STATE OF CALIFORNIA

AIR RESOURCES BOARD

AIR MONITORING QUALITY ASSURANCE

VOLUME V

AUDIT PROCEDURES
FOR
AIR QUALITY MONITORING

APPENDIX P

PERFORMANCE AUDIT PROCEDURES
FOR
PM1O DICHOTOMOUS SAMPLERS

MONITORING AND LABORATORY DIVISION

SEPTEMBER 2002

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FOR
PM10 DICHOTOMOUS SAMPLERS

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P.l.0 GENERAL OPERATING PROCEDURE

P.1.0.1 AUDITING PROCEDURES

The primary goal of an auditing program is to identify system errors that may result in suspect or invalid data. Accurate assessment of the PM10 dichotomous particulate measurement system can only be achieved by conducting an audit under the following guidelines:

1. Without special preparation or adjustment of the system to be audited.

2. By an individual with a thorough knowledge of the instrument or process being evaluated, but not by the routine operator.

3. With accurate calibrated National Institute of Standards Technology (NIST) traceable transfer standards that are completely independent of those used in routine calibration.

4. With complete documentation of audit data for submission to the operating agency. Audit information includes, but is not limited to, types of instruments and audit transfer standards, model and serial numbers, transfer standard traceability, calibration information, and collected audit data.

The audit procedures described here produce two quantitative estimates of a PM10 dichotomous sampler's performance: The audit flow rate percentage difference and the design flow rate percentage difference. The audit flow rate percentage difference determines the accuracy of the sampler's indicated flow rate by comparing it with a flow rate from the audit transfer standard. The design flow rate percentage difference determines how closely the sampler's rate matches the inlet design flow rate under normal operating conditions.

An independent observer should be present, preferably the routine operator of the sampling equipment. This practice not only contributes to the integrity of the audit, but also allows the operator to offer any explanations and information that will help the auditor to determine the cause of discrepancies between measured audit data and the sampling equipment response.

P.1.0.2 FLOW RATE PERFORMANCE AUDITS OF THE VOLUMETRIC FLOW CONTROLLED PM10 DICHOTOMOUS SAMPLER

Audit procedures presented here are specific to commercially available dichotomous samplers which operate at an actual total flow rate of 16.7 liters per minute (LPM) and a coarse flow of 1.67 LPM. Audit techniques may vary between different models of samplers due to differences in required flow rates and the sampler's sampling configuration.

The dichotomous sampler flow rate audit method involves using two calibrated transfer standard mass flow meters (MFMs). One is calibrated in the flow range of the total and bypass flow rates, 0-20 standard liters per minute, (SLPM) and the second is calibrated within the range of the coarse flow rate 0-2 SLPM. This enables the auditor to measure the critical flow rates directly without compounding transfer standard error through subtraction. This equipment is NIST traceable and calibrated once a quarter with the relative standard deviation within 1.0% of the last two calibrations.

Since accurate measurement of PM10 dichotomous mass concentration is dependent upon flow rates under actual conditions, the auditor must also audit in terms of actual conditions. If the audit transfer standard's calibration data have been corrected to EPA reference conditions (298°K, 760 mm Hg), a conversion must be calculated to adjust the SLPM flow rate (Qstd) to an actual LPM flow rate (Qa). The audit MFM calibration relationship is expressed in terms of standard volumetric flow rate (Qstd), as indicated by the audit MFM; these units are SLPM.

The dichotomous sampler (see Figures P.1.0.1 through P.1.0.3) draws air at an actual flow rate of 1 m^3/hour (16.70 actual liters/minute). Ninety percent of the air (15.03 liters/minute) flows through the fine particulate filter and the remaining ten percent (1.67 liters/minute) flows through the coarse particulate filter. In some cases the actual flow rate must be corrected in relationship to the elevation of the site (see Table P.1.0.1)

P.1.0.3 AUDIT APPARATUS

The audit transfer standard must be certified against a primary standard traceable to the NIST.

1. The following equipment are needed to perform an audit of the PM10 dichotomous sampler:

   a. Certified (NIST traceable) transfer standard MFMs (0-20 SLPM and 0-2 SLPM) with the most recent calibration report.

   b. 3/8 inch Teflon tubing (6 feet long) with a 1 1/4 inch adapter to connect the transfer standard outlet to the sampler inlet.

   c. A dichotomous coarse filter and holder (yellow holder), and a dichotomous fine filter and holder (white holder).

   d. A thermometer capable of accurately measuring temperature over the range of -20°C to +60°C and accurate to the nearest 1°C. It must be referenced to a NIST or American Society for Testing and Materials (ASTM) thermometer and checked annually. The thermometer should be within ±2°C on the annual check.

   e. A barometer capable of accurately measuring ambient pressure to the nearest millimeter of mercury (mm Hg) over the range of 500 to 800 mm Hg. The barometer must be referenced within ±5 mm Hg of a barometer of known accuracy at least annually.

   f. A 3/8 inch Swagelok cap, and a 1/4 inch Swagelok cap.

   g. A particle-free filter.

   h. Two adjustable wrenches (6 inch).

