ANSI/AMCA Standard 240-15

Laboratory Methods of Testing Positive Pressure Ventilators for Aerodynamic Performance Rating

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**AIR MOVEMENT AND CONTROL
ASSOCIATION INTERNATIONAL INC.**

The International Authority on Air System Components

ANSI/AMCA Standard 240-15

Laboratory Methods of Testing
Positive Pressure Ventilators for Aerodynamic Performance Rating

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AMCA Publications

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Related AMCA Documents

Related Publications	AMCA Publication 11, *Certified Ratings Program – Operating Manual*
	AMCA Publication 111, *Laboratory Accreditation Program*
	AMCA Publication 211, *Certified Ratings Program – Air Performance*
Related Standards	ANSI/AMCA Standard 210, *Laboratory Methods of Testing Fans for Aerodynamic Performance Rating*

Contents

Laboratory Methods of Testing
Positive Pressure Ventilators for Aerodynamic Performance Rating

1. Purpose

This standard establishes a uniform method of laboratory testing for the determination of the aerodynamic performance of a positive pressure ventilator (PPV) in terms of airflow rate, pressure, air density and rotational speed, for performance rating or guarantee purposes.

It is not the purpose of this standard to specify a testing procedure for the design, production or field test of any PPV, nor is it the purpose for the standard to serve as a manual for the construction, validation or calibration of the test facility.

Background:
Prior to the original publication of this standard in 1996, positive pressure ventilators (PPVs) were tested to ANSI/AMCA Standard 210 [1]. The scope of ANSI/AMCA Standard 210, however, includes only air moving devices designed with the impeller enclosed within a shroud or housing. Due to variations in the design of PPVs, some could be tested to ANSI/AMCA Standard 210 while others could not. In 1992, AMCA set out to develop a single method of test applicable to all PPVs by creating the AMCA Standard 240 Draft Committee.

The test method devised by the committee is substantially the same as the outlet chamber test setup described in ANSI/AMCA Standard 210. The principal difference between ANSI/AMCA Standard 210 and ANSI/AMCA Standard 240 is that in ANSI/AMCA Standard 210 the outlet of the test unit is either mounted directly to the test chamber or connected to a duct that is mounted on the test chamber. In ANSI/AMCA Standard 240, the test unit discharge is directed toward a doorway-sized opening into the test chamber. This setup approximates a real-world application of the equipment and also accounts for entrained airflow.

ANSI/AMCA Standard 240 is a special case of ANSI/AMCA Standard 210. Therefore, a sizeable portion of the standard originates in ANSI/AMCA Standard 210. This latest edition replaces many sections of text with reference to the parent standard in an effort to simplify the standard by emphasizing differences over similarities.

2. Scope

This standard may be used as the basis for the test of a PPV when air is used as the test gas. Each test shall be limited to one PPV per test. A PPV tested in accordance with this standard shall be freestanding and without a ductwork connection to the test chamber, thereby allowing for the measurement of entrained airflow.

Any item of equipment designed or intended for applications other than positive pressure ventilation is not within the scope of this standard.

The parties to a test for guarantee purposes may agree in writing on exceptions to this standard prior to the test. However, only a test that does not violate the mandatory requirements of this standard shall be designated as a test conducted in accordance with this standard.

3. Definitions/Units of Measure/Symbols

3.1 Definitions

For the purposes of this standard, the definitions in Section 3.1 apply. All other definitions shall conform to ANSI/AMCA Standard 210, Section 3.

3.1.1 Positive pressure ventilator (PPV)
A portable fan that can be positioned relative to an opening of an enclosure and cause it to be positively pressurized by discharge air velocity. It is principally used by firefighters to mitigate the effect of smoke and is also used to assist in inflating hot air balloons [2].

3.1.2 Motor
A drive device other than an internal combustion engine, such as an electric motor, water turbine, hydraulic motor, air motor and similar devices

3.1.3 Engine
A drive device that produces power through internal combustion and that uses a fuel such as gasoline.

3.1.4 PPV position
The point representing a PPV position in three-dimensional space is taken as the intersection between the PPV axial centerline and the plane perpendicular to the centerline that contains the PPV center of the PPV impeller hub. All measurements pertaining to the PPV must be referenced to this point.

3.1.5 Setback
The horizontal distance between the PPV position and the opening to the test chamber, within a vertical plane perpendicular to the plane defined by the chamber opening.

