: INSTRUMENTAL
ANALYSIS METH: ULTRAVIOLET ABSORPTION
SAMPLING INTR: 01 HOURS
SAROAD KEY: 06/0080/002/F/01
MINIMUM DETEC: .01

SLAMS/NAMS(3): OTHER/NOT CLASSIFIED
RPT AGNCY/SMSA: /
UTM ZONE:
UTM EASTING:
UTM NORTHING:

LOCALE: 8100 S. UNIVERSITY HIGHLAND RES. ARAPAHOE TIME ZONE( ):

FEDERAL STANDARD PRIMARY 235 UG/M3 (25 C) 0.12 PPM 1 HR. MAX, 1 PER YR. SECONDARY 235 UG/M3 (25 C) 0.12 PPM 1 HR. MAX, 1 PER YR.

HOUR

DAY	00	01	02	03	04	05	06	07	08	09	10	11
01	0.000	0.006	0.014	0.023	0.025	0.027	0.026	0.029	0.034	0.038	0.039	0.036
02	0.002	0.012	0.004	0.017	0.029	0.028	0.020	0.006	0.002	0.003	0.007	0.010
03	0.010	0.014	0.016	0.019	0.021	0.023	0.026	0.031	0.035	0.037	0.036	0.031
04	0.038	0.031	0.021	0.028	0.037	0.039	0.039	0.040	0.039	0.039	0.038	0.038
05	0.047	0.067	0.038	0.037	0.039	0.038	0.037	0.033	0.037	0.035	0.034	0.031
06	0.009	0.022	0.017	0.016	0.014	0.003	0.000	0.008	0.013	0.017	0.021	0.022
07	0.011	0.013	0.013	0.008	0.001	0.000	0.000	0.003	0.005	0.011	0.013	0.015
08	0.000	0.000	0.000	0.001	0.002	0.005	0.001	0.005	0.006	0.007	0.010	0.015
09	0.035	0.040	0.088	0.087	0.074	0.034	0.004	0.004	0.004	0.002	COLL	0.000
10	0.002	0.008	0.013	0.015	0.016	0.017	0.016	0.017	0.016	0.013	0.006	0.004
11	0.017	0.019	0.019	0.018	0.018	0.017	0.018	0.020	0.018	0.015	0.012	0.011
12	0.007	0.011	0.010	0.010	0.009	0.010	0.008	0.006	0.005	0.008	0.010	0.008
13	0.006	0.007	0.007	0.008	0.009	0.011	0.010	0.009	0.006	0.010	0.008	0.005
14	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.003	0.006	0.004	0.009	0.010
15	0.007	0.010	0.011	0.010	0.009	0.008	0.005	0.005	0.005	0.006	0.005	0.000
16	0.000	0.000	0.000	0.000	0.000	0.001	0.001	0.004	0.006	0.005	0.006	0.006
17	0.001	0.001	0.001	0.001	0.001	0.001	0.000	0.004	0.005	0.004	0.004	0.006
18	0.012	0.014	0.015	0.015	0.017	0.017	0.017	0.020	0.020	0.018	0.017	0.016
19	0.003	0.005	0.005	0.005	0.007	0.008	0.008	0.009	0.008	0.010	0.012	0.012
20	0.000	0.004	0.008	0.009	0.008	0.010	0.006	0.004	0.010	0.009	0.008	0.009
21	0.010	0.011	0.008	0.002	0.006	0.006	0.003	0.004	0.005	0.004	0.004	0.010
22	0.007	0.011	0.011	0.012	0.012	0.012	0.005	0.003	0.005	0.011	0.013	0.009
23	0.004	0.006	0.005	0.003	0.004	0.006	0.002	0.004	0.005	0.005	0.004	0.005
24	0.000	0.000	0.000	0.000	0.000	0.001	0.005	0.010	0.010	0.005	0.004	0.005
25	0.010	0.009	0.012	0.015	0.018	0.018	0.009	0.017	0.017	0.018	0.012	0.011
26	0.002	0.004	0.001	0.003	0.003	0.002	0.002	0.005	0.007	0.007	0.008	0.009
27	0.002	0.004	0.008	0.009	0.009	0.008	0.002	0.002	0.003	0.003	0.004	0.004
28	0.012	0.012	0.016	0.016	0.016	0.015	0.013	0.010	0.008	0.015	0.017	0.014
29	0.024	0.020	0.019	0.016	0.014	0.015	0.007	0.002	0.003	0.006	0.011	0.013
30	0.000	0.000	0.000	0.005	0.007	0.007	0.007	0.008	0.011	0.013	0.012	0.008
31	0.000	0.001	0.008	0.007	0.009	0.008	0.007	0.010	0.008	0.004	0.003	0.004
NO	31	31	31	31	31	31	31	31	31	31	30	31
MEAN	.0089	.0116	.0125	.0133	.014	.0127	.0098	.0108	.0116	.0123	.0129	.0121
MAX	0.047	0.067	0.088	0.087	0.074	0.039	0.039	0.040	0.039	0.039	0.039	0.038

FIGURE 2

AIR QUALITY DATA REPORT

AGENCY: STATE | STATE: COLORADO | PROJECT: POPULATION-ORIENTED SURV.

PARAMETER: TOTAL SUSPENDED PARTICULATE | UNITS: U-GMS/M3 (25 DEG C,1013 M-BARS | AREA CODE: 0920

COLLECTION METHOD: HI-VOL | ANALYSIS METHOD: GRAVIMETRIC

SAMPLING INTERVAL: DAILY | SITE: 46. GLENWOOD SPGS. - 8TH & COLORADO AVE. - GARFIELD | YEAR: 1980

TYPE	PRIMARY STANDARD(S)	SECONDARY STANDARD(S)
FEDERAL	75 UG/M3 (25 C) ANNUAL GEOMETRIC MEAN	60 UG/M3 (25 C) ANNUAL GEOMETRIC MEAN

MONTH

DAY	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	NO.	MEAN	MAX
01					32			60			80		3	57	80
02	64		136			66			41				4	76	136
03		79		105								175	3	119	175
04										75			1	75	75
05					41			44			102		3	62	102
06	87		56			108			32				4	70	108
07		52		30								55	3	45	55
08										116			1	116	116
09					30			90			117		3	79	117
10	50		43			71			30				4	48	71
11		126		51								60	3	79	126
12							97			50			2	73	97
13					42						67		2	54	67
14	44		136			78			51				4	77	136
15		54		92								106	3	84	106
16										28			1	28	28
17					37			47			82		3	55	82
18	35		102			78			71				4	71	102
19		75		85								134	3	98	134
20							175			94			2	134	175
21					67			51			93		3	70	93
22	203		103			87			54				4	111	203
23		62		56								109	3	75	109
24							58			84			2	71	84
25					104			23			64		3	63	104
26	86		33			76			68				4	65	86
27		199		57								133	3	129	199
28							56			76			2	66	76
29					62			47			61		3	56	62
30	56		45			51			69				4	55	69
31												106	1	103	106
NO	8	7	8	7	8	8	4	7	8	7	8	8	88		
MEAN	78	92	81	68	51	76	96	51	52	74	83	109		75	
MAX	203	199	136	105	104	108	175	90	71	116	117	175			203

P1TDB-03

FIGURE 3

STATISTICAL ANALYSIS

AGENCY: STATE — STATE-AREA: 06-0920 — PERIOD: 80/01/01 TO 80/12/31

STATE: COLORADO — PROJECT: POPULATION-ORIENTED SURV. — METHOD: HI-VOL

SITE: 46. GLENWOOD SPGS. - 8TH & COLORADO AVE - GARFIELD — ANALYSIS: GRAVIMETRIC

PARAMETER: TOTAL SUSPENDED PARTICULATE — SAMPLING INTERVAL: DAILY — UNITS: U-GMS/M3 (25 DEG C,1013 M-BARS

TYPE	PRIMARY STANDARD(S)	SECONDARY STANDARD(S)
FEDERAL	75 UG/M3 (25 C) ANNUAL GEOMETRIC MEAN	60 UG/M3 (25 C) ANNUAL GEOMETRIC MEAN

SITE NUM	NUM OBS	MIN OBS	10	25	50	75	90	95	96	97	98	99	MAX OBS
			PERCENTILES										
001	88	23.	35.	51.	67.	94.	126.	136.	175	175.	193.	199.	203.

HIGH READINGS (2)	HIGH READINGS (3)	PERCENT ACTUAL	ARITH MEAN	STD DEV	GEO MEAN	GEO DEV
199.	175.	24.1	75.72	37.12	67.98	1.59

VALUES SUM = 6663.00000000
VALUES SQUARED SUM = 624359.00000000
LOGS SUM = 371.28979492
LOGS SQUARED SUM = 1585.42041016

REDUCTION IN MONITORING AND REPORTING REQUIREMENTS

The Air Pollution Control Division (APCD) may consider a reduction of the monitoring and reporting requirements after a review of the first year's Quarterly and Annual Data Summary Reports.

USE OF PARTIAL YEAR DATA

"In general, the continuous air quality monitoring data that is required under subparagraph c or the preapplication monitoring of air quality related values required by Section XIV.B, shall have been gathered over a period of one year and shall represent the year preceding receipt of the application, except that the Division may determine that a complete and adequate analysis can be accomplished over a period shorter than one year (but not to be less than four months): or (2) by the use of existing representative air quality data. When existing background ambient air levels of a pollutant are reasonably estimated to be small and a monitoring network would not reliably measure the predicted background concentrations, the Division has the discretion to not require a source owner or operator to generate preconstruction monitoring data for that pollutant." (Regulation III.IV.D,3,a(iii(D).

If partial year data is gathered, it should represent the season(s) of maximum expected pollutant impact. These time periods vary from pollutant to pollutant. Maximum seasons also vary from location to location, according to sources impacting that area. Therefore, projects wishing to collect partial year data must first consult with the Division concerning the location and monitoring duration of any project.

UTILIZATION OF DATA COLLECTED BY OTHERS

In many instances, historical data has been or is being collected within the general area of the applicant's proposed project. It may be possible to utilize the historical data if it can be demonstrated that the data accurately represents the actual background conditions of the site of the proposed project. Use of historical data requires prior approval by the Air Pollution Control Division and may be conditioned upon the applicant's demonstrating the necessary correlations by conducting a short-term, but extensive, monitoring program. Such programs shall be planned on project-by-project basis prior to commencement of monitoring. The criteria for determining whether data is "representative" is listed below.

"REPRESENTATIVE" DATA POLICY

In the case of PSD or other permits, the State has the discretion to accept data collected in other locations as "representative" of a site. This policy states the factors that effect the state's decision in moving to accept or reject claims of representativeness. All determinations will be made on a case by case basis.

Quality Assurance

The quality assurance of the data set must be commensurate with that which would be required of an on-site data collection effort. Example: A data set proposed for a PSD monitoring exemption must meet PSD requirements. Records of quality control and the data recovery level must be acceptable.

Currentness

The data set must have been collected recently. Generally, this would mean within the past five years. In any case, if new major sources have located in the area since the data was collected, it might not be representative, and a new data base would be required.

Topography

The topography of the area where the data was originally collected should be similar to the project area. For example, data collected on the plains would not be representative of a river valley or mountainous area.

Population Centers

The relationship to population centers should be similar for the two sites. For example, rural data is not acceptable for an edge-of-town or in-town situation. Data collected in a small town is not acceptable for a city situation.

Pollutant Scale

The nature of the pollutant involved also affects the decision. Some pollutants, such as ozone, have similar levels on a region-wide scale. Others, such as CO, may vary widely within a small geographic area.

Sources

Proximity to sources, and the nature of those sources, must be similar for the two sites.

Meteorology

The meteorology of the project site must be comparable to that of the monitoring site. Factors such as elevation, precipitation, predominant wind direction, stabilities, and wind speeds should be similar.

APPENDIX A

GUIDELINES FOR LOCATING METEOROLOGICAL INSTRUMENTS

Exposure of Instruments

Ronald C. Hilfiker

Exposure of Surface Instruments

INTRODUCTION

Exposure of instrumentation is undoubtedly one of the most important steps in any air pollution study. It is absolutely necessary to locate the instrumentation in such a manner that the measurements are representative of the area in which one is interested. In some cases, such as street level measurements in a city, it is desirable to obtain measurements of extremely local phenomena, but generally in air pollution meteorology, measurements that are representative of a fairly large area are desired. In this latter case, extreme care must be taken to ensure that the parameter being measured is not influenced by nearby obstacles.

An example of the effect of a building on regional wind flow is shown in Figure 1. Figure 1a shows two identical aerovanes mounted on a tower approximately 20 feet south of a 12 foot high building. The only difference in exposure between the two aerovanes is the 6 foot difference in height. It can be seen from Figure 1b that when the wind is blowing from the west, both sensors are apparently free of building influence, with both wind traces indicating typical mechanical type turbulence. However, when the wind shifts to the north-west, the turbulence characteristics change markedly in the wind flow being sensed by the Bendix aerovane at the 6 foot level. At the 12 foot level, the Belfort aerovane continues to indicate typical mechanical type turbulence. Which trace is indicative of the regional wind flow? It is the purpose of this chapter to explore the concepts needed to answer this question.

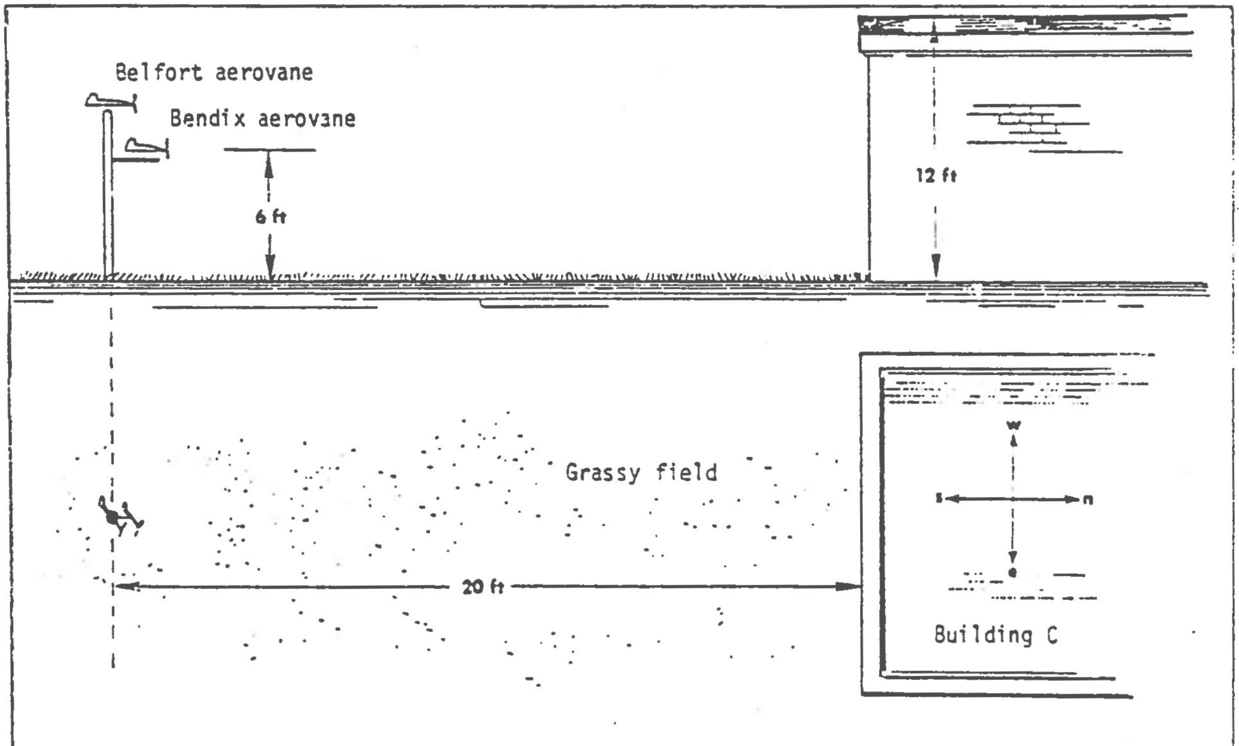
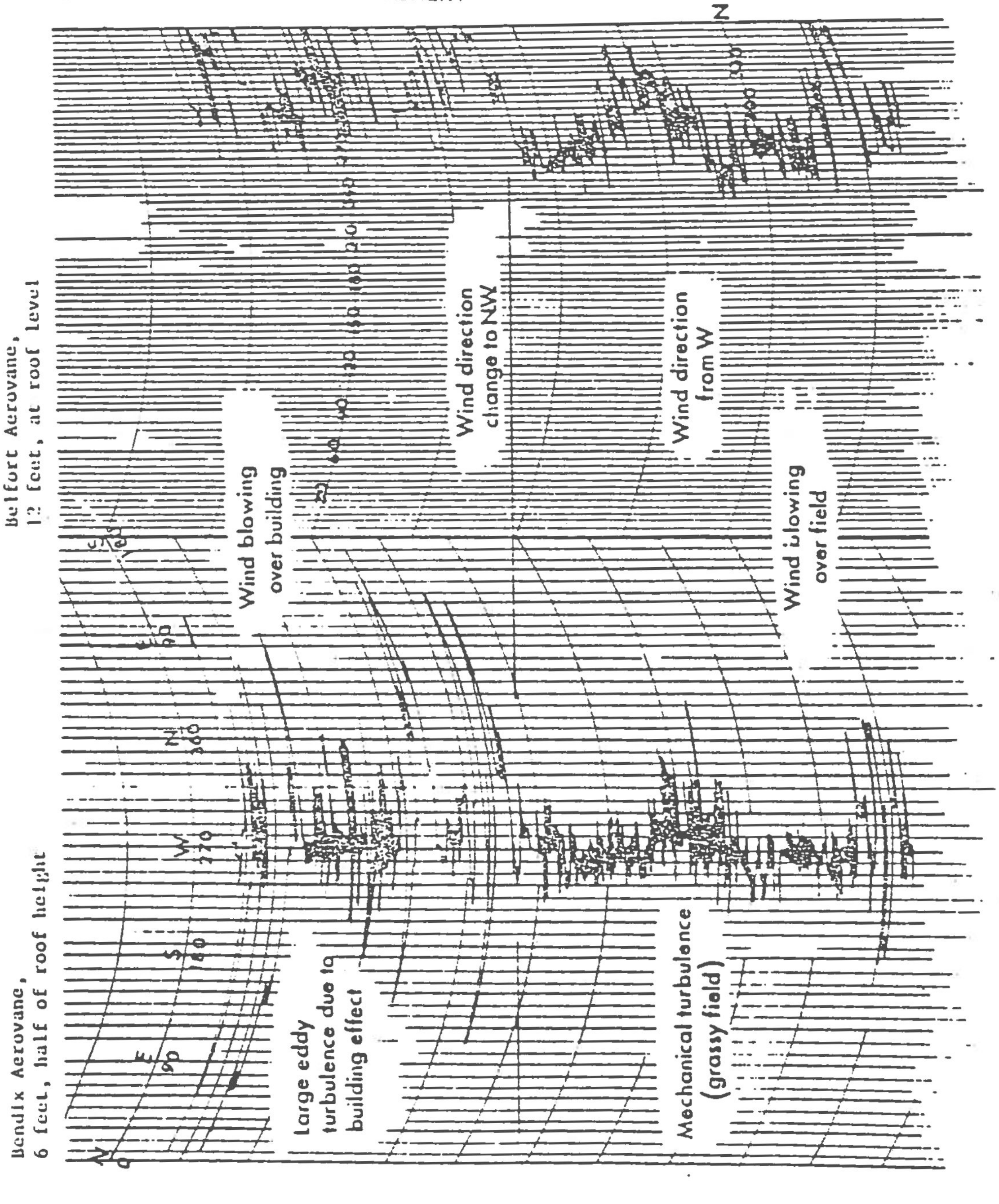


Figure 1 Location of wind equipment that produced the traces of figure 1b

Ronald C. Hilfker
Regional Meteorologist
EPA Region I
Boston, Massachusetts 02203

PA.ME.mm.13b.9.71

EXPOSURE OF INSTRUMENT



Wind trace produced by the Aerovane of Figure 1.