2. Also needed for the audit is an audit data worksheet (see Figure P.1.0.7, QA Audit PM10 Dichotomous Sampler Worksheet), used to document audit information. This information includes, but is not limited to, sampler and audit transfer standard type, model and serial numbers, transfer standard traceability and calibration information, ambient temperature and pressure conditions, and collected audit data.

NOTE: At some point during the audit, inspect the overall condition of the sampler, check the wiring, check the cleanliness of the sampler's aluminum filter holders and the sampler inlet, and inspect the maintenance records. Record comments in the comments section of the QA Audit PM10 Dichotomous Sampler Worksheet (see Figure P.1.0.7).

P.1.0.4 TOTAL FLOW RATE AUDIT PROCEDURES

1. Remove the fine filter and holder (white holder) and coarse filter and holder (yellow holder) from the sampler. Install new fine and coarse filters and holders with the deep side of the filter in the up position (see Figure P.1.0.1).

   NOTE: Filters for flow rate audits should not be used for sampling.

2. Open the control module door. Energize the dichotomous sampler by sliding the lever next to the timer to the on position (see Figure P.1.0.3).

   NOTE: Request that the operator be present during the audit. Let him/her know that an as is audit will be conducted. The sampler should have already been set up for its normal run day. If not already done so, let the operator adjust the rotameters to their set points following a 5 to 10 minute warm up period. This will be the only time the rotameters can be adjusted. Also, let the operator know that if he/she is not present, the auditor will assume that the sampler has already been set up for its normal run day and will perform an as is audit. The auditors will at no time make rotameter adjustments.

3. Have the operator adjust the rotameter flow control valves to set the total and coarse rotameters to their operational set points for routine sampling. These set points should correspond to the calculated set points for the total suspended particulate (TSP) rotameter and the coarse suspended particulate (CSP) rotameter as determined by the sampler's calibration relationship.

4. While maintaining the proper total and coarse rotameter set points allow the sampler to warm up a minimum of 5 minutes.

5. Energize the (0-20 SLPM) transfer standard MFM and allow a warm up time of at least 5 minutes.

   NOTE: The transfer standard MFM's should be shaded from direct sunlight, during the total, fine and coarse flow rate audits, to prevent heating the temperature element inside the MFM's. Also ensure that the transfer standard MFM display selector switch is in the proper position.

6. Complete the top half of the audit data worksheet with the required information, including ambient temperature (Ta), in degrees celsius, and ambient barometric pressure (Pa), in mm Hg. Under Sampler Calibration Data, record both the TSP and CSP values and the corresponding flow rates, total flow rate (TFR) and coarse flow rate (CFR), using the sampler calibration curve or the sampler calibration data in conjunction with Equation 1 of Section P.1.0.8 of this procedure.

7. Remove the sampler inlet and replace with the transfer standard MFM adaptive device (see Figure P.1.0.4).

8. Connect the adapter to the transfer standard (0-20 SLPM) MFM outlet with 3/8 inch Teflon tubing, being careful not to crimp the tubing.

9. Record the TSP and CSP rotameter values, on the audit worksheet under Audit Data Total Flow Audit, and their corresponding flow rates (TFR and CFR) as determined by the sampler's calibration data. (The TFR value obtained here will be temperature and pressure corrected per Equation 2 of Section P.1.0.8 of this procedure. This TFR corrected value will be recorded on the audit worksheet under the Qa (Sampler) total flow type.)

10. Record the transfer standard (TS) MFM reading on the audit worksheet under the total flow column. (This will be used later as Qind in Equation 1 of Section P.1.0.8 of this procedure.)

P.1.0.5 FINE FLOW RATE AUDIT PROCEDURES

1. Turn the sampler off by sliding the lever next to the timer, in the control module, to the off position.

2. Disconnect the coarse flow 1/4 inch outlet line located beneath the coarse dichotomous sampler filter holder. Cap the coarse flow outlet with a 1/4 inch Swagelok cap. This opens the coarse line to the vacuum pump (see Figure P.1.0.5). To prevent particle entrapment within the system, it is recommended that a particle-free filter be attached to the coarse flow line.

3. Turn the sampler on, let it stabilize for a minimum of 5 minutes, and check the rotameter set points. Record the new TSP and CSP rotameter values, on the audit worksheet under Audit Data Fine Flow Audit, and determine their corresponding flow rate values (TFR and CFR) from the sampler's calibration data.

   NOTE: A small flow imbalance occurs when the coarse line is disconnected; this may cause rotameter fluctuations.

4. Record the transfer standard MFM reading on the audit worksheet under the fine flow type column. (This will be used later as Qind in Equation 1 of Section P.1.0.8 of this procedure.)

5. On the audit worksheet, the fine flow for the sampler, Qa (Sampler), is determined by subtracting the coarse flow for the sampler from the total flow for the sampler.

P.1.0.6 COARSE FLOW RATE AUDIT PROCEDURES

1. Turn the sampler off and disconnect the adapter from the total and fine flow rate transfer standard (0-20 SLPM) MFM outlet. Connect the adapter to the coarse flow rate transfer standard (0-2 SLPM) MFM outlet.

   NOTE: Ensure that the transfer standard MFM display selector switch is in the proper position.