3.1.6 Height
The vertical distance between the PPV position and the flat, horizontal surface on which the PPV is situated.

3.1.7 Tilt

The angle between the PPV axial centerline and the horizontal plane.

3.1.8 PPV speed

The rotational speed of the PPV impeller.

3.1.9 Test

A series of determinations for various points of operation of a PPV.

3.1.10 Shall and should

The word "shall" is understood as mandatory and the word "should" as advisory.

3.2 Units of measure

The units of measure used in this standard shall conform to ANSI/AMCA Standard 210, Annex A.

3.3 Symbols

The symbols listed in Table 1 apply for the purposes of this standard. All others shall conform to ANSI/AMCA Standard 210, Section 4.

4. Instruments and Methods of Measurement

In addition to the following, the manufacturer shall adhere to the requirements of ANSI/AMCA Standard 210, Section 5, as applicable.

4.1 Manometers and other pressure indicating instruments

Pressure (except PPV static pressure) shall be measured on a manometer of the liquid column type using inclined legs, vertical legs or any other instrument having a maximum uncertainty of 1% over the maximum observed reading or 1 Pa (0.005 in. wg), whichever is larger.

4.2 Pressure indicating instrument – PPV static pressure

PPV static pressure shall be measured with a pressure transducer having an accuracy equal to or better than 0.5% as stated by the manufacturer.

4.3 Other pressure measurement systems

Pressure measurement systems consisting of sensors and indicators other than manometers and static pressure taps may be used for all pressures except PPV static pressure, if the combined uncertainty of the system does not exceed the combined error for an appropriate combination of manom-

eters and static pressure taps. For a system used to determine pressure, the contribution to the combined uncertainty of the pressure measurement shall not exceed that corresponding to 1% of the maximum observed pressure differential reading during a test (indicator tolerance) plus 1% of the actual reading (averaging accuracy). See ANSI/AMCA Standard 210, Section 5.2.5, note 1.

5. Equipment and Setup

In addition to the following, the manufacturer shall adhere to the requirements of ANSI/AMCA Standard 210, Section 6, as applicable.

5.1 Setup

The PPV under test shall be set up for test as shown in Figure 2.

The values for s, h, and φ are set to simulate the intended application.

5.2 Chamber

A chamber shall be incorporated in the laboratory setup to provide a measurement station and to simulate a condition the PPV is expected to encounter in service. The chamber shall meet the proportionality and performance requirements of ANSI/AMCA Standard 210. A chamber may have a circular or rectangular cross-sectional shape. The dimension M in the test setup diagram is the inside dimension of a circular chamber or the equivalent diameter of dimensions a and b where:

$$M = \sqrt{(4ab/\pi)}$$

The chamber shall have a cross-sectional area at least 10 times the included face area of the PPV impeller.

5.3 Chamber entrance

The entrance to a chamber shall be completely sealed with the exception of a "doorway" opening having a height of 2.03 m (80 in.) and a width of 0.91 m (36 in.) centered widthwise across the entrance plane of the chamber.

A flat, horizontal surface shall extend from the rear of the test unit to the front edge of the chamber entrance. This surface shall be level with the bottom edge of the chamber entrance and shall have a minimum width equal to or exceeding the width of the chamber entrance or the width of the test unit, whichever is greater.

Table 1
Symbols and Subscripts

Symbol	Description	SI Unit	I-P Unit
a_j	Variable in polynomial coefficient equation	dimensionless	
b_j	Variable in polynomial coefficient equation	dimensionless	
G	Variable in polynomial coefficient equation	dimensionless	
h	Height	m	ft
K_j	Polynomial coefficient	dimensionless	
m	Number of samples taken	dimensionless	
n	Number of determinations	dimensionless	
P_s	PPV static pressure	Pa	in. wg
P_{sx}	Static pressure at Plane X	Pa	in. wg
Q	PPV airflow rate	m^3/s	ft^3/min
Q_x	Airflow rate at Plane X	m^3/s	ft^3/min
Q_f	Airflow rate at free delivery	m^3/s	ft^3/min
s	Setback	m	ft
j	Tilt		degrees

5.4 Fuel

A PPV driven by a gasoline engine shall be tested with standard pump gasoline with an 87 octane rating and no more than 10% methanol. No additional chemical shall be added.

6. Observations and Conduct of Test

In addition to the following, the manufacturer shall adhere to the requirements of ANSI/AMCA Standard 210, Section 7, as applicable.