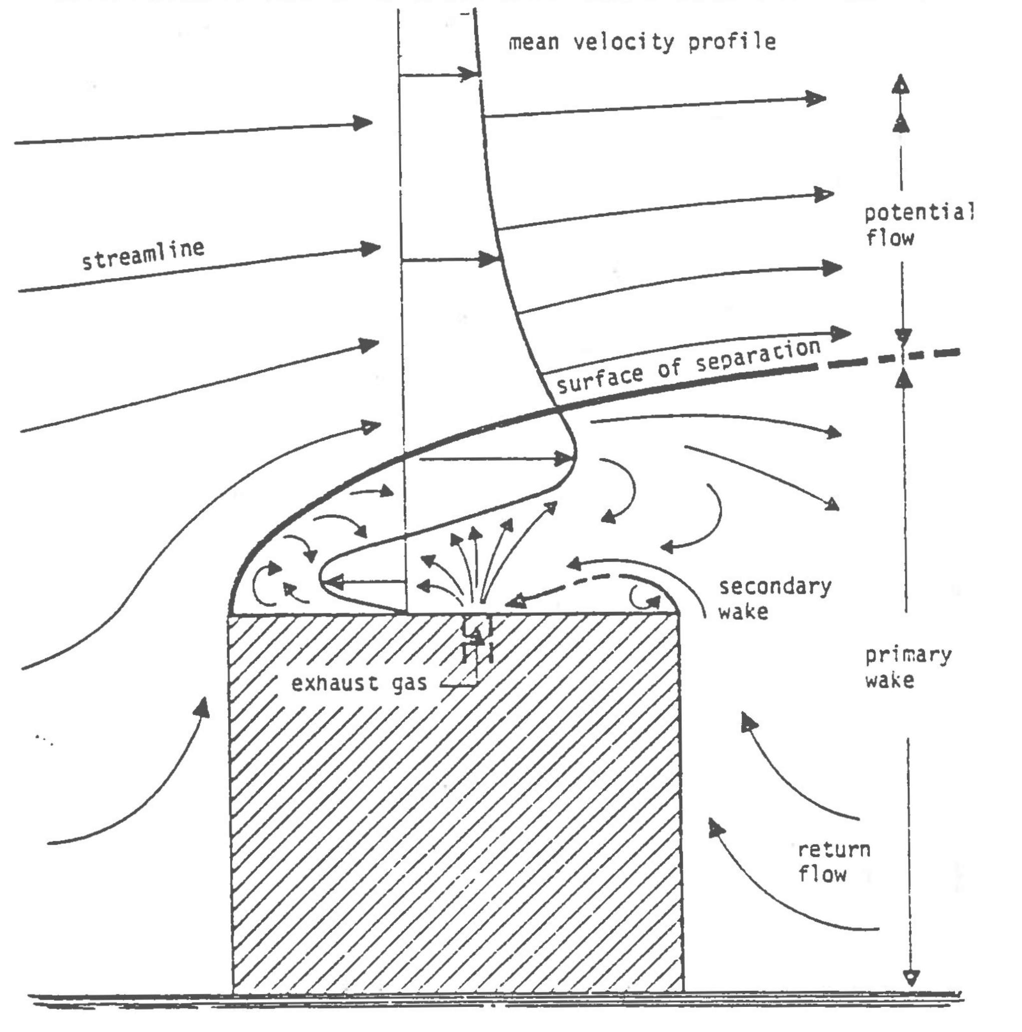


Figure 2 Typical flow pattern around a cube with one face to the wind

ANEMOMETERS AND WIND VANES

In recent years, an attempt has been made at standardizing the height above ground at which "surface wind" measurements will be taken. The World Meteorological Organization (WMO) and the National Oceanic and Atmospheric Administration (NOAA) have agreed on 10 meters for this standard height. Ideally the measurements would be taken over level, open terrain, but very rarely do these conditions exist in an air pollution survey area. What rules of thumb or guidelines can be followed if obstructions are present in the vicinity of the spot where wind measurements are to be taken?

Figure 2 illustrates a typical flow pattern around a cube that has one face normal to the wind flow. From Figure 2 several things can be noted:

1) The flow is disturbed on the upwind and downwind sides of the obstruction.

2) The flow is disturbed above the building to a height of about 1 to 1 1/2 building heights above the roof.

3) Very near the roof of the building a reverse flow occurs.

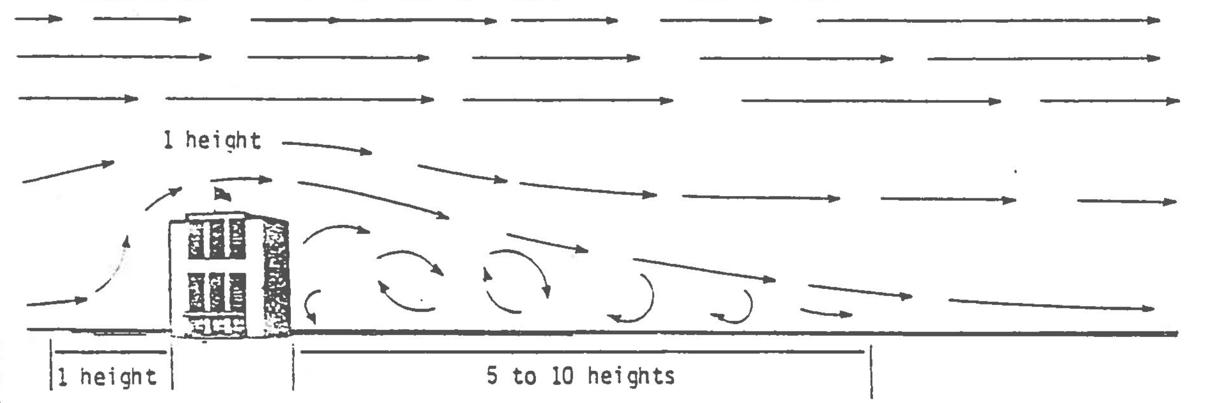


Figure 3 Building effect on wind

Figure 3 shows a more extensive view of the disruption in the ambient air flow around an obstruction. From Figure 3, one can formulate three rules of thumb for locating a wind system around an obstruction while keeping the sensor located in the ambient air flow:

1) The sensor must be located a distance upwind of the building equal to the building height.

2) If the sensor is to be located on the roof of the building it must be at least one building height above the roof.

3) The sensor must be located a distance of 5 to 10 building heights in the downwind direction.

These guidelines would apply most directly to a cubical obstruction standing by itself on open, level terrain. As the shape of the obstruction changes or as more obstructions become involved, the problem becomes much more complex. For example, suppose that it is desired to make measurements of the ambient air flow in the downtown area of a large city. Most probably the above guidelines could not be met because of the close proximity of the obstructions in a downtown area. A modification of these guidelines must be used. The sensor should be mounted on the roof of the tallest structure available, a distance above the roof determined by the proximity of taller buildings (using Guidelines 1 and 3), and the height of the building above the surrounding structures (utilizing Guideline 2). The exact height at which to locate the sensor would depend on the particular case.

In locating wind sensors in rough terrain or in valley situations, it will be necessary to determine if local effects such as channeling, slope and valley winds, etc., are of greatest importance, or whether flow above these influences is the parameter to be sensed. As in the urban situation, if the study centers upon elevated pollution sources, it may be desirable to avoid the local influences. However, if pollution from ground level sources is being emphasized, local influences may be of great importance. Remember that topographic influences such as hills, ridges, etc., produce flow patterns similar to those shown in Figures 2 and 3.

TEMPERATURE

As with wind sensors, thermometers are usually placed at a standard height above ground. This standard height has been set, by international agreement, at 1.25 to 2 meters (4-6.5 feet) above a grassy surface. Environmental considerations produce the following three rules of thumb for exposure of temperature sensors.

1) The sensor must be shielded from direct solar radiation.

2) The sensor must be well ventilated at a constant ventilation rate. (not less than 4-5 m/sec.)

3) The sensor must be uninfluenced by nearby features that might affect temperature.

If the sensor is of the thermocouple or thermister type, the aspirated shield of Figure 4 will fulfill the requirements of (1) and (2) above.

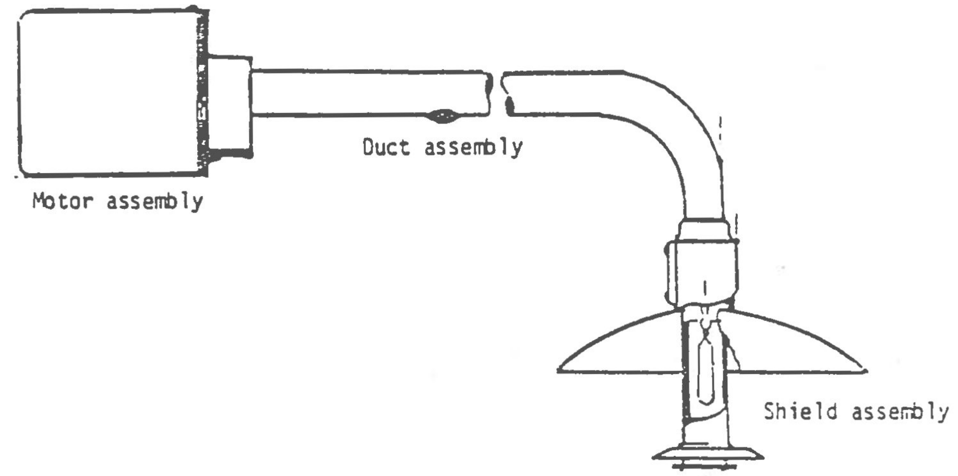


Figure 4 - Aspirated solar radiation shield

If a standard thermometer is to be exposed, the cotton region shelter of Figure 5 will fulfill requirement (1) above. Ventilation will be natural and therefore variable in rate so the requirement of rule (2) is not met exactly, but for standard thermometers, the error or effect is negligible.

If the shelter of Figure 5 is to be used, care should be taken to orient the door towards the north to eliminate solar heating of the thermometers while taking a reading. The thermometers should also be located as close to the center of the shelter as possible.

Requirement (3) above ensures that ambient air temperature is being measured, and not the temperature of a micro-environment such as the air very near the south side of a brick building or near an asphalt roadway or parking lot.

RELATIVE HUMIDITY

Since relative humidity is not only a function of the amount of water vapor in the atmosphere, but is also dependent on temperature, exposure criteria outlined for temperature should also be observed for relative humidity.

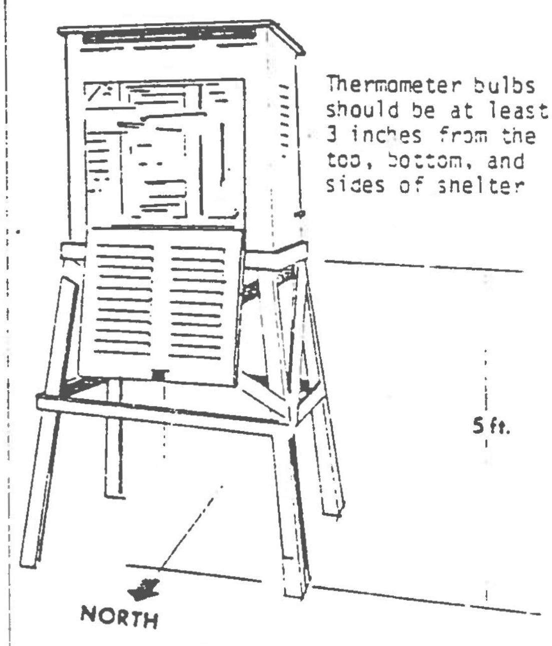


Figure 5 - Cotton region type instrument shelter

PRECIPITATION

The previous section describes the design and operation principles of rain gauges. Care must be taken in the exposure of a rain gauge to ensure that the collection efficiency of the gauge is not reduced. Wind and its associated turbulence are the two most important factors that would tend to change the collection efficiency of the gauge. If the wind blows the rain into the gauge on a slant, the collection area is changed and therefore the efficiency would be changed producing an error in the indicated rainfall. If considerable turbulence exists around the gauge, the rainfall itself will be disturbed, again producing errors in the indicated rainfall. These considerations produce the following guidelines:

1) The gauge should be free of overhanging obstructions.

2) The gauge should be a sufficient distance from obstacles to avoid local eddys.

3) The gauge should be sheltered from the possiblity of high wind speeds at the gauge.

Ideally, all three criteria could be met if the gauge was located in a clearing in a woods or orchard where the diameter of the clearing is about equal to the height of the surrounding trees. A windshield, such as the one shown in Figure 6, can also be installed to reduce the distortion of the air flow around the gauge.

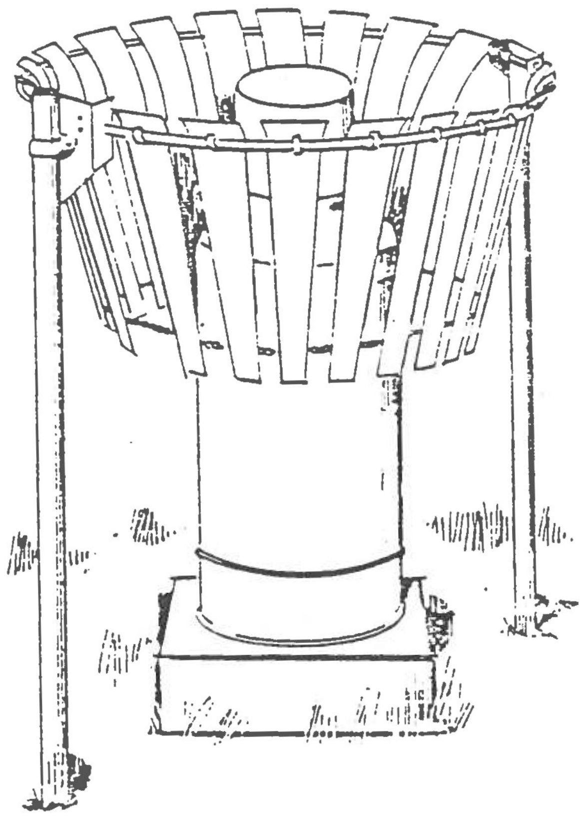


Figure 6 - Shielded rain gauge

RADIATION

Solar radiation measurements require exposure that will insure no obstructions between the sun and the sensor during any part of the year, and in the case of total solar radiation (direct and diffuse) as clear a view as possible of the entire sky is necessary.

The measurement of net radiation requires that the sensor be placed far enough away from the earth's surface to receive terrestial radiation over a representative area, yet not far enough from the surface to receive radiation from a thick air layer above the surface. For net radiation measurements, a height between 1 and 2 meters (3 to 6 feet) is generally recommended.

Exposure of Instruments on Towers or Stacks

INTRODUCTION

In striving to meet the exposure criteria outlined in the last section, it is often necessary to mount meteorological sensors on towers or masts. Unless these sensors are mounted properly, errors will be introduced in the measurements due to the influence of the tower on the parameter being sensed. It is the purpose of this section to set forth guidelines to eliminate these tower induced errors.

WIND SYSTEMS

If a wind system (anemometer and vane) are to be mounted on top of a tower, little concern is needed as to exposure. If, however, wind equipment is to be installed on the side of the tower, precautions should be taken to ensure that the wind measurements are not influenced by the tower. An analysis by Gill and Olsson (1967) has shown that the turbulence in the wake of lattice-type towers is moderate to severe, and that in the wake of solid towers and stacks is extreme, often with reversal of flow.

