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EMISSION MEASUREMENT TECHNICAL INFORMATION CENTER
CONDITIONAL TEST METHOD

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Prepared by **Emission Measurement Branch EMTIC CTM-019.WPF**
Technical Support Division, OAQPS, EPA 6/1986

DIRECT MEASUREMENT OF GAS VELOCITY AND VOLUMETRIC FLOWRATE UNDER CYCLONIC FLOW CONDITIONS (PROPELLER ANEMOMETER)

1. Applicability and Principle

1.1 Applicability. This method applies to the measurement of gas velocities in locations where cyclonic flow conditions exist and gas temperatures range from 0° to 50°C (e.g. cooling tower exhausts).

2. Apparatus

Specifications for the apparatus are given below.

2.1 Propeller Anemometer. A vane axial propeller anemometer capable of measuring gas velocities to within 2 percent. The manufacturer's recommended range (all-angle) shall be sufficient for the expected minimum flow rates at the sampling conditions. Temperature, pressure, moisture, corrosive characteristics, and sampling location are factors necessary to consider in choosing a suitable propeller anemometer.

2.2 Data Output Device. A digital voltmeter, analog voltmeter, stripchart recorder, data-logger, or computer capable of displaying propeller anemometer output to within 1 percent and at a minimum frequency of 1 reading per minute.

2.3 Temperature Gauge. Same as Method 2, Section 2.3 for volume correction to standard conditions.

2.4 Barometer. Same as Method 2, Section 2.5 for volume correction to standard conditions.

2.5 Calibration Equipment.

2.5.1 Synchronous Motor. A variable speed synchronous motor capable of providing a known constant rotational speed to the input shaft of the propeller anemometer for purposes of comparing and adjusting the output signal to known values.

2.5.2 Bearing Torque Disc. A variable torque applicator capable of applying a range of torques to the input shaft of the propeller anemometer from 0 to the manufacturer's recommended "poor performance" criterion.

2.5.3 Wind Tunnel. A wind tunnel capable of providing stable velocities over the expected range of velocities to be measured. Air flow should be fully developed turbulent flow in the axial direction only. Means shall be available to quantify ambient temperature and pressure for correction to standard conditions. Means shall also be available to rotate the propeller anemometer, within the wind tunnel, through 180° (±90° of the centerline) and note the angle of rotation in 10° increments.

2.5.4 Calibration Pitot Tube. Same as Method 2, Section 2.7 for determination of wind tunnel velocities to within 1 percent.

2.5.5 Differential Pressure Gauge for Calibration Pitot Tube. Same as Method 2, Section 2.8 for use with the standard pitot tube during wind tunnel velocity determinations.

3. <u>Procedure</u>

3.1 Proper Mounting of Propeller Anemometer. Attach the propeller anemometer to a suitable device (probe, rail, rod, etc.) to facilitate traversing the stack/duct cross-section. Ensure that all flow obstructions created by (1) the sampling support equipment (rail, etc.) are a minimum of 2 propeller diameters downstream of the propeller and (2) the sampling equipment (nozzles) are a minimum of 2 inches upstream of the propeller and have a maximum obstructive area (projected area) 10% the size of the propeller's area of rotation. Ensure that the propeller anemometer is properly aligned with the centerline of the stack/duct and stably mounted (vibration and subsequent misalignment will create serious errors in the velocity and volumetric flow rate results). Connect electrical connections for velocity data recording as shown in Figure 1.

3.2 Cross Sectional Area. Determine the stack/duct dimensions at the sampling location. Include the total area (at the sampling location) without regard to the velocity in the stack.

3.3 Zero Output System. Zero all recording devices by carefully bringing the propeller anemometer to a stand-still. Record ambient temperature and pressure data and note time and date as shown in the example data sheet Figure 2.

3.4 Determination of Gas Velocity. Measure the gas velocity and temperature at the traverse points specified by the applicable.

(<u>Note:</u> Due to the size of most propellers, traverse points within 10 cm of a side-wall will be unmeasurable.) Alternatively, based on the preliminary traverse or the previous measurement, the stack temperature may be measured at a single point if the gas temperatures at all points were within 5°F of the average temperature.

4. <u>Calibration</u>

4.1 Propeller Anemometer. The propeller anemometer shall be calibrated before its initial use in the field. Both electro/mechanical and performance parameters shall be checked during calibration according to the procedures supplied by the manufacturer. Calibration procedures in 4.1.1, 4.1.2 and 4.1.3 shall be conducted before the initial field use. Calibration procedures in 4.1.3 shall be conducted for each propeller in use and whenever the structural integrity of a propeller or shaft/generator housing is in question.

4.1.1 Generator Output Test. To assess the integrity of the electrical output, a variable speed synchronous motor to rotate the propeller anemometer input shaft at known rotational velocities will be required. A minimum of two speeds shall be used to check the electrical output of each shaft/generator housing. The two speeds chosen shall fall on either side of the expected shaft velocities under field use.