6.1 Determinations

To determine the aerodynamic performance of a PPV near free delivery, determinations shall be taken for chamber static pressures (P_{s7}) ranging from 25 Pa (0.1 in. wg) to -25 Pa (-0.1 in. wg). If a chamber static pressure of 25 Pa (0.1 in. wg) cannot be obtained, the highest obtainable static pressure shall be used as the upper limit, and the negative of this value shall be considered the lower limit. Plans shall be made to vary the throttling device such that the test points will be well spaced in terms of static pressure. At least 10 determinations shall be taken per test. Half of these determinations shall be taken at a positive static pressure and half shall be taken at a negative static pressure.

6.2 PPV engine test speed

For a PPV powered by an internal combustion engine, the maximum loaded engine rpm allowed by the manufacturer

is the maximum engine rpm allowed during the test. The maximum loaded rpm for the engine shall be attested to by letter or certificate from the engine manufacturer's corporate offices. Only stock or production model engines shall be used for testing.

6.3 Exhaust venting

A PPV driven by an internal combustion engine shall have exhaust fumes vented away from the test area.

Proper precautions shall be taken to minimize the inhalation of fuel or motor exhaust fumes during testing. Any type of fume exhaust system shall be designed so as to not interfere with the airflow in the test area or affect motor performance. The exhaust venting system shall maintain zero static pressure at the exhaust port throughout the test. Figure 1 illustrates a fume exhaust setup.

7. Calculations

In addition to the following, the manufacturer shall adhere to the requirements of ANSI/AMCA Standard 210, Section 8, as applicable.

7.1 PPV airflow rate

The PPV airflow rate (Q) at test conditions shall be obtained from the equation of continuity:

$$Q = Q_7 = Q_5 \left(\frac{\rho_5}{\rho_7} \right) \qquad \text{Eq. 7.1}$$

7.2 Static pressure as a function of airflow rate

The relationship between PPV static pressure and PPV airflow rate, for the range of static pressure tested, is represented by the second order polynomial:

$$P_s = K_2 Q^2 + K_1 Q + K_0 \qquad \text{Eq. 7.2}$$

Where the coefficients K_2, K_1 and K_0 are derived from:

$$a_0 = n \qquad \text{Eq. 7.3}$$

$$a_1 = \sum_{i=1}^{n} Q_i \qquad \text{Eq. 7.4}$$

$$a_2 = \sum_{i=1}^{n} Q_i^2 \qquad \text{Eq. 7.5}$$

$$a_3 = \sum_{i=1}^{n} Q_i^3 \qquad \text{Eq. 7.6}$$

$$a_4 = \sum_{i=1}^{n} Q_i^4 \qquad \text{Eq. 7.7}$$

$$b_0 = \sum_{i=1}^{n} P_{si} \qquad \text{Eq. 7.8}$$

$$b_1 = \sum_{i=1}^{n} (Q_i P_{si}) \qquad \text{Eq. 7.9}$$

$$b_2 = \sum_{i=1}^{n} (Q_i^2 P_{si}) \qquad \text{Eq. 7.10}$$

$$G = a_4 a_2 a_0 - a_4 a_1^2 - a_3^2 a_0 \\ + 2a_3 a_2 a_1 - a_2^3 \qquad \text{Eq.7.11}$$

$$K_2 = (1/G)(a_2 a_0 b_2 - a_1^2 b_2 - a_3 a_0 b_1 \\ + a_2 a_1 b_1 + a_3 a_1 b_0 - a_2^2 b_0) \qquad \text{Eq. 7.12}$$

$$K_1 = -(1/G)(a_3 a_0 b_2 - a_2 a_1 b_2 - a_4 a_0 b_1 \\ + a_2^2 b_1 + a_4 a_1 b_0 - a_3 a_2 b_0) \qquad \text{Eq. 7.13}$$

$$K_0 = (1/G)(a_3 a_1 b_2 - a_2^2 b_2 - a_4 a_1 b_1 \\ + a_3 a_2 b_1 + a_4 a_2 b_0 - a_3^2 b_0) \qquad \text{Eq. 7.14}$$

The value for K_2 must be negative, indicating that the static pressure vs. airflow curve is concave inward. If K_2 is positive, then additional determinations should be selected in such a way as to broaden the range of static pressure for which airflow is determined.