Another study by Moses and Daubek (1961) revealed that the air flow on the lee side of a tower may be reduced to about one-half its true value under light wind conditions and about 25% for higher winds (10-14 mph). The study also revealed that when the wind blowing toward the anemometer made an angle of 20 to 40° with respect to the sides of the tower adjacent to the anemometer, the measured wind speed exceeded the true wind speed by about 30%.

These studies illustrate the necessity of proper exposure.

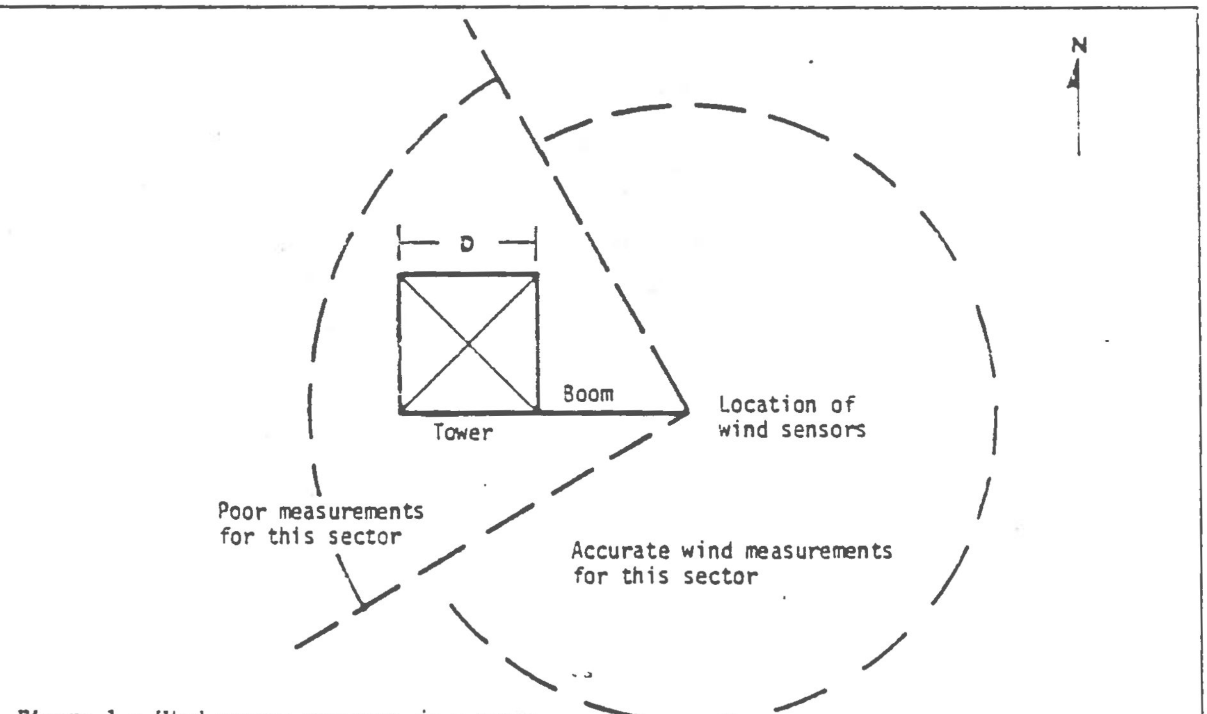


Figure 1 - Wind sensor exposure on a tower

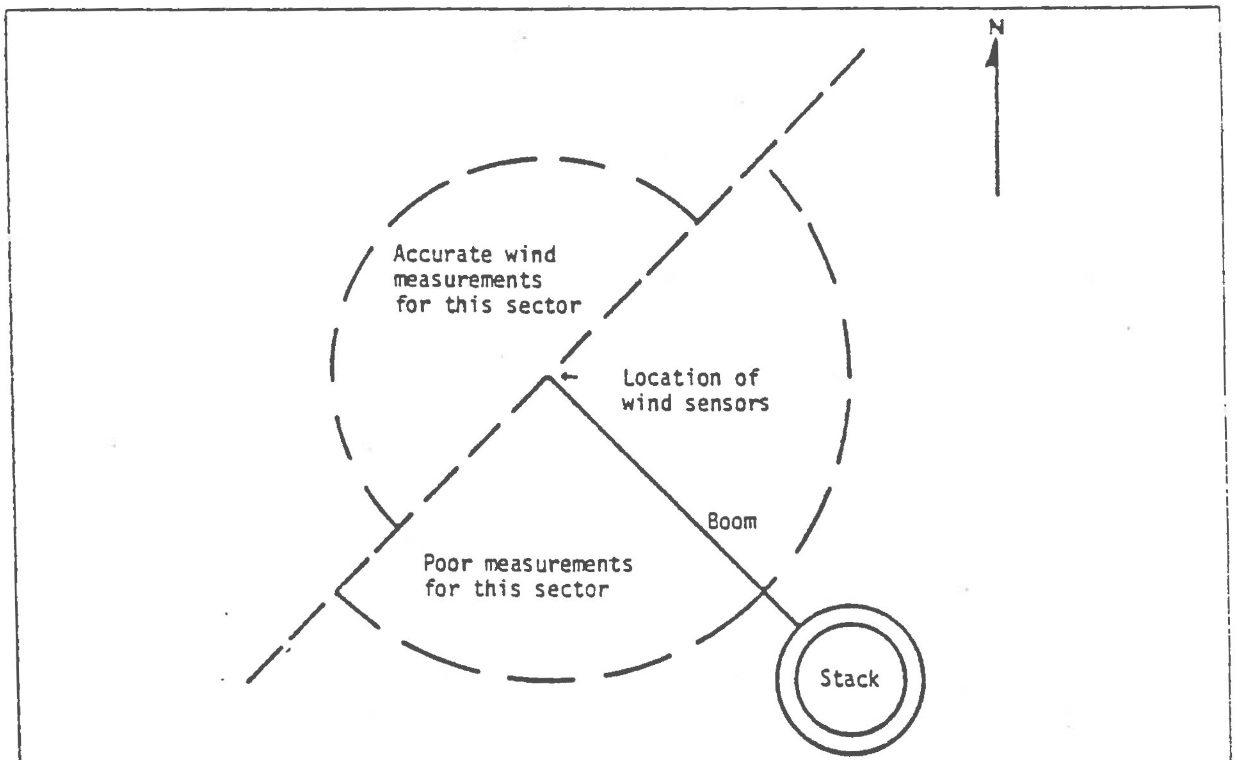


Figure 2 - Wind sensor exposure on a stack

Figure 1 illustrates the correct exposure of a wind sensor on an open tower. The following exposure criteria should be observed:

1) The boom should extend outward from a corner of the tower into the wind direction of primary concern.

2) The boom should place the sensor out from the tower a distance not less than the length of a side of the tower. (length D in Figure 1)

3) The wind sensors should be located at heights of minimum tower density, and above or below horizontal cross members.

If the above guidelines are followed, the following accuracies can be expected:

1) For a boom length of 1D, measurements of wind speed are true within $\pm$ 10% for a 310° sector of arc.

2) For a boom length of 2D the wind speed is accurate within $\pm$ 10% for a 330° sector of arc.

3) For these two arcs, wind direction is accurate to within approximately $\pm$ 5%.

With a boom length of 1 -2D, wind speed and direction measurements within $\pm$ 5% can only be obtained for a 240 - 270° sector of arc. This is the case illustrated in Figure 1.

It has been found in practice that the maximum practical boom length is about 20-30 feet. If the wind sensors are to be mounted on very large towers (TV towers or fire look-out towers), the sector of arc yielding accurate wind measurements may drop to 180° due to the fact that the boom length may be less than 1D.

In any case, if accurate wind measurements are required for an arc sector greater than that produced by the above exposure criteria, it is recommended that two sets of speed and direction sensors be placed at 180° apart in the manner prescribed in the above guidelines.

EXPOSURE OF WIND SENSORS ON CLOSED TOWERS OR STACKS

Preferably, closed towers or stacks should not be used to support meteorological sensors. If a stack must be used, the following exposure guidelines should be observed:

1) The boom should place the sensor out from the stack a distance not less than 2 stack diameters.

2) Instruments should never be located within 2-5 stack diameters of the top of an active stack.

Figure 2 illustrates the correct exposure of a wind sensor on a stack. If the above guidelines are used one can expect accurate wind measurements (± 5 to 10% of true value) through an arc of only 180° as shown in Figure 2. As with towers, if accurate wind measurements through a full 360° of Azimuth are desired, it is recommended that two sets of wind systems be used. These two systems should be located 180° apart, and exposed according to the above guidelines.

TEMPERATURE SYSTEMS

Temperature sensors should also be exposed on booms out from the tower structure to assure that the temperature of the air sampled is not influenced by thermal radiation from the tower itself. Temperature sensors should never be mounted on stacks.

Booms for temperature sensors need not be as long as for wind sensors, but generally, both wind and temperature sensors are located on the same boom at about the same distance from the tower. The temperature sensors themselves must be shielded and ventilated as described in the previous section.

SPACING OF WIND AND TEMPERATURE SYSTEMS

Figure 3 illustrates a typical spacing of wind and temperature systems on a tower. Wind sensors are normally spaced at logarithmic height intervals (10,20,40,80, 160 meters) because of the normally logarithmic change of wind speed with height.

Temperature measurements should be made at close intervals near the ground, and at approximately equal intervals at greater heights as shown in Figure 3. A logarithmic spacing is not necessary since temperature profiles become approximately linear a short distance from the surface.

With both wind and temperature, provisions must be made for swinging or telescoping the boom in order to service the sensors. Provisions also must be made for orienting the wind vane correctly when the boom is in the service position.

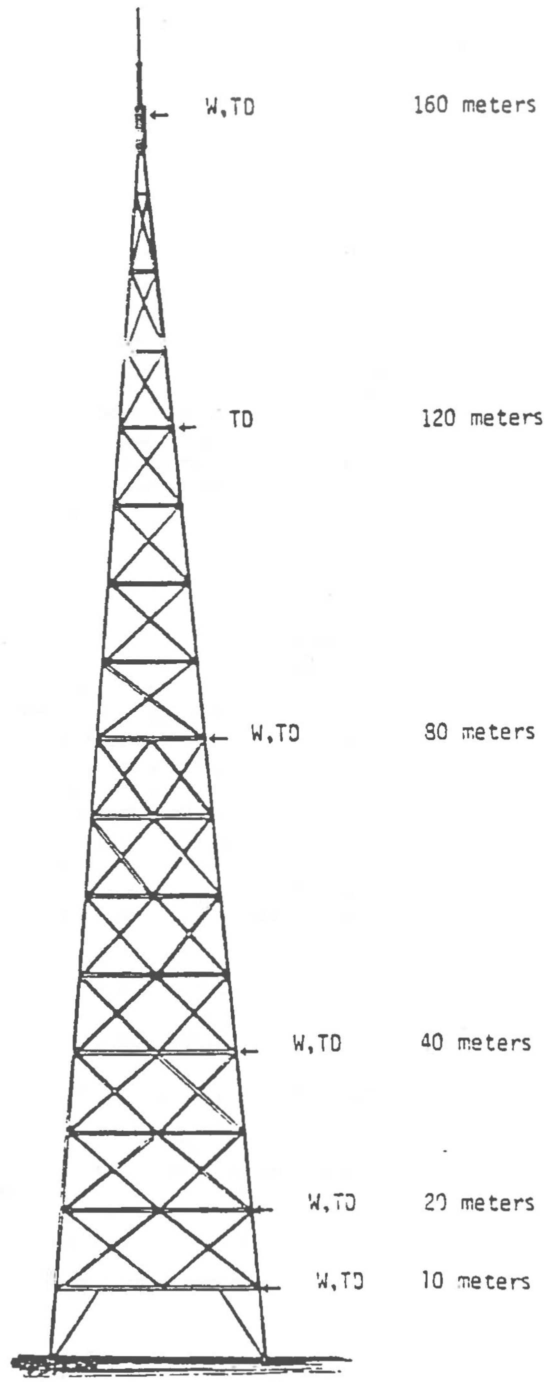


Figure 3 - Vertical spacing on a tower

Exposure of Airborne Instruments

INTRODUCTION

The measurement of meteorological parameters aloft may require the use of such devices as balloons, aircraft, rockets, etc. With many of these methods, surface-based receiving and recording instrumentation is necessitated. Therefore, a discussion of the exposure of airborne instruments must also include a discussion of the exposure of the surface-based support equipment.

EXPOSURE OF SURFACE BASED SYSTEMS

The measurement of wind aloft by balloon tracking may involve the use of radar or radio direction-finding equipment. Sites for radio and radar equipment should be on relatively high ground with the horizon as free from obstructions as possible. Of greatest importance to free balloon launchings is that there be no nearby obstructions to hinder the flight of the balloon. The operation of captive balloons (wiresondes) should be carried out only in open areas and never near power lines. Particular care should be taken to properly ground all captive balloon equipment and operations should be carried out only during periods of minimal atmospheric electrical potential. It should be noted that FAA authorization is necessary for most captive balloon operations.

EXPOSURE OF AIRCRAFT MOUNTED SYSTEMS

The main exposure problem associated with measurements from an aircraft is the fact that the sensors must be exposed to undisturbed air. Fixed wing propellor slipstreams and helicopter downwash must be avoided. For temperature measurements, engine and cabin heat must also be avoided, and a correction must be made for airspeed. Vibration of receiving and recording instrumentation in the aircraft may also be a problem.

The following guidelines are suggested for exposure of aircraft mounted sensors:

1) On fixed wing aircraft, sensors are most effectively mounted on the wingtips, forward of the wing not less than two feet.

2) On a helicopter, sensors are most effectively mounted on the forward tip of one of the skids, provided a forward speed of about 15 m/sec is maintained. This forward speed would project the downwash behind the sensor.

3) To reduce recorder vibrations, mountings of sponge rubber or plastic should be used.

REFERENCES:

Exposure of Meteorological Instruments

1) Gill, G.C., Olsson, L.E., Sela, J., and Suda, M., "Accuracy of Wind Measurements on Towers or Stacks", Bulletin of the A.M.S., Vol. 48, No. 9, Sept 1967 pp 665-674

2) Moses, H., and Daubek, H.G., "Errors in Wind Measurements Associated with Tower-mounted Anemometers", Bulletin of the A.M.S., Vol. 42, No. 3, 1961 pp 190-194

The following section is taken from the EPA document, "On-Site Meteorological Program Guidance for Regulatory Modeling Applications", EPA-450/4-87-013. June 1987.

The APCD recommends that this reference be consulted for guidance in preparing meteorological monitoring plans.

3.0 SITING AND EXPOSURE

The concepts of siting (i.e., horizontal and vertical probe placement) and exposure (i.e., spacing from obstructions) of meteorological instruments and towers are covered in this section for the eight variables of interest. General guidance is provided by variable, followed by discussions of special siting considerations for complex terrain, coastal, and urban sites. As a general rule of thumb, an instrument should be sited away from the influence of obstructions such as buildings and trees, and in such a position that it can make measurements that are representative of the general state of the atmosphere in the area of interest. Secondary considerations such as accessibility and security must be taken into account, but should not be allowed to compromise the quality of the data. In addition to the standard quality assurance procedures mentioned in Section 8.0, annual site inspections are recommended to verify the siting and exposure of the instruments. Approval for a particular site selection should be obtained from the permit granting agency prior to installation.

3.1 General Guidance

3.1.1 Wind Speed and Wind Direction

3.1.1.1 Probe placement

The standard exposure height of wind instruments over level, open terrain is 10m above the ground.[13] Open terrain is defined as an area where the distance between the instrument and any obstruction is at least ten times the height of that obstruction.[3,5,6,13]. The slope of the terrain in the vicinity of the site should be taken into account when determining the relative height of the obstruction.[3] An obstruction may be man-made (such as a building or stack) or natural (such as a hill or a tree). The sensor height, its height above obstructions, and the height/character of nearby obstructions should be documented. Where such an exposure cannot be obtained, the anemometer should be installed at such a height that it is reasonably unaffected by local obstructions and represents the approximate wind values that would occur at 10m in the absence of the obstructions. This height, which depends on the extent, height, and distance of obstructions and on site availability, should be determined on a case-by-case basis. Additional guidance on the evaluation of vertical profiles (Section 6.1.3) and surface roughness (Section 6.4.2) may be helpful in determining the appropriate height.

If the source emission point is substantially above 10m, then additional wind measurements should be made at stack top or 100m, whichever is lower.[4] In cases with stack heights of 200m or above, the appropriate measurement height should be determined by the Regional Office on a case-by-case basis. Because maximum practical tower heights are on the order of 100m, wind data at heights greater than 100m will most likely be determined by some other means. Elevated wind measurements can be obtained via remote sensing (see Section 9.0). Indirect values can be estimated by using a logarithmic wind-speed profile relationship. For this purpose, instruments should be located at multiple heights (at least three) so that site-specific wind profiles can be developed.

3.1.1.2 Obstructions

(a) Buildings

Aerodynamic effects due to buildings and other major structures, such as cooling towers, are discussed in the "Guideline for Determination of Good Engineering Practice Stack Height (Technical Support Document for the Stack Height Regulations) -Revised,"[14] and "Handbook on Atmospheric Diffusion."[15] If wind instruments must be mounted on a building (or other large structure) due to the lack of suitable open space, then the measurement should be made at sufficient height to avoid the aerodynamic wake area. This height can be determined by on-site measurements (e.g., smoke releases) or wind tunnel studies. As a rule of thumb, the total depth of the building wake is estimated to be approximately 2.5 times the height of the building.[3]

(b) Trees

In addition to the general rules concerning obstructions noted above, additional considerations may be important for vegetative features (e.g., growth rates). Seasonal effects should also be considered for sites near deciduous trees. For dense, continuous forests where an open exposure cannot be obtained, measurements should be taken at 10m above the height of the general vegetative canopy.

