

AHRI Standard 431 (SI) with Addendum 1

2014 Standard for

Performance Rating of Central Station Air-handling Unit Supply Fans



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AHRI STANDARD 431 (SI)-2014 WITH **ADDENDUM 1,** **PERFORMANCE RATING OF CENTRAL** **STATION AIR-HANDLING UNIT SUPPLY FANS**

December 2015

Addendum 1 (dated December 2015) of AHRI Standard 431 (SI)-2014, “Changes to AHRI Standard 431 (I-P)-2014” is provided as follows. The following changes have been incorporated (deletions are shown by ~~strikethroughs~~, additions are shown by **shading**) into the already published 2014 version of AHRI Standard 431 (SI) to avoid confusion.

Note: This addendum is not ANSI approved and is currently going through the process to become so.

The changes include:

- 1) The scope of the standard was updated.

2.1.1 This standard applies to Supply Fan ratings **to** for Central Station Air-handling Units with **supply fan ratings for Plenum Fans in a cabinet with a Full Face Opening Axial Discharge, Fan Arrays, Housed Centrifugal Fans, and Axial Fans.**

- 2) The exclusions to the scope of the standard were updated.

~~**2.2.1** This standard does not apply to forced-circulation, free-delivery air coolers for refrigeration, which are covered in ANSI/AHRI Standard 420.~~

~~**2.2.5** This standard does not apply to variable refrigerant flow equipment as defined in ANSI/AHRI Standard 4230.~~

- 3) Changed Unit Appurtenances to Appurtenances in Section 3 and renumbered accordingly.

~~**3.6** *Unit Appurtenances.* Equipment added to Central Station Air-handling Units for purposes of control, isolation, safety, static pressure regain, energy/heat recovery, wear, etc. Such appurtenances include coils, filters, dampers, air mixers, spray assemblies, energy recovery devices, acoustical silencers, eliminators, etc.~~

3.2 Appurtenances. Equipment added to a CSAHU for purposes including but not limited to control, isolation, safety, static pressure regain, wear, etc. Appurtenances include, but are not limited to coils, filters, energy recovery devices, dampers, air-mixers, spray assemblies, eliminators, discharge plenums, and inlet plenums.

- 4) Clarified the definition for Central Station Air-handling Unit.

3.3 Central Station Air-handling Unit (CSAHU). A factory-made encased assembly consisting of a supply fan or fans in parallel which may also include other necessary equipment to perform one or more of the

functions of circulating, cleaning, heating, cooling, humidifying, dehumidifying and mixing of air. It shall not contain a source of mechanical cooling. The CSAHU must have a maximum design external static pressure (ESP) greater than 250 Pa. ~~This assembly is capable of use with duct work having a total static resistance of at least 125 Pa.~~

Note: While the ESP for a specific application may be less than 250 Pa, any units generally capable of delivering greater than 250 Pa ESP shall be considered to be a CSAHU.

- 5) Added definitions for Fan Array, Contained Fan, Partially Contained Fan, Uncontained Fan, Identical Construction, Variable Frequency Drive, and Controller to Section 3.

3.4 *Controller.* A power electronic device that regulates the speed of a motor (typically used for direct current (DC) motors).

3.6.4 *Fan Array.* A matrix of regularly spaced direct-drive Supply Fans operating in parallel with inflow from a common inlet plenum and with outflow into a common outlet plenum. All impellers and motors must be of Identical Construction. All Operating Fans must run at the same speed. If applicable, all Variable Frequency Drives must be programmed to provide identical frequency and voltage.

3.6.4.1 *Contained Fan.* Fans in a Fan Array that are within substantially uniform enclosure(s) and do not aerodynamically interact with each other within the array.

3.6.4.2 *Partially Contained Fan.* Fans in a Fan Array that are within non-uniform enclosure(s) and some Supply Fans aerodynamically interact with each other within the array.

3.6.4.3 *Uncontained Fan.* Fans in an array that aerodynamically interact with each other.

3.6.8 *Identical Construction.* A product which has the same manufacturer, the same model number, and is intended to have the same performance under the same conditions. Exception: the model numbers may differ if the only difference between the models is something which does not affect performance (e.g. color).

3.6.9 *Operating Fan.* Any Supply Fan which is designated by the CSAHU manufacturer to be energized and rotating at the specified Rating Condition.

3.11 *Variable Frequency Drive (VFD).* A power electronic device that regulates the speed of an alternating current (AC) motor by adjusting the frequency and the voltage of the electrical power supplied to the motor.

- 6) Updated the angle in Figure 3 from 20° to 70°.
7) Added classifications for Fan Arrays to Section 4.

4.1.2.3.1 Single Plenum Fan

4.1.2.3.2 Plenum Fan Array

- 8) Added wording to Section 5.1.1.3.

5.1.1.3 *Unducted Fan Discharge Central Station Air-handling Units.* Unducted Fan Discharge Central Station Air-handling Units shall be tested in accordance with ANSI/AMCA Standard 210/ANSI/ASHRAE Standard 51, except when an outlet chamber with multiple nozzles within the chamber is used. The test chamber cross-sectional area shall be sized so that the maximum air velocity does not exceed ~~400 fpm~~ 2 m/s. The test chamber height and width shall be at least 5% greater than the respective height and width of the duct connection at the test chamber. Discharge area cannot exceed the test chamber area. For an example, see Figure 4. Corrections for static pressure losses created by the test apparatus (e.g. the addition of ductwork) shall be made according to Appendix E and the ASHRAE Duct Fitting Database CD.

- 9) Updated the wording in Section 5.1.1.4.

5.1.1.4 *Plenum Fan Units.* The rating configuration for either Ducted Fan Discharge or Unducted Fan Discharge plenum fan units shall be Full Face Opening Axial Discharge ~~full face discharge~~ with the minimum spacing allowed per the manufacturer's specifications between the coil and the fan. If Full Face Opening Axial Discharge is not possible due to the size of the unit compared to the test chamber, the unit shall be provided with an inlet or discharge plenum and a suitably sized duct shall extend from the plenum. Corrections for static pressure losses created by the test apparatus (e.g. the addition of ductwork) shall be made according to Appendix E and the ASHRAE Duct Fitting Database CD. The discharge or inlet plenum shall be considered as an Appurtenance to the CSAHU for the purpose of testing. Figure 15 in the 2007 revision of AMCA 210 shall be used for the test set-up of belt-drive plenum fan units (see Figure 5). Figures 12 or Figure 15 in the 2007 revision of AMCA 210 shall be used for the test set-up of direct-drive plenum fan units (see Figures 5 and 6).

- 10) Added Section 5.1.1.7.

5.1.1.7 *Units with Fan Arrays.* The rating configuration for Units with Fan Arrays shall be Full Face Opening Axial Discharge with the minimum spacing allowed per the manufacturer's specifications between the coil and the fan. If Full Face Opening Axial Discharge is not possible due to the size of the unit, the unit shall be provided with an inlet or discharge plenum and a suitably sized duct shall extend from the plenum. Corrections for static pressure losses created by the test apparatus (e.g. the addition of ductwork) shall be made according to Appendix E and the ASHRAE Duct Fitting Database CD. The discharge or inlet plenum shall be considered as an Appurtenance to the CSAHU for the purpose of testing. The power measurement for units with Fan Arrays shall use the calibrated motor method as defined in Section 4.4.3 of AMCA 210.

5.1.1.7.1 Calibrate at least the number of motors as specified in Table 1.

5.1.1.7.1.1 Refer to NEMA MG-1 for acceptable tolerances between motor calibrations. If the requirements in NEMA MG-1 are not met, then all motors must be calibrated.

5.1.1.7.2 Motor calibrations shall be performed at the same frequency and voltage as used during the test.

5.1.1.7.3 Average the calibrated motors to get the composite motor calibration.

5.1.1.7.3.1 To get the average composite motor calibration, create a scatterplot of the data and use simple linear regression to find the equation for the line fit in the form of $y=mx+b$.

5.1.1.7.3.1.1 Alternatively, a polynomial regression can be computed to improve accuracy instead of a linear regression.

5.1.1.7.4 During the test, measure total power input after the VFD/controller.

5.1.1.7.4.1 If unable to measure total power input after the VFD/Controller, measurements shall be simultaneously recorded for the power input into all individual motors to get the total power input.

5.1.1.7.4.2 Shaft power is calculated as shown below. An example is shown in Appendix D.

5.1.1.7.4.2.1 Divide the total input power by the number of operating fans.

5.1.1.7.4.2.2 Determine the shaft power per fan using the composite motor calibration data.

5.1.1.7.4.2.3 Multiply the shaft power per fan by the number of fans to get the total unit shaft power.

Table 1. Number of Motors to be Calibrated ¹	
Number of Supply Fans in the Fan Array	Number of motors to be calibrated
2-4	2
5-8	3
9-12	4
13+	5
Notes:	
1) An equal distribution of contained and uncontained fans must be measured.	

11) Updated normative references.

A1.5 ~~ANSI/AHRI Standard 420-2008, Performance Rating of Forced Circulation Free Delivery Unit Coolers for Refrigeration, 2008, American National Standards Institute and Air Conditioning & Refrigeration Institute, 2111 Wilson Blvd, Suite 500, Arlington, VA 22201, U.S.A.~~

A1.6 ~~ANSI/AHRI Standard 840-1998~~2015, Performance Rating of ~~Standard~~ for Unit Ventilators, 19982015, American National Standards Institute and Air-Conditioning & Refrigeration Institute, 2111 Wilson Blvd, Suite 500, Arlington, VA 22201, U.S.A.

A1.8 ANSI/AMCA Standard 99, *Standards Handbook*, 2007, Air Movement and Control Association, Inc., 30 West University Drive, Arlington Heights, IL 60004, U.S.A.

A1.11 ASHRAE Duct Fitting Database CD Version 6.00.04, 2015, American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc., 1791 Tullie Circle, N.E. Atlanta, GA 30329, U.S.A.

A1.12 ASHRAE Fundamentals, 2013, American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc., 1791 Tullie Circle, N.E. Atlanta, GA 30329, U.S.A.

12) Added note to Figure C2.

Note: Contained Fan Arrays and Partially Contained Fan Arrays (for fans which do not aerodynamically interact) will follow this figure.

13) Added note to Figure C4.

Note: Uncontained Fan Arrays and Partially Contained Fan Arrays (for fans which aerodynamically interact) will follow this figure.

14) Added Figures C5 and C6.

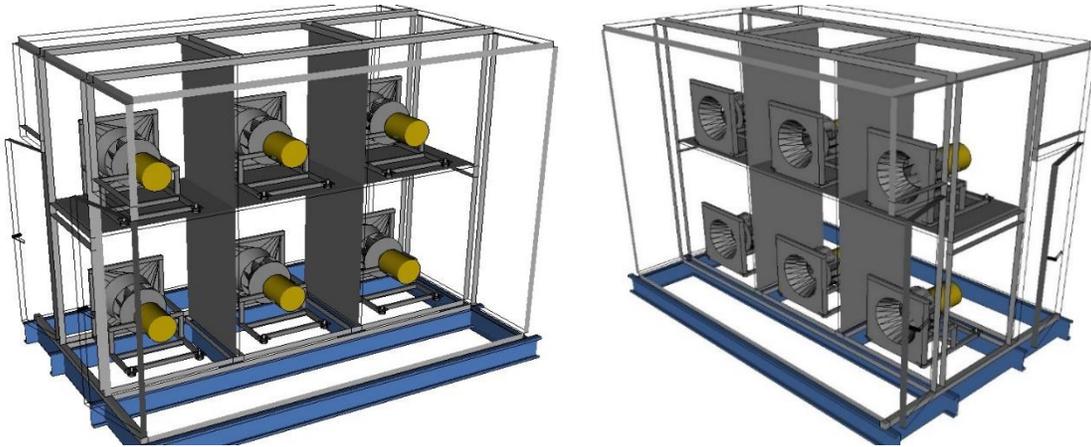


Figure C5. Example Contained Fan Array

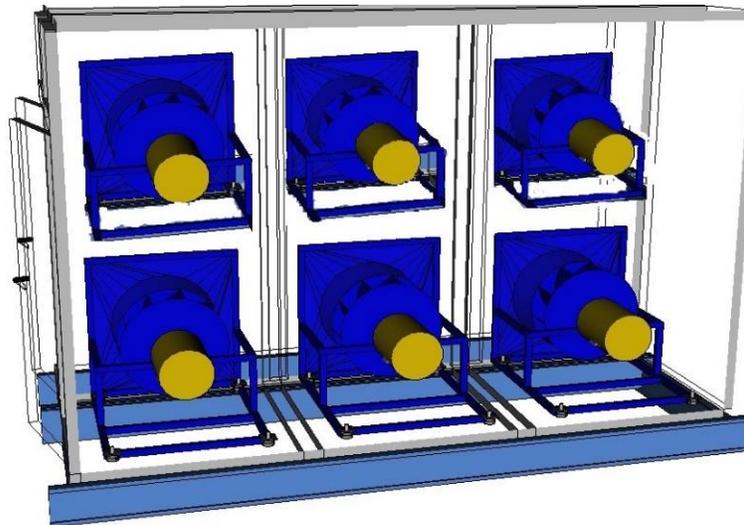


Figure C6. Example Uncontained Fan Array

15) Added Appendix D

APPENDIX D. EXAMPLE FAN ARRAY CALCULATION - INFORMATIVE

D1. The data shown in Table D1 was taken from a 2x2 Fan Array with four pole motors. The motor calibration was performed at nominal frequency of 60 Hz. The first example will use the methodology where Table 1 is followed. For 4 Operating Fans in the array, 2 were measured.

Table D1. Example Motor Calibration Data Following Table 1			
Motor calibration (Motor 1)		Motor calibration (Motor 2)	
<u>Watts</u>	<u>BHP</u>	<u>Watts</u>	<u>BHP</u>
247.2	0.000	251.9	0.000
387.3	0.180	345.1	0.126
519.9	0.340	494.0	0.326
617.0	0.488	611.6	0.474
768.7	0.688	751.0	0.677

888.3	0.851	854.6	0.805
1050.0	1.062	1023.1	1.033
1143.0	1.182	1124.8	1.178
1279.4	1.358	1304.6	1.395
1380.0	1.495	1365.9	1.481

This data was plotted in Excel™ using the scatterplot function and then a trendline was added. The equation for the trendline is shown in Figure D1.

