SOUTH COAST AIR QUALITY MANAGEMENT DISTRICT

METHOD 4.1

DETERMINATION OF MOISTURE CONTENT IN STACK GASES

METHOD 4.1

DETERMINATION OF MOISTURE CONTENT IN STACK GASES

TABLE OF CONTENTS

4. Engineering Calculations

4.1 Nomenclature

4.2 Calculations

METHOD 4.1

DETERMINATION OF MOISTURE CONTENT IN STACK GASES

Section 1 of 4

1. Overview

    1.1   Principle

        A gas sample is extracted from the source.
Moisture is removed from the sample stream and
determined either volumetrically or
gravimetrically.

    1.2   Applicability

        This method accurately determines moisture
content needed to calculate emission data.
Alternate means may be used to approximate
percent moisture in setting isokinetic sampling
rates prior to a pollutant emission measurement
run. These include drying tubes, wet bulb-dry

bulb techniques, condensation techniques,
stoichiometric calculations, and previous source
testing data.

Method 4.1 is conducted simultaneously with a
pollutant emission measurement run. Calculation
of percent isokinetic emission rate for the run
must be based on the results of this method
rather than an approximation method.

This method will likely yield inaccurate results
when applied to saturated gas streams or gas
streams that contain large quantities of water
droplets.

Alternatively, with the approval of the Executive
Officer, any system may be used that cools the
sample gas stream and allows measurement of both
the water that has been condensed and the
moisture leaving the train, each to within 1 ml
or 1 g.

Acceptable means involve measuring the condensed
water, either gravimetrically or volumetrically,

and measuring moisture leaving the train by (1)
monitoring the temperature and pressure at the
exit of the condenser and using Dalton's Law of
Partial Pressures, or (2) passing the sample gas
stream through a tared silica gel (or equivalent
desiccant) trap, with exit gases kept below $15^O C$
($60^O F$), and determining the weight gain.

DETERMINATION OF MOISTURE CONTENT IN STACK GASES

Section 2 of 4

2. Field Procedures

2.1   Sampling Apparatus

A schematic of the sampling train is shown in Figure 4.1-1. All components should be maintained and calibrated according to the procedure outlined in Method 5.1.

2.1.1   Sampling Train

a.   Probe

The probe is constructed of stainless steel or glass tubing. When stack conditions permit, other metals or plastic tubing may be

used, subject to the approval of Executive Officer.

b. Impinger Train

The train consists of four impingers connected in series with ground leak-free fittings or any similar leak-free non-contaminating fittings. The first and second impingers must be of Greenburg-Smith design with the standard tip. The third and fourth impingers must be of Greenburg-Smith design modified by cutting the insert so the tube end is 14 mm (0.5 in.) above the bottom of the flask. Materials other than glass, or flexible vacuum lines to connect the probe and impingers, are acceptable modifications. If desired, use a backup filter between the last impinger and the pump to prevent any accidental

suction of silica gel into the

pump.

c.	Cooling System

This system is an ice bath
container and dry ice pellets in
water or crushed ice.

d.	Metering System

This system includes a vacuum
gauge, leak-free pump, thermometer
capable of measuring temperature to
within $3^{O}C$ ($5.4^{O}F$), dry gas meter
capable of measuring volume to
within 2 percent, and related
equipment as shown in Figure 4.1-1.
Other metering systems capable of
maintaining a constant sampling
rate and determining sample gas
volume may be used, subject to the
approval of the Executive Officer.

2.1.2	Barometer

A mercury, aneroid, or other barometer
capable of measuring atmospheric
pressure to within 2.5 mm (0.1 in.) Hg
is used. The barometric readings may be
obtained from a nearby National Weather
Service station. Request the station
value (which is the absolute barometric
pressure) and adjust for elevation
difference between the NWS station and
the sampling point at the rate of minus
2.5 mm (0.1 in.) Hg per 30 m (100 ft)
elevation increase, or plus the same
adjustment for elevation decrease.

2.1.3   Graduated Cylinder and/or Balance

These are used to measure condensed
water and moisture caught in the silica
gel to within 1 ml or 0.5 g. Graduated
cylinders should have subdivisions no
greater than 2 ml and tolerance limits
of ± 1 percent. Most laboratory
balances are capable of weighing to the

nearest 0.5 g or less. Such balances
are suitable here.