7.3 Airflow rate at free delivery

Figures 3 and 4 show graphically the curve defined by the equation in Section 7.2 to the determinations taken in an example test for SI and I-P units, respectively. The free air point of operation is the point where the curve intersects the x axis ($P_s = 0$).

Mathematically, the PPV airflow rate at free delivery (Q_f) is calculated from:

$$Q_f = \left| \frac{-K_1 - \sqrt{K_1^2 - 4K_0 K_2}}{2K_2} \right|$$

8. Results of Test and Report

In addition to the following, the manufacturer shall adhere to the requirements of ANSI/AMCA Standard 210, Section 9, as applicable.

8.1 Results

Test results shall include atmospheric data (ρ_0), static pressure (P_{si}) and airflow (Q_i) for each determination taken, static pressure-airflow curve constants (K_0, K_1 and K_2), and airflow at free air delivery (Q_f).

8.2 Report

The laboratory report of an aerodynamic performance test of a PPV shall include identification and description of the test unit (including appurtenances, if any), test results, raw test data, test setup description, list of test instruments used (including calibration), and test personnel. The laboratory shall be identified by name and location.

8.3 Performance curve

The results of a PPV test shall include a performance curve. Typical performance curves are shown in Figure 3. Detailed requirements are given in ANSI/AMCA 210, Sections 9.2.1 through 9.2.5, inclusive.

Connection Fitting
with Piezometer Ring

PPV Engine

Variable
Exhaust
System

Exhaust Adapter Piece
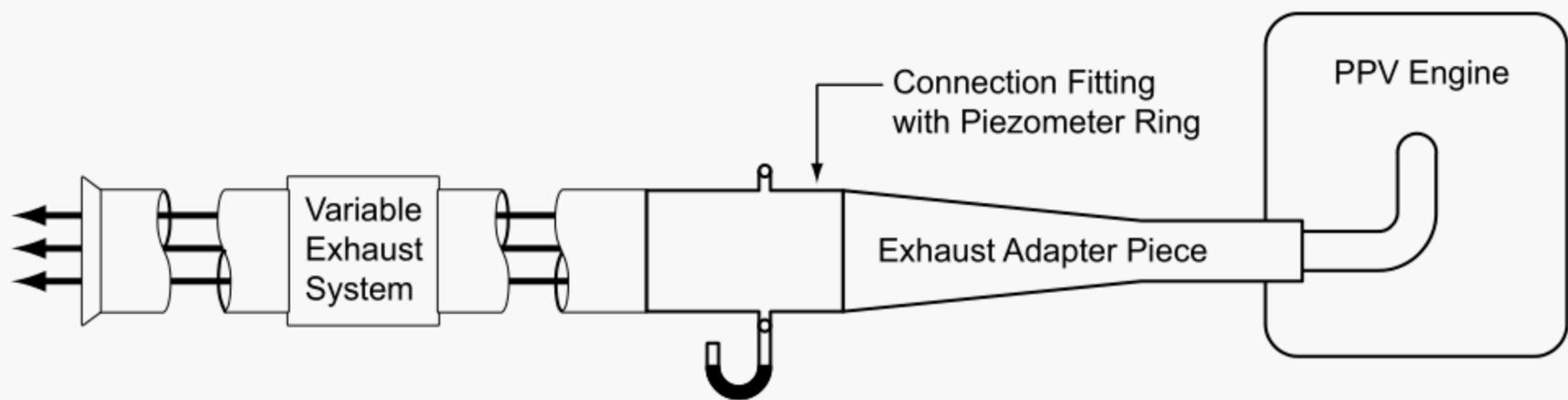
Notes:

1. Fume exhaust system is required only for tests run on PPVs driven by internal combustion engines.

2. Static pressure measured at connection fittings shall be maintained at zero throughout the test.

3. Fume exhaust shall be vented away from the laboratory in a safe manner.

Figure 1
Laboratory Fume Exhaust Setup
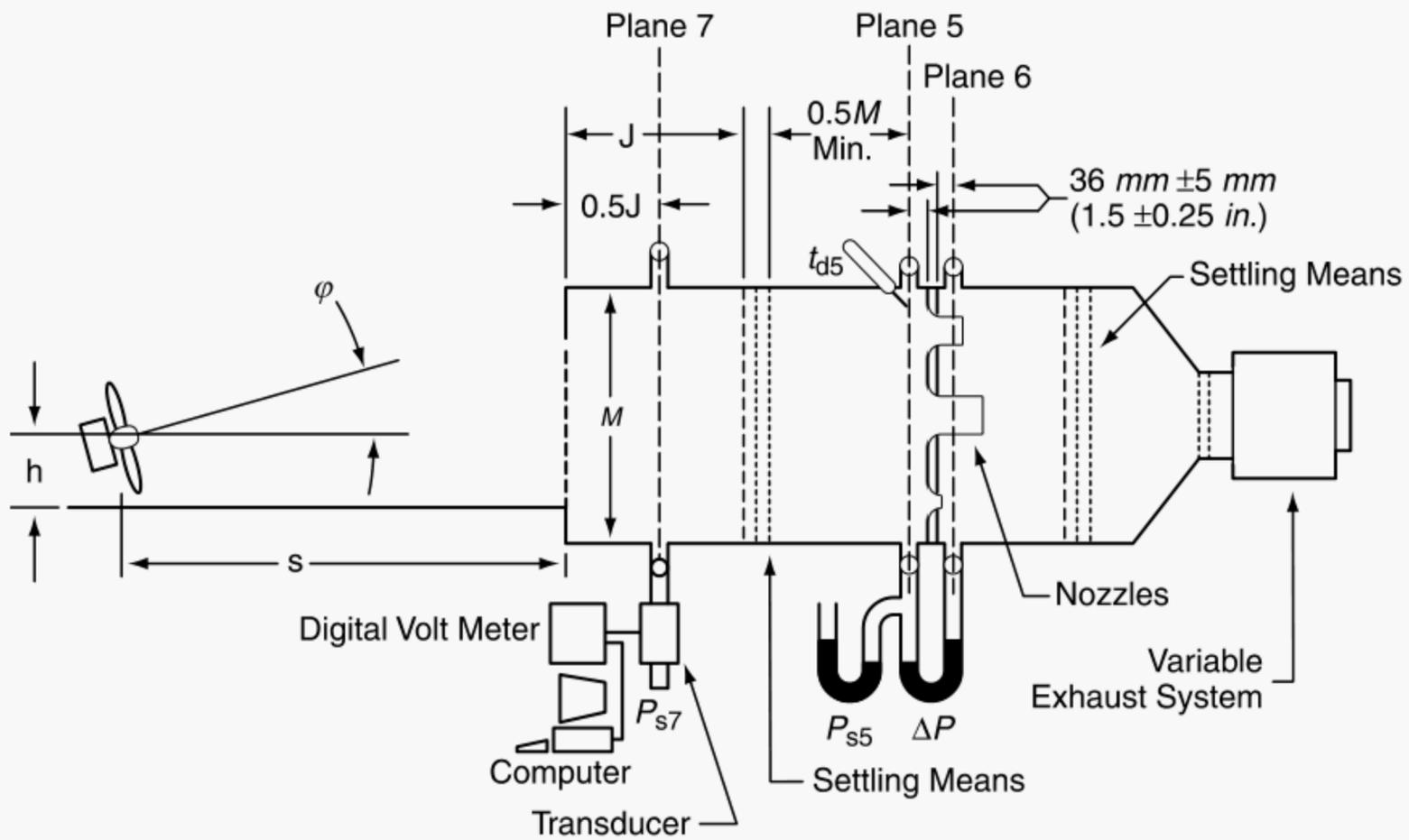
Airflow and Pressure Formulae

$$Q_5 = \sqrt{2}Y\sqrt{\frac{\Delta P}{\rho_5}}\sum(CA_6) \qquad \text{(SI)}$$

$$Q_5 = 1097.8Y\sqrt{\frac{\Delta P}{\rho_5}}\sum(CA_6) \qquad \text{(I-P)}$$

$$Q = Q_7 = Q_5\left(\frac{\rho_5}{\rho_7}\right)$$

$$P_s = P_{s7}$$

Notes:

1. Variable exhaust system may be an auxiliary fan or a throttling device.

2. The distance from the exit face of the largest nozzle to the downstream settling means shall be a minimum of 2.5 throat diameters of the largest nozzle.