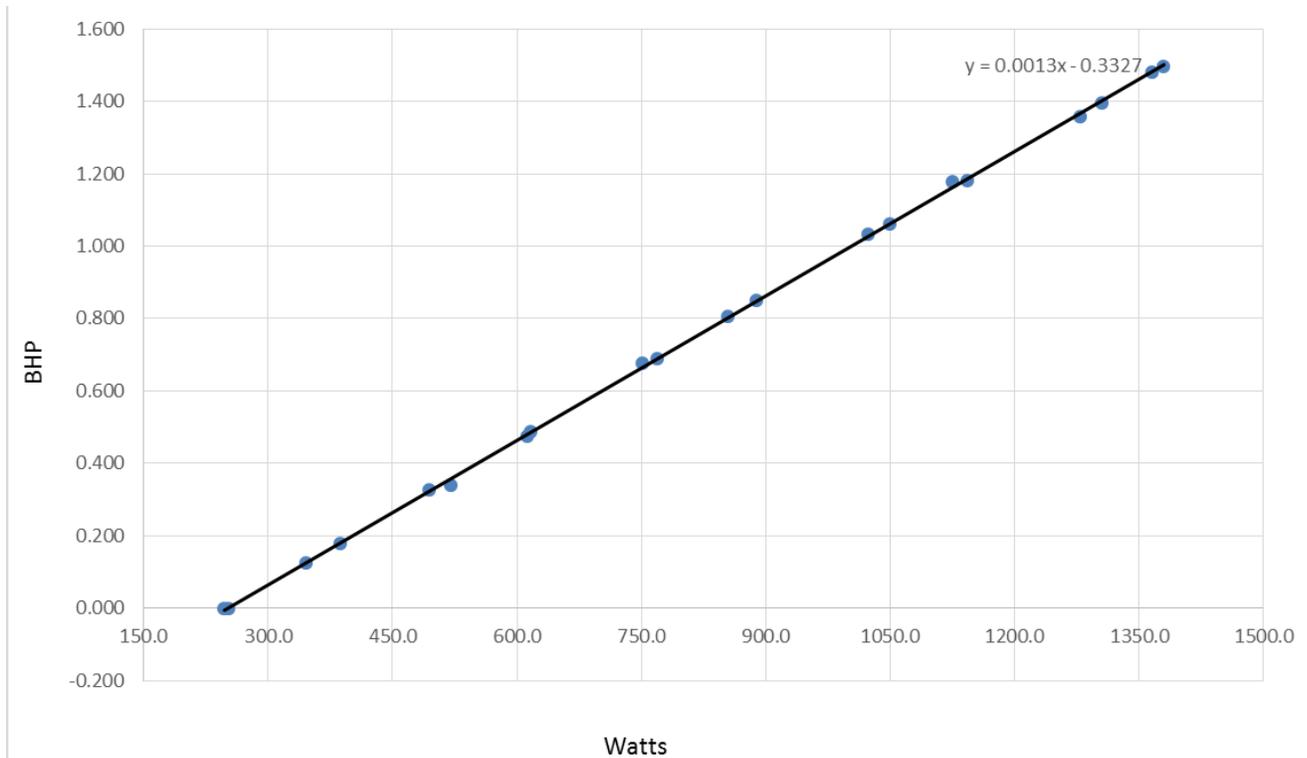


Figure D1. Example Scatterplot with Motor Calibration Data According to Table 1

The total input power measured was 3852.0 watts according to AMCA 210. With 4 Operating Fans, the input power per fan calculates to 963.0 using Equation E1. Using the formula found in the trendline (Equation E2), the BHP per fan is calculated to be 0.9192 using Equation E3. Since there are 4 fans, the total unit shaft power can be determined using Equation E4 and is calculated to 3.6768 BHP.

$$\frac{\text{Overall Input Power}}{\text{Number of Operating Fans}} = \frac{3852.0}{4} = 963.0 \quad \text{E1}$$

$$y = 0.0013x - .3327 \quad \text{E2}$$

$$\text{BHP Per Fan} = 0.0013 \cdot (\text{Input Power per Fan}) - 0.3327 = (0.0013 \cdot 963.0) - 0.3327 = 0.9192 \quad \text{E3}$$

$$\text{Overall BHP} = \text{BHP Per Fan} \cdot (\text{Number of Operatings Fans}) = 0.9192 \cdot 4 = 3.6768 \text{ BHP} \quad \text{E4}$$

D2. The data shown in Table D2 was taken from a 2x2 Fan Array with four pole motors. The motor calibration was performed at nominal frequency of 60 Hz. This example has all 4 fans being measured.

Table D2. Example Motor Calibration Data Not Following Table 1							
Motor calibration (Motor 1)		Motor calibration (Motor 2)		Motor calibration (Motor 3)		Motor calibration (Motor 4)	
Watts	BHP	Watts	BHP	Watts	BHP	Watts	BHP
247.2	0.000	251.9	0.000	249.4	0.000	249.2	0.000
387.3	0.180	345.1	0.126	387.8	0.183	353.4	0.120
519.9	0.340	494.0	0.326	509.7	0.354	487.1	0.303
617.0	0.488	611.6	0.474	636.5	0.520	603.8	0.463
768.7	0.688	751.0	0.677	780.2	0.722	722.2	0.619
888.3	0.851	854.6	0.805	897.0	0.871	861.4	0.808
1050.0	1.062	1023.1	1.033	1009.7	1.019	1001.4	0.990
1143.0	1.182	1124.8	1.178	1128.9	1.167	1130.5	1.159
1279.4	1.358	1304.6	1.395	1250.3	1.349	1244.9	1.315
1380.0	1.495	1365.9	1.481	1375.4	1.509	1386.9	1.506

This data was plotted in Excel™ using the scatterplot function and then a trendline was added. The equation for the trendline is shown in Figure D2.

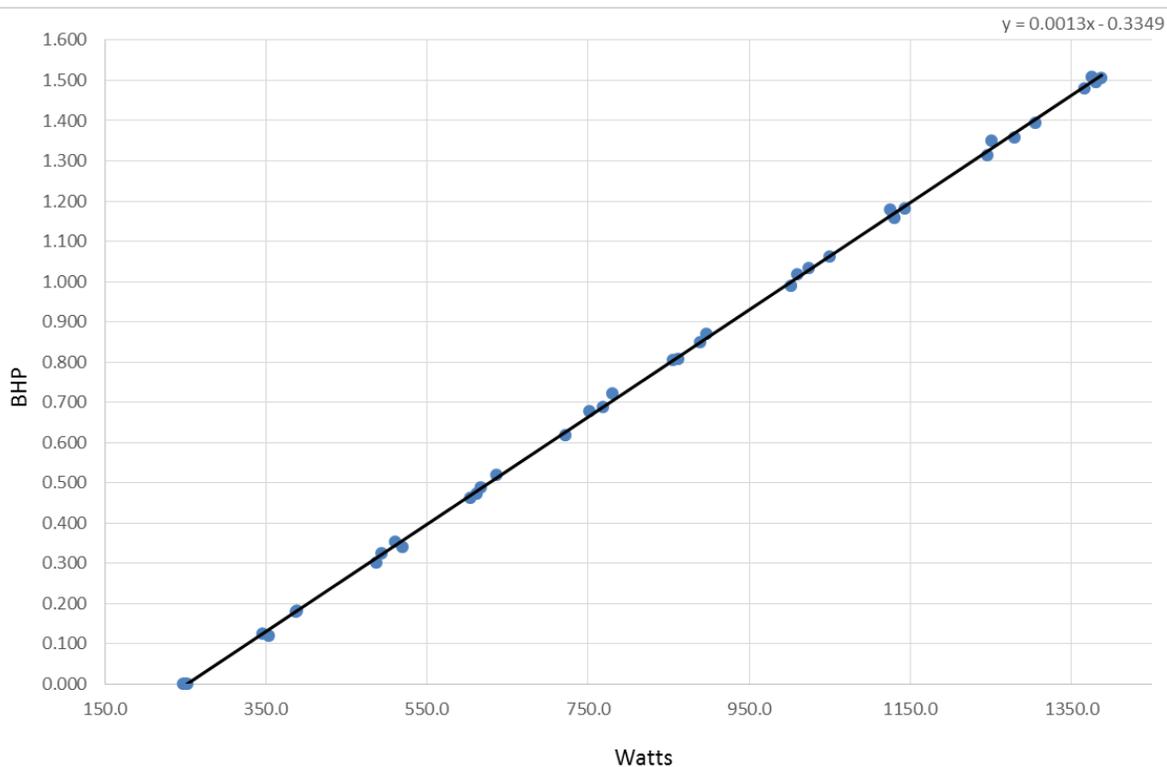


Figure D2. Example Scatterplot with Motor Calibration Data Not According to Table 1

The total input power measured was 3852.0 watts according to AMCA 210. With 4 Operating Fans, the input power per fan can be calculated using Equation E5 to be 963. Using the formula found in the trendline (Equation E6) in Figure D2, the BHP per fan can be calculated using Equation E7 to be 0.917. Since there are 4 Operating Fans, the total unit shaft power is calculated by Equation E8 to be 3.668 BHP.

$$\frac{\text{Overall Input Power}}{\text{Number of Operating Fans}} = \frac{3852.0}{4} = 963.0 \quad \text{E5}$$

$$y = 0.0013x - 0.3349 \quad \text{E6}$$

$$\text{BHP Per Fan} = 0.0013 \cdot (\text{Input Power per Fan}) - 0.3349 = (0.0013 \cdot 963.0) - 0.3349 = 0.917 \quad \text{E7}$$

$$\text{Overall BHP} = \text{BHP Per Fan} \cdot (\text{Number of Operatings Fans}) = 0.917 \cdot 4 = 3.668 \text{ BHP} \quad \text{E8}$$

16) Added Appendix E.

APPENDIX E. CORRECTING FOR PRESSURE DROP THROUGH THE TEST EQUIPMENT FOR UNDUCTED DISCHARGE TESTS-NORMATIVE

E1 This appendix shows which air pressure losses created by the laboratory test equipment must be accounted for when testing units with inlet or discharge plenums either supplied by the manufacturer or constructed by the laboratory.

E2 Definitions.

E2.1 *Constructed by the Laboratory.* Any portion of the test set up that was not supplied by the manufacturer and was built solely to connect the unit to the test chamber for the purpose of the test. Any plenum extension shall have the same internal height and width as the test Unit Height and Unit Width.

E2.2 Duct Dimensions.

E2.2.1 *Duct Height (H_D).* The internal vertical dimension of the duct.

E2.2.2 *Duct Length (L_D).* The length of the duct between the test chamber and either the inlet plenum or discharge plenum, depending on the test configuration.

E2.2.3 *Duct Width (W_D).* The internal horizontal dimension of the duct.

E2.3 *Duct Total Pressure Loss (P_{TD}).* The total pressure loss in the duct. This loss is often negligible.

E2.4 *Plenum Length (L_P).* The distance from the internal wall of the plenum Constructed by the Laboratory to either the nearest fan or appurtenance. The manufacturer may designate this value as either fixed or a minimum.

E2.5 *Total Pressure Loss Entering Test Chamber (P_{TEC}).* The reduction in total air pressure caused by the expansion of the air flow as the air leaves the duct and enters the test chamber. This is used only when testing using the setup in Figure 12.

E2.6 *Total Pressure Loss Entering Unit (P_{TEU}).* The reduction in total air pressure caused by the contraction of the air when it leaves the duct and enters the unit. This is used only when testing using the setup in Figure 15. If the manufacturer provided the inlet plenum, this loss shall not be included.

E2.7 *Total Pressure Loss Leaving Test Chamber (P_{TLC}).* The reduction in total air pressure caused by the contraction of the air flow between the test chamber and the duct. This is used only when testing using the setup in Figure 15.

E2.8 *Total Pressure Loss Leaving Unit (P_{TLU}).* The reduction in total air pressure caused by the contraction

of the air when it leaves the unit and enters the duct. This is used only when testing using the setup in Figure 12. If the manufacturer provided the discharge plenum, this loss shall not be included.

E2.9 Total Pressure Loss of Test Equipment. The sum of the total pressure losses created by the portion of the test setup Constructed by the Laboratory.

E2.10 Unit Dimensions.

E2.10.1 Unit Height (H_U). The internal vertical dimension of the unit under test.

E2.10.2 Unit Width (W_U). The internal horizontal dimension of the unit under test.

E3 Procedure.

E3.1 Determine which components of pressure loss must be calculated.

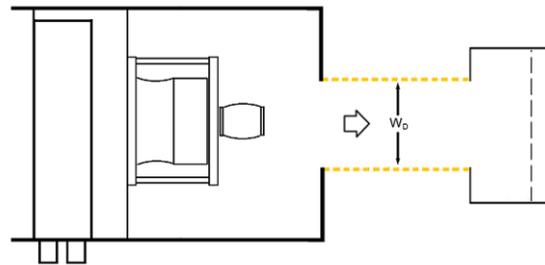
E3.1.1 Testing using Figure 12 and manufacturer provides the discharge plenum (Figure E1): P_{TD} and P_{TEC} .

E3.1.2 Testing using Figure 12 and laboratory constructs the discharge plenum (Figure E2): P_{TEC} , P_{TD} and P_{TLU} .

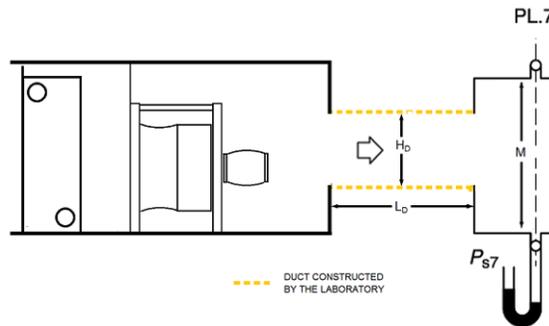
E3.1.3 1 Testing using Figure 15 and manufacturer provides the inlet plenum (Figure E3): P_{TLC} and P_{TD} .

E3.1.4 Testing using Figure 15 and laboratory constructs the inlet plenum (Figure E4): P_{TLC} , P_{TD} and P_{TEU} .

E3.2 Calculate each of the pressure losses using the values for H_D , W_D , L_D , H_U , W_U , the air flow, and air density based on the procedures in ASHRAE Fundamentals 2013 Chapter 21 and the values in the ASHRAE Duct Fitting Database CD.



TOP VIEW



SIDE VIEW

Figure E1. Unit Tested Per Figure 12 of AMCA 210 with Discharge Plenum Supplied By the Manufacturer

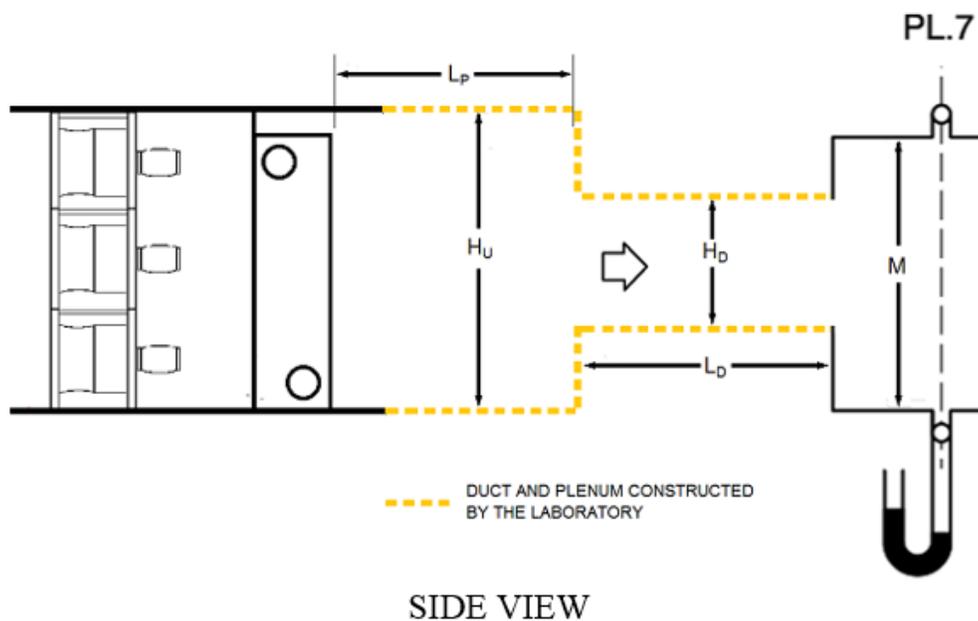
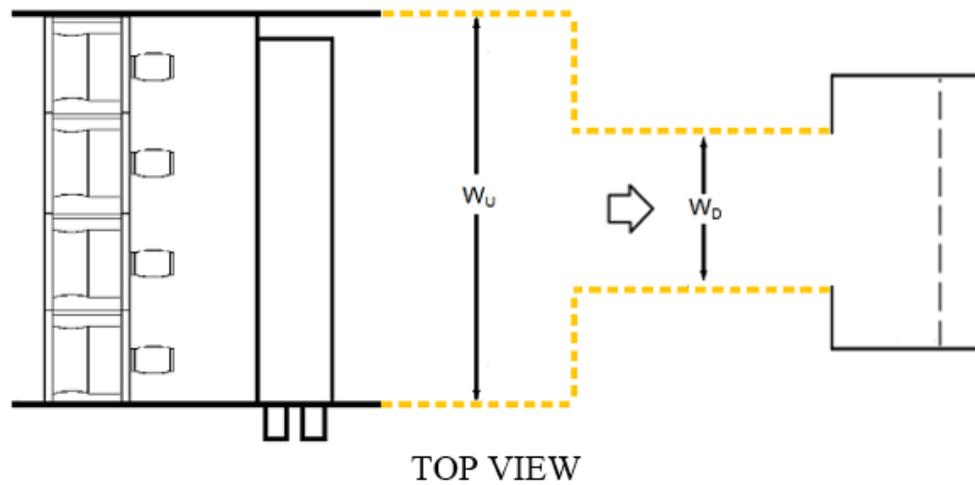