2.2   Procedure

This procedure is written for an impinger train
incorporating volumetric analysis to measure the
condensed moisture, and for silica gel and
gravimetric analysis to measure the moisture
leaving the dry impinger.

The sampling point in the stack should be either
at the center of the cross section or at a point
no closer to the walls than 1.00 m (3.3 ft),
unless the stack vents more than one source or
dilution air is introduced just before the
sampling location. In these cases, use a minimum
of eight traverse points for circular stacks, a
minimum of nine points for rectangular stacks
having equivalent diameters less than 61 cm (24
in.), and a minimum of twelve traverse points in
all other cases.

Locate the traverse points (if required) according to Method 1.1. The use of fewer points is subject to the approval of the Executive Officer. Select a probe and probe length suitable for sampling all traverse points. For large stacks, consider sampling from opposite sides of the stack (four sampling ports), to permit shorter probe lengths.

Mark the probe with heat-resistant tape or other method to indicate the probe distance into the stack or duct for each sampling point.

Determine a total sampling time to collect a minimum total gas volume of 0.60 scm (21 scf) at a rate no greater than 0.021 m^3/min (0.75 ft^3/min). When both moisture content and pollutant emission rate are to be measured, the moisture determination must be simultaneous with, and for the same total length of time as, the pollutant emission rate run unless moisture varies less than 2 percent over time.

Set up the sampling equipment as shown in Figure 4.1-1 (see Section 3 for train assembly). Place dry ice pellets in the water of the ice bath container. Perform a leak check before and after each test. Plug the probe and draw a 380 mm (15 in.) Hg vacuum; a lesser vacuum may be used if it is not exceeded during the test. A leakage rate in excess of either 4 percent of the average sampling rate or 0.0007 m^3/min (0.02 ft^3/min) is unacceptable.

During the sample run, maintain a sampling rate within 10 percent of constant rate unless the stack flow rate changes by more than 20 percent, in which case the sample rate should be changed in proportion to the stack flow rate change. For each run record the data required on the example data sheet shown in Figure 4.1-2. Be sure to record the dry gas meter reading at the beginning and end of each sampling time increment and whenever sampling is halted. Take other appropriate readings at each sample point at least once during each time increment.

To begin sampling, position the probe tip at the first traverse point. Immediately start the pump and adjust flow to the desired rate. Traverse the cross section (if required), sampling at each traverse point for an equal length of time. Add more dry ice pellets, if necessary, to maintain a temperature below 15°C (60°F) at the silica gel outlet.

After collecting the sample, conduct a leak check (mandatory) as described in Section 2.2.5. Record the leak rate. If the leakage rate exceeds the allowable rate, the tester must either reject the test results or correct the sample volume, as described in Chapter X. Conduct a gas volume meter check as described in Method 5.1, Section 2.4 (mandatory). Measure the amount of condensed moisture as described in Section 3, Laboratory Procedures. Calculate the percentage moisture as described in Section 4, Engineering Calculations.

2.3   Calibration

Refer to Chapter III.

DETERMINATION OF MOISTURE CONTENT IN STACK GASES

Section 3 of 4

3. Laboratory Procedures

3.1 Apparatus

3.1.1 Sampling Train

See Section 2.1.1.

3.1.2 Graduated Cylinder and/or Balance

See Section 2.1.3.

3.2 Reagents

a. Silica gel

Indicating-type, 6 to 16 mesh. Fresh or dried at 175°C for 2 hours.

b. Water

Deionized, distilled water to conform to ASTM specification D-1193-Type 3.

At the option of the chemist, the $KMnO_4$ test for oxidizable organic matter may be eliminated when high concentrations of organic matter are not expected to be present. Reference to water throughout this method implies deionized, distilled water.

c. Stopcock Grease

d. Crushed Ice or Dry Ice Pellets

3.3 Pretest Preparation

No special pretest preparation is required.

3.4 Preparation of Sample Collection Train

Assemble the impingers as shown in Figure 4.1-1.
Load the first two impingers with exactly 100 ml
of water each. Leave the third impinger empty.
Place about 200 g of silica gel in the fourth
impinger and record its weight to the nearest
0.5 g. For volumetric analysis, the impingers may
be connected at this point and the train sealed
at both ends. For gravimetric analysis, weigh
each impinger plus its contents to the nearest
0.5 g and record the weights. Connect the
impingers and seal the train.