Couple the synchronous motor to the anemometer input shaft according to the manufacturer's specifications (to ensure no slippage occurs). Attach an output device to the anemometer electrical outputs and start motor. Obtain the first rotational test speed and record the anemometer output in either mV DC or rpm. Obtain the second rotational test speed and record the anemometer output. Continue with additional rotational test speeds if applicable. Repeat each test speed in order to obtain a total of three output readings for each speed.

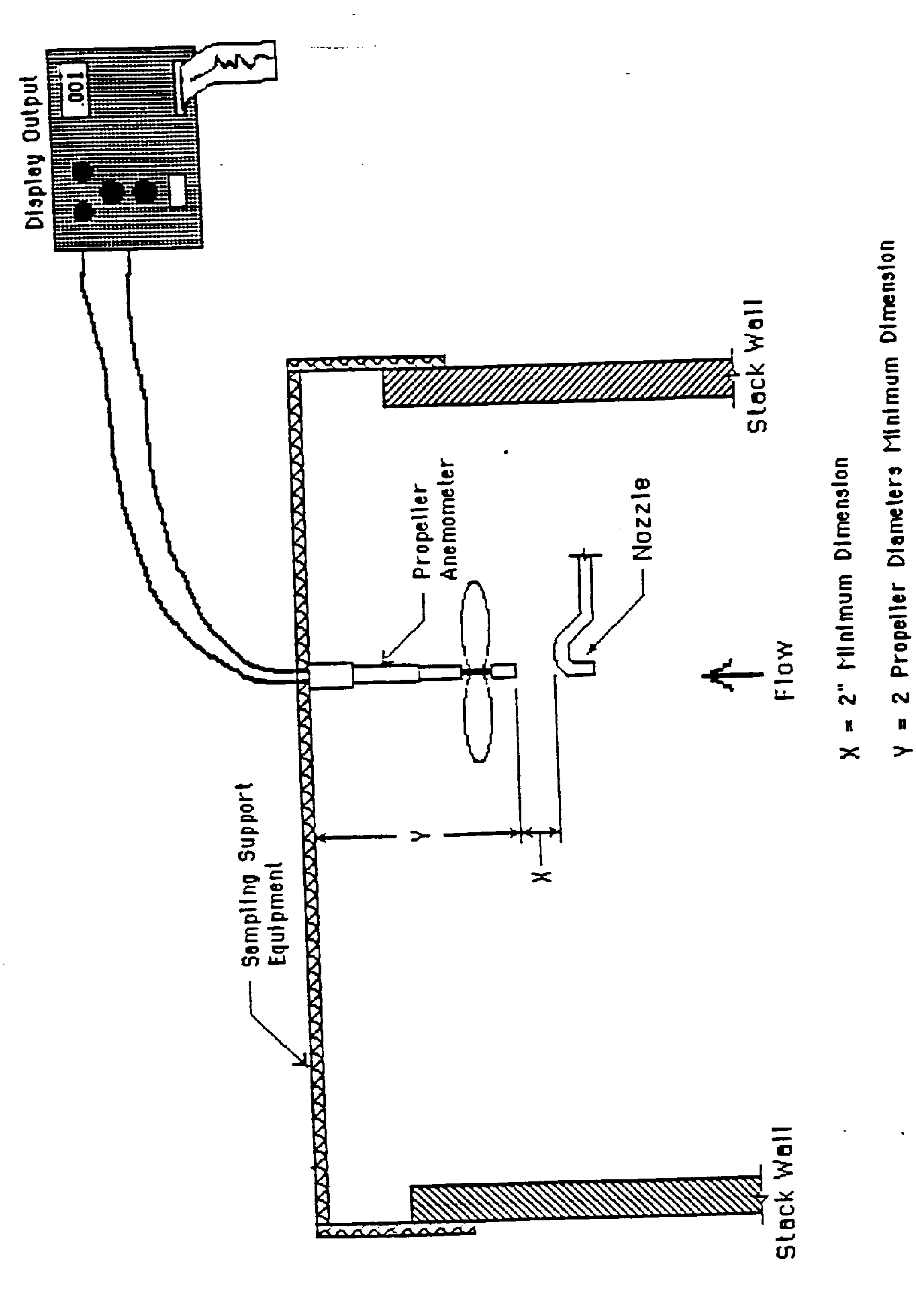

Figure A-1. Propeller Anemometer Positioning and Mounting in Cooling Tower Fan Stack.

Figure 1

FIGURE 2. EXAMPLE VELOCITY AND VOLUMETRIC FLOWRATE DAT

Plant/Location ____________________

Date ____________ Run ____________

Operators ____________ Time (start/finish) ____________

Stack/duct dimensions ____________ m (in.)

Cross sectional area ____________ m^2 (in.^{2})

Anemometer ID no. ____________ Calibration Date ____________

Anemometer electromechanical ratio ____________

Anemometer axial/rotational velocity ratio ____________

Ambient Temperature ______ °C (°F) Barometric Pressure ______ mm Hg (in. Hg)

Traverse point no.	Stack/Duct Temp.		Anemometer Output		Gas Velocity
	t_s, °C (°F)	T_s, °K (°R)	V_a, mV	v_r, rpm	v_s, m/s (A/s)

Figure 2

Average the three output readings from each rotational test speed applied and compare these results with the manufacturer's specifications (e.g., linear rpm/mV ratio). Results should compare with specifications to within 2 percent.