Figure E2. Unit Tested Per Figure 12 of AMCA 210 with Discharge Plenum Constructed By the Laboratory

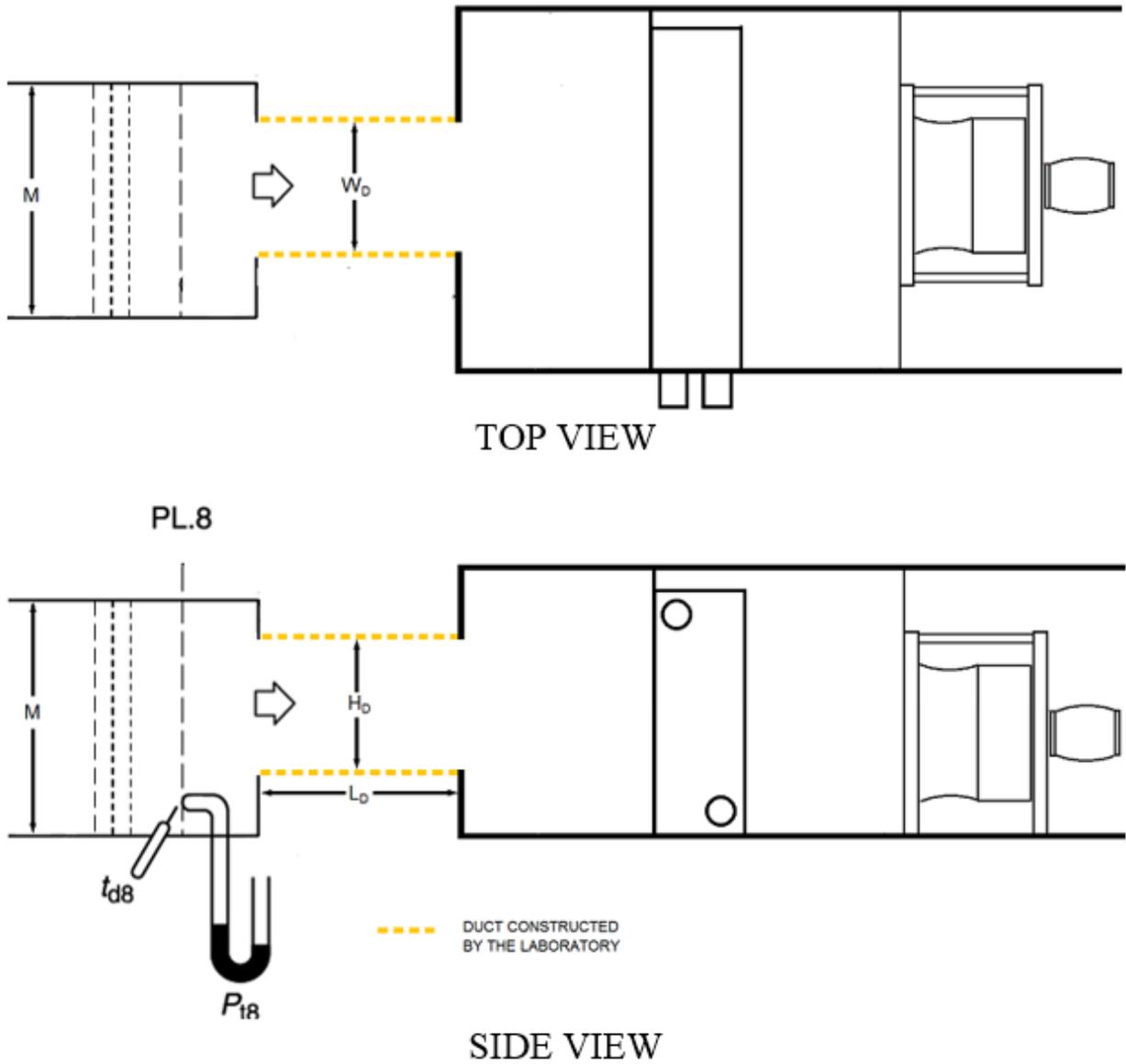
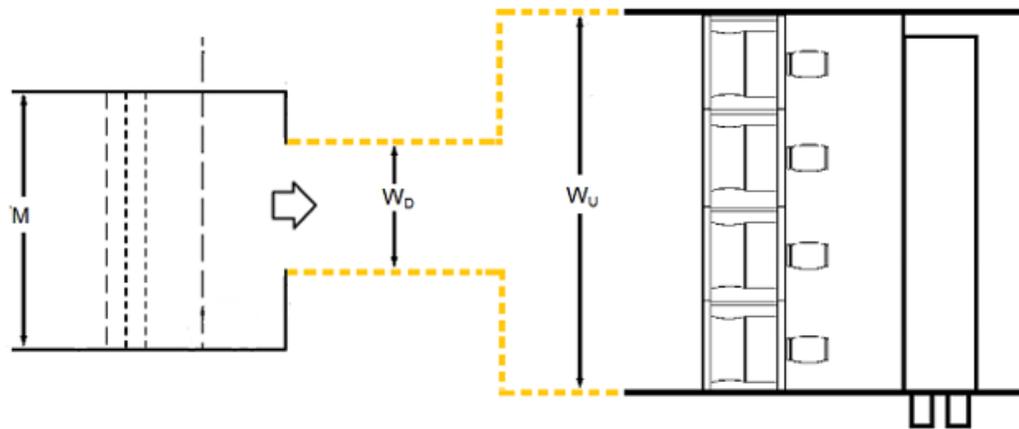
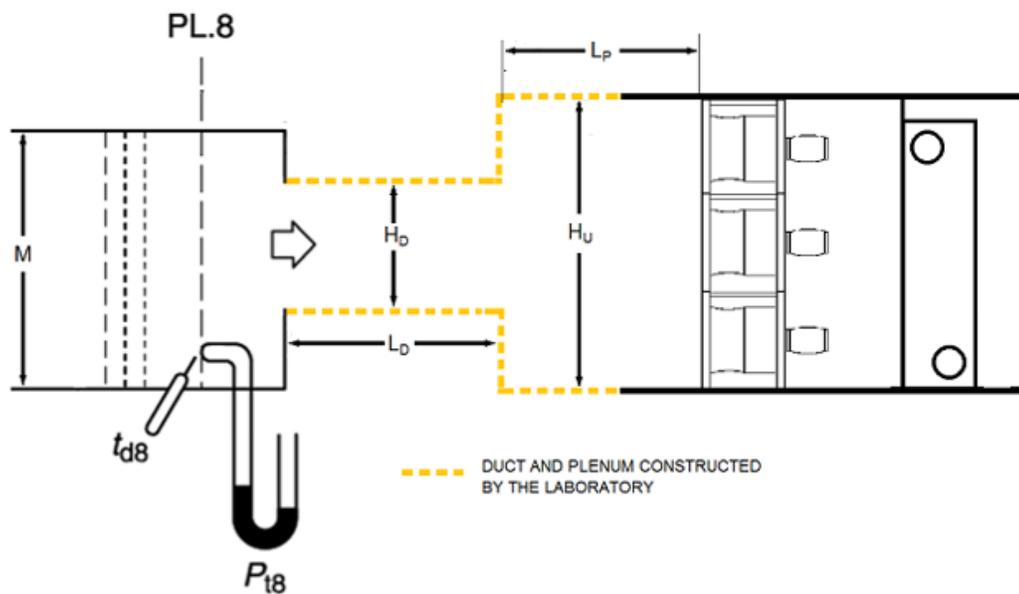


Figure E3. Unit Tested Per Figure 15 of AMCA 210 with Inlet Plenum Provided by the Manufacturer



TOP VIEW



SIDE VIEW

Figure E4. Unit Tested Per Figure 15 Of AMCA 210 With Inlet Plenum Constructed By The Laboratory.

IMPORTANT

SAFETY DISCLAIMER

AHRI does not set safety standards and does not certify or guarantee the safety of any products, components or systems designed, tested, rated, installed or operated in accordance with this standard/guideline. It is strongly recommended that products be designed, constructed, assembled, installed and operated in accordance with nationally recognized safety standards and code requirements appropriate for products covered by this standard/guideline.

AHRI uses its best efforts to develop standards/guidelines employing state-of-the-art and accepted industry practices. AHRI does not certify or guarantee that any tests conducted under its standards/guidelines will be non-hazardous or free from risk.

Note:

This standard supersedes AHRI Standard 430-2009.
See AHRI Standard 430 for I-P ratings.

Scope of Certification Program and Certified Ratings

Please refer to the most current version of the Central Station Air-handling Unit's Supply Fans Certification Program Operations Manual (OM) for the Scope of the Certification Program and Certified Ratings.

TABLE OF CONTENTS

SECTION	PAGE
Section 1. Purpose.....	1
Section 2. Scope.....	1
Section 3. Definitions.....	1
Section 4. Classifications.....	4
Section 5. Test Requirements.....	4
Section 6. Rating Requirements.....	13
Section 7. Symbols and Subscripts.....	14
Section 8. Minimum Data Requirements for Published Ratings.....	14
Section 9. Marking and Nameplate Data.....	15
Section 10. Conformance Conditions.....	15

TABLES

Table 1. Number of Motors to be Calibrated	8
--	---

FIGURES

Figure 1. Unducted Fan Discharge - Horizontal Arrangement.....	3
Figure 2. Ducted Fan Discharge - Horizontal Arrangement.....	3
Figure 3. Outlet Test Unit Configuration for Multiple Parallel Housed Fans in CSAHUs with Individual Ducted Discharges.....	5
Figure 4. Single Outlet Test Unit Configuration for Single or Multiple Parallel Plenum Fans in CSAHUs with Full Face Opening Axial Discharge.....	6
Figure 5. Figure 15 Reprinted from “AMCA Publication 210-07, Laboratory Methods of Testing Fans for Certified Aerodynamic Performance Rating”.....	6
Figure 6. Figure 12 Reprinted from “AMCA Publication 210-07, Laboratory Methods of Testing Fans for Certified Aerodynamic Performance Rating”.....	7
Figure 7. Dimensions for Inlet Vane Proportionality.....	8
Figure 8. Ducted Fan Discharge CSAHU with Airflow Direction Change.....	9

TABLE OF CONTENTS (continued)

Figure 9. Fan and Unit Characteristics - Fan Rated and Unit Tested	12
Figure 10. Fan and Unit Characteristics - Fan Rated and Unit Calculated.....	13

APPENDICES

Appendix A. References - Normative.....	16
Appendix B. References - Informative.....	17
Appendix C. Criteria for Proportionality-Informative.....	18
Appendix D. Example Fan Array Calculation-Informative.....	23
Appendix E. Correcting for Pressure Drop Through the Test Equipment for Unducted Discharge Tests-Normative.....	26

FIGURES FOR APPENDICES

Figure C1. Dimensions Used for Proportionality Equations - Housed Fan.....	20
Figure C2. Dimensions Used for Proportionality Equations - Plenum Fan.....	20
Figure C3. Dimensions Used for Proportionality Equations - Axial Fan.....	21
Figure C4. Dimensions Used for Proportionality Equations - Multiple Fans (End Views).....	21
Figure C5. Example Contained Fan Array.....	21
Figure C6. Example Uncontained Fan Array.....	22
Figure D1. Example Scatterplot with Motor Calibration Data According to Table 1.....	23
Figure D2. Example Scatterplot with Motor Calibration Data Not According to Table 1.....	25
Figure E1. Unit Tested per Figure 12 of AMCA 210 with Discharge Plenum Supplied by the Manufacturer.....	27
Figure E2. Unit Tested per Figure 12 of AMCA 210 with Discharge Plenum Constructed by the Laboratory.....	28
Figure E3. Unit Tested per Figure 15 of AMCA 210 with Inlet Plenum Provided by the Manufacturer.....	29
Figure E4. Unit Tested per Figure 15 of AMCA 210 with Inlet Plenum Constructed by the Laboratory.....	30

TABLE OF CONTENTS (continued)

TABLES FOR APPENDICES

Table D1. Example Motor Calibration Data Following Table 1.....	23
Table D2. Example Motor Calibration Data Not Following Table 1.....	24

PERFORMANCE RATING OF CENTRAL STATION AIR-HANDLING UNIT SUPPLY FANS

Section 1. Purpose

1.1 Purpose. The purpose of this standard is to establish for Central Station Air-handling Units: definitions; classifications; test requirements; rating requirements; minimum data requirements for Published Ratings; marking and nameplate data; and conformance conditions.

1.1.1 Intent. This standard is intended for the guidance of the industry, including manufacturers, engineers, installers, contractors, and users.

1.1.2 Review and Amendment. This standard is subject to review and amendment as technology advances.

Section 2. Scope

2.1 Scope. This standard applies to Central Station Air-handling Units, as defined in Section 3.

2.1.1 This standard applies to Supply Fan ratings for Central Station Air-handling Units with supply fan ratings for Plenum Fans in a cabinet with a Full Face Opening Axial Discharge, Fan Arrays, Housed Centrifugal Fans, and Axial Fans.

2.2 Exclusions.

~~**2.2.1** This standard does not apply to forced-circulation, free-delivery air-coolers for refrigeration, which are covered in ANSI/AHRI Standard 420.~~

2.2.1 This standard does not apply to unit heaters intended for free delivery of heated air or to room fan-coils as defined in ANSI/AHRI Standard 440.

2.2.2 This standard does not apply to units that have direct expansion coils incorporated by the manufacturer in a matched split system air-conditioner, or as otherwise defined in the product scope definition of the AHRI Unitary Small Equipment and Unitary Large Equipment Sections and covered in AHRI Standard 210/240 or in AHRI Standard 340/360.

2.2.3 This standard does not apply to unit ventilators as defined in ANSI/AHRI Standard 840.

~~**2.2.5** This standard does not apply to variable refrigerant flow equipment as defined in ANSI/AHRI Standard 1230.~~

2.2.4 This standard does not apply to DX Dedicated Outdoor Air System Units as defined in ANSI/AHRI Standard 920.

2.2.5 This standard does not apply to Computer and Data Processing Room Air Conditioners as defined in ANSI/AHRI Standard 1360.

Section 3. Definitions

All terms in this document will follow the standard industry definitions in the ASHRAE Terminology website (<https://www.ashrae.org/resources--publications/free-resources/ashrae-terminology>) unless otherwise defined in this Section.

3.1 Actual Cubic Meters Per Second (Actual m^3/s), m^3/s . The unit of airflow uncorrected for air density. All airflow in this standard is considered to be actual airflow rate.

3.2 Appurtenances. Equipment added to a CSAHU for purposes including but not limited to control, isolation, safety, static pressure regain, wear, etc. Appurtenances include, but are not limited to coils, filters, energy recovery devices, dampers, air-mixers, spray assemblies, eliminators, discharge plenums, and inlet plenums.

3.3 Central Station Air-handling Unit (CSAHU). A factory-made encased assembly consisting of a supply fan or fans in parallel which may also include other necessary equipment to perform one or more of the functions of circulating, cleaning, heating, cooling, humidifying, dehumidifying and mixing of air. It shall not contain a source of mechanical cooling. The CSAHU must have a maximum design external static pressure (ESP) greater than 250 Pa. ~~This assembly is capable of use with duct work having a total static resistance of at least 125 Pa.~~

Note: While the ESP for a specific application may be less than 250 Pa, any units generally capable of delivering greater than 250 Pa ESP shall be considered to be a CSAHU.