3. Dimension J shall be at least 2.0 times the PPV equivalent discharge diameter.

4. Temperature t_{d7} may be considered equal to t_{d5}.

Test Figure 2
Test Setup

Free Air $P_s = 0$
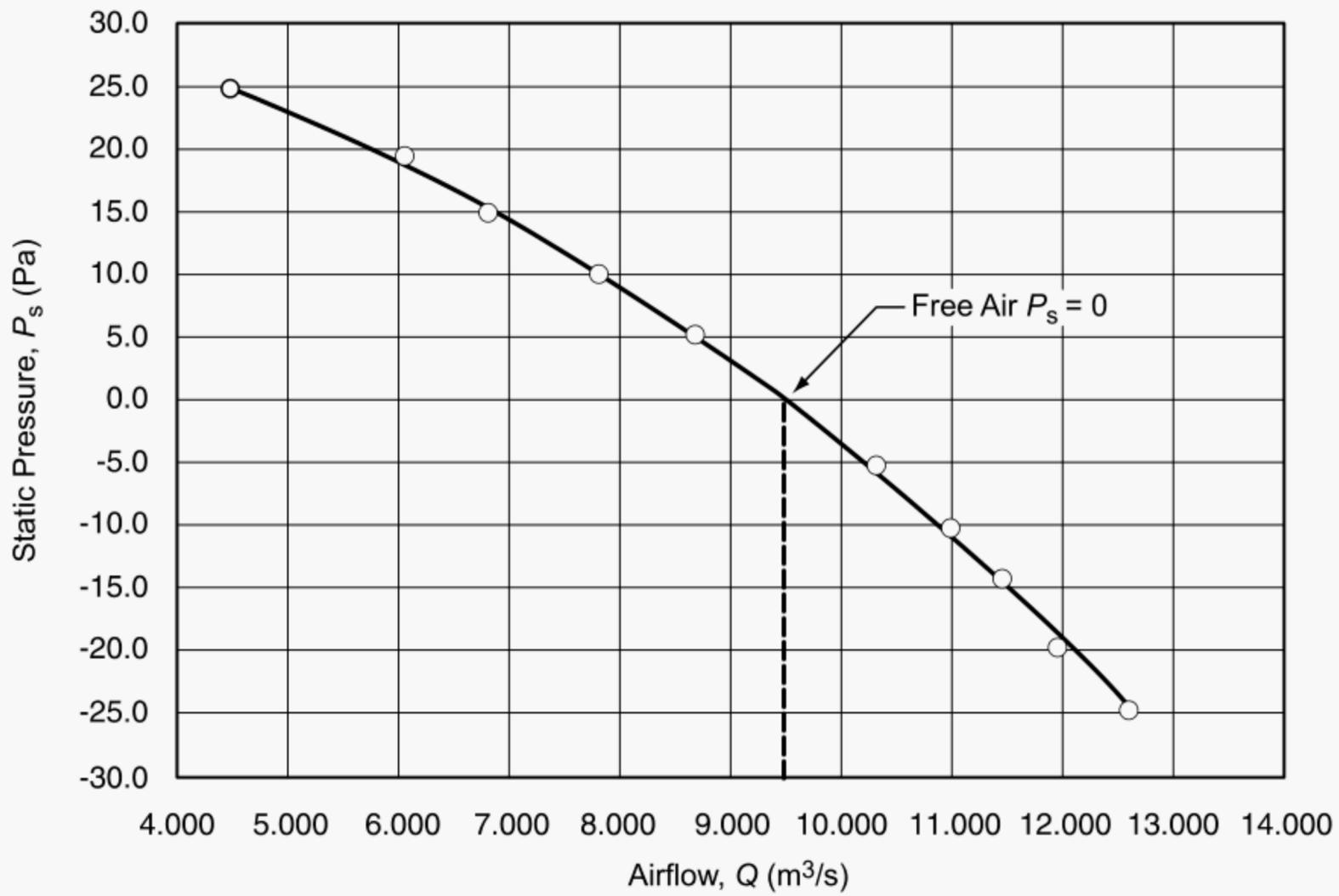
$\bigcirc\ P_{si}$ $P_s = K_2\,Q_2 + K_1\,Q + K_0$

(SI)