3.5   Leak Check

If preferred, perform leak check in the
laboratory following the procedure outlined in
Section 2.2.

3.6   Sample Recovery

Inspect the train for general condition. Note if
the silica gel is completely expended and if the
train or its components are sealed. Shake any

condensed moisture from the probe and impinger
connectors into the impingers.

3.7   Analysis

For volumetric analysis, carefully pour the
impinger catches into a suitably sized graduated
cylinder; measure and record the volume to the
nearest ml. Weigh the last impinger plus
contents (silica gel) to the nearest gram and
record. For gravimetric determination, weigh
each impinger plus its contents to the nearest
0.5 g and record the weights.

3.8   Calculations

Subtract 200 ml initial volume from the
volumetric measurement to obtain impinger gain in
ml. Subtract impinger tare weights from the
received weights to obtain impinger gain in
grams. Subtract the silica gel tare weights from
received weight to obtain silica gel gain in
grams. Report the total impinger gain and the

silica gel gain to the nearest g or ml. Also
report if the silica gel was expended.

3.9   Calibrations

Check balance calibration against NBS traceable
    weights. Balance must be accurate and
repeatable to 0.5 g. Use graduated cylinders
with subdivisions no greater than 2 ml and
tolerance limits of 1 percent for volumetric
analysis.

METHOD 4.1

DETERMINATION OF MOISTURE CONTENT IN STACK GASES

Section 4 of 4

4. Engineering Calculations

Perform the following calculations, retaining at least one decimal figure beyond that of the acquired data. Round off figures after final calculation.

4.1   Nomenclature:

B_w = Water percent

P_{bar} = Barometric pressure, in Hg

P_{m_a} = Absolute pressure at the gas meter, in. Hg

$-P$ = Orifice pressure, in. H_2O (if used)

$V_{m_{std}}$ = Dry gas volume metered, corrected to standard conditions, dscf

V_m = Dry gas volume metered, dcf

y = Meter correction factor (no units)

T_m = Absolute temperature at meter, ^{O}R

$V_{w_{std}}$ = Volume of total water caught, corrected to standard conditions, scf

$V_1 = (V_C + V_S)$ = Volume of total water in the train, ml

V_C = Volume of water condensed, ml

V_S = Volume of water absorbed by silica gel, ml

Note: If the post test leak rate (Section 2.2) exceeds the allowable rate, correct the value of V_m as described in Chapter X.

4.2   Calculations

Perform the calculation shown on the Reporting

Sheet (Figure 4.1-3).

Table 4.1-1

Temperature-Moisture Relation

Temp. ^{o}F	% H_2O	Temp. ^{o}F	% H_2O	Temp. ^{o}F	% H_2O
50	1.2	130	15.1	180	51.1
60	1.7	140	19.7	185	57.0
70	2.5	150	25.3	190	63.6
80	3.5	155	28.7	195	70.8
90	4.8	160	32.3	200	78.6
100	6.5	165	36.4	205	87.0
110	8.7	170	40.8	210	96.2
120	11.5	175	45.7	212	100.0
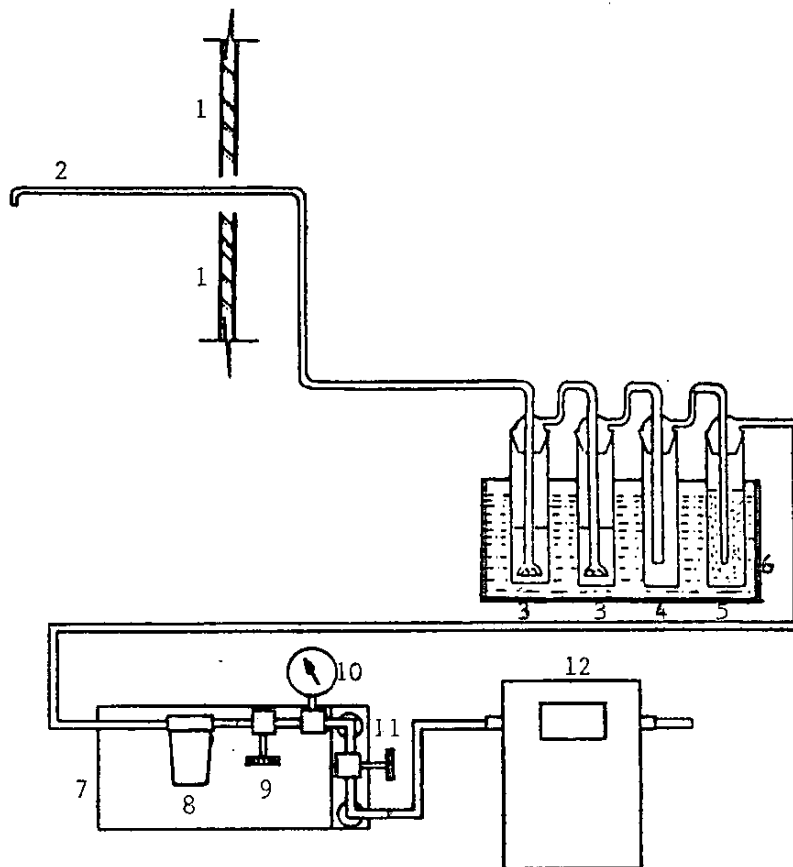
1. Stack Wall	8. Filter for Pump
2. Probe	9. Metering Valve
3. Impinger with 100 ml of H_2O	10. Vacuum Gauge
4. Empty Bubbler	11. By-pass Valve
5. Bubbler with Silica Gel	12. Temperature Compensated
6. Ice Bath	Dry Gas Meter
7. Sealed Pump (Leak Free)	