3.3.1 Ducted Fan Discharge Central Station Air-handling Unit. A unit that has a ducted fan outlet. (See Figure 2. Note that Figure 2 applies to Housed Centrifugal Fans and Axial Fans and that a Housed Centrifugal Fan is shown.)

3.3.2 Unducted Fan Discharge Central Station Air-handling Unit. A unit containing a fan that does not have a ducted fan outlet. (See Figure 1. Note that Figure 1 applies to all fan types in the standard but a Housed Centrifugal Fan is shown)

3.4 Controller. A power electronic device that regulates the speed of a motor (typically used for direct current (DC) motors).

3.5 Full Face Opening Axial Discharge. Where the discharge opening of the CSAHU is the same cross-sectional dimensions as the interior of the CSAHU's casing and the direction of the airflow is parallel with the shaft of the fan or fans.

3.6 Supply Fan. The fan that provides enough pressure to overcome the supply air restriction and may provide some or all of the pressure to overcome the return air restriction to provide air into the conditioned space.

3.6.1 Axial Fan. A housed fan that moves air in the general direction of the axis about which it rotates. This includes tubeaxial fans, centaxial fans, and vaneaxial fans. Fan rotor or wheel within a tubular-type casing that includes supports for either Belt Drive or Direct Drive.

3.6.2 Belt Drive. Driver and driven fans with positive belted connections for rotations at any speed.

3.6.3 Direct Drive. Driver and driven fans with positive direct connections for rotations at the same speed.

3.6.4 Fan Array. A matrix of regularly spaced direct-drive Supply Fans operating in parallel with inflow from a common inlet plenum and with outflow into a common outlet plenum. All impellers and motors must be of Identical Construction. All Operating Fans must run at the same speed. If applicable, all Variable Frequency Drives must be programmed to provide identical frequency and voltage.

3.6.4.1 Contained Fan. Fans in a Fan Array that are within substantially uniform enclosure(s) and do not aerodynamically interact with each other within the array.

3.6.4.2 Partially Contained Fan. Fans in a Fan Array that are within non-uniform enclosure(s) and some Supply Fans aerodynamically interact with each other within the array.

3.6.4.3 Uncontained Fan. Fans in an array that aerodynamically interact with each other.

3.6.5 Fan Housing. The stationary element which guides the air before and after the fan's impeller.

3.6.6 Horizontal Shaft. A fan shaft that is parallel to the ground.

3.6.7 Housed Centrifugal Fan. Fan in which the air enters the impeller axially and leaves it substantially in a radial direction. Fan rotor or wheel within a scroll-type casing (shroud) that includes supports for either Belt Drive or Direct Drive.

3.6.8 Identical Construction. A product which has the same manufacturer, the same model number, and is intended to have the same performance under the same conditions. Exception: the model numbers may differ if the only difference between the models is something which does not affect performance (e.g. color).

3.6.9 Operating Fan. Any Supply Fan which is designated by the CSAHU manufacturer to be energized and rotating at the specified Rating Condition.

3.6.10 Plenum Fan. A fan assembly consisting of a single inlet impeller mounted perpendicular to airflow that pressurizes a plenum chamber in an air-distribution system.

3.6.11 Vertical Shaft. A fan shaft that is perpendicular to the ground.

3.6 Unit Appurtenances. Equipment added to Central Station Air handling Units for purposes of control, isolation, safety, static pressure regain, energy/heat recovery, wear, etc. Such appurtenances include coils, filters, dampers, air mixers, spray assemblies, energy recovery devices, acoustical silencers, eliminators, etc.

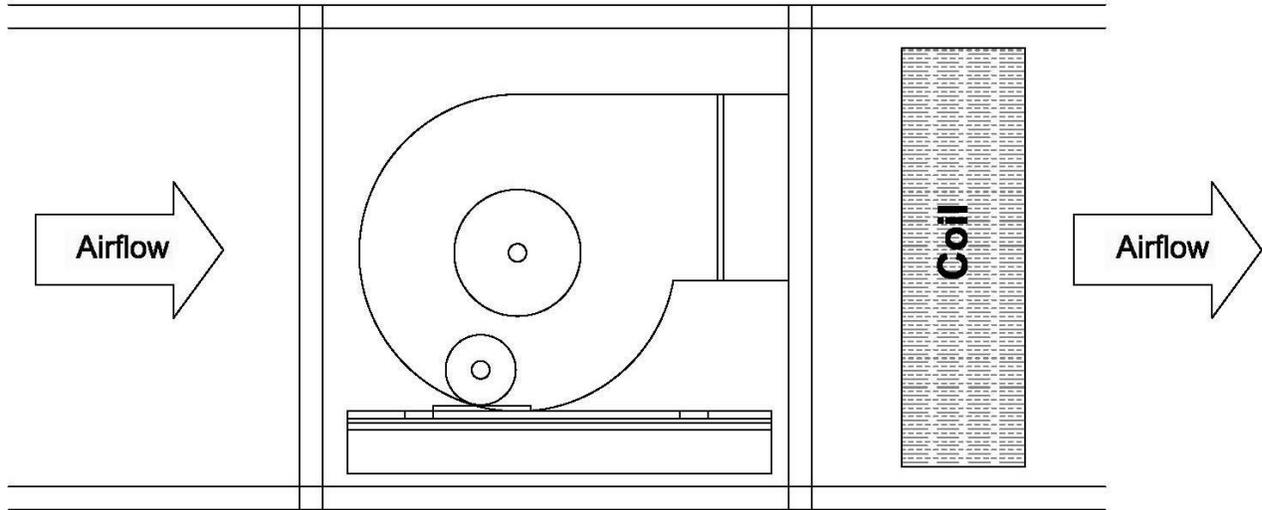


Figure 1. Unducted Fan Discharge – Horizontal Arrangement

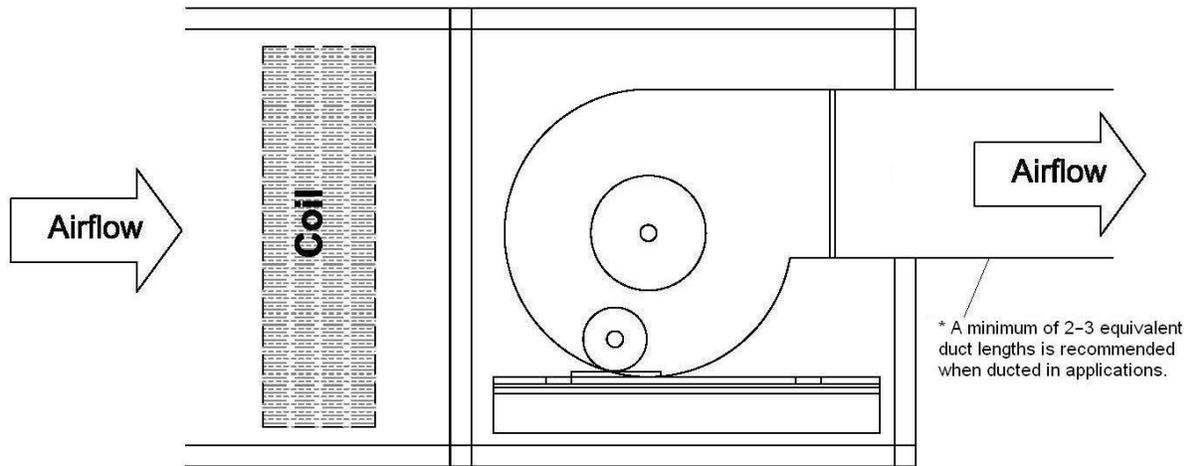


Figure 2. Ducted Fan Discharge – Horizontal Arrangement

3.7 Published Rating. A statement of the assigned values of those performance characteristics, under stated Rating Conditions, by which a unit may be chosen to fit its application. These values apply to all units of like nominal capacity and type (identification) produced by the same manufacturer. As used herein, the term Published Rating includes the rating of all performance characteristics shown on the unit or published in specifications, advertising or other literature controlled by the manufacturer, at stated Rating Conditions.

3.8 Rating Conditions. Any set of operating conditions under which a single level of performance results, and causes only that level of performance to occur.

3.9 "Shall" or "Should". "Shall" or "should" shall be interpreted as follows:

3.9.1 *Shall*. Where "shall" or "shall not" is used for a provision specified, that provision is mandatory if compliance with the standard is claimed.

3.9.2 *Should*. "Should" is used to indicate provisions which are not mandatory but which are desirable as good practice.

3.10 *Standard Air*. Air weighing 1.204 kg/m³ which approximates dry air at 21°C and at a barometric pressure of 101.3 kPa.

3.11 *Variable Frequency Drive (VFD)*. A power electronic device that regulates the speed of an alternating current (AC) motor by adjusting the frequency and the voltage of the electrical power supplied to the motor.

Section 4. Classifications

4.1 *Methods of Classification*. Equipment covered within the scope of this standard shall be classified as shown:

4.1.1 *Unit Type*.

4.1.1.1 Ducted Discharge

4.1.1.2 Unducted Discharge

4.1.2 *Fan Type*.

4.1.2.1 Housed Centrifugal

4.1.2.1.1 Airfoil/Backward Inclined/Backward Curved

4.1.2.1.2 Forward Curved

4.1.2.2 Axial

4.1.2.3 Plenum

4.1.2.3.1 Single Plenum Fan

4.1.2.3.2 Plenum Fan Array

4.1.3 *Fan Drive Type*.

4.1.3.1 Belt Drive

4.1.3.2 Direct Drive

Section 5. Test Requirements

5.1 *Test Requirements*. All Standard Ratings shall be verified by tests conducted in accordance with ANSI/AMCA Standard 210 and ANSI/ASHRAE Standard 51, except as modified by Section 5.1.1.3 and Section 5.1.1.7.

5.1.1 *Arrangements for Testing*.

5.1.1.1 *Single Outlet Ducted Fan Discharge Central Station Air-handling Units*. Single outlet Ducted Fan Discharge Central Station Air-handling Units shall be tested in accordance with ANSI/AMCA Standard 210 and ANSI/ASHRAE Standard 51.

5.1.1.2 *Multiple Outlet Ducted Fan Discharge Central Station Air-handling Units*. Multiple outlet Ducted Fan Discharge Central Station Air-handling Units shall be tested as in Section 5.1.1.1 with each fan outlet ducted as shown in Figure 3 to the airflow measuring test setup. No corrections for individual fan outlet duct friction losses shall be made.

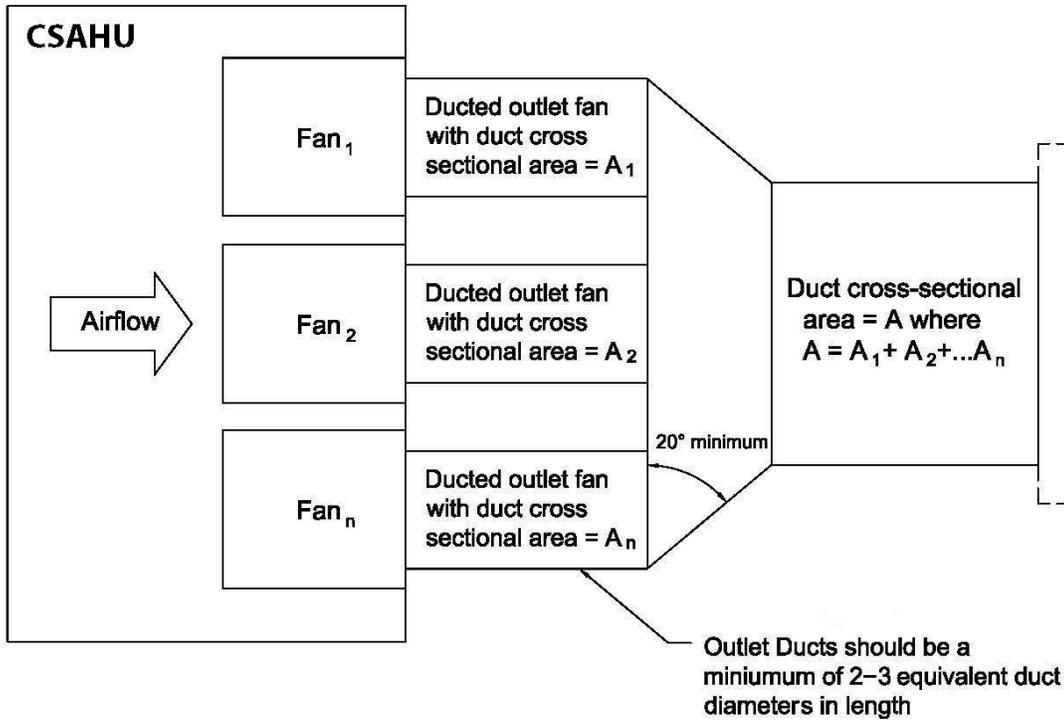


Figure 3. Outlet Test Unit Configuration for Multiple Parallel Housed Fans in CSAHUs with Individual Ducted Discharges

5.1.1.3 Unducted Fan Discharge Central Station Air-handling Units. Unducted Fan Discharge Central Station Air-handling Units shall be tested in accordance with ANSI/AMCA Standard 210/ANSI/ASHRAE Standard 51, except when an outlet chamber with multiple nozzles within the chamber is used. The test chamber cross-sectional area shall be sized so that the maximum air velocity does not exceed 400 fpm ~~2~~ 2 m/s. The test chamber height and width shall be at least 5% greater than the respective height and width of the duct connection at the test chamber. Discharge area cannot exceed the test chamber area. For an example, see Figure 4. Corrections for static pressure losses created by the test apparatus (e.g. the addition of ductwork) shall be made according to Appendix E and the ASHRAE Duct Fitting Database CD.

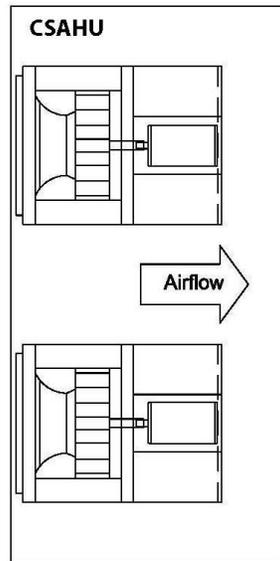


Figure 4. Single Outlet Test Unit Configuration for Single or Multiple Parallel Plenum Fans in CSAHUs with Full Face Opening Axial Discharge

5.1.1.4 Plenum Fan Units. Plenum Fan Units. The rating configuration for either Ducted Fan Discharge or Unducted Fan Discharge plenum fan units shall be Full Face Opening Axial Discharge ~~full face discharge~~ with the minimum spacing allowed per the manufacturer’s specifications between the coil and the fan. If Full Face Opening Axial Discharge is not possible due to the size of the unit compared to the test chamber, the unit shall be provided with an inlet or discharge plenum and a suitably sized duct shall extend from the plenum. Corrections for static pressure losses created by the test apparatus (e.g. the addition of ductwork) shall be made according to Appendix E and the ASHRAE Duct Fitting Database CD. The discharge or inlet plenum shall be considered as an Appurtenance to the CSAHU for the purpose of testing. Figure 15 in the 2007 revision of AMCA 210 shall be used for the test set-up of belt-drive plenum fan units (see Figure 5). Figures 12 or Figure 15 in the 2007 revision of AMCA 210 shall be used for the test set-up of direct-drive plenum fan units (see Figures 5 and 6).