Free Air $P_s = 0$
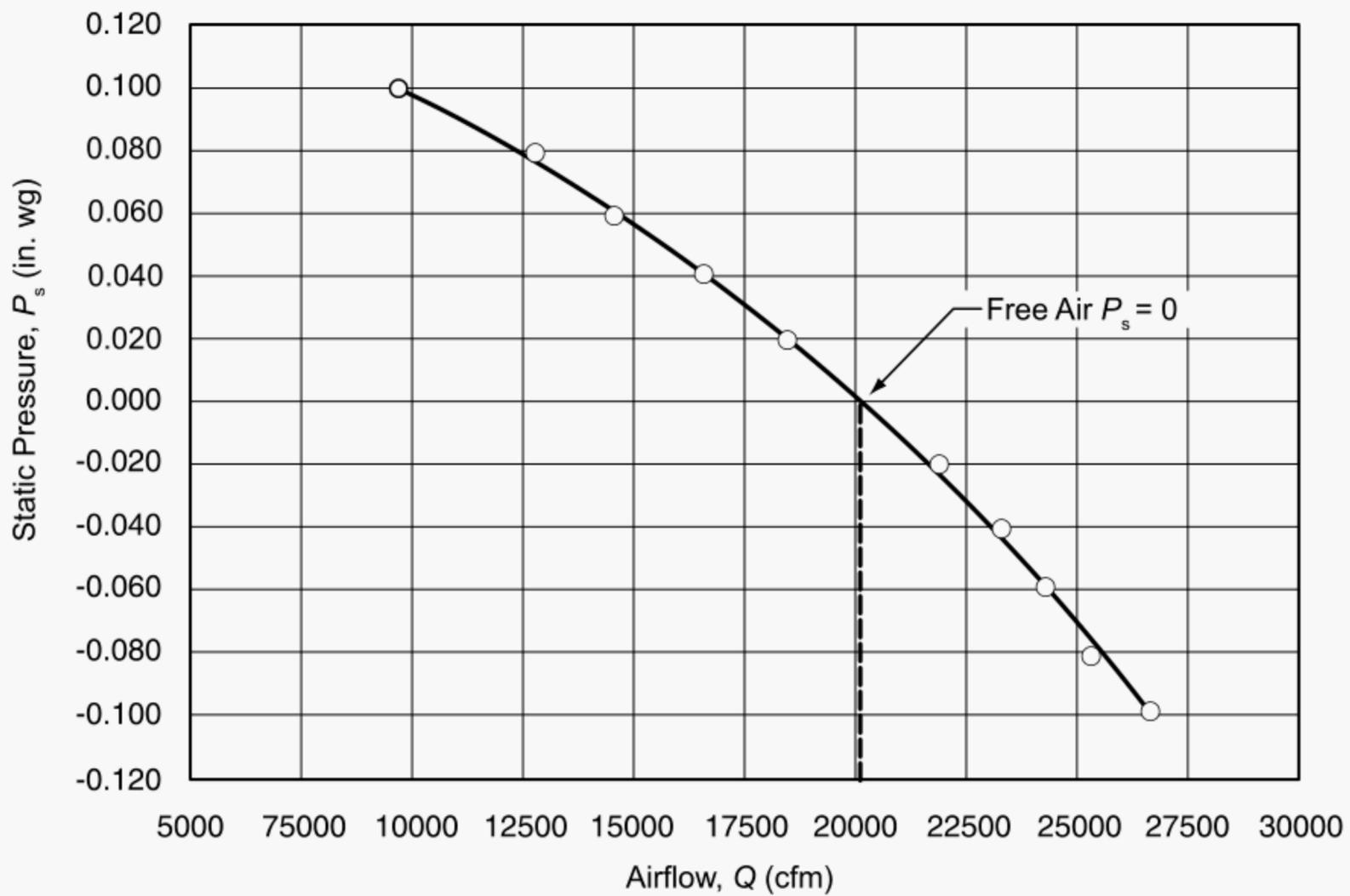
$\bigcirc\ P_{si}$ $P_s = K_2\,Q_2 + K_1\,Q + K_0$

(I-P)

Figure 3
Airflow vs. Static Pressure Curve

TEST #761-P04   **02/08/95**

AMCA Laboratory – Arlington Heights, Illinois

<u>**UNIT**</u>   <u>**SETUP**</u>

Name:	Windmaker 324	$s =$	3.05 m
Model No.:	ADF1-P24	$\Phi =$	11 °
Impeller Dia:	0.61 m	$h =$	0.46 m
Appurtenance(s):	Windmaker, Type D Misting Nozzles		