(c) Towers

Sensors mounted on towers are frequently used to collect wind speed measurements at more than one height. To avoid the influence of the structure itself, closed towers, stacks, cooling towers, and similar solid structures should not be used to support wind instruments. Open-lattice towers are preferred. Towers should be located at or close to plant elevation in an open area representative of the area of interest.

Wind instruments should be mounted on booms at a distance of at least twice the diameter/diagonal of the tower (from the nearest point on the tower) into the prevailing wind direction or wind direction of interest.[1,3,5] Where the wind distribution is strongly bimodal from opposite directions, such as in the case of up-valley and down-valley flows, then the booms should be at right angles to the predominant wind directions. The booms must be strong enough so that they will not sway or vibrate sufficiently to influence standard deviation (sigma) values in strong winds. Folding or collapsible towers are not recommended since they may not provide sufficient support to prevent such vibrations, and also may not be rigid enough to ensure proper instrument orientation. The wind sensors should be located at heights of minimum tower density (i.e., minimum number of diagonal crossmembers) and above/below horizontal cross-members.[3] Since practical considerations may limit the maximum boom length, wind sensors on large towers (e.g., TV towers and fire look-out towers) may only provide accurate measurements over a certain arc. In such cases, two systems on opposite sides of the tower may be needed to provide accurate measurements over the entire 360°. If such a dual system is used, the method of switching from one system to the other should be carefully specified. A wind instrument mounted on top of a tower should be mounted at least one tower diameter/diagonal above the top of the tower structure.[1]

(d) Surface roughness

The surface roughness over a given area reflects man-made and natural obstructions, and general surface features. These roughness elements effect the horizontal and vertical wind patterns. Differences in the surface roughness over the area of interest can create differences in the wind pattern that may necessitate additional measurement sites. A method of estimating surface roughness length, z_0, is presented in

Section 6.4.2. If an area has a surface roughness length greater than 0.5m, then there may be a need for special siting considerations (see discussion in Sections 3.2 and 3.4).

3.1.1.3 Siting considerations

A single well-located measurement site can be used to provide representative wind measurements for non-coastal, flat terrain, rural situations. Wind instruments should be placed taking into account the purpose of the measurements. The instruments should be located over level, open terrain at a height of 10m above the ground, and at a distance of at least ten times the height of any nearby obstruction. For elevated releases, additional measurements should be made at stack top or 100m, whichever is lower.[4] In cases with stack heights of 200m or above, the appropriate measurement height should be determined by the Regional Office on a case-by-case basis.

3.1.2 Temperature, Temperature Difference, and Water Vapor

The siting and exposure criteria for the three temperature-related variables are similar and, thus, will be discussed together here. Where important, differences between variables are mentioned. Although water vapor content may be measured in a number of ways, the recommended procedure is to measure dew point temperature, T_d.

3.1.2.1 Probe placement

The recommended vertical heights for probe placement are 2m for temperature and 10m and 2m for temperature difference.[5] Where vertical temperature difference measurements are used in determining stable plume rise, the measurements should be made across the plume rise layer, with a minimum separation of 50m. For sites that experience large amounts of snow, adjustments to the temperature measurement height may be necessary, but the temperature probe should not be above 10m. For analysis of cooling tower impacts, measurements of temperature and dew point should also be obtained at source height and within the range of final plume height. The measurement of temperature difference for analysis of critical dividing streamline height, H_{crit}, a parameter used in complex terrain modeling, is discussed in Section 3.2.3.

The sensor should be located over an open, level area at least 9m in diameter. The surface should be covered by short grass, or, where grass does not grow, the natural earth surface.[3,13] Instruments should be protected from thermal radiation (from the earth, sun, sky, and any surrounding objects) and adequately ventilated using aspirated shields.[1] Forced aspiration velocity should exceed 3 m/s, except for lithium chloride dew cells which operate best in still air.[3] If louvered shelters are used instead for protection (at ground level only), then they should be oriented with the door facing north. Temperature data obtained from naturally-ventilated shelters will be subject to large errors when wind speeds are light (less than about 3m/s).

Temperature sensors on towers should be mounted on booms at a distance of about one diameter/diagonal of the tower (from the nearest point on the tower).[3] In this case, downward facing aspiration shields are necessary.

3.1.2.2 Obstructions

Temperature sensors should be located at a distance of at least four times the height of any nearby obstruction and at least 30m from large paved areas.[3,16] Other situations to avoid include: large industrial heat sources, rooftops, steep slopes, sheltered hollows, high vegetation, shaded areas, swamps, areas where frequent snow drifts occur, low places that hold standing water after rains, and the vicinity of air exhausts (e.g., from a tunnel or subway).[3,13]

3.1.2.3 Siting considerations

In siting temperature sensors, care must be taken to preserve the characteristics of the local environment, especially the surface. Recommended measurement heights are 2m for temperature and 10m and 2m for temperature difference. Protection from thermal radiation (with aspirated radiation shields) and significant heat sources and sinks is critical. Siting recommendations are similar for dew point measurements, which may be used for modeling input in situations involving moist releases, such as cooling towers. For temperature difference measurements, sensors should be housed in identical aspirated radiation shields with equal exposure.

3.1.3 Precipitation

3.1.3.1 Probe placement

A rain gage should be sited on level ground so the mouth is horizontal and open to the sky.[3] The underlying surface should be covered with short grass or gravel. The height of the opening should be as low as possible (minimum of 30 cm), but should be high enough to avoid splashing in from the ground.

Rain gages mounted on towers should be located above the average level of snow accumulation.[16] In addition, collectors should be heated if necessary to properly measure frozen precipitation.[6]

3.1.3.2 Obstructions

Nearby obstructions can create adverse effects on precipitation measurements (e.g., funneling, reflection, and turbulence) which should be avoided. On the other hand, precipitation measurements may be highly sensitive to wind speed, especially where snowfall contributes a significant fraction of the total annual precipitation.[5] Thus, some sheltering is desirable. The need to balance these two opposite effects requires some subjective judgment.

The best exposure may be found in orchards, openings in a grove of trees, bushes, or shrubbery, or where fences or other objects act together to serve as an effective wind-break. As a general rule, in sheltered areas where the height of the objects and their distance to the instrument is uniform, their height (above the instrument) should not exceed twice the distance (from the instrument).[16] In open areas, the distance to obstructions should be at least two, and preferably four, times the height of the obstruction. It is also desirable in open areas which experience significant snowfall to use wind shields such as those used by the National Weather Service.[3,13,16]

3.1.3.3 Siting considerations

In view of the sensitivity to wind speed, every effort should be made to minimize the wind speed at the mouth opening of a precipitation gage. This can be done by using wind shields. Where snow is not expected to occur in significant amounts or with significant frequency, use of wind shields is less important. However, the catch of either frozen or liquid precipitation is influenced by turbulent flow at the collector, and this can be minimized by the use of a wind shield.

3.1.4 Pressure

On-site measurements of pressure are desirable, but not necessary. The standard atmospheric pressure for the station elevation will often be of sufficient accuracy to represent true pressure for dispersion calculations.[5]

3.1.5 Radiation

3.1.5.1 Probe placement

Pyranometers used for measuring incoming (solar) radiation should be located with an unrestricted view of the sky in all directions during all seasons, with the lowest solar elevation angle possible. Sensor height is not critical for pyranometers. A tall platform or rooftop is a desirable location.[3] Net radiometers should be mounted about 1m above the ground.[3,5]

3.1.5.2 Obstructions

Pyranometers should be located to avoid obstructions casting a shadow on the sensor at any time. Also, light colored walls and artifical sources of radiation should be avoided.[3,5] Net radiometers should also be located to avoid obstructions to the field of view both upward and downward.[3,5]

3.1.5.3 Siting considerations

Solar radiation measurements should be taken in open areas free of obstructions. The ground cover under a net radiometer should be representative of the general site area. The given application will govern the collection of solar or net radiation data.

3.2 Complex Terrain Sites

The regulatory definition of complex terrain can include a wide variety of topographic settings, ranging from a single isolated hill rising out of an otherwise flat plain to very rugged terrain where the terrain exerts a major influence on the local flow, affecting transport and dispersion of the pollutant plume(s) of concern. While terrain features can be considered obstructions to the wind flow and should be avoided, siting decisions must take into account which features of the altered flow should actually be measured, if those features have an effect on the plume.

Because of vertical inhomogeneity in complex terrain, it is more important than in the flat terrain case to take measurements at the level of the plume that is being modeled. Horizontal inhomogeneities caused by channeling and other flow distortions further complicate the siting process. Density-driven downslope and upslope flows, channeling of the flow around terrain obstacles or along the axis of a valley, wind speed-up over the crest of terrain, and lingering stagnant conditions in the bottoms of closed valleys, are but a few of the physical phenomena that can be important in a siting decision.

The ideal siting solution in complex terrain involves siting a tall tower between the source in question and the terrain obstacle of concern. The tower should be tall enough to produce measurements at the level of the plume, and should provide measurements of all variables at several levels.

Other terrain in the area should not be so severe as to affect plume transport in a different manner than what is measured by the tower.

Since there are not many situations where this ideal can be achieved, a siting decision in complex terrain must involve some compromises. The basic choices in siting a meteorological tower in complex terrain include siting one tower, siting multiple towers, or utilizing a Doppler SODAR (see Section 9.0) that would include at least a 10-meter tower and may be supplemented by additional tower measurements. Other components of the siting decision include determining specific tower locations, whether or not a tower can be sited on nearby terrain, and measurement heights. Careful planning is essential in any siting decision. Since each complex terrain situation has unique features to consider, no specific recommendations can be given to cover all cases. However, the siting process should be essentially the same in all complex terrain situations. Recommended steps in the siting process are as follows:

1. Define the variables that are needed for a particular application.

2. Develop as much information as possible to define what terrain influences are likely to be important. This should include examination of topographic maps of the area with terrain above physical stack height outlined. Preliminary estimates of plume rise should be made to determine a range of expected plume heights. If any nearby or on-site meteorological data are available, they should be analyzed to see what can be learned about the specific terrain effects on air flow patterns. An evaluation by a meteorologist based on a site visit would also be desirable.

3. For each required variable, alternative measurement locations and techniques should be examined. Advantages and disadvantages of each technique/location should be considered, utilizing as a starting point the discussions presented above and elsewhere in this document.

4. Optimum network design should be determined by balancing the advantages and disadvantages identified in step 3.

It is particularly important in complex terrain to consider the end use of each variable separately. Guidance and concerns specific to the measurement of wind speed, wind direction, and temperature difference in complex terrain are discussed in the following sections.

3.2.1 Wind Speed

At a minimum, wind speed should be measured at stack top or 100m, whichever is lower, for plume rise calculations. It is preferable to measure wind speed from a tower located near stack base elevation, however, a tower on nearby terrain may also be used to measure wind speed in some circumstances. In this latter case, the higher the tower above terrain the better (i.e. less compression effect); a 10-meter tower generally will not be sufficient. The measurement location should be evaluated for representativeness of both the dilution process and plume rise.

Great care should be taken to ensure that the tower is not sheltered in a closed valley (which would tend to over-estimate the occurrence of stable conditions) or placed in a location that is subject to streamline compression effects (which would tend to underestimate the occurrence of stable conditions). It is not possible to completely avoid both of these concerns. If a single suitable location cannot be found, then alternative approaches, such as siting two or more towers, should be evaluated in consultation with the Regional Office.

A Doppler SODAR has the potential to provide the required measurements without the problems entailed by locating a tower on nearby terrain. SODARs have their own special siting requirements and limitations which are discussed in Section 9.0.

3.2.2 Wind Direction

The most important consideration in siting a wind direction sensor in complex terrain is that the measured direction should not be biased in a particular direction that is not experienced by the pollutant plume. For example, instruments on a meteorological tower located at the bottom of a well-defined valley may measure directions that are influenced by channeling or density-driven upslope or downslope flows. If the pollutant plume will be affected by the same flows, then the tower site is adequate. Even if the tower is as high as the source's stack, however, appreciable plume rise may take the plume out of the valley influence and the tower's measured wind direction may not be appropriate for the source (i.e., biased away from the source's area of critical impact).

The determination of potential bias in a proposed wind direction measurement is not an easy judgement to make. Quite often the situation is complicated by multiple flow regimes, and the existence of bias is not evident. This potential must be considered, however, and a rationale developed for the choice of measurement location.

Research has indicated that a single wind measurement location/site may not be adequate to define plume transport direction in some situations.[5] While the guidance in this document is concerned primarily with means to obtain a single hourly averaged value of each variable, it may be appropriate to utilize more than one measurement of wind direction to calculate an "effective" plume transport direction for each hour.

3.2.3 Temperature Difference

The requirements of a particular application should be used as a guide in determining how to make measurements of vertical temperature difference in complex terrain. Stable plume rise and the critical dividing streamline height (H_{crit}), which separates flow that tends to move around a hill (below H_{crit}) from flow that tends to pass over a hill (above H_{crit}), are both sensitive to the vertical temperature gradient. The height ranges of interest are from stack top to plume height for the former and from plume height to the top of the terrain feature for the latter. The direct measurement of the complete temperature profile is often desirable but not always practical. The following discussion presents several alternatives for measuring the vertical temperature gradient along with some pros and cons.

Tower measurement: A tower measurement of temperature difference can be used as a representation of the temperature profile. The measurement should be taken between two elevated levels on the tower (e.g. 50 and 100 meters) and should meet the specifications for temperature difference discussed in Section 5.0. A separation of 50m between the two sensors is preferred. The tower itself could be located at stack base elevation or on elevated terrain: optimum location depends on the height of the plume. Both locations may be subject to radiation effects that may not be experienced by the plume if it is significantly higher than the tower.

The vertical extent of the temperature probe may be partially in and partially out of the surface boundary layer, or may in some situations be entirely contained in the surface boundary layer while the plume may be above the surface boundary layer.

Balloon-based temperature measurements: Temperature profiles taken by balloon-based systems can provide the necessary information but are often not practical for developing a long-term data base. One possible use of balloon-based temperature soundings is in developing better "default" values of the potential temperature gradient on a site-specific basis. A possible approach would be to schedule several periods of intensive soundings during the course of a year and then derive appropriate default values keyed to stability category and wind speed and/or other appropriate variables. The number and scheduling of these intensive periods should be established as part of a sampling protocol.

Deep-layer absolute temperature measurements: If the vertical scale of the situation being modeled is large enough (200 meters or more), it may be acceptable to take the difference between two independent measurements of absolute temperature (i.e., temperature measurements would be taken on two different towers, one at plant site and one on terrain) to serve as a surrogate measurement of the temperature profile. This approach must be justified on a case-by-case basis, and should be taken only with caution. Its application should be subject to the following limitations:

- Depth of the layer should be 200 meters at a minimum;
- The measurement height on each tower should be at least 60 meters;

- Horizontal separation of the towers should not exceed 2 kilometers;
- No internal boundary layers should be present, such as near shorelines; and
- Temperature profiles developed with the two-tower system should be verified with a program of balloon-based temperature profile measurements.

3.3 Coastal Sites

The unique meteorological conditions associated with local scale land-sea breeze circulations necessitate special considerations. For example, a stably stratified air mass over water can become unstable over land due to changes in roughness and heating encountered during daytime conditions and onshore flow. An unstable thermal internal boundary layer (TIBL) can develop, which can cause rapid downward fumigation of a plume initially released into the stable onshore flow. To provide representative measurements for the entire area of interest, multiple sites would be needed: one site at a shoreline location (to provide 10m and stack height/plume height wind speed), and additional inland sites perpendicular to the orientation of the shoreline to provide wind speed within the TIBL, and estimates of the TIBL height. Where terrain in the vicinity of the shoreline is complex, measurements at additional locations, such as bluff tops, may also be necessary.[5] Further specific measurement requirements will be dictated by the data input needs of a particular model. A report prepared for the Nuclear Regulatory Commission[17] provides a detailed discussion of considerations for conducting meteorological measurement programs at coastal sites. However, due to the lack of any recommended model for EPA regulatory applications that specifically addresses a shoreline source, no specific recommendations are made for the collection of measurements beyond those generally required for a non-coastal, rural source.

3.4 Urban Sites

Urban areas are characterized by increased heat flux and surface roughness. These effects, which vary horizontally and vertically within the urban area, alter the wind pattern relative to the outlying rural areas (e.g., average wind speeds are decreased). The close proximity of buildings in downtown urban areas often precludes strict compliance with the previous sensor exposure guidance. For example, it may be necessary to locate instruments on the roof of the tallest available building. In such cases, the measurement height should take into account the proximity of nearby tall buildings and the difference in height between the building (on which the instruments are located) and the other nearby tall buildings.

In general, multiple sites are needed to provide representative measurements in a large urban area. This is especially true for ground-level sources, where low-level, local influences, such as street canyon effects, are important, and for multiple elevated sources scattered over an urban area. However, due to the limitations of the recommended guideline models (i.e. they recognize only a single value for each input variable on an hourly basis), and resource and practical constraints, the use of a single site is necessary. At the very least, the single site should be located as close to the source in question as possible.

3.5 Recommendations

It is recommended that for non-coastal, flat terrain, rural situations, wind instruments should be located over level, open terrain at a height of 10m above the ground, and at a distance of at least ten times the height of any nearby obstruction. For elevated releases, additional measurements should be made at stack top or 100m, whichever is lower. For stack heights of 200m or above the appropriate measurement height should be determined by the Regional Office on a case-by-case basis.