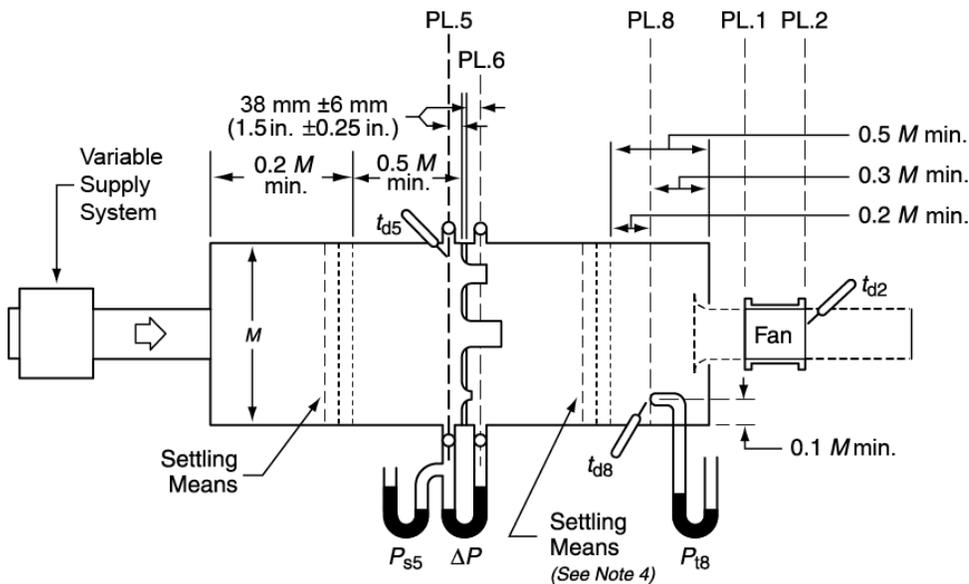


Figure 5. Figure 15 Reprinted from “AMCA Publication 210-07, Laboratory Methods of Testing Fans for Certified Aerodynamic Performance Rating”

5.1.1.7.4.1 If unable to measure total power input after the VFD/controller, measurements shall be simultaneously recorded for the power input into all individual motors to get the total power input.

5.1.1.7.4.2 Shaft power is calculated as shown below. An example is shown in Appendix D.

5.1.1.7.4.2.1 Divide the total input power by the number of operating fans.

5.1.1.7.4.2.2 Determine the shaft power per fan using the composite motor calibration data.

5.1.1.7.4.2.3 Multiply the shaft power per fan by the number of fans to get the total unit shaft power.

Table 1. Number of Motors to be Calibrated ¹	
Number of Supply Fans in the Fan Array	Number of motors to be calibrated
2-4	2
5-8	3
9-12	4
13+	5
Notes:	
1) An equal distribution of contained and uncontained fans must be measured.	

5.2 *Description of Test Unit.* The test unit shall have an internal pressure drop of at least 0.020 kPa.

5.3 *Extension of Test Data.* In lieu of testing every configuration, it is acceptable to extend test data to other configurations in accordance with the provisions of the following subsections:

5.3.1 *Application of Fan Laws to Units with Inlet Vanes.* Units with inlet vanes may be rated one of three ways: 1) using the fan laws as described by Section 5.3.2 for proportional units with proportional fans and inlet vanes; 2) using the fan laws as described in Section 5.3.3 for proportional units with non-proportional fans and inlet vanes; or 3) using the fan laws by applying the appropriate inlet vane derate factors to units without inlet vanes rated per Sections 5.3.2 or 5.3.3 when the inlet vanes of the test unit are proportional to the inlet vanes of the rated units. (Since all requirements for proportionality of cabinets, fan impellers, and housing are satisfied by provisions in either Section 5.3.2 or 5.3.3 without inlet vanes, rated units with inlet vanes derived by inlet vane derate factors must only meet inlet vane proportionality criteria.)

Inlet vanes shall be considered to be proportional when the inlet vanes result in net airflow areas not less than 92.5% of those derived from exact proportionality (as defined in Section 5.3.2) when located within 0.5 impeller diameter from the fan inlet. The test unit shall be tested with vanes in the wide open position as specified by the manufacturer. Vane shaft angle, θ (with respect to fan shaft centerline), and the number of vane blades for the rated unit must be the same as for the test unit (Figure 7). When evaluating geometrical proportionality of inlet vanes, the distance between vane and impeller (defined as dimensions between impeller inlet plane and the closest point of vanes with the vanes at wide open position, as set by the manufacturer) and the distance between cabinet side and fan inlet shall be linearly proportional within 1.5%.

The method of rating one unit with inlet vanes from the test of another is described in Sections 5.3.3.1 through 5.3.3.7.

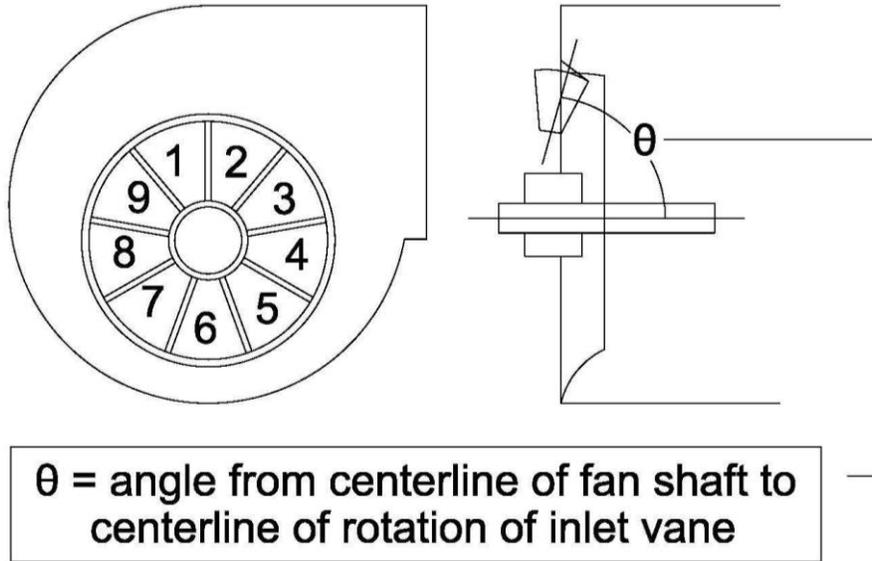


Figure 7. Dimensions for Inlet Vane Proportionality

5.3.2 Application of Fan Laws to Proportional Units with Proportional Fans. Test data may be extended by use of the fan laws to units containing fans, geometrically proportional fan cabinets and impellers (Appendix C). The fan impeller diameter of the unit to be calculated shall not be less than 65% of the fan impeller diameter of the test unit.

Fans are considered to be proportional when:

- a. Impeller width, housing development radii, and housing width are proportional within $\pm 1.5\%$.
- b. Fan housing outlet area is proportional within $\pm 3\%$.

Fan cabinets are considered to be proportional when:

- a. The clearance between the cabinet and the nearest fan housing are proportional or greater.
- b. The clearance between adjacent fan housings, as measured parallel to the fan shaft, is proportional or greater.
- c. The fan cabinet inlet and the fan cabinet outlet airflow cross sectional areas are not less than 92.5% of the respective geometrically proportionate values.
- d. Arrangement and location of internal bearings and their supports, inlet vanes, motors and drives, shall result in net airflow areas not less than 92.5% of those derived from exact proportionality when located within 0.5 impeller diameter of the fan inlet.

The basis for proportionality in every case shall be the respective impeller diameters. Linear dimensions shall be proportional to the diameter and areas shall be proportional to the square of the diameter.

Single fan units may be rated from the test of a multiple fan unit, provided that the units are otherwise proportional and that the clearance between fans on the multiple fan unit is not more than twice the proportionate clearance between the cabinet and the fan housing on a single fan unit. In no case, shall the ratings of a multiple fan unit from tests of a single fan unit be accepted. Airflow and fan shaft power are considered to be proportional to the number of fans when all fans are equal size.

Ducted Fan Discharge Central Station Air-handling Units which have a change in airflow direction between the coil and the fan (Figure 8) may be rated from tests of units which do not have this flow direction change provided the plenum causing the air direction change be considered an appurtenance and the effect of its application added to those of other appurtenances as provided in Section 6.1.1. There is no distinction in rating between a vertical discharge and a horizontal discharge Unducted Fan Discharge Central Station Air-handling Units.

The effects of bolts, nuts, rivets, etc. on proportions, shall be considered to be negligible.

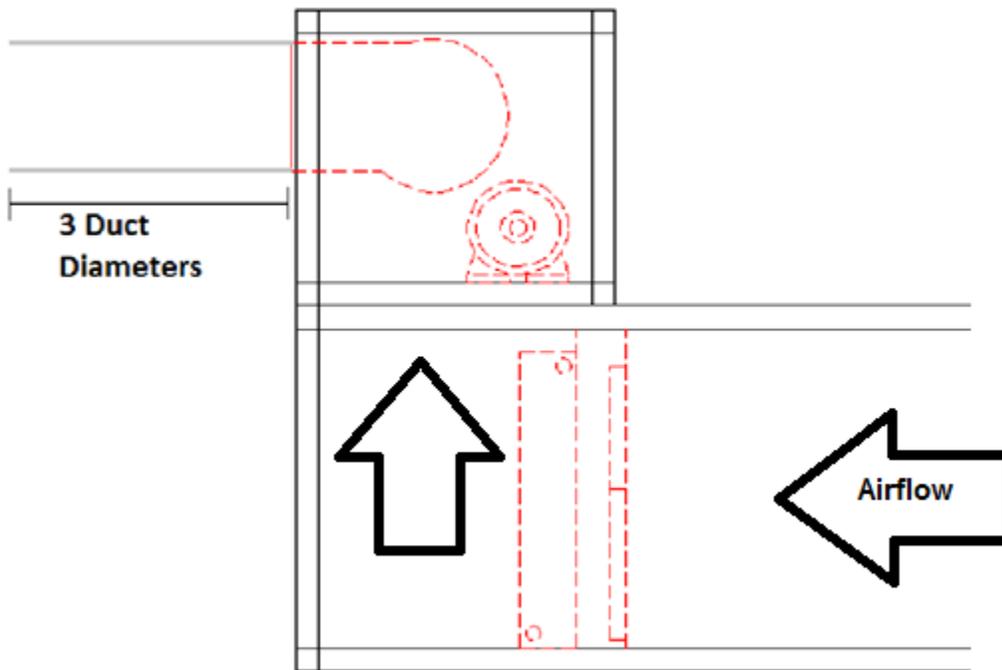


Figure 8. Ducted Fan Discharge CSAHU with Airflow Direction Change

5.3.3 Application of Fan Laws to Proportional Units with Non-proportional Fans. The requirements for proportional fan impellers and scrolls set forth in Section 5.3.2 are waived when all fans which are not geometrically proportional are rated as fans alone on the basis of tests performed in accordance with ANSI/AMCA Standard 210/ANSI/ASHRAE Standard 51. This applies only to fans of the same blade design. Backward inclined fan impellers are not considered to be the same design as airfoil impellers. All other requirements of Section 5.3.2 shall be met.

The method of rating one unit from the test of another is as follows:

5.3.3.1 Using the rating performance curve of the fan alone (with or without inlet vanes) or the unit (without inlet vanes), create non-dimensional performance curves including percentage wide-open airflow rate, m^3/s , percentage blocked tight static pressure and percentage wide-open fan shaft power, W (Figure 9).

5.3.3.2 To derive the rating performance curve for the test unit without coil, add the test unit static pressure data to the static resistance of the dry coil as determined in accordance with AHRI Standard 410 (Figure 9).

5.3.3.3 Superimpose on Figure 9 the unit rating performance curve (with or without inlet vanes) as derived under Section 5.3.3.2 at the same rev/s, expressing the values in percentages of wide-open airflow rate, m^3/s , blocked tight static pressure in kPa and wide-open fan shaft power, W , of the fan alone (with or without inlet vanes) or unit (without inlet vanes) (Figure 9).

5.3.3.4 For the unit which is to be rated, but not tested, use the rating performance curve of the fan alone (with or without inlet vanes) or unit (without inlet vanes) and plot percentages of wide open m^3/s , blocked tight static pressure kPa and wide-open fan shaft power, W , in the same way as for the solid line curve in Figure 9 (Figure 10).

5.3.3.5 Adjust the curves in Figure 9 by the performance corrections between pairs of curves as indicated in Figure 10. The resultant curves are the calculated performance ratings for the unit not tested, expressed in percentages of performance of the fan alone (with or without inlet vanes) or unit (without inlet vanes) (dashed lines in Figure 10).

5.3.3.6 To determine the actual rating performance values for the specific unit, multiply the percentage values by the wide open airflow rate, m^3/s , blocked tight static pressure and wide open fan shaft power, W , of the

specific unit's fan alone (with or without inlet vanes) or specific unit (without inlet vanes) at the same rev/s as in Figure 9 performance curves.

5.3.3.7 The same procedure as for Section 5.3.3.6 applies to multiple fan units, except that the airflow rate, m^3/s , and fan shaft power, W , values for the fan alone (with or without inlet vanes) are multiplied by the number of fans before applying to the unit, with the restrictions shown in the second paragraph of Section 5.3.2. Single fan units may be rated from the tests of multiple fan units, but multiple fan units shall not be rated from tests of single fan units.

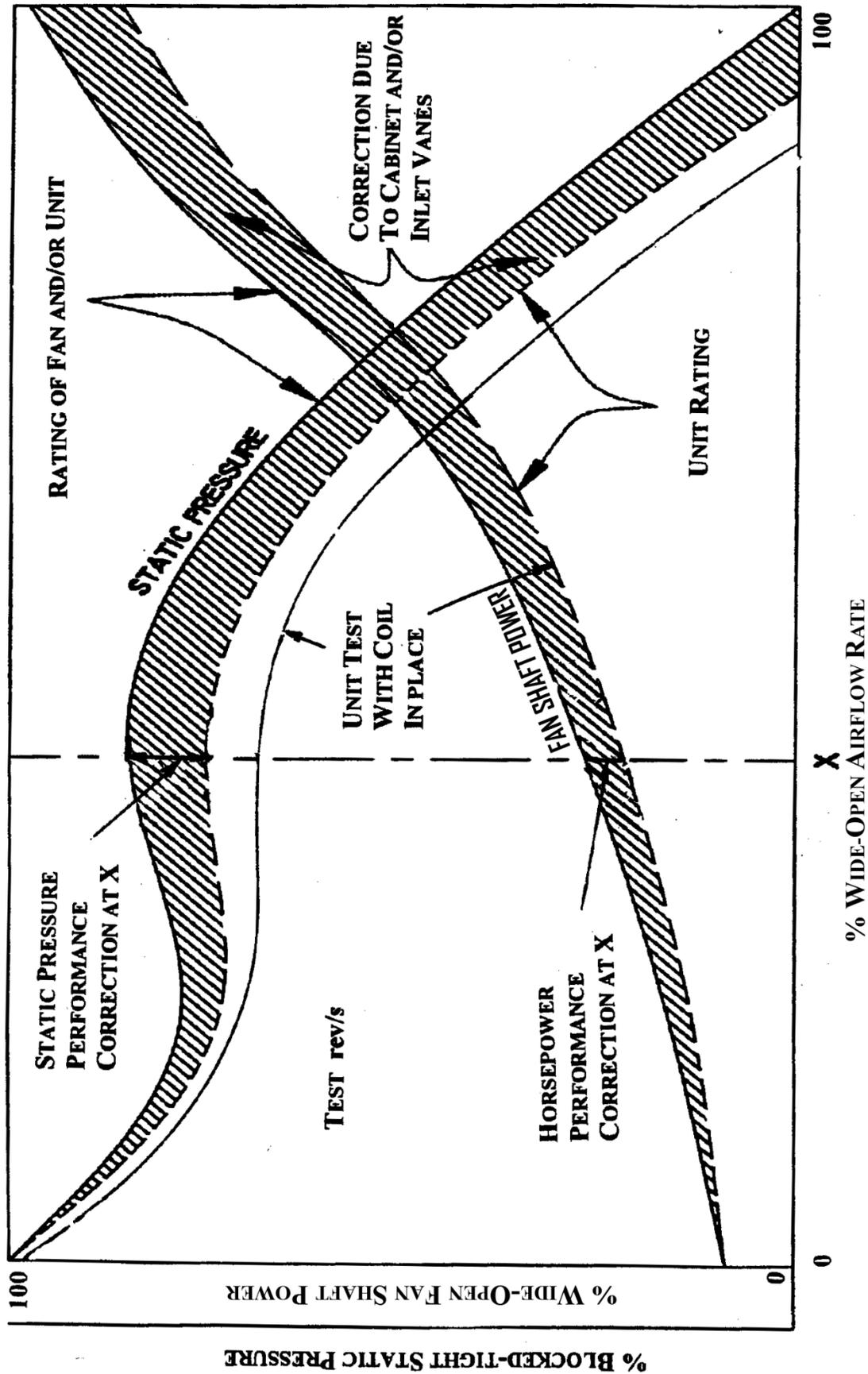


Figure 9. Fan and Unit Characteristics- Fan Rated and Unit Tested
 Note: All Percentages Referred to Fan Alone with or without Inlet Vanes and/or Unit without Inlet Vanes