2. Reconnect the coarse flow line (1/4 inch line) and disconnect the fine flow 3/8 inch line. Cap the fine flow outlet located beneath the dichotomous sampler filter holders with a 3/8 inch Swagelok cap. This opens the fine line to the vacuum pump (see Figure P.1.0.6). To prevent particle entrapment within the system, it is recommended that a particle-free filter be attached to the fine flow line.

3. Turn the sampler on, let it stabilize for a minimum of 5 minutes, and check rotameter set pointsb Record the new TSP and CSP rotameter values, on the audit worksheet under Audit Data Coarse Flow Audit, and their corresponding flow rates (TFR and CFR) as determined from the sampler's calibration data. (The CFR value obtained here will be temperature and pressure corrected per Equation 2 of Section P.1.0.8 of this procedure. This CFR corrected value will be recorded on the audit worksheet under the Qa (Sampler) coarse flow type.)

   NOTE: A small flow imbalance may occur when the fine line is disconnected; this may cause rotameter fluctuations.

4. Record the transfer standard MFM reading on the audit worksheet under the coarse flow type column. (This will be used later as Qind in Equation 1 of Section P.1.0.8 of this procedure.)

P.1.0.7 POST AUDIT CONFIGURATION

1. Turn the sampler off.

2. Reconnect the fine flow line.

3. Remove the transfer standard MFM adaptive device from the sampler and replace the sampler inlet.

4. Remove the fine and coarse filters and holders that were used during the audit. Replace the fine filter and holder (white holder) and coarse filter and holder (yellow holder) that were removed from the sampler prior to the audit.

5. Close the control module door.

6. The dichotomous sampler is now in its normal operating configuration.

7. Have the operator set the sampler up for its normal run day.

P.1.0.8 AUDIT DATA CALCULATIONS

A computer program calculates audit data results. This section includes calculations to compute audit results by hand should the computer program not be available at the time of the audit.

1. Calculate the audit total, fine and coarse standard flow rates using the transfer standard MFM calibration data. (See Equation 1 below.)

   Standard Flow Qstd = Qind x m ± i (Equa. 1)

   Where: Qstd = Flow rate at standard temperature and pressure, SLPM
   Qind = The transfer standard reading or (total of coarse rotameter reading)
   m = Slope
   i = Intercept

   NOTE: It may be necessary to correct audit flow rates, if they are in standard conditions, to actual conditions. (See Equation 2 below.)

$$Qa = Qstd\ (Ta/298.15)\ (760/Pa)\ \text{(Equa. 2)}$$

Where:
- Qa = flow rate at actual conditions, LPM
- Qstd = Standard flow rate at standard temperature and pressure (298.15°K, 760 mm Hg), SLPM
- Ta = ambient temperature,°K
- Pa = ambient barometric pressure, mm Hg

Using Equation 2 above, calculate and record the transfer standard mass flow rate Qa (Audit) for total, coarse, and fine on the audit worksheet.

2. Ask the operator to calculate (using the sampler's calibration relationship) the corresponding sampler standard flow rates (TFR and CFR) and record these values under the Sampler Calibration Data section and the Audit Data section, as appropriate, on the audit worksheet. (See Equation 1 above.)

3. Using Equation 2 above, calculate and record the Qa (Sampler) total and coarse flow rates on the audit worksheet under flow type.

   NOTE: The fine flow for the Qa (Sampler), on the audit worksheet, is calculated by subtracting the coarse flow from the total flow.

4. Determine the percentage difference between - the sampler indicated flow rates and the audit measured flow rates as:

$$\text{Audit \% Difference} = \frac{Qa(Sampler) - Qa(Audit)\ (100)}{Qa(Audit)}$$

5. Determine the percentage difference between the sampler design flow rates and the Qa (Audit) flow rates as:

$$\text{Design Condition \% Difference} = \frac{Qa(Audit) - Design\ Flow\ Rate(100)}{Design\ Flow\ Rate}$$

6. Record percent differences. Any deviation greater than ±7% will require an investigation or a recalibration. Differences exceeding ±10% require an Air Quality Data Action (AQDA) request to be issued. Upon investigation the invalidation or correction of all data from the last calibration forward or known date of change (to be determined by the reporting agency) may result.

7. Upon completion of the audit, before leaving the site, a comparison between the flows determined using the audit device should be made

(i.e., fine + coarse = total). If the sum of the individual flows (fine and coarse) does not equal the total flow (within ±2.5%), the audit data should be checked. If necessary, the audit should be repeated.

P.1.0.9 AUDIT DATA REPORTING

The operating agency should be given a copy of the preliminary audit results when the audit is completed. The preliminary data should never be used to make monitoring system adjustments. A post audit verification of audit equipment and data is essential before inferences can be drawn regarding the sampler's performance. An auditor should be able to support audit data with quarterly pre- or post-audit equipment verification documentation. (See Figure P.1.0.9 for a sample of preliminary audit results.)

Final verified audit data should be submitted to the operating agency as soon as possible. Delays may result in data loss; a sampler out of audit limits is also out of calibration limits, and the data collected may be invalid. If a sampler exhibits unsatisfactory agreement with the verified audit results (audit differences exceed ±7%), a calibration should be performed before the next run day.