In siting temperature sensors, it is recommended that care be taken to preserve the characteristics of the local environment, especially the surface. Recommended measurement heights are 2m for temperature and 10m and 2m for temperature difference. Protection from thermal radiation (with aspirated radiation shields) and significant heat sources and sinks is critical. If temperature difference is to be used in determining stable plume rise, it should be measured across the plume rise layer. A separation of 50m between the two sensors is preferred for these elevated temperature difference measurements.

Every effort should be made to minimize the wind speed at the mouth opening of a precipitation gage. This should be done by using wind shields where significant snowfall occurs. Radiation measurements should be taken in open areas free of obstructions.

Specific siting recommendations cannot be given to cover all possible situations in complex terrain. The process of siting instruments in complex terrain should begin with defining the variables that are needed for a given application. The process should also include defining what terrain influences are likely to be important, using information from topographic maps in conjunction with preliminary estimates of expected plume height range, and any nearby meteorological data. Alternative measurement locations and techniques should then be identified and an optimum design selected by balancing the advantages and disadvantages of the various options.

Special siting considerations also apply to coastal and urban sites. Multiple sites are often desirable in these situations, but model input limitations usually require selection of a single "best" site for modeling applications. Judgements on siting in these specials situations should be made in consultation with the appropriate Regional Office.

If the siting recommendations in this section cannot be achieved, then alternate approaches should be developed in conjunction with the Regional Office. Approval for a particular site selection should be obtained from the permit granting agency prior to installation of a meteorological monitoring system.

Appendix B

GUIDELINE FOR DETERMINATION OF ATMOSPHERIC STABILITY CATEGORIES

Colorado Department of Health
Air Pollution Control Division

Updated July 1988

STABILITY CATEGORIES

Atmospheric stability is an expression of the diffusive potential of the lower atmosphere in estimating the dispersion of air pollutants.[1] There are a number of methods utilized for estimating atmospheric stability categories depending on the availability of input data and the actual output need.

The National Climatic Center's STAR program relies on the establishment of hourly stability data and it is suggested the method of classification be that of Pasquill.[2] This method is designed to utilize data normally available from National Weather Observation sites which may or may not apply to background air monitoring situations.

Since Pasquill's method was established, a number of other classification schemes have been developed. These other refinements are designed to utilize different meteorological measurements in an effort to more closely relate the atmospheric stability category to a true dispersion characteristic.

The following methods are considered to be acceptable to the Colorado Air Pollution Division for the purposes of establishing stability categories as input to the STAR classifications. Many people consider some methods to be better than others for various reasons.[1,4,5] It is the position of the Air Pollution Division that each group determine which method they feel is the most applicable to their situation or input data. The preparation of the STAR data should specify which method was utilized when the data submittal is made.

<u>Method I</u>

Pasquill Stability Categories (1)

Surface wind speed at 10m ($m\ sec^{-1}$)	Insolation			Night	
	Strong	Moderate	Slight	Thinly overcast or $\geq$ 4/8 low cloud	$\leq$ 3/8 cloud
2	A	A-B	B	—	—
2-3	A-B	B	C	E	F
3-4	B	B-C	C	D	E
4-6	C	C-D	D	D	D
>6	C	D	D	D	D

Method II

Lapse Rate (3)

Stability Class	Lapse Rate Centigrade Degrees/100 meters	Wind Speed (meters per second)[a]
A	Greater than 1.9	$\leq$ 1.0
B	1.7 to 1.9	$\leq$ 2.6
C	1.5 to 1.7	$\leq$ 3.1
D	0.5 to 1.5	All speeds
E	-1.5 to 0.5	$\leq$ 2.6
F	Less than -1.5	$\leq$ 1.5

[a] One meter per second equals 2.2 mph.

The lapse rate is defined as the rate of decrease of temperature in the atmosphere with height. Thus, a positive lapse rate indicates a decrease in temperature with height, while a negative lapse rate indicates an increase in temperature with height.

If a temperature lapse rate indicated a particular stability class but the wind speed does not meet the criteria for that stability class, then the stability is moved one stability class closer to neutral stability. If the wind speed is greater than 6 knots, the stability is D, or neutral, independent of the lapse rate (Burns and McDonnell, 1980a)

Method III

Sigma Theta (4)

The sigma theta method involves either a) the direct measurement of the standard deviation of the horizontal wind direction, b) estimation of the standard deviation by dividing the hourly range by 6, c) hand calculating the standard deviation by visually reading a representative number of wind directions within the hour. It is suggested that this method be used only when machine determined standard deviations are collected during the monitoring process or when only a very limited number of hourly values need be determined.

Stability Category	Range of Standard Deviation, Degrees
A	$\sigma\theta \geq 22.5$
B	$22.5 > \sigma\theta \geq 17.5$
C	$17.5 > \sigma\theta \geq 12.5$
D	$12.5 > \sigma\theta \geq 7.5$
E	$7.5 > \sigma\theta \geq 3.8$
F	$3.8 > \sigma\theta$

These criteria are appropriate for steady-state conditions, a measurement height of 10 m, for level terrain, and an aerodynamic surface roughness length of 15 cm. Care should be taken that the wind sensor is responsive enough for use in measuring wind direction fluctuations.[7]

A surface roughness factor of $(z_0/15\ \mathrm{cm})^{0.2}$, where z_0 is the average surface roughness in centimeters within a radius of 1-3 km of the source, may be applied to the table values. It should be noted that this factor, while theoretically sound, has not been subjected to rigorous testing and may not improve the estimates in all circumstances. A table of z_0 values that may be used as a guide to estimating surface roughness is given in Smedman-Hogstrom and Hogstrom.[8]

These criteria are from a NRC proposal.[9] It would seem reasonable to restrict the possible categories to A through D during daytime hours with a restriction that for 10-m wind speeds above 6 m/s, conditions are neutral.

Method IV

Modified Sigma Theta (5)

This method, utilized by NUS Corporation, is a modification which is applied to altering nightime sigma theta values to correct for wind meander. Nighttime is defined as the accepted Pasquill values of 1 hour before sunset to one hour after sunrise. During daylight, the normal sigma theta values would be utilized. The following table shows the night adjustments.

Method For Estimating Stability Class for σ_Z
At Night From Measurement of $\sigma 0$

Night is defined as the period of one hour prior to sunset to one hour after sunrise.

If the $\sigma 0$ stability class is	And if the wind speed u is (m/s)	(mi/h)	Then the stability class for σ_Z is
A			
	$u < 2.9$	$u < 6.4$	F
	$2.9 \leq u < 3.6$	$6.4 \leq u < 7.9$	E
	$3.6 \leq u$	$7.9 \leq u$	D
B	$u < 2.4$	$u < 5.3$	F
	$2.4 \leq u < 3.0$	$5.3 \leq u < 6.6$	E
	$3.0 \leq u$	$6.6 \leq u$	D
C	$u < 2.4$	$u < 5.3$	E
	$2.4 \leq u$	$5.3 \leq u$	D
D	no restriction		D
E	no restriction**		E
F	no restriction***		F

**The original Mitchell and Timbre[10] table had no wind speed restrictions; However, the original Pasquill criteria suggest that for wind speeds greater than 5 m/s, neutral conditions should be used.

***The original Mitchell and Timbre[10] table had no wind speed restrictions; however, the original Pasquill criteria suggest that for wind speeds greater than or equal to 5 m/s, the D category would be appropriate, and for wind speeds between 3 m/s and 5 m/s, the E category should be used.

Method V

Vertical Sigma Phi

Stability Class	Ophi
A	$>$11.50
B	10-11.5^{0}
C	7.8^{0}-10^{0}
D	5.0^{0}-7.8^{0}
E	2.4^{0}-5.0^{0}
F	$<$2.4^{0}

The sigma phi method involves the determination of the standard deviation of the vertical wind by direct measurement. This method relies on the utilization of a vertical wind speed sensor equipped to record the speed and standard deviation of the speed.

These criteria are appropriate for steady-state conditions, a measurement height of 10 m, for level terrain, and an aerodynamic surface roughness length of 15 cm. Care should be taken that the wind sensor is responsive enough for use in measuring wind direction fluctations.[7]

A surface roughness factor of $(z_0/15\ cm)^{0.2}$, where z_0 is the average surface roughness in centimeters within a radius of 1-3 km of the source, may be applied to the table values. It should be noted that this factor, while theoretically sound, has not been subjected to rigorous testing and may not improve the estimates in all circumstances. A table of z_0 values that may be used as a guide to estimating surface roughness is given in Smedman-Hogstrom and Hogstrom.[8]

These criteria were adapted from those presented by Smith and Howard.[11] It would seem reasonable to restrict the possible categories to A through D during the daytime hours and to categories D through F during the nighttttime hours. During the daytime, conditions are neutral for 10-m wind speeds equal to or greater than 6 m/s, and during the night, conditions are neutral for 10-m wind speeds equal to or greater than 5 m/s.

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(6). T.E. Smith, S.M. Howard "Methodology for Treating Diffusivity" MRI 72 FR-1080, September 6, 1972.

(7). Environmental Protection Agency, 1980. Ambient Air Monitoring Guidelines for Prevention of Significant Deterioration (PSD). EPA Publication No. EPA-450/4-80-012. U.S. Environmental Protection Agency, Research Triangle Park, NC. (NTIS No. PB 81-153231).

(8). Smedman - Hogstrom, A. and V. Hogstrom, 1978. A Practical Method for Determining Wind Frequency Distributions for the Lowest 200m from Routine Meteorological data. Journal of Applied Meteorology, 17(7):942-953.

(9). Nuclear Regulatory Commission, 1972. Meteorological Programs in Support of Nuclear Power Plants. Regulatory Guide 1.23 (Draft). U.S. Nuclear Regulatory Commission, Office of Standards Development, Washington, DC. (Docket Reference No. II-P11).

(10). Mitchell, Jr., A.E. and K.O. Timbre, 1979. Atmospheric Stability Class from Horizontal Wind Fluctuation. Presented at 72nd Annual Meeting of Air Pollution Control Association, Cincinnati, OH, June 24-29, 1979. (Docket Reference No. II-P-9).

(11). Smith, T.B. and S.M. Howard, 1972. Methodology for Treating Diffusivity. MRI 72 FR-1030. Meteorology Research, Incorporated, Altadena, CA. (Docket Reference No. II-P-8).

APPENDIX C

TRACER GUIDELINES FOR WESTERN COLORADO

TRACER TEST GUIDELINES FOR WESTERN COLORADO

Many residential developments and industrial projects are now locating in mountainous regions of Colorado. The assessment of air pollution impacts is a problem in complex topography where air flow is dominated by terrain-induced effects. Simple dispersion models have a difficult time simulating diffusion and transport processes in this environment. Several well-designed, site-specific tracer tests can prove very useful in surmounting these difficulties and providing the development with a proper impact assessment. The objectives of a tracer gas experiment are twofold:

1) To simulate pollutant movement from its source to the impact areas in order to better understand the diffusion and transport processes of the site;
2) to provide a data base for evaluation and calibration of an air pollution dispersion model.

There are several factors which need to be considered when designing and conducting a tracer test. Some of these factors have been enumerated by EPA (1981). Other factors have been brought to the Air Pollution Control Division's (APCD) attention during the review of previously submitted tracer studies. APCD recommends the following guidelines be addressed when performing tracer tests in Colorado.

1. Tracer Gas

A suitable atmospheric tracer should be used. Ideally an atmospheric tracer should be a substance which when introduced into the atmosphere is dispersed and transported in a manner similar to a selected pollutant. It must be something not normally present in the atmosphere at concentrations in the experimental range of interest. Experimentally, the tracer gas should be easy to release, collect, and analyze; it should be relatively inexpensive, non-toxic, and unaffected by fallout and washout. The tracer should be nondepositing so long as the pollutant in question can be assumed to be nondepositing.

Among the atmospheric tracers that come closest to meeting these criteria are sulfur hexafluoride (SF_6), fluorescent particles, halocarbons, uranine dye and glass spheres. Of these SF_6 is probably the best choice. It has been used extensively in mountainous terrain and techniques for its release, sampling, and analysis are well established and reliable.

2. Tracer Sampling Period

The tracer tests should provide a data base over a sampling period which is easily related to the standard in question. Short-term (1 to 24 hour) concentrations will usually be the constraining standard for mountain developments.

3. Meteorological Conditions

The meteorological conditions necessary for a successful tracer test should be defined prior to conducting the test. These conditions should be defined to assess the impact of the source during worst-case meteorological regimes. To increase the chances that the worst-case conditions exist during the test period it is suggested that at least two tracer tests are run for each selected worst-case regime. Two tracer tests is definitely the minimum for obtaining a defendable statistical data base during a given set of worst-case conditions. A minimum of three tests per regime should be considered in a test plan to improve the statistical basis and to compensate for tests that may have been during meteorological conditions that deteriorated from the design criteria during the test period. It is a rare occurence that all tests conducted during a field intensive take place under design conditions.

Each project should conduct its own analyses to determine worst-case meteorological conditions. Most mountain developments will consist of sources with relatively low release heights (less than 30 meters) located in the valleys. Due to the strong temperature inversions and channeling of winds that occur at night in valleys, drainage wind conditions will usually create the highest, short-term concentrations from these sources (Mahoney and Spengler, 1975). Seasonal variation of worst-case conditions and emission rates must also be examined. For example, a ski town will experience much higher emissions during the winter (ski season). Whiteman (1980) found very little seasonal variation in the depth of the nocturnal inversions in western Colorado valleys. During winter, drainage winds will tend to have a longer persistance (usually causing higher impacts) and higher wind speeds (usually causing lower impacts) than they have in the summer. All these factors must be considered when deciding on a worst-case meteorological regime.

It is sometimes possible to get a rough estimate of how close the meteorological conditions that existed during the tracer test were to true worst-case conditions. If air pollutant monitors and similar emission sources already exist in the area, pollutant concentrations measured the day of the tracer test can be compared to high values previously measured at these same monitors. When relatively high concentrations are measured by monitors during the tracer test it gives justification to the notion that worst-case conditions existed while the tracer test was conducted. This corrrelation of tracer test data to air quality data from nearby sites should take into consideration site specific differences in the source/receptor relationship (elevation differences, wind direction, and distance). A comparison of this type should be made whenever possible.

4. Number and Location of Samplers

The number and location of the tracer samplers should be sufficient to obtain a general understanding of the transport and dispersion characteristics of the study area. The number and location of tracer samplers should also insure measurement of the maximum impact. Tracer samplers should be placed at sensitive receptors which could potentially be impacted by the source. Tracer samplers which are capable of operating on their own power (i.e., do not need a direct electrical hookup) should be used if needed to meet these objectives. Use of continuous tracer gas samplers is often advantageous. Since measurements are instantaneous, data can be used to interpret hourly readings at fixed stations during variable winds or flow reversal situations. Another useful sampling technique is a mobile tracer gas analyzer.

In some situations consideration should be given to obtaining a vertical profile of the tracer gas distribution. This information could be useful in cases when the plume is kept aloft by an inversion and suddenly brought to the ground in a morning fumigation episode. The possibilities of this phenomena occuring could be analyzed if a vertical profile were available.

5. <u>Tracer Release Height</u>

The release height of the tracer should correspond as closely as possible to the estimated effective stack height (stack height plus plume rise) of the proposed source. One of the plume rise equations available (ex. Briggs, 75) could be used to calculate the effective plume height under the predefined meteorological conditions if the necessary stack parameters are available. If these parameters are not available a legitimate estimate of the effective stack height should be made. When making this estimate, the effective stack height used should insure maximum source impact at the areas of concern, under meteorological conditions targeted as worst-case.

6. <u>Location of Tracer Release</u>

The location of the tracer release should correspond as closely as possible to the source location. If multiple-sources are involved the location of the sources and the existing airsheds at the site should be examined. The tracer release point would preferably be centrally located and in the airshed which will influence a majority of emissions. An area source (or line source) release could be considered if the air quality analysis does not require the impact from each specific source. In some cases two tracer gases may have to be released.

7. <u>Meteorological Data</u>

There are two reasons for collecting meteorological data during tracer tests. One is that the meteorological data taken can help explain the transport and diffusion characteristics of the site and the tracer concentrations found. The other is that the data can be used for validation and calibration of a dispersion model. The meteorological data system should be designed with these factors in mind (Section 9).

The complex circulation of a mountain-valley environment, with its slope, valley, and anti-valley flows, emphasizes the need for adequate data collection. In almost all cases temperature, wind direction, and wind speed will be needed at several locations; the tracer release point and sensitive receptors being the most important.

Other important meteorological variables are atmospheric stability and inversion height. The sigma-phi (vertical wind direction fluctuation) and modified sigma-theta methods of calculating stability are anticipated to be better correlated to actual dispersion rates in complex terrain (EPA, 1981). Vertical soundings of wind speed, wind direction, and temperature are useful in understanding the vertical structure of the atmosphere and inversion height. This information can be obtained from vertical soundings by a tethersonde or similar system by tall meteorological instrument towers, or by doppler acoustic sounders. For some tracer tests, especially those involving a relatively high tracer gas release height, vertical sounding may have to be taken at several locations. If a tethersonde system is used an effort should be made to take vertical measurements near the time of critical atmospheric events, such as valley wind flow reversals.

8. Background Tracer Gas

Allow a sufficient amount of time between tracer tests to insure that non-negligable amount of tracer gas released in an earlier tracer test have not persisted in the immediate airshed. The fact that no tracer gas from an earlier test remains can be verified by taking tracer gas samples an hour or two before the tracer gas is released for the next test. The appearance of an area of low tracer gas concentration would be possible indicator of this phenomenon. Pretest and upwind monitoring can also determine if there is a significant background concentration of the tracer test gas. SF_6 is used throughout the world as an insulating gas in high-voltage power transformers and switches. Leakage of SF_6 from this equipment to the atmosphere has produced a current SF_6 background concentration of 0.5 parts per trillion by volume. Pretest monitoring will help discover any local sources of SF_6 which could affect tracer test results.