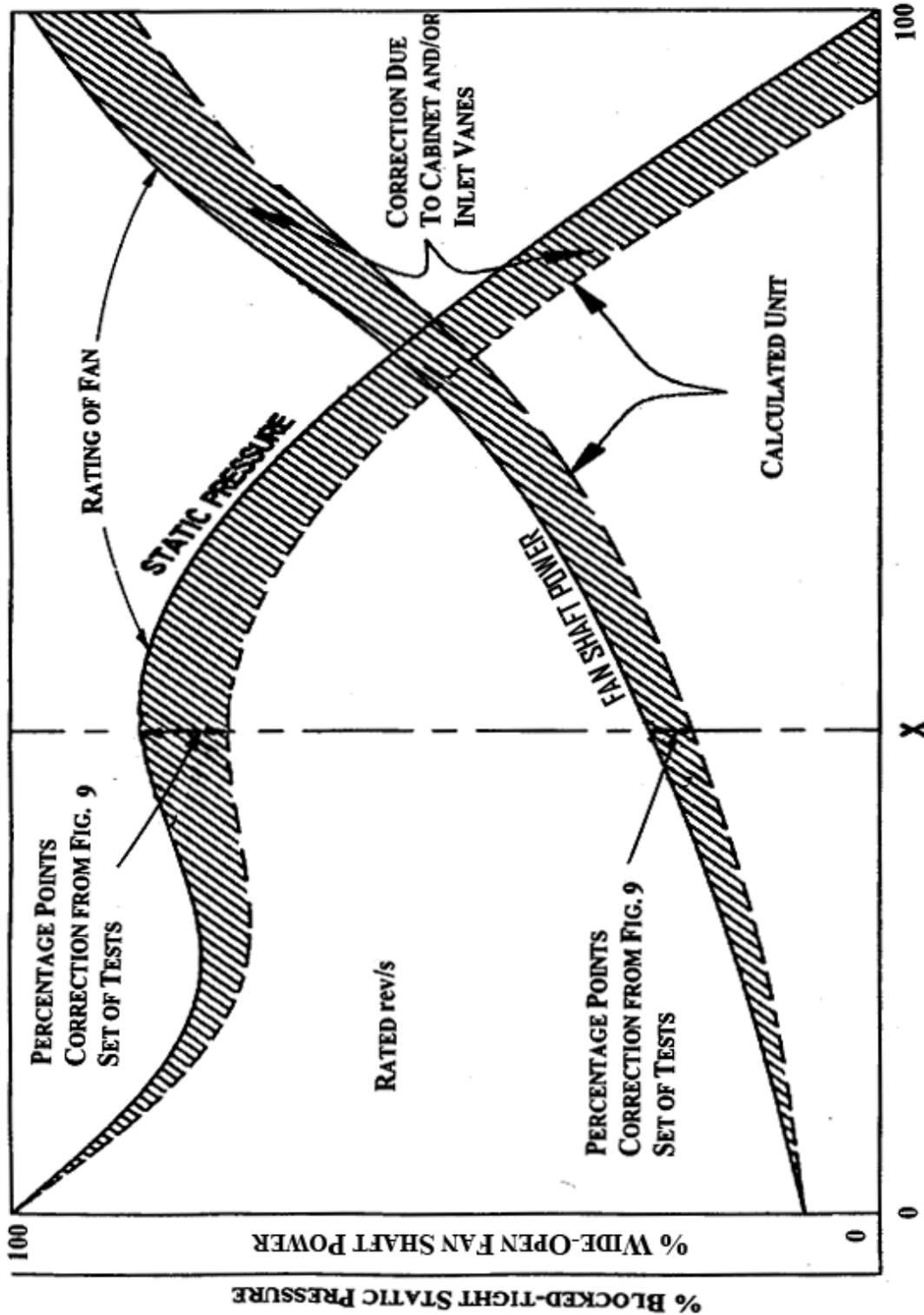


Figure 10. Fan and Unit Characteristics- Fan Rated and Unit Calculated
 Note: All Percentages Referred to Fan Alone with or without Inlet Vanes and/or Unit without Inlet Vanes

Section 6. Rating Requirements

6.1 *Air-handling Ratings.* Published air-handling ratings represent the performance of the fan section alone without coil and shall be expressed in terms of the airflow rate, Actual m^3/s , static pressure, kPa (corrected for Standard Air), fan speed, rev/s, and the power required at the fan shaft, fan shaft power, W, (corrected for Standard Air) based on the procedures outlined in Sections 5.2 and 5.3 of this standard.

6.1.1 Appurtenances. The effects of non-rated Appurtenances such as coils, filters, dampers, air mixers, spray assemblies, eliminators, silencers, humidifiers, etc., included as part of the unit CSAHU shall be taken into account in order to establish the overall performance of the combined unit. These effects shall be provided by the manufacturer and stated in terms of pressure drop, in H₂O, measured across the Appurtenance over the range of air quantities for which the unit is rated.

6.2 Tolerances. To comply with this standard, measured Fan Speed, rev/s shall not exceed 105% of Published Rating and fan shaft power, W, shall not exceed 107.5% of Published Rating at the published volume and pressure.

Section 7. Symbols and Subscripts

7.1 Symbols and Subscripts. The symbols and subscripts used in this standard are as follows:

A	=	Combined area of individual fan outlets, m ²
A _i	=	Area of individual fan outlets, m ²
C	=	Distance from inside wall to entering plane of inlet cone (Housed Centrifugal Fans only), cm
D	=	Distance from opposite side wall to entering plane of opposite inlet cone (Housed Centrifugal Fan only), cm
D ₁	=	Impeller diameter measured at the blade outer tip, m
D ₂	=	Inlet cone diameter at inlet edge of cone for all fan types, m
E _{1,2,n}	=	For multiple parallel fans, distance from the fan shaft centerline to the adjacent fan shaft centerline (plenum and axial fans) or distance from the inlet plane of one fan to the inlet plane of the adjacent fan (Housed Centrifugal Fan), m
G	=	Internal cabinet height from top of bottom panel or floor to inside of top panel, m
H ₁	=	Closest vertical dimension from fan wheel outside diameter to inside of cabinet, cm
J	=	Perpendicular distance from top of fan cutoff to inside of top discharge duct surface, cm
K _w	=	Width of the housed opening from inside of fan housing surface to inside of opposite fan housing surface measured at the outlet plane of the fan housing, m
K _t	=	Height of the housed opening from inside of fan housing surface to inside of opposite fan housing surface measured at the outlet plane of the fan housing, m
L ₁	=	Closest horizontal dimension from fan wheel outside diameter to inside of the cabinet, cm
L _c	=	Cabinet length in direction of airflow from inlet plane to outlet plane (axial flow fans) or from inlet plane to inside of discharge panel (Plenum Fans and Housed Centrifugal Fans), m
L _i	=	Closest distance from coil leaving face to fan inlet plane for Housed Centrifugal Fans and Plenum Fans, m. (For Housed Centrifugal Fan, it is the distance from coil leaving face to the centerline of the fan shaft.)
L _o	=	Distance from axial fan exit plane or plenum fan hub-plate to downstream heat exchanger entering face, m. (For Housed Centrifugal Fans, it is the distance from the fan discharge face to the downstream heat exchanger entering face.)
M	=	Fan wheel width, m
n	=	Number of outlets
R _{max}	=	Proportional linear dimension, m
R _{min}	=	Proportional linear dimension, m
S	=	Discharge opening height from inside of top of discharge duct surface to inside of bottom duct surface measured at the outlet plane of the unit, m
t	=	Refers to a unit with tested performance rating
T	=	Discharge opening width from inside of side of discharge duct surface to inside of opposite side discharge duct surface measured at the outlet plane of the unit, m
θ	=	Angle from centerline of fan shaft to centerline of rotation of inlet vane, degrees
v	=	Refers to a unit with calculated performance rating
W	=	Internal cabinet width from inside of panel to opposite inside of panel, m

Section 8. Minimum Data Requirements for Published Ratings

8.1 Minimum Data Requirements for Published Ratings. As a minimum, Published Ratings shall include all Standard Ratings. All claims to ratings within the scope of this standard shall include the statement "Rated in accordance with AHRI Standard 431 (SI)". All Claims to ratings outside the scope of this standard shall include the statement "Outside the scope of

AHRI Standard 431 (SI)". Wherever Application Ratings are published or printed, they shall include a statement of the conditions at which the ratings apply. The following information shall be published for all Standard Ratings:

8.1.1 Static Pressure, kPa

8.1.2 Airflow Rate, Actual m³/s

8.1.3 Fan Speed, rev/s

8.1.4 Fan Shaft Power, W

Section 9. Marking and Nameplate Data

9.1 *Marking and Nameplate Data.* As a minimum, the nameplate shall display the manufacturer's name and model designation.

If the nameplate shows electrical characteristics, then nameplate voltages for 60 Hz systems shall include one or more of the equipment nameplate voltage ratings shown in Table 1 of ANSI/AHRI Standard 110. Nameplate voltages for 50 Hz systems shall include one or more of the utilization voltages shown in Table 1 of IEC Standard 60038.

Section 10. Conformance Conditions

10.1 *Conformance.* While conformance with this standard is voluntary, conformance shall not be claimed or implied for products or equipment within the standard's *Purpose* (Section 1) and *Scope* (Section 2) unless such product claims meet all of the requirements of the standard and all of the testing and rating requirements are measured and reported in complete compliance with the standard. Any product that has not met all the requirements of the standard shall not reference, state, or acknowledge the standard in any written, oral, or electronic communication.

APPENDIX A. REFERENCES - NORMATIVE

A1 Listed here are all standards, handbooks and other publications essential to the formation and implementation of the standard. All references in this appendix are considered as part of the standard.

A1.1 ANSI/AHRI Standard 110, *Air-Conditioning and Refrigerating Equipment Nameplate Voltages*, 2012, Air-Conditioning, Heating, and Refrigeration Institute, 2111 Wilson Boulevard, Suite 500, Arlington, VA 22201, U.S.A.

A1.2 ANSI/AHRI Standard 210/240-2008 with Addendum 1 and 2, *Performance Rating of Unitary Air-Conditioning & Air-Source Heat Pump Equipment*, 2008, American National Standards Institute and Air-Conditioning & Refrigeration Institute, 2111 Wilson Blvd, Suite 500, Arlington, VA 22201, U.S.A.

A1.3 ANSI/AHRI Standard 340/360-2007 with Addendum 2, *Performance Rating of Commercial and Industrial Unitary Air-conditioning and Heat Pump Equipment*, 2007, American National Standards Institute and Air-Conditioning & Refrigeration Institute, 2111 Wilson Blvd, Suite 500, Arlington, VA 22201, U.S.A.

A1.4 ANSI/AHRI Standard 410, *Forced-Circulation Air-Cooling and Air-Heating Coils with Addenda 1,2, and 3*, 2001, Air-Conditioning, Heating, and Refrigeration Institute, 2111 Wilson Boulevard, Suite 500, Arlington, VA 22201, U.S.A.

~~**A1.5** ANSI/AHRI Standard 420-2008, *Performance Rating of Forced Circulation Free-Delivery Unit Coolers for Refrigeration*, 2008, American National Standards Institute and Air-Conditioning & Refrigeration Institute, 2111 Wilson Blvd, Suite 500, Arlington, VA 22201, U.S.A.~~

A1.5 ANSI/AHRI Standard 440-2009 with Addendum 1, *Performance Rating of Room Fan-Coils*, 2009, American National Standards Institute and Air-Conditioning & Refrigeration Institute, 2111 Wilson Blvd, Suite 500, Arlington, VA 22201, U.S.A.

A1.6 ANSI/AHRI Standard 841-1998/2015, *Performance Rating of Standard for Unit Ventilators*, 1998/2015, American National Standards Institute and Air-Conditioning & Refrigeration Institute, 2111 Wilson Blvd, Suite 500, Arlington, VA 22201, U.S.A.

A1.7 ANSI/AMCA Standard 210, *Laboratory Methods of Testing Fans for Aerodynamic Performance Rating*, 2007, Air Movement and Control Association, Inc., 30 West University Drive, Arlington Heights, IL 60004, U.S.A.

A1.8 ANSI/AMCA Standard 99, *Standards Handbook*, 2007, Air Movement and Control Association, Inc., 30 West University Drive, Arlington Heights, IL 60004, U.S.A.

A1.9 ANSI/ASHRAE Standard 51, *Laboratory Methods of Testing Fans for Ratings*, 2007, American Society of Heating, Refrigerating, and Air-Conditioning Engineers, Inc., 11 West 42nd Street, New York, NY 10036, U.S.A./1791 Tullie Circle N.E., Atlanta, GA 30329, U.S.A.

A1.10 ASHRAE Terminology website (<https://www.ashrae.org/resources--publications/free-resources/ashrae-terminology>), 2014, American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc., 1791 Tullie Circle, N.E. Atlanta, GA 30329, U.S.A.

A1.11 ASHRAE Duct Fitting Database CD Version 6.00.04, 2015, American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc., 1791 Tullie Circle, N.E. Atlanta, GA 30329, U.S.A.

A1.12 ASHRAE Fundamentals, 2013, American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc., 1791 Tullie Circle, N.E. Atlanta, GA 30329, U.S.A.

A1.13 IEC Standard 60038, *IEC Standard Voltages*, 2009, International Electrotechnical Commission, 3, rue de Varembe, P.O. Box 131, 1211 Geneva 20, Switzerland.

APPENDIX B. REFERENCES - INFORMATIVE

None.

APPENDIX C. CRITERIA FOR PROPORTIONALITY- INFORMATIVE

C1 This appendix sets forth procedures and equations that should be used to determine the proportionality requirements of Central Station Air-handling Units as defined by this standard.

C2 *Basis of Proportionality.*

C2.1 The following denotes the type of Central Station Air-handling Unit being rated:

C2.1.1. "t" refers to a unit with tested performance rating.

C2.1.2. "v" refers to a unit with calculated performance rating.

C2.2 Proportional linear dimensions (Figure C1-Figure C4) are determined using the following generic equation:

$$\frac{(LinearDimension)_v}{(LinearDimension)_t} = \frac{Diameter_v}{Diameter_t} \tag{C1}$$

This ratio of the wheel diameters shall not be less than 0.65.

C2.3 Proportional areas (Figure C1-Figure C4) are determined using the following generic equation:

$$\frac{Area_v}{Area_t} = \left(\frac{Diameter_v}{Diameter_t} \right)^2 \tag{C2}$$

C3 *Cabinet Proportionality.*

C3.1 Linear dimensions C, D, E₁, E₂, G, J, K, L, M, S, T, W (Figure C1-Figure C4).

C3.1.1

$$\frac{LinearDimension_v}{LinearDimension_t} \geq \frac{Diameter_v}{Diameter_t} \tag{C3}$$

C3.1.2 The ratio of the rated unit linear dimension from the tested unit linear dimension shall be proportional within ± 1.5 percent.