<u>**DATA**</u>

$t_{d0} =$	27.3	°C
$t_{w0} =$	18.5	°C
$p_b =$	745.4	mm Hg

i determination	N (rev/s)	t_{d5} (°C)	P_{s5} (Pa)	ΔP (Pa)	t_{d7} (°C)	P_{s7} (Pa)
1	58.32	28.9	-24.6	1461.1	28.9	-24.6
2	58.37	28.8	-20.1	1307.1	28.8	-20.1
3	58.38	28.8	-14.4	1210.3	28.8	-14.4
4	58.43	28.7	-9.9	1106.4	28.7	-9.9
5	58.43	28.4	-5.2	988.2	28.4	-5.2
6	58.48	28.2	4.7	702.4	28.2	4.7
7	58.43	28.1	9.9	557.1	28.1	9.9
8	58.50	28.0	14.7	422.2	28.0	14.7
9	58.52	27.8	19.4	338.3	27.8	19.4
10	58.52	27.8	24.6	189.5	27.8	24.6

i determination	ρ_0 (kg/m³)	$P_{si} = P_{s7}$ (Pa)	$Q_i = Q_7$ (m³/s)
1	1.1460	-24.6	12.609
2	1.1460	-20.1	11.921
3	1.1460	-14.4	11.469
4	1.1460	-9.9	10.963
5	1.1460	-5.2	10.380
6	1.1460	4.7	8.740
7	1.1460	9.9	7.779
8	1.1460	14.7	6.788
9	1.1460	19.4	6.070
10	1.1460	24.6	4.535

CURVE COEFFICIENTS

$K_0 =$	30.589620
$K_1 =$	0.318340
$K_2 =$	-0.372880

AIRFLOW AT FREE AIR

$Q_f =$ 9.494 m³/s

Tested by RDK

(SI)

Figure 4 (SI)
Example Test Report   **Con't**

AMCA Laboratory – Arlington Heights, Illinois

UNIT   _SETUP_

Name:	Windmaker 324	
Model No.:	ADF1-P24	
Impeller Dia:	24 in.	
Appurtenance(s):	Windmaker, Type D Misting Nozzles	

$s =$	120	in.
$\Phi =$	11	°
$h =$	18	in.

DATA

$t_{d0} =$	81.1	°F
$t_{w0} =$	65.3	°F
$p_b =$	29.35	in. Hg

i determination	N (rpm)	t_{d5} (°F)	P_{s5} (in. wg)	ΔP (in. wg)	t_{d7} (°F)	P_{s7} (in. wg)
1	3499	84.0	-0.099	5.883	84.0	-0.099
2	3502	83.8	-0.081	5.263	83.8	-0.081
3	3503	83.8	-0.058	4.873	83.8	-0.058
4	3506	83.7	-0.040	4.455	83.7	-0.040
5	3506	83.1	-0.021	3.979	83.1	-0.021
6	3509	82.7	0.019	2.828	82.7	0.019
7	3506	82.6	0.040	2.243	82.6	0.040
8	3510	82.4	0.059	1.700	82.4	0.059
9	3511	82.1	0.078	1.362	82.1	0.078
10	3511	82.0	0.099	0.000	82.0	0.099

i determination	ρ_0 (lbm/ft³)	$P_{si} = P_{s7}$ (in. wg)	$Q_i = Q_7$ (cfm)
1	0.07155	-0.099	26717
2	0.07155	-0.081	15259
3	0.07155	-0.058	24301
4	0.07155	-0.040	23229
5	0.07155	-0.021	21993
6	0.07155	0.019	18519
7	0.07155	0.040	16482
8	0.07155	0.059	14382
9	0.07155	0.078	12861
10	0.07155	0.099	9609

CURVE COEFFICIENTS

$K_0 =$	1.231664×10^{-01}
$K_1 =$	6.049324×10^{-07}
$K_2 =$	$-3.344101 \times 10^{-10}$

AIRFLOW AT FREE AIR

$Q_f =$ 20117   cfm

Tested by RDK

Figure 4 (I-P)
Example Test Report

(I-P)

Annex A
References

A.1 Normative References

The following standard contains provisions that, through specific reference in this text, constitute provisions of this American National Standard. At the time of publication, the edition indicated was valid. All standards are subject to revision, and parties to agreements based on this American National Standard are encouraged to investigate the possibility of applying the most recent edition of the standard listed below.

[1] ANSI/AMCA 210. *Laboratory Methods of Testing Fans for Aerodynamic Performance Rating.* Arlington Heights, IL: AMCA International, 2007.

A.2 References

[2] ANSI/AMCA Standard 99. *Standards Handbook*. Arlington Heights, IL: AMCA International, 2010.