Depending on the type of tracer test, background concentrations as high as 5-10 ppt may be acceptable as long as the following conditions are met:

A. Primary plume impact concentrations are at least 1 or 2 orders of magnitude greater than the background.

B. The background concentrations do not change significantly during the experiment.

C. The background concentrations are uniform throughout the study area.

It is important in this situation to collect samples at several locations outside the plume impact region to properly assess the background concentration.

9. Dispersion Modeling

As stated earlier one of the primary objectives of a tracer test is to provide a data base for evaluation and calibration of an air pollutant dispersion model. The choice of which model to use should be made on a case-by-case basis. Numerical, Gaussian Puff, and box are all types of models which have had some success in simulating dispersion and transport processes in complex terrain. It is highly desirable to select a model type or even better a specific model prior to designing the tracer program. The required inputs in the model will dictate the minimum specifications to the collection of meteorological data (Section 7) as well as the tracer sampler array (Section 4).

There are several reasons why tracer test data by itself should not be used for estimating air pollution impacts. A project may have multiple sources in different locations with different plume rises. Releasing tracer gas at every location at every height would be difficult. Often the exact location of the various sources is not known at the time of the tracer test study. Tracer tests are run under a limited number of meteorological conditions and with a limited number of tracer gas samplers. It is virtually impossible for a tracer test to provide concentration estimates at all locations during all types of meteorological conditions. Dispersion modeling can overcome many of these limitations and provide for a more complete analysis of future concentrations.

10. Quality Assurance

A written quality assurance program should be prepared prior to conducting a tracer test program. Some of the important points which should be considered when formulating a tracer test quality assurance program are summarized below. Meteorology Research, Inc. has assisted in compiling the list.

Tracer Release

- Verify the amount and rate of tracer release by measuring the weight loss from the tracer cylinders at specified time intervals.
- Accuracy of scales verified by a local weights and measures department or in-house calibration.
- Utilize regulator and flowmeter system to maintain a steady release rate.
- Leak-check release plumbing using bubble solution.
- Pressure check release lines.
- Document procedures in field notebook or on forms.

Tracer Samplers

- Check operational integrity of samplers, i.e., timing, flow rate -- document operational parameters of samplers when checking in field.
- Run collocated samplers at one or more sites.
- Conduct preventive maintenance on on the tracer gas samplers to insure a data recovery rate of at least 75% for each sampler in operation. High data recovery rates are especially important in "Key" sampling locations.

Sample Detection

- Document the chain of possession of tracer samples.

- Multiple calibrations of gas chromatograph (calibration drift occurs as contaminants build up in the column). This should include a pre and post test calibration as a minimum.

- One point calibration check during analysis to determine if calibration is drifting. If a significant deviation is noted, the gas chromatograph should be recalibrated.

- Multipoint calibration of gas chromatograph -- at least three different concentrations should be used on the most commonly used sensitivity range.

- Document source of calibration gas (NBS standards do not exist).

- Repeat 5 to 7 percent of analyses.

- Laboratory room air analysis -- it is desirable to have the laboratory in a "clean" environment to minimize possible contamination of samples during storage and injection into the gas chromatograph.

- Release personnel should not be allowed near the analysis lab without a change of clothing and "clean up."

- It is important to make sure that reused sample bags and syringes are tracer gas free each time they are used. Bags should be purged with tracer gas free air or nitrogen and fully evacuated at least twice to purge the bag of any residual tracer gas. Syringes should be purged in the same manner.

- Document all of the above items.

Independent Audit

o Includes an audit of the program by a team independent of the project manager.

In the reporting phase of the program an attempt should be made to assign an error bound to the data set. At the present quality control level with all aspects of the tracer system included an error bound between 10 and 20 percent is more common when using SF6 as the tracer gas.

There have been several successful tracer tests run in Western Colorado. Documentation of these studies (Baskett, 1982; Chan, 1979) provide additional guidance on conducting tracer tests.

It is recommended that prior to conducting a tracer test program the test plan and quality assurance program be reviewed by the APCD. This type of review will help minimize problems when the tracer test study is later submitted for approval.

References

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Appendix D

Federal Registers

Appendix B—Quality Assurance Requirements for Prevention of Significant Deterioration (PSD) Air Monitoring

1. General Information

This Appendix specifies the minimum quality assurance requirements of an organization operating a network of PSD stations. These requirements are regarded as the minimum necessary for the control and assessment of the quality of the PSD ambient air monitoring data submitted to EPA. Organizations are encouraged to develop and implement quality assurance programs more extensive than the minimum required or to continue such programs where they already exist.

Quality assurance consists of two distinct and equally important functions. One function is the assessment of the quality of the monitoring data by estimating their precision and accuracy. The other function is the control, and improvement, of the quality of the monitoring data by implementation of quality control policies, procedures and corrective actions. These two functions form a control loop: When the assessment function indicates that the data quality is inadequate, the control effort must be increased until the data quality is acceptable.

In order to provide uniformity in the assessment and reporting of data quality, the assessment procedures are specified explicitly in sections 3, 4, 5 and 6 of this Appendix.

In contrast, the control and corrective action function encompasses a variety of policies, procedures, specifications, standards, and corrective measures which have varying effects on the resulting data quality. The selection and degree of specific control measures and corrective actions used depend on a number of factors such as the monitoring methods and equipment used, field and laboratory conditions, the objectives of the monitoring, the level of data quality needed, the expertise of personnel, the cost of control procedures, pollutant concentration levels, etc. Accordingly, quality control requirements are specified in general terms, in section 2 of this Appendix, to allow each organization to develop a quality control system which is most effective for its own circumstances.

For purposes of this Appendix "organization" is defined as a source owner/operator, a government agency, or their contractor which operates an ambient air pollution monitoring network for PSD purposes.

2. Quality Control Requirements

2.1 Each organization must develop and implement a quality control program consisting of policies, procedures, specifications, standards and documentation necessary to:

(1) Meet the monitoring objectives and quality assurance requirements of the permit granting authority.

(2) Minimize loss of air quality data due to malfunctions or out-of-control conditions.

The quality control program must be described in detail, suitably documented, and approved by the permit granting authority.

2.2 Primary guidance for developing the quality control program is contained in references 1 and 2, which also contain many suggested procedures, checks, and control specifications. Section 2.09 of Reference 2 describes specific guidance for the development of a quality control program for PSD automated analyzers and manual methods. Many specific quality control checks and specifications for manual methods are included in the respective reference methods described in Part 50 of this chapter, or in the respective equivalent method descriptions available from EPA (see reference 5). Similarly, quality control procedures related to specifically designated reference and equivalent analyzers are contained in their respective operation and instruction manuals. This guidance, and any other pertinent information from appropriate sources, should be used by organizations in developing their quality control programs.

As a minimum each quality control program must have operational procedures for each of the following activities:

(1) Selection of methods, analyzers, or samplers.

(2) Installation of equipment.

(3) Calibration.

(4) Zero and span checks and adjustments of automated analyzers.

(5) Control checks and their frequency.

(6) Control limits for zero, span and other control checks, and respective corrective actions when such limits are surpassed.

(7) Calibration and zero/span checks for multiple range analyzers.

(8) Preventive and remedial maintenance.

(9) Recording and validating data.

(10) Documentation of quality control information.

2.3 *Pollutant Standards.*

2.3.1 Gaseous standards (permeation tubes, permeation devices or cylinders of compressed gas) used to obtain test concentrations for CO, SO_2, and NO_2 must be working standards certified by comparison to a National Bureau of Standards (NBS) gaseous Standard Reference Material (SRM). A traceability protocol for certifying a working standard by direct comparison to an NBS SRM is given in reference 3. Direct use of an NBS SRM as a working standard is not prohibited but is discouraged because of the limited supply and expense of NBS SRM's.

2.3.2 Test concentrations for ozone must be obtained in accordance with the UV photometric calibration procedure specified in Appendix D of Part 50 of this chapter, or by means of an ozone transfer standard which has been certified. Consult reference 4 for guidance on ozone transfer standards.

2.3.3 Flow measurements must be made by a flow measuring instrument which is traceable to an authoritative volume or other standard.

2.4 Performance and System Audit Programs

The organization operating a PSD monitoring network must participate in EPA's national performance audit program. The permit granting authority, or EPA, may conduct system audits of the ambient air monitoring programs of organizations operating PSD networks. See section 1.4.16 of reference 1 and reference 6 for additional information about these programs. Organizations should contact either the appropriate EPA Regional Quality Control Coordinator or the Quality Assurance Branch, EMSL/RTP, at the address given in reference 3 for instructions for participation.

3. Data Quality Assessment Requirements

3.1 *Precision of Automated Methods.*

A one-point precision check must be carried out at least once every two weeks on each automated analyzer used to measure SO_2, NO_2, O_3 and CO. The precision check is made by challenging the analyzer with a precision check gas of known concentration between 0.08 and 0.10 ppm for SO_2, NO_2 and O_3 analyzers, and between 8 and 10 ppm for CO analyzers. The standards from which precision check test concentrations are obtained must meet the specifications of section 2.3. Except for certain CO analyzers described below, analyzers must operate in their normal sampling mode during the precision check, and the test atmosphere must pass through all filters, scrubbers, conditioners, and other components used during normal ambient sampling and as much of the ambient air inlet system as is practicable. If permitted by the associated operation or instruction manual, a CO analyzer may be temporarily modified during the precision check to reduce vent or purge flows, or the test atmosphere may enter the analyzer at a point other than the normal sample inlet, *provided that* the analyzer's response is not likely to be altered by these deviations from the normal operational mode.

If a precision check is made in conjunction with zero/span adjustment, it must be made prior to such zero and span adjustments. The difference between the actual concentration of the precision check gas and the concentration indicated by the analyzer is used to assess the precision of the monitoring data as described in section 4.1. Report data only from automated analyzers that are approved for use in the PSD network.

3.2 *Accuracy of Automated Methods.*

Each sampling quarter, audit each analyzer that monitors for SO_2, NO_2, O_3 or CO at least once. The audit is made by challenging the analyzer with at least one audit gas of known concentration from each of the following range which fall within the measurement range of the analyzer being audited:

Audit point	Concentration range, ppm	
	SO_2, NO_2, O_3	CO
1	0.03-0.08	3-8
2	0.15-0.20	15-20
3	0.35-0.45	35-45
4	0.80-0.90	80-90

The standards from which audit gas test concentrations are obtained must meet the specifications of section 2.3. Working and transfer standards and equipment used for auditing must be different from the standards and equipment used for calibration and spanning. The auditing standards and calibration standards may be referenced to the same NBS SRM or primary UV photometer. The auditor must not be the operator/analyst who conducts the routine monitoring, calibration and analysis.

The audit shall be carried out by allowing the analyzer to analyze an audit test atmosphere in the same manner as described for precision checks in section 3.1. The exception given in section 3.1 for certain CO analyzers does not apply for audits.

The difference between the actual concentration of the audit test gas and the concentration indicated by the analyzer is used to assess the accuracy of the monitoring data as described in section 4.2. Report data only from automated analyzers that are approved for use in the PSD network.

3.3 *Precision of Manual Methods.*

3.3.1 *TSP Method.* For a given organization's monitoring network, one sampling site must have collocated samplers. A site with the highest expected 24-hour pollutant concentration must be selected. The two samplers must be within 4 meters of each other but at least 2 meters apart to preclude airflow interference. Calibration, sampling and analysis must be the same for both collocated samplers as well as for all other samplers in the network. The collocated samplers must be operated as a minimum every third day when continuous sampling is used.

D-2

When a less frequent sample schedule is used, the collocated samplers must be operated at least once each week. For each pair of collocated samplers, designate one sampler as the sampler which will be used to report air quality for the site and designate the other as the duplicate sampler. The differences in measured concentration ($\mu g/m^3$) between the two collocated samplers are used to calculate precision as described in section 5.1.

3.3.2 *Pb Method.* The operation of collocated samplers at one sampling site must be used to assess the precision of the reference or an equivalent Pb method. The procedure to be followed for Pb methods is the same as described in 3.3.1 for the TSP method. If approved by the permit granting authority, the collocated TSP samplers may serve as the collocated lead samplers.

3.4 *Accuracy of Manual Methods.*

3.4.1 *TSP Method.* Each sampling quarter audit the flow rate of each high-volume sampler at least once. Audit the flow rate at one flow rate using a reference flow device described in section 2.2.8, pages 3-5, of reference 2, or a similar transfer flow standard. The device used for auditing must be different from the one used to calibrate the flow of the high-volume sampler being audited. The auditing device and the calibration device may both be referenced to the same primary flow standard. With the audit device in place, operate the high-volume sampler at its normal flow rate. The difference in flow rate (in m^3/min) between the audit flow measurement and the flow indicated by the sampler's normal flow indicator are used to calculate accuracy as described in section 5.2.

Great care must be used in auditing high-volume samplers having flow regulators because the introduction of resistance plates in the audit device can cause abnormal flow patterns at the point of flow sensing. For this reason, the orifice of the flow audit device should be used with a normal glass fiber filter in place and without resistance plates in auditing flow regulated high-volume samplers, or other steps should be taken to assure that flow patterns are not perturbed at the point of flow sensing.

3.4.2 *Pb Method.* For the reference method (Appendix G of Part 50 of this chapter) during each sampling quarter audit the flow rate of each high-volume Pb sampler at least once. The procedure to be followed for lead methods is the same as described in section 3.4.1 for the TSP method.

For each sampling quarter, audit the Pb analysis using glass fiber filter strips containing a known quantity of lead. Audit samples are prepared by depositing a Pb solution on 1.9 cm by 20.3 cm (¾ inch by 8 inch) unexposed glass fiber filter strips and allowing to dry thoroughly. The audit samples must be prepared using reagents different from those used to calibrate the Pb analytical equipment being audited. Prepare audit samples in the following concentration ranges:

Ranges	Pb concentration μg/strip	Equivalent ambient Pb concentration $\mu g/m^3$ [1]
1	100 to 300	0.5 to 1.5
2	600 to 1,000	3.0 to 5.0

[1] Equivalent ambient Pb concentration in $\mu g/m^3$ is based on sampling at 1.7 m^3/min for 24 hours on 20.3 cm × 25.4 cm (8 inch × 10 inch) glass fiber filter.

Audit samples must be extracted using the same extraction procedure used for exposed filters.

Analyze at least one audit sample in each of the two ranges each day that samples are anlayzed. The difference between the audit concentration (in μg Pb/strip) and the analyst's measured concentration (in μg Pb/strip) is used to calculate accuracy as described in section 5.4.

The accuracy of an equivalent method is assessed in the same manner as the reference method. The flow auditing device and Pb analysis audit samples must be compatible with the specific requirements of the equivalent method.

4. Calculations for Automated Methods

4.1 *Single Analyzer Precision.*

Each organization, at the end of each sampling quarter, shall calculate and report a precision probability interval for each analyzer. Directions for calculations are given below and directions for reporting are given in section 6. If monitoring data are invalidated during the period represented by a given precision check, the results of that precision check shall be excluded from the calculations. Calculate the percentage difference (d_i) for each precision check using equation 1.

$$d_i = \frac{Y_i - X_i}{X_i} \times 100 \qquad (1)$$

where:

Y_i analyzer's indicated concentration from the i-th precision check

X_i known concentration of the test gas used for the i-th precision check.

For each instrument, calculate the quarterly average ($\bar{d}_j$), equation 2, and the standard deviation (S_j), equation 3.

$$\bar{d}_j = \frac{1}{n} \sum_{i=1}^{n} d_i \qquad (2)$$

$$S_j = \sqrt{\frac{1}{n-1}\left[\sum_{i=1}^{n} d_i^2 - \frac{1}{n}\left(\sum_{i=1}^{n} d_i\right)^2\right]} \qquad (3)$$

where n is the number of precision checks on the instrument made during ther sampling quarter. For example, n should be 6 or 7 if span checks are made biweekly during a quarter.

Calculate the 95 percent probability limits for precision using equation 4 and 5.

Upper 95 Percent Probability Limit $= \bar{d}_j + 1.96\, S_j$ (4)

Lower 95 Percent Probability Limit $= \bar{d}_j - 1.96\, S_j$ (5)

4.2 *Single Analyzer Accuracy.*

Each organization, at the end of each sampling quarter, shall calculate and report the percentage difference for each audit concentration for each analyzer audited during the quarter. Directions for calculations are given below (directions for reporting are given in section 6).

Calculate and report the percentage difference (d_i) for each audit concentration using equation 1 where Y_i is the analyzer's indicated concentration from the i-th audit check and X_i is the known concentration of the audit gas used for the i-th audit check.

5. Calculations For Manual Methods

5.1 *Single Instrument Precision for TSP and Pb.* Estimates of precision for ambient air quality measurements from the TSP and Pb methods are calculated from results obtained from the collocation of two samplers at one sampling site as described in section 3.3.1 for TPS and 3.3.2 for Pb. At the end of each sampling quarter, calculate and report a precision probability interval using weekly collocation sampler results. Directions for calculation are given below and directions for reporting are given in section 6.

For the paired measurements described in section 3.3.1 or 3.3.2 calculate the percentage difference (d_i) using equation 1 where Y_i is the TSP or Pb concentration measured by the duplicate sampler and X_i is the TSP or Pb concentration measured by the sampler reporting air quality for the site. Calculate the quarterly average percentage difference ($\bar{d}_j$), equation 2, standard deviation (S_j), equation 3, and upper and lower 95 percent probability limits for precision (equations 6 and 7).