C3.2 *Areas.*

C3.2.1 *Fan Cabinet Air Inlet.*

$$\frac{G_v \cdot W_v}{G_t \cdot W_t} \geq 0.925 \cdot \left(\frac{Diameter_v}{Diameter_t} \right)^2 \tag{C4}$$

C3.2.2 *Fan Cabinet Air Outlet.*

$$\frac{S_v \cdot T_v}{S_t \cdot T_t} \geq 0.925 \cdot \left(\frac{\text{Diameter}_v}{\text{Diameter}_t} \right)^2 \quad \text{C5}$$

C3.2.3 The ratio of the rated unit area from the tested unit area shall be proportional within ± 3 percent.

C4 *Fan Proportionality.*

C4.1 *Proportional Linear Dimensions.*

C4.1.1 *Fan Wheel Width.*

$$\frac{M_v}{M_t} \geq \frac{\text{Diameter}_v}{\text{Diameter}_t} \quad \text{C6}$$

C4.1.2 *Fan Outlet Width.*

$$\frac{K_v}{K_t} \geq \frac{\text{Diameter}_v}{\text{Diameter}_t} \quad \text{C7}$$

C4.1.3 *Fan Housing Radii.*

$$\frac{R_{\max v}}{R_{\max t}} \geq \frac{\text{Diameter}_v}{\text{Diameter}_t} \quad \text{C8}$$

$$\frac{R_{\min v}}{R_{\min t}} \geq \frac{\text{Diameter}_v}{\text{Diameter}_t} \quad \text{C9}$$

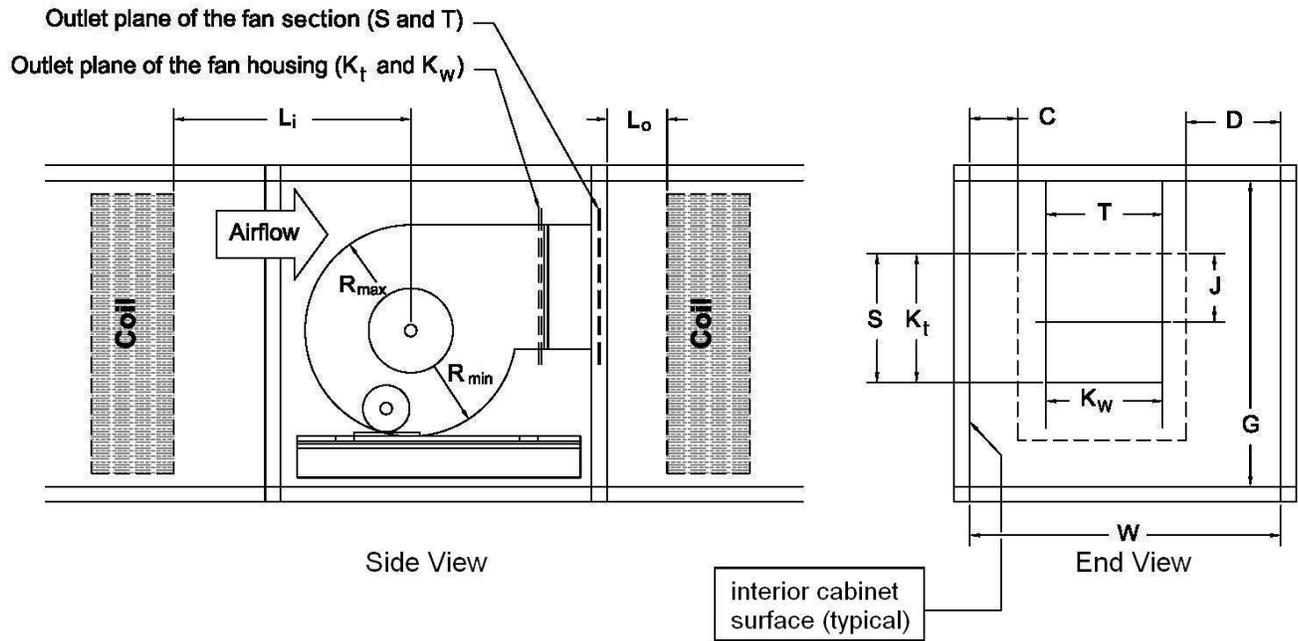
C4.1.4 The ratio of the rated unit radial dimension from the tested unit radial dimension shall be proportional within ± 1.5 percent.

C4.2 *Proportional Areas.*

C4.2.1 *Fan Outlet Area.*

$$\frac{J_v \cdot K_v}{J_t \cdot K_t} \geq \left(\frac{\text{Diameter}_v}{\text{Diameter}_t} \right)^2 \quad \text{C10}$$

C4.2.2 The ratio of the rated unit area from the tested unit area shall be proportional within ± 3 percent.



S and T are inside dimensions of the cabinet outlet. R_{min} and R_{max} are measured from the center of the shaft.

Figure C1. Dimensions Used for Proportionality Equations – Housed Fan

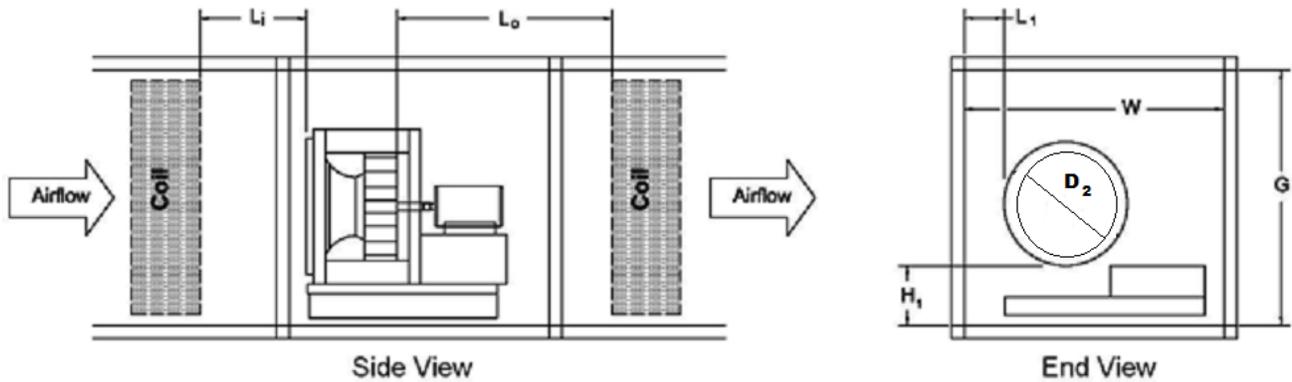


Figure C2. Dimensions Used for Proportionality Equations – Plenum Fan

Note: Contained Fan Arrays and Partially Contained Fan Arrays (for fans which do not aerodynamically interact) will follow this figure.

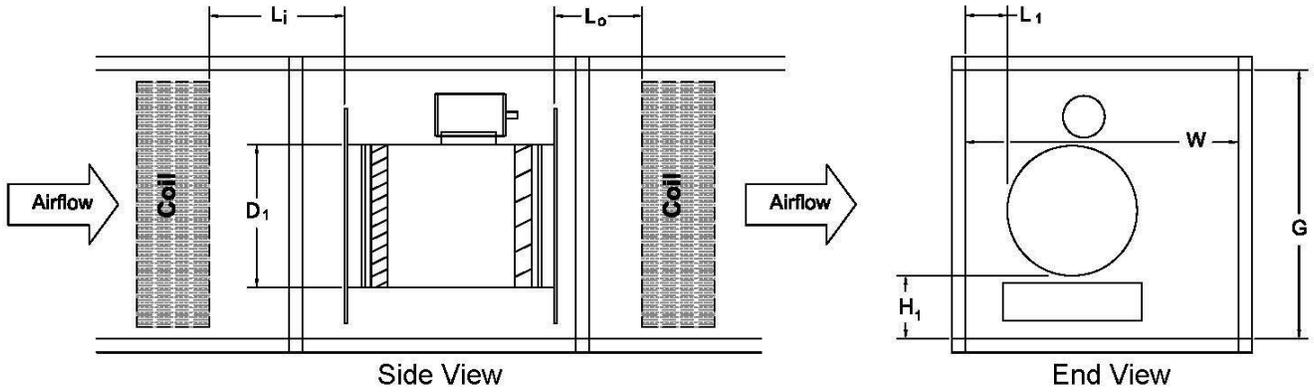
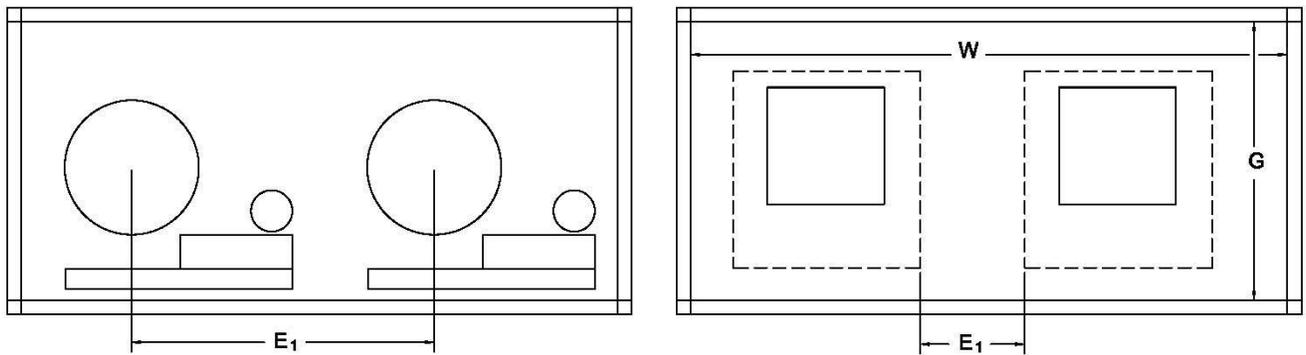


Figure C3. Dimensions Used for Proportionality Equations – Axial Fan



Plenum (shown) and Axial Fans

DWDI Housed Fans

Figure C4. Dimensions Used for Proportionality Equations – Multiple Fans (End Views)

Note: Uncontained Fan Arrays and Partially Contained Fan Arrays (for fans which aerodynamically interact) will follow this figure.

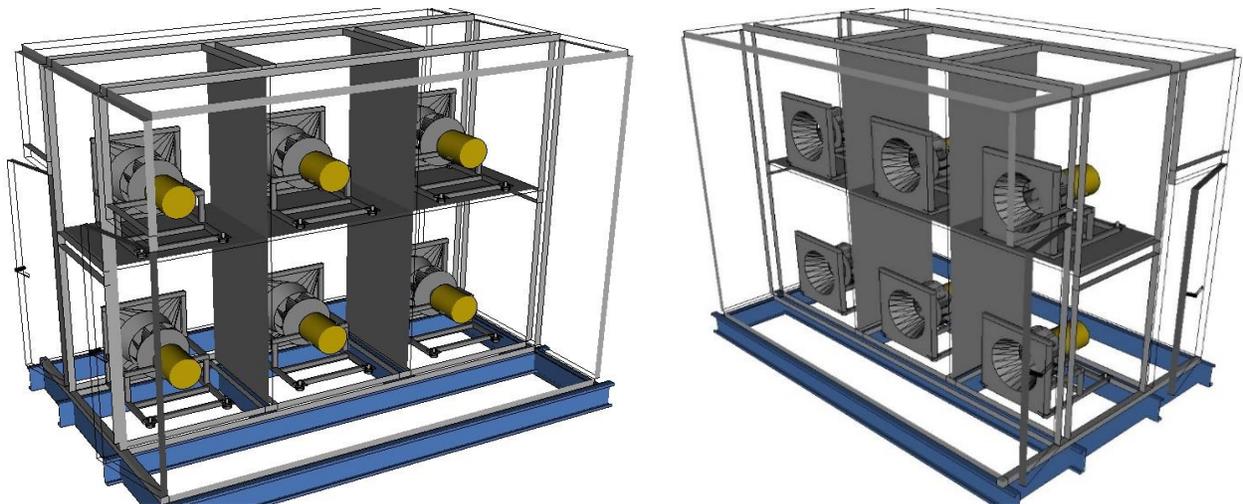


Figure C5. Example Contained Fan Array

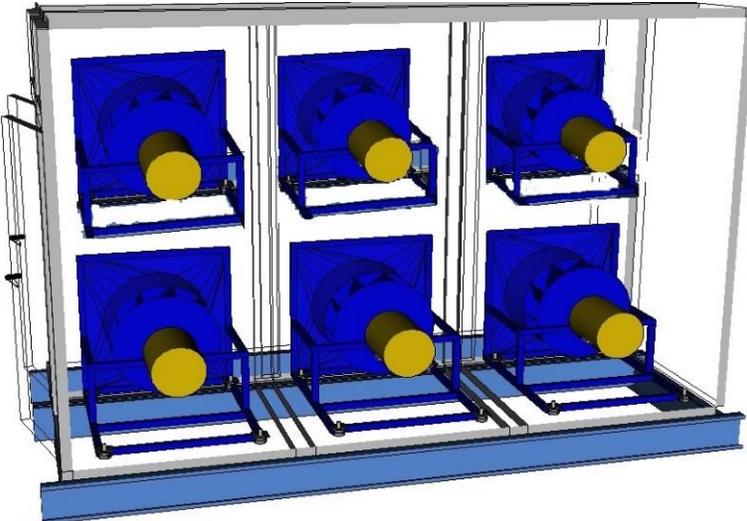


Figure C6. Example Uncontained Fan Array

APPENDIX D. EXAMPLE FAN ARRAY CALCULATION - INFORMATIVE

D1. The data shown in Table D1 was taken from a 2x2 Fan Array with four pole motors. The motor calibration was performed at nominal frequency of 60 Hz. The first example will use the methodology where Table 1 is followed. For 4 Operating Fans in the array, 2 were measured.

Table D1. Example Motor Calibration Data Following Table 1			
Motor calibration (Motor 1)		Motor calibration (Motor 2)	
<u>Watts</u>	<u>BHP</u>	<u>Watts</u>	<u>BHP</u>
247.2	0.000	251.9	0.000
387.3	0.180	345.1	0.126
519.9	0.340	494.0	0.326
617.0	0.488	611.6	0.474
768.7	0.688	751.0	0.677
888.3	0.851	854.6	0.805
1050.0	1.062	1023.1	1.033
1143.0	1.182	1124.8	1.178
1279.4	1.358	1304.6	1.395
1380.0	1.495	1365.9	1.481

This data was plotted in Excel™ using the scatterplot function and then a trendline was added. The equation for the trendline is shown in Figure D1.