P.1.0.10 PERFORMANCE AUDIT FREQUENCY

For State and Local Air Monitoring Stations (SLAMS), audit the flow rate of at least 25% of the samplers per monitoring network each quarter. Each sampler, therefore is audited at least once per year. If there are fewer than four PM10 dichotomous samplers within a reporting organization, re-audit one or more randomly selected samplers so that one sampler is audited each calendar quarter.

NOTE: Sections of the above procedure were taken from the reference "Method for Determination of Particulate Matter as PM10 in the Atmosphere", Section 2.10.7, published by the Environmental Protection Agency, dated April 11, 1990.

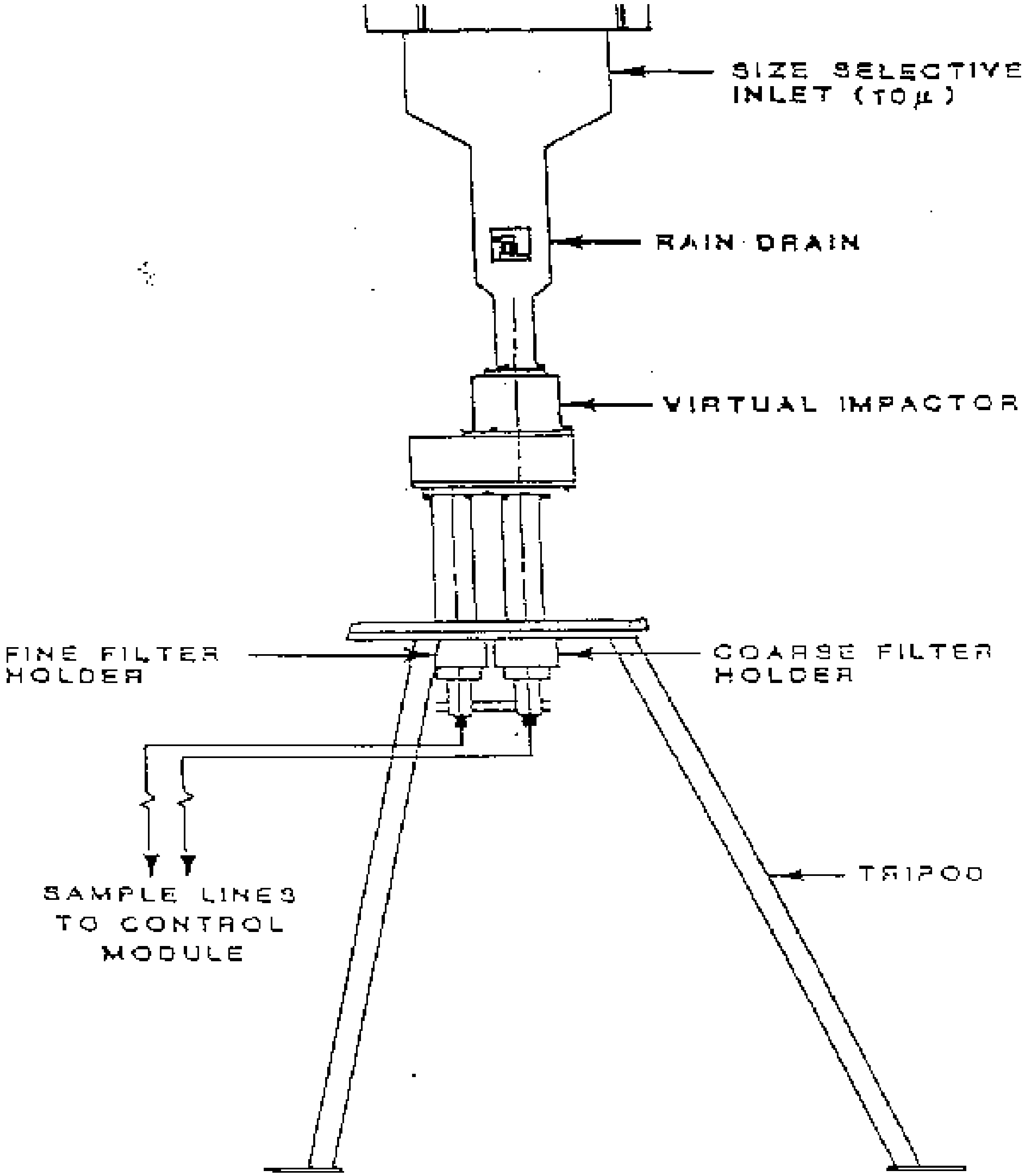

Figure P.1.0.1
Sampling Module

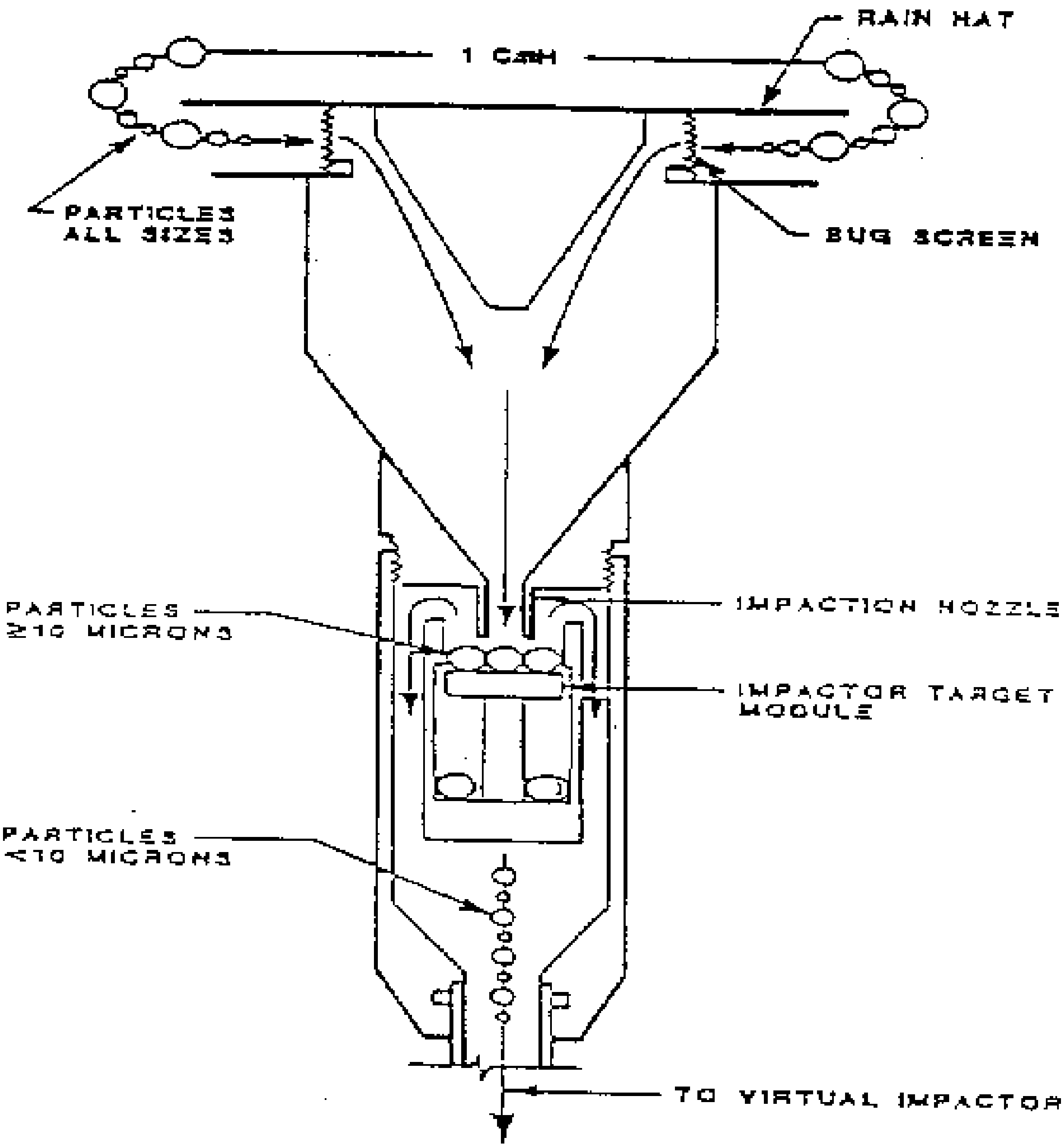

Figure P.1.0.2
Sampler Inlet Assembly

Figure P.1.0.3
Control Module for Anderson Dichotomous Sampler

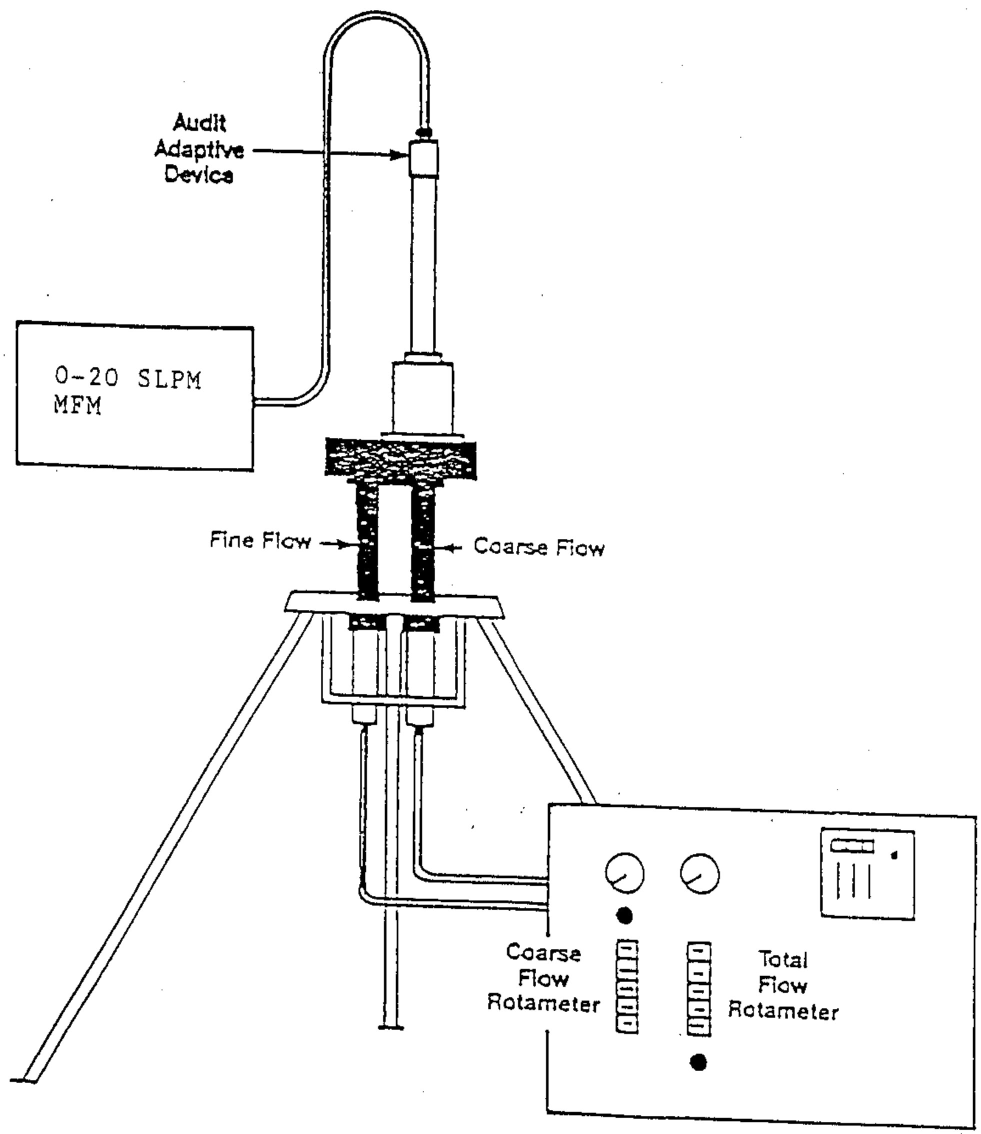

Figure P.1.0.4