Upper 95 Percent Probability Limit

$\bar{d}_j + 1.96 S_j / \sqrt{2}$ (6)

Lower 95 Percent Probability Limit

$\bar{d}_j - 1.96 S_j / \sqrt{2}$ (7)

5.2 *Single Instrument Accuracy for TSP.* Each organization, at the end of each sampling quarter, shall calculate and report the percentage difference for each high-volume sampler audited during the quarter. Directions for calculation are given below and directions for reporting are given in section 6.

For the flow rate audit described in section 3.4, let X_i represent the known flow rate and Y_i represent the indicated flow rate. Calculate the percentage difference (d_i) using equation 1.

5.3 *Single Instrument Accuracy for Pb.* Each organization, at the end of each sampling quarter, shall calculate and report the percentage difference for each high-volume lead sampler audited during the quarter. Directions for calculation are given in 5.2 and directions for reporting are given in section 6.

5.4 *Single-Analysis-Day Accuracy for Pb.* Each organization, at the end of each sampling quarter, shall calculate and report the percentage difference for each Pb analysis audit during the quarter. Directions for calculations are given below and directions for reporting are given in section 6.

For each analysis audit for Pb described in section 3.4.2, let X_i represent the known value of the audit sample and Y_i the indicated value of Pb. Calculate the percentage difference (d_i) for each audit at each concentration level using equation 1.

6. Organization Reporting Requirements

At the end of each sampling quarter, the organization must report the following data assessment information:

(1) For automated analyzers—precision probability limits from section 4.1 and percentage differences from section 4.2, and

(2) For manual methods—precision probability limits from section 5.1 and percentage differences from sections 5.2 and 5.3.

The precision and accuracy information for the entire sampling quarter must be submitted with the air monitoring data. All data used to calculate reported estimates of precision and accuracy including span checks, collocated sampler and audit results must be made available to the permit granting authority upon request.

References

1. "Quality Assurance Handbook for Air Pollution Measurement Systems, Volume I—Principles." EPA 600/9 76 005, March 1976. Available from U.S. Environmental Protection Agency, Environmental Monitoring and Support Laboratory (MD-77), Research Triangle Park, North Carolina 27711.

2. "Quality Assurance Handbook for Air Pollution Measurement Systems, Volume II Ambient Air Specific Methods." EPA-

600/4-77-027a, May 1977. Available from U.S. Environmental Protection Agency, Environmental Monitoring and Support Laboratory (MD-77), Research Triangle Park, North Carolina 27711.

3. "Traceability Protocol for Establishing True Concentrations of Gases Used for Calibration and Audits of Air Pollution Analyzers." (Protocol No. 2), June 1978. Available from U.S. Environmental Protection Agency, Environmental Monitoring and Support Laboratory, Quality Assurance Branch (MD 77), Research Triangle Park, North Carolina 27711.

4. "Transfer Standards for Calibration of Ambient Air Monitoring Analyzers for Ozone," June 1978. Available from U.S. Environmental Protection Agency, Department E (MD 77), Research Triangle Park, North Carolina 27711.

5. "List of Reference and Equivalent Methods." Available from U.S. Environmental Protection Agency, Department E (MD-77), Research Triangle Park, North Carolina 27711.

6. "Criteria, Procedures, and Forms for the Evaluation of Ambient Air Monitoring Programs—Laboratory and Field," June 1978. Available from U.S. Environmental Protection Agency, Environmental Monitoring and Support Laboratory, Quality Assurance Branch (MD-77), Research Triangle Park, North Carolina 27711.

[44 FR 27571, May 10, 1979; 44 FR 65070, Nov. 9, 1979; 44 FR 72592, Dec. 14, 1979, as amended at 46 FR 44168, Sept. 3, 1981]

Appendix C—Ambient Air Quality Monitoring Methodology

1.0 Purpose

This appendix specifies the monitoring methods (manual methods or automated analyzers) which must be used in State ambient air quality monitoring stations.

2.0 State and Local Air Monitoring Stations (SLAMS)

2.1 Except as otherwise provided in this appendix, a monitoring method used in a SLAMS must be a reference or equivalent method as defined in § 50.1 of this chapter.

2.2 Any analyzer for SO_2, CO, or O_3, purchased before February 18, 1976, may be used in a SLAMS until February 18, 1980. Any analyzer for NO_2 purchased before January 3, 1978, may be used in a SLAMS until January 3, 1980. Any method for lead in use before June 6, 1979, may be used in a SLAMS until June 6, 1980.

2.2.1 Any analyzer for SO_2, CO, or O_3, purchased before February 18, 1976, may be used in a SLAMS until February 18, 1980.

2.2.2 Any analyzer for NO_2 purchased before January 3, 1978, may be used in a SLAMS until January 3, 1980.

2.3 Any manual method or analyzer purchased prior to cancellation of its reference or equivalent method designation under § 53.11 or § 53.16 of this chapter may be used in a SLAMS following cancellation for a reasonable period of time to be determined by the Administrator.

2.4 *Use of Nonconforming Analyzers in Certain Geographical Areas.*

2.4.1 The State may use an analyzer that is not a reference or equivalent method in a SLAMS in a particular geographical area if the analyzer was purchased prior to February 18, 1975, and the Administrator determines:

2.4.1.1 That the analyzer (or the method of which the analyzer is representative) meets all the requirements of Part 53 of this chapter that would apply if an application for a reference or equivalent method determination were submitted for the method of which the analyzer is representative except: (A) the test for interference equivalent specified in § 53.23(d) of this chapter, and (B) requirements of Subpart C of Part 53 of this chapter, if applicable, to the extent that failure to meet the Subpart C requirements results from sensitivity to interferants; and

2.4.1.2 That interferants that cause or would cause the analyzer to fail the requirements of § 53.23(d) and Subpart C of Part 53 of this chapter do not occur in significant concentrations in the geographical area in which use of the analyzer is proposed. For purposes of this section (2.4), a "significant concentration" means one that would cause a measurement error equal to or greater than the lower detectable limit specification in Table B-1 in Subpart B of Part 53 of this chapter.

2.4.2 Requests for approval under this section (2.4) must meet the submittal requirements of section 2.7. Except as provided in subsection 2.7.3, each such request must contain the information specified in subsection 2.7.2 in addition to the following:

2.4.2.1 The date on which the analyzer was purchased;

2.4.2.2 An identification and description of the geographical area in which use of the analyzer is proposed;

2.4.2.3 Such data or other information as may be necessary to demonstrate that the interferants referred to in section 2.4.1.2 do not occur in significant concentrations in the geographical area in which use of the analyzer is proposed; and

2.4.2.4 Test data for tests conducted with the analyzer in accordance with Subpart C of Part 53 of this chapter in the geographical area in which use of the analyzer is proposed. If Subpart C would apply if an application for a reference or equivalent method

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concentrations for CO, SO_2, and NO_2 must be traceable to either a National Bureau of Standards (NBS) Standard Reference Material (SRM) or an NBS/EPA-approved commercially available Certified Reference Material (CRM). CRM's are described in Reference 7, and a list of CRM sources is available from the address shown for Reference 7. A recommended protocol for certifying gaseous standards against an SRM or CRM is given in References 2 and 3. Direct use of a CRM as a working standard is acceptable, but direct use of an NBS SRM as a working standard is discouraged because of the limited supply and expense of SRM's

6. By adding "CRM," to the third sentence of the fourth paragraph of section 3.1.2 of Appendix A to read:

* * * The auditing standards and calibration standards may be referenced to the same NBS SRM, CRM, or primary UV photometer. * * *

7. By adding the following reference to Appendix A:

References

* * * * *

7. A procedure for Establishing Traceability of Gas Mixtures to Certain National Bureau of Standards Standard Reference Materials. EPA-600/7-81-010. Joint publication by NBS and EPA. Available from the U.S. Environmental Protection Agency, Environmental Monitoring Systems Laboratory (MD-77), Research Triangle Park, North Carolina 27711. May 1981.

Appendix B—[Amended]

8. By revising paragraph 2.3.1 of Appendix B, "Quality Assurance Requirements for Prevention of Significant Deterioration (PSD) Air Monitoring," to read as follows:

* * * * *

2.3.1 Gaseous standards (permeation tubes, permeation devices or cylinders of compressed gas) used to obtain test concentrations for CO, SO_2, and NO_2 must be traceable to either a National Bureau of Standards (NBS) gaseous Standard Reference Material (SRM) or an NBS/EPA-approved commercially available Certified Reference Material (CRM). CRM's are described in Reference 7, and a list of CRM sources is available from the address shown for Reference 7. A recommended protocol for certifying gaseous standards against an SRM or CRM is given in References 2 and 3. Direct use of a CRM as a working standard is acceptable, but direct use of an NBS SRM as a working standard is discouraged because of the limited supply and expense of SRM's.

9. By adding, "CRM," to the third sentence of the second paragraph of section 3.2 of Appendix B to read: * * * The auditing standards and calibration standards may be referenced to the same NBS SRM, CRM, or primary UV photometer. * * *

10. By adding the following reference to Appendix B:

References

* * * * *

7. "A Procedure for Establishing Traceability of Gas Mixtures to Certain National Bureau of Standards Standard Reference Materials." EPA-600/7-81-010, Joint publication by NBS and EPA. Available from the U.S. Environmental Protection Agency, Environmental Monitoring Systems Laboratory (MD-77), Research Triangle Park, North Carolina 27711 May 1981.

[FR Doc. 83-1447 Filed 1-19-83; 8:45 am]

BILLING CODE 6560-50-M

*** Please note that the 1982 CFR contains a major typographical error. The 95% Probability Limits in Section 5.1 should be -

$$d_i +/- 1.96Sj/\sqrt{2}$$

a. The first phrase in the first sentence of section 3.3 is revised to read as follows: "For each network of manual methods," * * *

b. The following sentence is inserted after the second sentence in section 3.3 "For particulate matter, a network for measuring PM_{10} shall be separate from a TSP network."

c. The measurement limits for PM_{10} are added to the list of limits in section 5.3.1: "PM_{10}: 20$\mu g/m^3$."; the word "and" is deleted from the third limit; and the period at the end of the fourth limit is replaced by a comma and the word "and."

d. Table A-1 is revised to read as follows:

TABLE A-1.—MINIMUM DATA ASSESSMENT REQUIREMENTS

Method	Assessment method	Coverage	Minimum frequency	Parameters reported
Precision:				
Automated methods for SO_2, NO_2, O_3, and CO.	Response check at concentration between .08 and .10 ppm (8 & 10 ppm for CO).	Each analyzer	Once per 2 weeks	Actual concentration and measured concentration.
Manual methods including lead.	Collocated samplers	1 site for 1-5 sites; 2 sites 6-20 sites; 3 sites >20 sites; (sites with highest conc.).	Once per week	Two concentration measurements.
Accuracy:				
Automated methods for SO_2, NO_2, O_3, and CO.	Respose check at .03-.08 ppm;[1] .15-.20 ppm;[1] .35-.45 ppm;[1] .80-.90 ppm[1] (if applicable).	1. Each analyzer; 2. 25% of analyzers (at least 1).	1. Once per year; 2. Each calendar quarter.	Actual concentration and measured (indicated) concentration for each level.
Manual methods for SO_2, and NO_2.	Check of analytical procedure with audit standard solutions.	Analytical system	Each day samples are analyzed, at least twice per quarter.	Actual concentration and measured (indicated) concentration for each audit solution.
TSP, PM_{10}	Check of sampler flow rate	1. Each sampler; 2. 25% of samplers (at least 1).	1. Once per year; 2. Each calendar quarter.	Actual flow rate and flow rate indicated by the sampler.
Lead	1. Check sample flow rate as for TSP; 2. Check analytical system with Pb audit strips.	1. Each sampler; 2. Analytical system.	1. Include with TSP; 2. Each quarter.	1. Same as for TSP; 2. Actual cocentration and measured (indicated) concentration of audit samples (μg Pb/strip).

[1] Conc. times 100 for CO.

Appendix B—[Amended]

10. Appendix B is amended as follows:

a. The heading of paragraph 3.3.1 is revised to read as follows:

3.3.1 *TSP and PM_{10}* Methods. * * *

b. The first paragraph of 3.4.1 is revised to read as follows:

3.4.1 *TSP and PM_{10}* Methods. Each sampling quarter, audit the flow rate of each sampler at least once. Audit the flow at the normal flow rate, using a certified flow transfer standard (see reference 2). The flow transfer standard used for the audit must not be the same one used to calibrate the flow of the sampler being audited, although both transfer standards may be referenced to the same primary flow or volume standard. The difference between the audit flow measurement and the flow indicated by the sampler's flow indicator is used to calculate accuracy, as described in paragraph 5.2.

* * * * *

C. Section 5.1 is revised to read as follows:

5.1 *Single Instrument Precision for TSP, Pb and PM_{10}*. Estimates of precision for ambient air quality particulate measurements are calculated from results obtained from collocated samplers as described in section 3.3. At the end of each sampling quarter, calculate and report a precision probability interval, using weekly result from the collecated samplers. Directions for calculations are given below, and directions for reporting are given in section 6.

For the paired measurements obtained as described in sections 3.3.1 and 3.3.2, calculate the percent difference (d_i) using equation 1a, where Y_i is the concentration of pollutant measured by the duplicate sampler, and X_i is the concentration measured by the sampler reporting air quality for the site. Calculate the quarterly average percent difference (d_j), equation 2; standard deviation (S_j), equation 3; and upper and lower 95 percent probability limits for precision, equations 6 and 7.

$$d_i = \frac{Y_i - X_i}{(Y_i + X_i)/2} \times 100 \quad (1a)$$

$$\text{Upper 95 percent probability limit} = d_j + 1.96 S_j/\sqrt{2} \quad (6)$$

$$\text{Lower 95 percent probability limit} = d_j - 1.96 S_j/\sqrt{2} \quad (7)$$

d. In paragraph 5.2, change the heading to read *"Single Instrument Accuracy for TSP and PM_{10},"* and replace the phrase "each high volume sampler" with the phrase "each high-volume or PM_{10} sampler."

Appendex C—[Amended]

11. In Appendix C, sections 2.0, 4.0, and 5.0 are amended as follows:

a. In section 2.0, paragraphs 2.2.1 and 2.2.2 are deleted and paragraph 2.2 is revised to read as follows:

* * * * *

2.2 For purposes of showing compliance with the NAAQS for particulate matter, the high volume sampler described in Appendix B of Part 50 of this chapter may be used in a SLAMS as long as the ambient concentration of particles measured by the high volume sampler is below the PM_{10} NAAQS.

If the TSP sampler measures a single value which is higher than the PM_{10} 24-hour standard or has an annual average greater than the PM_{10} annual standard, the high volume sampler designated as a substitute PM_{10} sampler must be replaced with a PM_{10} sampler. For the 24-hour standard, the TSP sampler should be replaced with a PM_{10} sampler before the end of the calendar quarter following the quarter in which the exceedance occurred. For the annual standard, the PM_{10} sampler should be diameter less than or equal to a nominal 10 micrometers) by:

(1) A reference method based on Appendix J and designated in accordance with Part 53 of this chapter, or

(2) An equivalent method designated in accordance with Part 53 of this chapter.

§50.7 [Removed and reserved]

3. Section 50.7 is removed and reserved.

4. In Appendix G, reference 10 is removed and reserved and section 5.1.1 is revised to read as follows:

5.1.1 *High-Volume Sampler.* Use and calibrate the sampler as described in Appendix B to this Part.

5. Appendix I is added and reserved.

Appendix I [Reserved]

6. Appendix J is added to read as follows:

Appendix J—Reference Method for the Determination of Particulate Matter as PM_{10} in the Atmosphere

1.0 *Applicability.*

1.1 This method provides for the measurement of the mass concentration of particulate matter with an aerodynamic diameter less than or equal to a nominal 10 micrometers (PM_{10}) in ambient air over a 24-hour period for purposes of determining attainment and maintenance of the primary and secondary national ambient air quality standards for particulate matter specified in § 50.6 of this chapter. The measurement process is nondestructive, and the PM_{10} sample can be subjected to subsequent physical or chemical analyses. Quality assurance procedures and guidance are provided in Part 58, Appendices A and B, of this chapter and in References 1 and 2.

2.0 *Principle.*

2.1 An air sampler draws ambient air at a constant flow rate into a specially shaped inlet where the suspended particulate matter is inertially separated into one or more size fractions within the PM_{10} size range. Each size fraction in the PM_{10} size range is then collected on a separate filter over the specified sampling period. The particle size discrimination characteristics (sampling effectiveness and 50 percent cutpoint) of the sampler inlet are prescribed as performance specifications in Part 53 of this chapter.

2.2 Each filter is weighed (after moisture equilibration) before and after use to determine the net weight (mass) gain due to collected PM_{10}. The total volume of air sampled, corrected to EPA reference conditions (25° C, 101.3 kPa), is determined from the measured flow rate and the sampling time. The mass concentration of PM_{10} in the ambient air is computed as the total mass of collected particles in the PM_{10} size range divided by the volume of air sampled, and is expressed in micrograms per standard cubic meter ($\mu g/std\ m^3$). For PM_{10} samples collected at temperatures and pressures significantly different from EPA reference conditions, these corrected concentrations sometimes differ substantially from actual concentrations (in micrograms per actual cubic meter), particularly at high elevations. Although not required, the actual PM_{10} concentration can be calculated from the corrected concentration, using the average ambient temperature and barometric pressure during the sampling period.

2.3 A method based on this principle will be considered a reference method only if (a) the associated sampler meets the requirements specified in this appendix and the requirements in Part 53 of this chapter, and (b) the method has been designated as a reference method in accordance with Part 53 of this chapter.