Figure 4.1-1

Impingement Train For Moisture

SOUTH COAST AIR QUALITY MANAGEMENT DISTRICT

Test No._____   Date_____

Sampling Location_____

_____

GAS VELOCITY DATA
_____

Pre-Test Velocity Leak Check   Post-Test Velocity Leak Check

_____   _____

Time	Trav. Point		Vel. Head ("H₂0)	Temp. (°F)	Calc. Vel. (fps)		Vel. Head ("H₂0)	Temp. (°F)	Calc. Vel. (fps)		Vel. Head ("H₂0)	Temp. (°F)	Calc. Vel. (fps)

Static Pressure in Stack_____ "HgA (+/-_____ "H₂0)   (Average)

Barometric Pressure....._____ "HgA   Pitot Factor................._____

Recorded By_____

Calibration Data

Inclined Manometer_____	(Cal: __N/A__)
Magnehelic No._____	(Cal:_____)
Pitot Tube No._____	(Cal:_____)
Potentiometer No._____	(Cal:_____)
Thermocouple No._____	(Cal:_____)

Stack Dimensions

Figure 4.1-2

Gas Velocity Data Sheet

MOISTURE CONTENT CALCULATION SHEET

Time	Gas Vol. Metered (V_m) ft^3	Meter Temp. (T_m) $^{\circ}$F	Orifice Pressure (ΔP), in. H_2O

_____ SAMPLING LOCATION

Ambient conditions_____ $^{\circ}$F _____in. Hg

Assume 1 g H_2O = 1 ml H_2O

A. Gas Volume Metered $(V_{m_{std}})$

$$V_{m_{std}} = y \cdot \frac{520^{\circ}R}{29.92 \text{ in. Hg}} \cdot \frac{V_m \; P_{m_a}}{T_m} = (17.38)(\;)(\;) = \underline{\quad} \text{ dscf}$$

where:

$$P_{m_a} = P_{bar} + (\Delta P/13.6) = (\quad) + (\frac{\quad}{13.6}) = \underline{\quad}\text{in. Hg}$$

B. Volume of Water Condensed $(V_{w_{std}})$

$$V_{w_{std}} = (0.0464 \text{ ft}^3/\text{ml})(V_1) = (0.0464)(\quad) = \text{scf}$$

C. Moisture in Stack Gas (B_w)

$$B_w = \frac{V_{w_{std}}}{V_{m_{std}} + V_{w_{std}}} \times 100 = \frac{(\quad)}{(\quad)} \times 100 = \underline{\quad}\%$$

Figure 4.1-3

Reporting and Calculation Sheet for Moisture Content

D.   If calculated moisture content is greater than at
     saturation temperature (e.g. 212°F or below) use the
     Table 4.1-1 for moisture content.

Figure 4.1-3 (Cont.)

Reporting and Calculation Sheet for Moisture Content