Audit Assembly and Dichotomous Sampler Set Up to Audit Total Flow

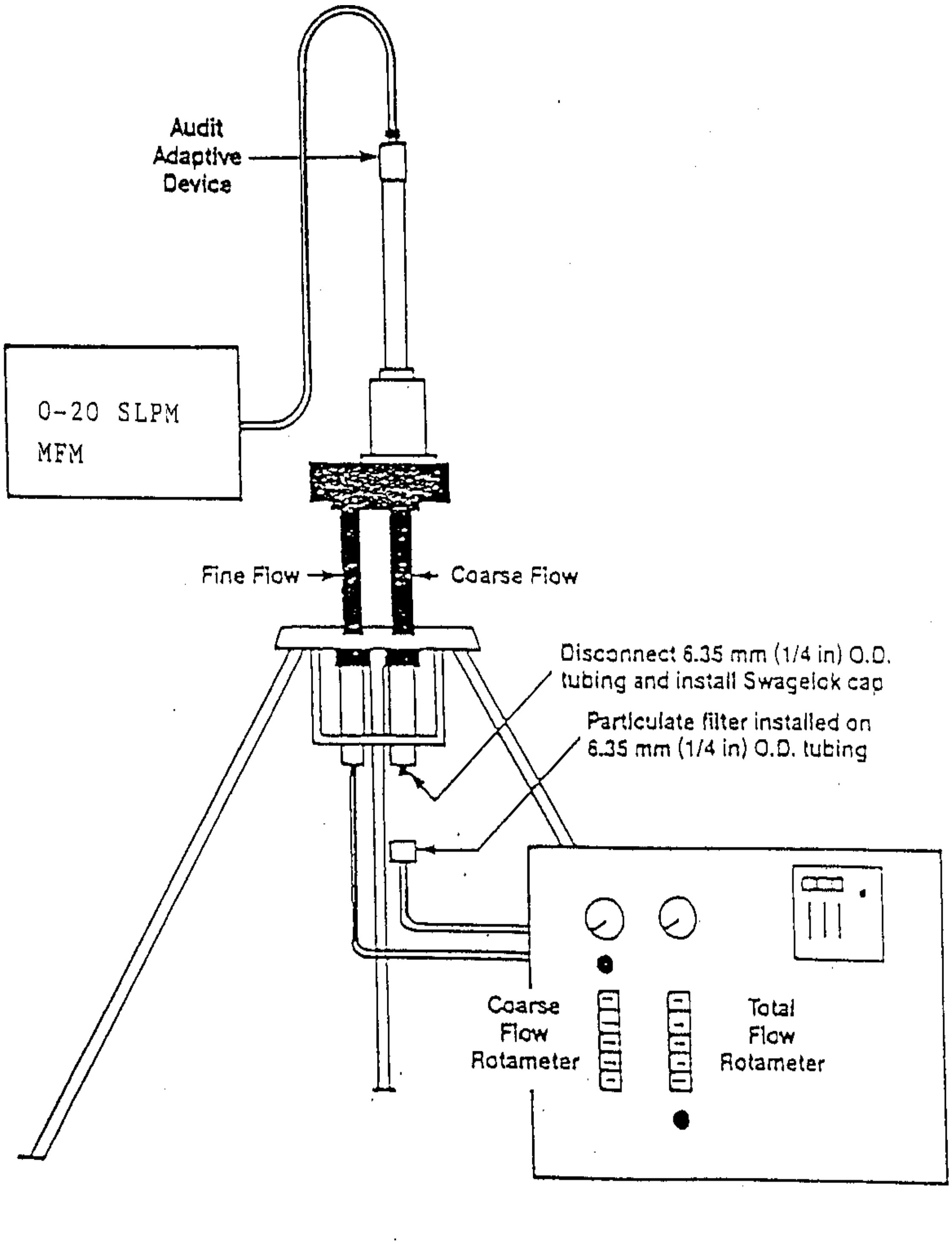

Figure P.1.0.5
Audit Assembly and Dichotomous Sampler Set Up to Audit Fine Flow

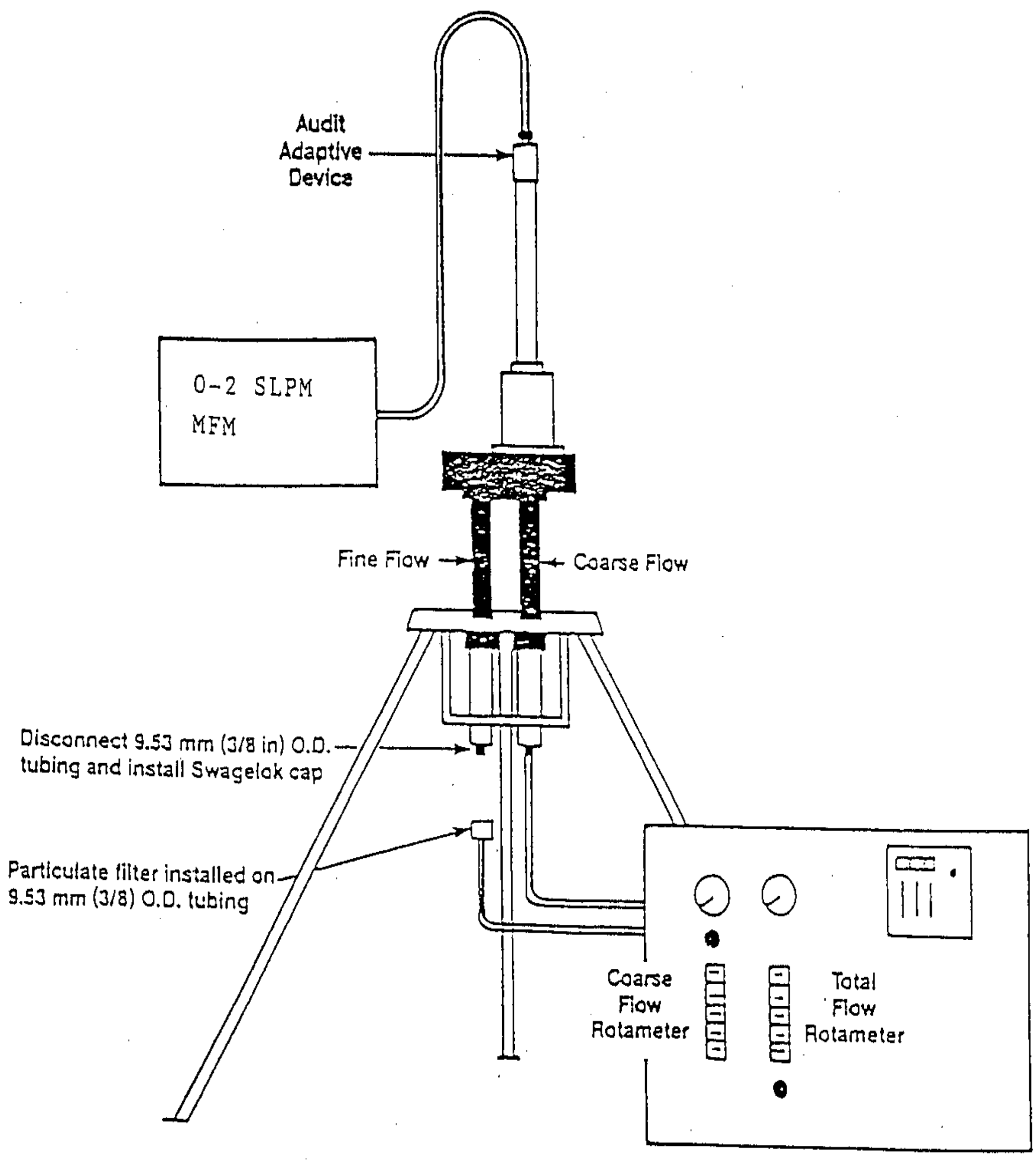

Figure P.1.0.6
Audit Assembly and Dichotomous Sampler Set Up to Audit Coarse Flow