3.0 *Range.*

3.1 The lower limit of the mass concentration range is determined by the repeatability of filter tare weights, assuming the nominal air sample volume for the sampler. For samplers having an automatic filter-changing mechanism, there may be no upper limit. For samplers that do not have an automatic filter-changing mechanism, the upper limit is determined by the filter mass loading beyond which the sampler no longer maintains the operating flow rate within specified limits due to increased pressure drop across the loaded filter. This upper limit cannot be specified precisely because it is a complex function of the ambient particle size distribution and type, humidity, filter type, and perhaps other factors. Nevertheless, all samplers should be capable of measuring 24-hour PM_{10} mass concentrations of at least 300 $\mu g/std\ m^3$ while maintaining the operating flow rate within the specified limits.

4.0 *Precision.*

4.1 The precision of PM_{10} samplers must be 5 $\mu g/m^3$ for PM_{10} concentrations below 80 $\mu g/m^3$ and 7 percent for PM_{10} concentrations above 80 $\mu g/m^3$, as required by Part 53 of this chapter, which prescribes a test procedure that determines the variation in the PM_{10} concentration measurements of identical samplers under typical sampling conditions. Continual assessment of precision via collocated samplers is required by Part 58 of this chapter for PM_{10} samplers used in certain monitoring networks.

5.0 *Accuracy.*

5.1 Because the size of the particles making up ambient particulate matter varies over a wide range and the concentration of particles varies with particle size, it is difficult to define the absolute accuracy of PM_{10} samplers. Part 53 of this chapter provides a specification for the sampling effectiveness of PM_{10} samplers. This specification requires that the expected mass concentration calculated for a candidate PM_{10} sampler, when sampling a specified particle size distribution, be within ±10 percent of that calculated for an ideal sampler whose sampling effectiveness is explicitly specified. Also, the particle size for 50 percent sampling effectiveness is required to be 10±0.5 micrometers. Other specifications related to accuracy apply to flow measurement and calibration, filter media, analytical (weighing) procedures, and artifact. The flow rate accuracy of PM_{10} samplers used in certain monitoring networks is required by Part 58 of this chapter to be assessed periodically via flow rate audits.

6.0 *Potential Sources of Error.*

6.1 *Volatile Particles.* Volatile particles collected on filters are often lost during shipment and/or storage of the filters prior to the post-sampling weighing [3]. Although shipment or storage of loaded filters is sometimes unavoidable, filters should be reweighed as soon as practical to minimize these losses.

6.2 *Artifacts.* Positive errors in PM_{10} concentration measurements may result from retention of gaseous species on filters [4, 5]. Such errors include the retention of sulfur dioxide and nitric acid. Retention of sulfur dioxide on filters, followed by oxidation to sulfate, is referred to as artifact sulfate formation, a phenomenon which increases with increasing filter alkalinity [6]. Little or no artifact sulfate formation should occur using filters that meet the alkalinity specification in section 7.2.4. Artifact nitrate formation, resulting primarily from retention of nitric acid, occurs to varying degrees on many filter types, including glass fiber, cellulose ester, and many quartz fiber filters [5, 7, 8, 9, 10]. Loss of true atmospheric particulate nitrate during or following sampling may also occur due to dissociation or chemical reaction. This phenomenon has been observed on Teflon® filters [8] and inferred for quartz fiber filters [11, 12]. The magnitude of nitrate artifact errors in PM_{10} mass concentration measurements will vary with location and ambient temperature; however, for most sampling locations, these errors are expected to be small.

6.3 *Humidity.* The effects of ambient humidity on the sample are unavoidable. The filter equilibration procedure in section [illegible] is designed to minimize the effects of moisture on the filter medium.

6.4 *Filter Handling.* Careful handling of filters between presampling and postsampling weighings is necessary to avoid errors due to damaged filters or loss of collected particles from the filters. Use of a filter cartridge or cassette may reduce the magnitude of these errors. Filters must also meet the integrity specification in section 7.2.3.

6.5 *Flow Rate Variation.* Variations in the sampler's operating flow rate may alter the particle size discrimination characteristics of the sampler inlet. The magnitude of this error will depend on the sensitivity of the inlet to variations in flow rate and on the particle distribution in the atmosphere during the sampling period. The use of a flow control device (section 7.1.3) is required to minimize this error.

6.6 *Air Volume Determination.* Errors in the air volume determination may result from errors in the flow rate and/or sampling time measurements. The flow control device serves to minimize errors in the flow rate determination, and an elapsed time meter (section 7.1.5) is required to minimize the error in the sampling time measurement.

7.0 *Apparatus.*

7.1 *PM_{10} Sampler.*

7.1.1 The sampler shall be designed to:

a. Draw the air sample into the sampler inlet and through the particle collection filter at a uniform face velocity.

b. Hold and seal the filter in a horizontal position so that sample air is drawn downward through the filter.

c. Allow the filter to be installed and removed conveniently.

d. Protect the filter and sampler from precipitation and prevent insects and other debris from being sampled.

e. Minimize air leaks that would cause error in the measurement of the air volume passing through the filter.

f. Discharge exhaust air at a sufficient distance from the sampler inlet to minimize the sampling of exhaust air.

g. Minimize the collection of dust from the supporting surface.

7.1.2 The sampler shall have a sample air inlet system that, when operated within a specified flow rate range, provides particle size discrimination characteristics meeting all of the applicable performance specifications prescribed in Part 53 of this chapter. The sampler inlet shall show no significant wind direction dependence. The latter requirement can generally be satisfied by an inlet shape that is circularly symmetrical about a vertical axis.

7.1.3 The sampler shall have a flow control device capable of maintaining the sampler's operating flow rate within the flow rate limits specified for the sampler inlet over normal variations in line voltage and filter pressure drop.

7.1.4 The sampler shall provide a means to measure the total flow rate during the sampling period. A continuous flow recorder is recommended but not required. The flow measurement device shall be accurate to ± 2 percent.

7.1.5 A timing/control device capable of starting and stopping the sampler shall be used to obtain a sample collection period of 24 ± 1 hr (1,440 ± 60 min). An elapsed time meter, accurate to within ± 15 minutes, shall be used to measure sampling time. This meter is optional for samplers with continuous flow recorders if the sampling time measurement obtained by means of the recorder meets the ± 15 minute accuracy specification.

7.1.6 The sampler shall have an associated operation or instruction manual as required by Part 53 of this chapter which includes detailed instructions on the calibration, operation, and maintenance of the sampler.

7.2 *Filters.*

7.2.1 *Filter Medium.* No commercially available filter medium is ideal in all respects for all samplers. The user's goals in sampling determine the relative importance of various filter characteristics (e.g., cost, ease of handling, physical and chemical characteristics, etc.) and, consequently, determine the choice among acceptable filters. Furthermore, certain types of filters may not be suitable for use with some samplers, particularly under heavy loading conditions (high mass concentrations), because of high or rapid increase in the filter flow resistance that would exceed the capability of the sampler's flow control device. However, samplers equipped with automatic filter-changing mechanisms may allow use of these types of filters. The specifications given below are minimum requirements to ensure acceptability of the filter medium for measurement of PM_{10} mass concentrations. Other filter evaluation criteria should be considered to meet individual sampling and analysis objectives.

7.2.2 *Collection Efficiency.* $\geq$99 percent, as measured by the DOP test (ASTM-2986) with 0.3 μm particles at the sampler's operating face velocity.

7.2.3 *Integrity.* $\pm 5\ \mu g/m^3$ (assuming sampler's nominal 24-hour air sample volume). Integrity is measured as the PM_{10} concentration equivalent corresponding to the average difference between the initial and the final weights of a random sample of test filters that are weighed and handled under actual or simulated sampling conditions, but have no air sample passed through them (i.e., filter blanks). As a minimum, the test procedure must include initial equilibration and weighing, installation on an inoperative sampler, removal from the sampler, and final equilibration and weighing.

7.2.4 *Alkalinity.* <25 microequivalents/gram of filter, as measured by the procedure given in Reference 13 following at least two months storage in a clean environment (free from contamination by acidic gases) at room temperature and humidity.

7.3 *Flow Rate Transfer Standard.* The flow rate transfer standard must be suitable for the sampler's operating flow rate and must be calibrated against a primary flow or volume standard that is traceable to the National Bureau of Standards (NBS). The flow rate transfer standard must be capable of measuring the sampler's operating flow rate with an accuracy of ± 2 percent.

7.4 *Filter Conditioning Environment.*

7.4.1 Temperature range: 15° to 30° C.

7.4.2 Temperature control: ± 3° C.

7.4.3 Humidity range: 20% to 45% RH.

7.4.4 Humidity control: ± 5% RH.

7.5 *Analytical Balance.* The analytical balance must be suitable for weighing the type and size of filters required by the sampler. The range and sensitivity required will depend on the filter tare weights and mass loadings. Typically, an analytical balance with a sensitivity of 0.1 mg is required for high volume samplers (flow rates >0.5 m^3/min). Lower volume samplers (flow rates <0.5 m^3/min) will require a more sensitive balance.

8.0 *Calibration.*

8.1 *General Requirements.*

8.1.1 Calibration of the sampler's flow measurement device is required to establish traceability of subsequent flow measurements to a primary standard. A flow rate transfer standard calibrated against a primary flow or volume standard shall be used to calibrate or verify the accuracy of the sampler's flow measurement device.

8.1.2 Particle size discrimination by inertial separation requires that specific air velocities be maintained in the sampler's air inlet system. Therefore, the flow rate through the sampler's inlet must be maintained throughout the sampling period within the design flow rate range specified by the manufacturer. Design flow rates are specified as actual volumetric flow rates, measured at existing conditions of temperature and pressure (Q_a). In contrast, mass concentrations of PM_{10} are computed using flow rates corrected to EPA reference conditions of temperature and pressure (Q_{std}).

8.2 *Flow Rate Calibration Procedure.*

8.2.1 PM_{10} samplers employ various types of flow control and flow measurement devices. The specific procedure used for flow rate calibration or verification will vary depending on the type of flow controller and flow indicator employed. Calibration in terms of actual volumetric flow rates (Q_a) is generally recommended, but other measures of flow rate (e.g., Q_{std}) may be used provided the requirements of section 8.1 are met. The general procedure given here is based on actual volumetric flow units (Q_a) and serves to illustrate the steps involved in the calibration of a PM_{10} sampler. Consult the sampler manufacturer's instruction manual and Reference 2 for specific guidance on calibration. Reference 14 provides additional information on the use of the commonly used measures of flow rate and their interrelationships.

8.2.2 Calibrate the flow rate transfer standard against a primary flow or volume standard traceable to NBS. Establish a calibration relationship (e.g., an equation or family of curves) such that traceability to the primary standard is accurate to within 2 percent over the expected range of ambient conditions (i.e., temperatures and pressures) under which the transfer standard will be used. Recalibrate the transfer standard periodically.

8.2.3 Following the sampler manufacturer's instruction manual, remove the sampler inlet and connect the flow rate transfer standard to the sampler such that the transfer standard accurately measures the sampler's flow rate. Make sure there are no leaks between the transfer standard and the sampler.

8.2.4 Choose a minimum of three flow rates (actual m^3/min), spaced over the acceptable flow rate range specified for the inlet (see 7.1.2) that can be obtained by suitable adjustment of the sampler flow rate. In accordance with the sampler manufacturer's instruction manual, obtain or verify the calibration relationship between the flow rate (actual m^3/min) as indicated by the transfer standard and the sampler's flow indicator response. Record the ambient temperature and barometric pressure. Temperature and pressure corrections to subsequent flow indicator readings may be required for certain types of flow measurement devices. When such corrections are necessary, correction on an individual or daily basis is preferable. However, seasonal average temperature and average barometric pressure for the sampling site may be incorporated into the sampler calibration to avoid daily corrections. Consult the sampler manufacturer's instruction manual and Reference 2 for additional guidance.

8.2.5 Following calibration, verify that the sampler is operating at its design flow rate (actual m^3/min) with a clean filter in place.

8.2.6 Replace the sampler inlet.

9.0 *Procedure.*

9.1 The sampler shall be operated in accordance with the specific guidance provided in the sampler manufacturer's instruction manual and in Reference 2. The general procedure given here assumes that the sampler's flow rate calibration is based on flow rates at ambient conditions (Q_a) and serves to illustrate the steps involved in the operation of a PM_{10} sampler.

9.2 Inspect each filter for pinholes, particles, and other imperfections. Establish a filter information record and assign an identification number to each filter.

9.3 Equilibrate each filter in the conditioning environment (see 7.4) for at least 24 hours.

9.4 Following equilibration, weigh each filter and record the presampling weight with the filter identification number.

9.5 Install a preweighed filter in the sampler following the instructions provided in the sampler manufacturer's instructional manual.

9.6 Turn on the sampler and allow it to establish run-temperature conditions. Record the flow indicator reading and, if needed, the ambient temperature and barometric pressure. Determine the sampler flow rate (actual m^3/min) in accordance with the instructions provided in the sampler manufacturer's instruction manual. NOTE.—No onsite temperature or pressure measurements are necessary if the sampler's flow indicator does not require temperature or pressure corrections or if seasonal average temperature and average barometric pressure for the sampling site are incorporated into the sampler calibration (see step 8.2.4). If individual or daily temperature and pressure corrections are required, ambient temperature and barometric pressure can be obtained by on-site measurements or from a nearby weather station. Barometric pressure readings obtained from airports must be station pressure, not corrected to sea level, and may need to be corrected for differences in elevation between the sampling site and the airport.

9.7 If the flow rate is outside the acceptable range specified by the manufacturer, check for leaks, and if necessary, adjust the flow rate to the specified setpoint. Stop the sampler.

9.8 Set the timer to start and stop the sampler at appropriate times. Set the elapsed time meter to zero or record the initial meter reading.

9.9 Record the sample information (site location or identification number, sample date, filter identification number, and sampler model and serial number).

9.10 Sample for 24±1 hours.

9.11 Determine and record the average flow rate (Q_a) in actual m^3/min for the sampling period in accordance with the instructions provided in the sampler manufacturer's instruction manual. Record the elapsed time meter final reading and, if needed, the average ambient temperature and barometric pressure for the sampling period (see note following step 9.6).

9.12 Carefully remove the filter from the sampler, following the sampler manufacturer's instruction manual. Touch only the outer edges of the filter.

9.13 Place the filter in a protective holder or container (e.g., petri dish, glassine envelope, or manila folder).

9.14 Record any factors such as meteorological conditions, construction activity, fires or dust storms, etc., that might be pertinent to the measurement on the filter information record.

9.15 Transport the exposed sample filter to the filter conditioning environment as soon as possible for equilibration and subsequent weighing.

9.16 Equilibrate the exposed filter in the conditioning environment for at least 24 hours under the same temperature and humidity conditions used for presampling filter equilibration (see 9.3).

9.17 Immediately after equilibration, reweigh the filter and record the postsampling weight with the filter identification number.

10.0 *Sampler Maintenance.*

10.1 The PM_{10} sampler shall be maintained in strict accordance with the maintenance procedures specified in the sampler manufacturer's instruction manual.

11.0 *Calculations.*

11.1 Calculate the average flow rate over the sampling period corrected to EPA reference conditions as Q_{std}. When the sampler's flow indicator is calibrated in actual volumetric units (Q_a), Q_{std} is calculated as:

$$Q_{std} = Q_a \times (P_{av}/T_{av})(T_{std}/P_{std})$$

where

Q_{std} = average flow rate at EPA reference conditions, std m^3/min;

Q_a = average flow rate at ambient conditions, m^3/min;

P_{av} = average barometric pressure during the sampling period or average barometric pressure for the sampling site, kPa (or mm Hg);

T_{av} = average ambient temperature during the sampling period or seasonal average ambient temperature for the sampling site, K;

T_{std} = standard temperature, defined as 298 K;

P_{std} = standard pressure, defined as 101.3 kPa (or 760 mm Hg).

11.2 Calculate the total volume of air sampled as:

$$V_{std} = Q_{std} \times t$$

where

V_{std} = total air sampled in standard volume units, std m^3;

t = sampling time, min.

11.3 Calculate the PM_{10} concentration as:

$$PM_{10} = (W_f - W_i) \times 10^6 / V_{std}$$

where

PM_{10} = mass concentration of PM_{10}, µg/std m^3;

W_f, W_i = final and initial weights of filter collecting PM_{10} particles, g;

10^6 = conversion of g to µg.

Note.—If more than one size fraction in the PM_{10} size range is collected by the sampler, the sum of the net weight gain by each collection filter [$\Sigma(W_f - W_i)$] is used to calculate the PM_{10} mass concentration.

12.0 *References.*

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7. Appendix K is added to read as follows:

Appendix E

Federal Standards

Pollutant	Type of Standard	Time Interval	Effective Year	Concentration ug/m^3	PPM
Carbon Monoxide	Federal				
	Primary &	1-hour	1977	40,000	35
	Secondary	8-hour	1977	10,000	9
Nitrogen Dioxide	Federal				
	Primary & Secondary	1 year (arith)	1971	100	0.05
Ozone	Federal				
	Primary & Secondary	1-hour	1979	235	.12
Sulfur Dioxide	Federal				
	Primary &	24 hour	1975	365	0.14
		1 yr. (arith.)	1975	80	0.03
	Secondary	3-hour	1975	1,300	0.50
	Federal				
Particulates 10 microns or less in diameter (PM10)	Primary &	24-hour	1987	150	--
	Secondary	1 yr. (arith.)	1987	50	--
Lead	Federal				
	Primary	Ave. 3-months	1978	1.5	--

Appendix F

Colorado State Standards

These are the same as the Federal, with additional Standards as noted below.

Pollutant	Type of Standard	Time Interval	Effective Year	Concentration ug/m3	PPM
Total Suspended Particulates	State Primary	24-hour	1975	260	--
		1 year (geo.)	1975	75	--
	State Secondary	24-hour	1975	150	--
		1 yr (geom.)	1975	60	
Lead	State	1 month	1978	1.5	
Hydrogen Sulfide	State	1 hour	1978	142	.100
Beryllium	State	30 day average	1986	0.01	--

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