4.1.2 Bearing Torque Test. To assess the integrity of the mechanical bearings supporting the input shaft, a bearing torque test shall be conducted. Attach to the anemometer input shaft a torque applicator (e.g., bearing torque disc) which will apply a range of known, repeatable torques beyond the manufacturer's "poor performance" criterion. Starting with a 0.1 gm-cm torque, continually increase the applied torque in 0.1 gm-cm increments until the shaft begins to turn. Record the applied torque required to create shaft rotation and repeat two times. Results from all three tests should be below the manufacturer's specification for "poor performance." Conduct this check after the non-axial flow calibration to document the torque required during the calibration.

4.1.3 Non-Axial Flow Test. Assess the representativeness of manufacturer's angular flow calibration curve by conducting a wind tunnel test on each propeller in use and generating a percent response-vs-wind angle curve for comparison. Attach the propeller anemometer to the wind tunnel to allow a full 180° rotation (±90° from the center line) within the tunnel. Connect all other apparatus to display/record anemometer outputs.

With the wind tunnel operating at 15 to 25 fps. determine the velocity at the propeller location using a standard pitot, differential pressure gauge, barometric pressure and temperature. Starting with the propeller anemometer oriented into the direction of flow (0°) rotate and record the output readings at 10° increments from 0° to + 90° and 0° to -90°. Plot these results on a percent response-vs-wind angle graph and compare to the manufacturer's specifications. Differences should be within 3 percent at each point for the 100% axial flow response. Using the 100% axial flow response compute a velocity result and compare it to the velocity results measured using the standard pitot probe. This difference should be within 3 percent of the pitot probe results at 0°. Repeat this test at a velocity of 25 to 40 fps; compute the percent deviations as above.

Note: If the results of the propeller anemometer initial calibration tests are not within the required specifications, then either corrective maintenance should be implemented to correct the deficiencies or the equipment in question should be considered unsatisfactory and replaced.

4.1.4 Field Use and Recalibration.

4.1.4.1 Field Use. When the propeller anemometer is used in the field, the manufacturer's electromechanical ratio and axial/rotational velocity ratio shall be used to perform the velocity calculations.

4.1.4.2 Recalibration. After each test run, both a bearing torque check and a generator output test shall be conducted. If the bearing torque check is more than twice the torque recorded after calibration or is in the range of "poor performance' as described by the manufacturer, the anemometer must be repaired or replaced and the run repeated. The generator output test results must be within 5 percent of the predicted value or the system must be repaired or replaced and the run repeated. Alternatively the tester may opt to conduct both checks at the conclusion of all runs. However, if both criteria are not met, all runs must be repeated.

If both checks meet the above criteria and a visual inspection of the propeller shows no apparent changes, no additional calibrations must be conducted. Whenever the propeller anemometer fails to meet either of the above requirements or the propeller becomes damaged, a complete recalibration as described in 4.1.1, 4.1.2 and 4.1.3 must be conducted.

4.2 Temperature Gauge. After each test series, check the temperature gauge at ambient temperature. Use an American Society for Testing and Materials (ASTM) mercury-in-glass reference thermometer, or equivalent, as a reference. If the gauge being checked does not agree within 2 percent (absolute temperature) of the reference, the temperature data collected in the field shall be considered invalid or adjustments of the test results shall be made, subject to the approval of the Administrator.

4.3 Barometer. Calibrate the barometer used against a mercury barometer prior to the field test as described in Method 2.

5. Calculations

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

5.1 Nomenclature.

A^s = Stack cross-sectional area, m_2.

C^e = Constant, anemometer manufacturer's electromechanical ratio, rpm/mV.

C^r = Constant, anemometer manufacturer's axial/rotational velocity ratio, cm/rev.

P^{bar} = Barometric pressure, mm Hg.

P^g = Average static pressure, mm Hg.

Q^s = Volumetric flow rate at standard conditions (20°C and 760 mm Hg), m_3/min.

T^s = Absolute stack temperature, °K.

t^s = Stack temperature, °C.

V^a = Anemometer voltage output, mV.

v^r = Rotational velocity, anemometer output, rpm.

v^s = Stack gas velocity, m/sec.

5.2 Velocity.

$$v^r = C^e V^a \qquad \text{(Eq. 1)}$$

$$v^s = C^r v^r/100 \qquad \text{(Eq. 2)}$$

$$= C^r C^e V^a/100$$

5.3 Volumetric Flow Rate.

$$Q^s = A^s v^s \qquad \text{(Eq. 3)}$$

$$= 60 A^s C^r V^a/100$$

6. Bibliography

1. Gill, G.C., H.W. Carson, and R.M. Holmes. A Propeller-Type

Vertical Anemometer. J. Applied Meteorology, December 1964.
2. Gill, G.C. The Helicoid Anemometer. Atmosphere, Vol. 11, No 4, 1973.