QA AUDIT WORKSHEET
DICHOTOMOUS SAMPLER

Site Name: ____________________ Site #: __________ Date: __________

Address: ____________________ Agency: ____________________

Technician: ____________________ Auditors: ____________________

Model: __________ ID#: __________ NAMS[ ] SLAMS[ ] PAMS[ ] SPM[ ]

Rotameter Setting		
Coarse	Fine	Total

Audit MFC Indicated Flow		
Coarse	Fine	Total

Cal. Date: __________ Cal. Equip. Cert. Date: __________ EPA Equiv: __________

Coarse Setting: Slope: __________ Intercept: __________ Temperature: __________

Fine Setting: Slope: __________ Intercept: __________ Barometer: __________

Model: __________ ID#: __________ NAMS[ ] SLAMS[ ] PAMS[ ] SPM[ ]

Rotameter Setting		
Coarse	Fine	Total

Audit MFC Indicated Flow		
Coarse	Fine	Total

Cal. Date: __________ Cal. Equip. Cert. Date: __________ EPA Equiv: __________

Coarse Setting: Slope: __________ Intercept: __________ Temperature: __________

Fine Setting: Slope: __________ Intercept: __________ Barometer: __________

Model: __________ ID#: __________ NAMS[ ] SLAMS[ ] PAMS[ ] SPM[ ]

Rotameter Setting		
Coarse	Fine	Total

Audit MFC Indicated Flow		
Coarse	Fine	Total

Cal. Date: __________ Cal. Equip. Cert. Date: __________ EPA Equiv: __________

Coarse Setting: Slope: __________ Intercept: __________ Temperature: __________

Fine Setting: Slope: __________ Intercept: __________ Barometer: __________

Air Resources Board
Quality Assurance Section

QA-DC1
Revised 03/02

Figure P.1.0.7
QA Audit PM10 Dichotomous Sampler Worksheet

Technical Appendix - Dichot

Station/Van Audit Data & Results

	Van Data		Station Data		
	Audit MFM Display Reading	Van Flows (SLPM)	Indicated Flow (LPM)	Actual Flow (LPM)	**Average Percent Difference**
Coarse	0.55	1.57	1.70	1.67	***1.8%***
Fine	15.0	14.5	15.0	15.5	***-3.2%***
Total	17.1	16.7	16.7	17.8	***-6.2%***

	Design Flows Lower Limit	Design Flows Upper Limit	**Percent Difference from Design**
Based on an actual flow of 1.67 LPM , the sampler **meets the coarse design flow criteria.**	1.503	1.837	***0.0%***
Based on an actual flow of 15.5 LPM , the sampler **meets the fine design flow criteria.**	13.53	16.53	***3.1%***
Based on an actual flow of 17.8 LPM , the sampler **meets the total design flow criteria.**	15.03	18.37	***6.6%***

Audit Calculations

Actual Flow = ((Ambient Temp in Kelvin/298.15)*760/Ambient Pressure in mmhg)*(Display Reading*MFM Slope+ MFM Int.)

MFM Coarse Slope =	2.7049	MFM Coarse Intercept =	0.0779
MFM Fine Slope =	1.0350	MFM Fine Intercept =	-0.9826
Ambient Pressure in mmhg =	751	Temperature in Kelvin =	313.65

Instrument/AIRS Information

ARB Number	10246	AIRS Number	060190008
Audit Date	07/10/2001	Instrument Manf.	ANDERSON
Version	0	Model	
Quarter	3	Serial Number	20004389
Van	B	Last Calibration	03/21/2001

General Comments

* Primary sampler.

California Air Resources Board
Monitoring and Laboratory Division
Quality Assurance Section

Figure P.1.0.8
Preliminary Audit Results

Elevation (Feet)	Altitude Correction Factor	Total Flow Rate Setpoint (SLPM)	Coarse Flow Rate Setpoint (SLPM)
0-999	1.000	16.70	1.67
1000	.965	16.11	1.61
1250	.956	15.96	1.60
1500	.947	15.81	1.58
1750	.938	15.67	1.57
2000	.930	15.52	1.55
2250	.921	15.38	1.54
2500	.913	15.24	1.52
2750	.904	15.10	1.51
3000	.896	14.96	1.50
3250	.888	14.82	1.48
3500	.879	14.68	1.47
3750	.871	14.55	1.46
4000	.863	14.41	1.44
4250	.855	14.28	1.43
4500	.847	14.15	1.42
4750	.840	14.02	1.40
5000	.832	13.89	1.39
5250	.824	13.76	1.38
5500	.817	13.63	1.36
5750	.809	13.51	1.35
6000	.802	13.38	1.34
6250	.794	13.26	1.33
6500	.787	13.14	1.31
6750	.780	13.01	1.30
7000	.772	12.89	1.29
7250	.765	12.77	1.28
7500	.758	12.66	1.27
7750	.751	12.54	1.25
8000	.744	12.42	1.24
8250	.737	12.31	1.23
8500	.731	12.20	1.22

TABLE P.1.0.1
Elevation vs. Altitude Correction Factor and Standard Flow Rate PM10
Dichotomous Air Sampler