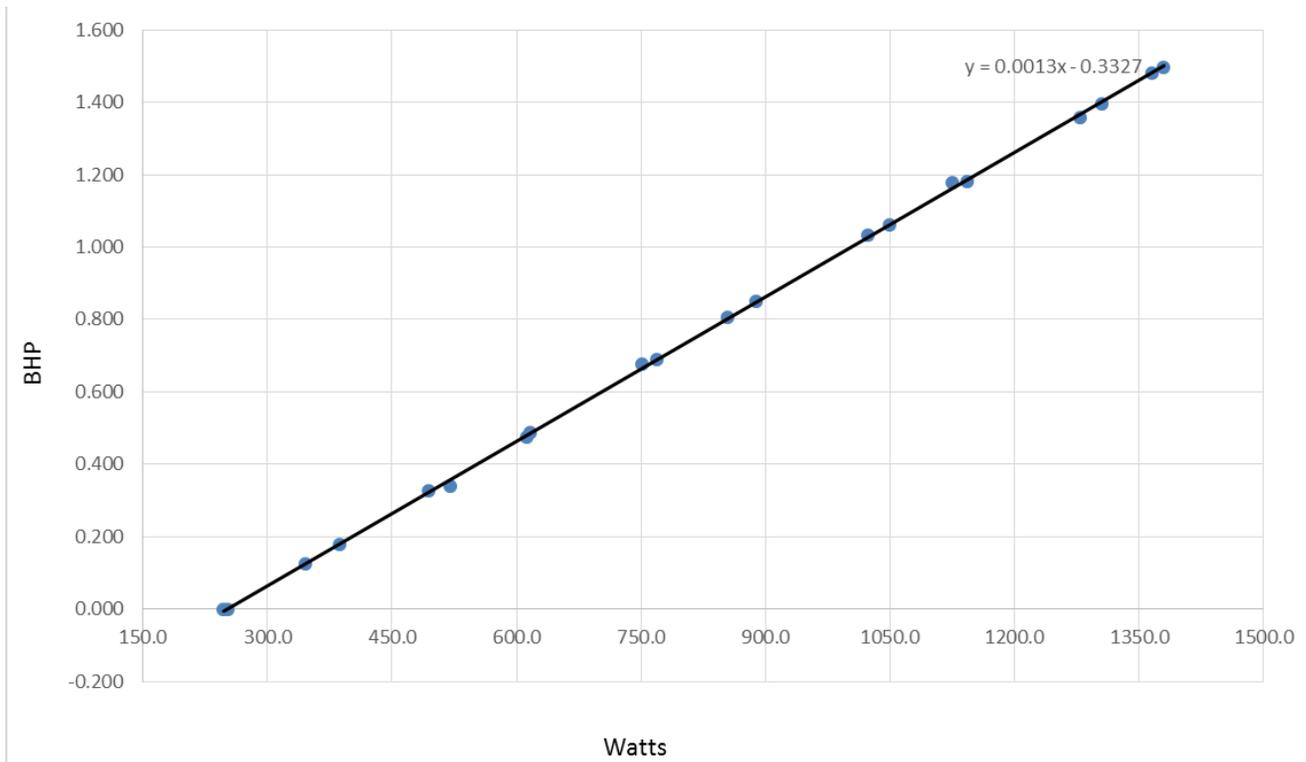


Figure D1. Example Scatterplot with Motor Calibration Data According to Table 1

The total input power measured was 3852.0 watts according to AMCA 210. With 4 Operating Fans, the input power per fan calculates to 963.0 using Equation E1. Using the formula found in the trendline (Equation E2), the BHP per fan is calculated to be 0.9192 using Equation E3. Since there are 4 fans, the total unit shaft power can be determined using Equation E4 and is calculated to 3.6768 BHP.

$$\frac{\text{Overall Input Power}}{\text{Number of Operating Fans}} = \frac{3852.0}{4} = 963.0 \tag{E1}$$

$$y = 0.0013x - .3327 \tag{E2}$$

$$\text{BHP Per Fan} = 0.0013 \cdot (\text{Input Power per Fan}) - 0.3327 = (0.0013 \cdot 963.0) - 0.3327 = 0.9192 \tag{E3}$$

$$\text{Overall BHP} = \text{BHP Per Fan} \cdot (\text{Number of Operatings Fans}) = 0.9192 \cdot 4 = 3.6768 \text{ BHP} \tag{E4}$$

D2. The data shown in Table D2 was taken from a 2x2 Fan Array with four pole motors. The motor calibration was performed at nominal frequency of 60 Hz. This example has all 4 fans being measured.

Motor calibration (Motor 1)		Motor calibration (Motor 2)		Motor calibration (Motor 3)		Motor calibration (Motor 4)	
Watts	BHP	Watts	BHP	Watts	BHP	Watts	BHP
247.2	0.000	251.9	0.000	249.4	0.000	249.2	0.000
387.3	0.180	345.1	0.126	387.8	0.183	353.4	0.120
519.9	0.340	494.0	0.326	509.7	0.354	487.1	0.303
617.0	0.488	611.6	0.474	636.5	0.520	603.8	0.463
768.7	0.688	751.0	0.677	780.2	0.722	722.2	0.619
888.3	0.851	854.6	0.805	897.0	0.871	861.4	0.808
1050.0	1.062	1023.1	1.033	1009.7	1.019	1001.4	0.990
1143.0	1.182	1124.8	1.178	1128.9	1.167	1130.5	1.159
1279.4	1.358	1304.6	1.395	1250.3	1.349	1244.9	1.315
1380.0	1.495	1365.9	1.481	1375.4	1.509	1386.9	1.506

This data was plotted in Excel™ using the scatterplot function and then a trendline was added. The equation for the trendline is shown in Figure D2.

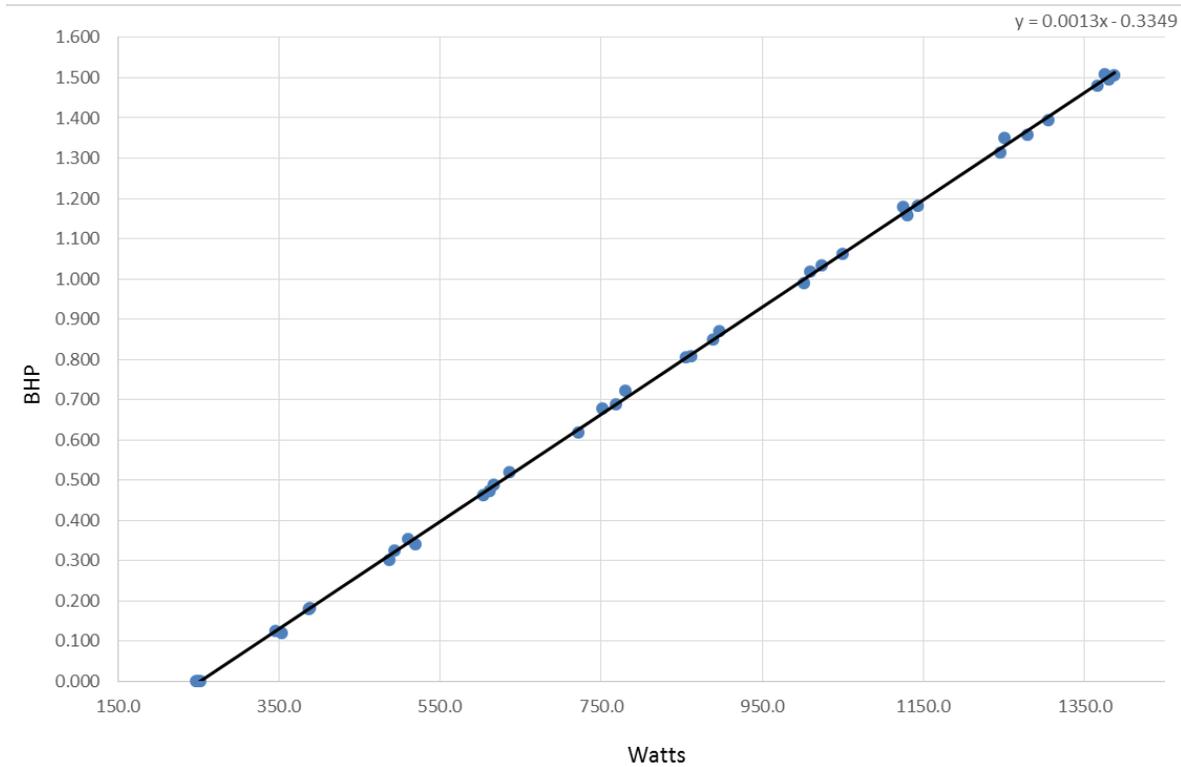


Figure D2. Example Scatterplot with Motor Calibration Data Not According to Table 1

The total input power measured was 3852.0 watts according to AMCA 210. With 4 Operating Fans, the input power per fan can be calculated using Equation E5 to be 963. Using the formula found in the trendline (Equation E6) in Figure D2, the BHP per fan can be calculated using Equation E7 to be 0.917. Since there are 4 Operating Fans, the total unit shaft power is calculated by Equation E8 to be 3.668 BHP.

$$\frac{\text{Overall Input Power}}{\text{Number of Operating Fans}} = \frac{3852.0}{4} = 963.0 \tag{E5}$$

$$y = 0.0013x - 0.3349 \tag{E6}$$

$$\text{BHP Per Fan} = 0.0013 \cdot (\text{Input Power per Fan}) - 0.3349 = (0.0013 \cdot 963.0) - 0.3349 = 0.917 \tag{E7}$$

$$\text{Overall BHP} = \text{BHP Per Fan} \cdot (\text{Number of Operatings Fans}) = 0.917 \cdot 4 = 3.668 \text{ BHP} \tag{E8}$$

APPENDIX E. CORRECTING FOR PRESSURE DROP THROUGH THE TEST EQUIPMENT FOR UNDUCTED DISCHARGE TESTS- NORMATIVE

E1 This appendix shows which air pressure losses created by the laboratory test equipment must be accounted for when testing units with inlet or discharge plenums either supplied by the manufacturer or constructed by the laboratory.

E2 Definitions.

E2.1 *Constructed by the Laboratory.* Any portion of the test set up that was not supplied by the manufacturer and was built solely to connect the unit to the test chamber for the purpose of the test. Any plenum extension shall have the same internal height and width as the test Unit Height and Unit Width.

E2.2 Duct Dimensions.

E2.2.1 *Duct Height (H_D).* The internal vertical dimension of the duct.

E2.2.2 *Duct Length (L_D).* The length of the duct between the test chamber and either the inlet plenum or discharge plenum, depending on the test configuration.

E2.2.3 *Duct Width (W_D).* The internal horizontal dimension of the duct.

E2.3 *Duct Total Pressure Loss (P_{TD}).* The total pressure loss in the duct. This loss is often negligible.

E2.4 *Plenum Length (L_P).* The distance from the internal wall of the plenum Constructed by the Laboratory to either the nearest fan or appurtenance. The manufacturer may designate this value as either fixed or a minimum.

E2.5 *Total Pressure Loss Entering Test Chamber (P_{TEC}).* The reduction in total air pressure caused by the expansion of the air flow as the air leaves the duct and enters the test chamber. This is used only when testing using the setup in Figure 12.

E2.6 *Total Pressure Loss Entering Unit (P_{TEU}).* The reduction in total air pressure caused by the contraction of the air when it leaves the duct and enters the unit. This is used only when testing using the setup in Figure 15. If the manufacturer provided the inlet plenum, this loss shall not be included.

E2.7 *Total Pressure Loss Leaving Test Chamber (P_{TLC}).* The reduction in total air pressure caused by the contraction of the air flow between the test chamber and the duct. This is used only when testing using the setup in Figure 15.

E2.8 *Total Pressure Loss Leaving Unit (P_{TLU}).* The reduction in total air pressure caused by the contraction of the air when it leaves the unit and enters the duct. This is used only when testing using the setup in Figure 12. If the manufacturer provided the discharge plenum, this loss shall not be included.

E2.9 *Total Pressure Loss of Test Equipment.* The sum of the total pressure losses created by the portion of the test setup Constructed by the Laboratory.

E2.10 Unit Dimensions.

E2.10.1 *Unit Height (H_U).* The internal vertical dimension of the unit under test.

E2.10.2 *Unit Width (W_U).* The internal horizontal dimension of the unit under test.

E3 Procedure.

E3.1 Determine which components of pressure loss must be calculated.

E3.1.1 Testing using Figure 12 of AMCA 210 (Figure 6) and manufacturer provides the discharge plenum

(Figure E1): P_{TD} and P_{TLU} .

E3.1.2 Testing using Figure 12 of AMCA 210 (Figure 6) and laboratory constructs the discharge plenum (Figure E2): P_{TEC} , P_{TD} and P_{TEC} .

E3.1.3 1 Testing using Figure 15 of AMCA 210 (Figure 5) and manufacturer provides the inlet plenum (Figure E3): P_{TLC} and P_{TD} .

E3.1.4 Testing using Figure 15 of AMCA 210 (Figure 5) and laboratory constructs the inlet plenum (Figure E4): P_{TLC} , P_{TD} and P_{TEU} .

E3.2 Calculate each of the pressure losses using the values for H_D , W_D , L_D , H_U , W_U , the air flow, and air density based on the procedures in ASHRAE Fundamentals 2013 Chapter 21 and the values in the ASHRAE Duct Fitting Database CD.

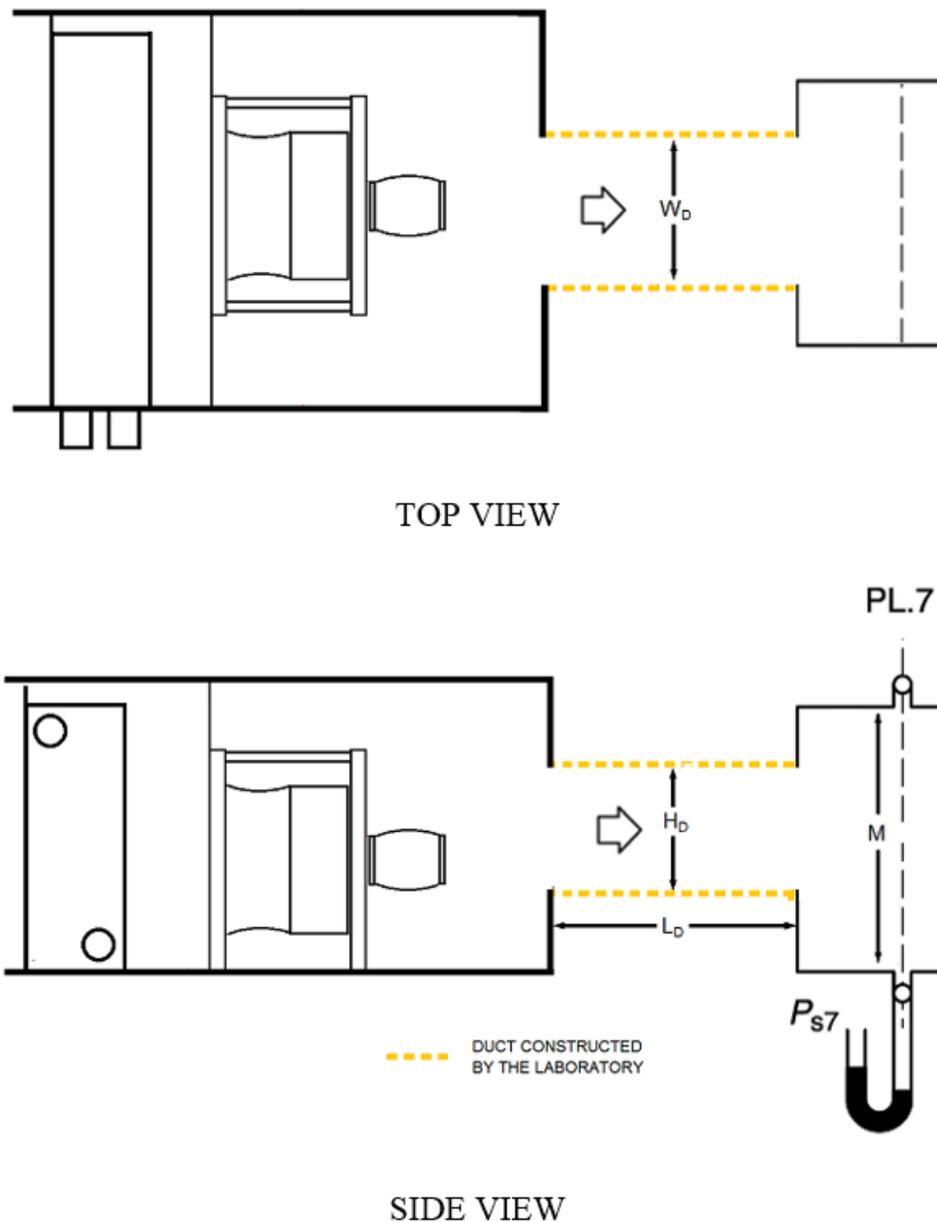


Figure E1. Unit Tested Per Figure 12 of AMCA 210 with Discharge Plenum Supplied By the Manufacturer

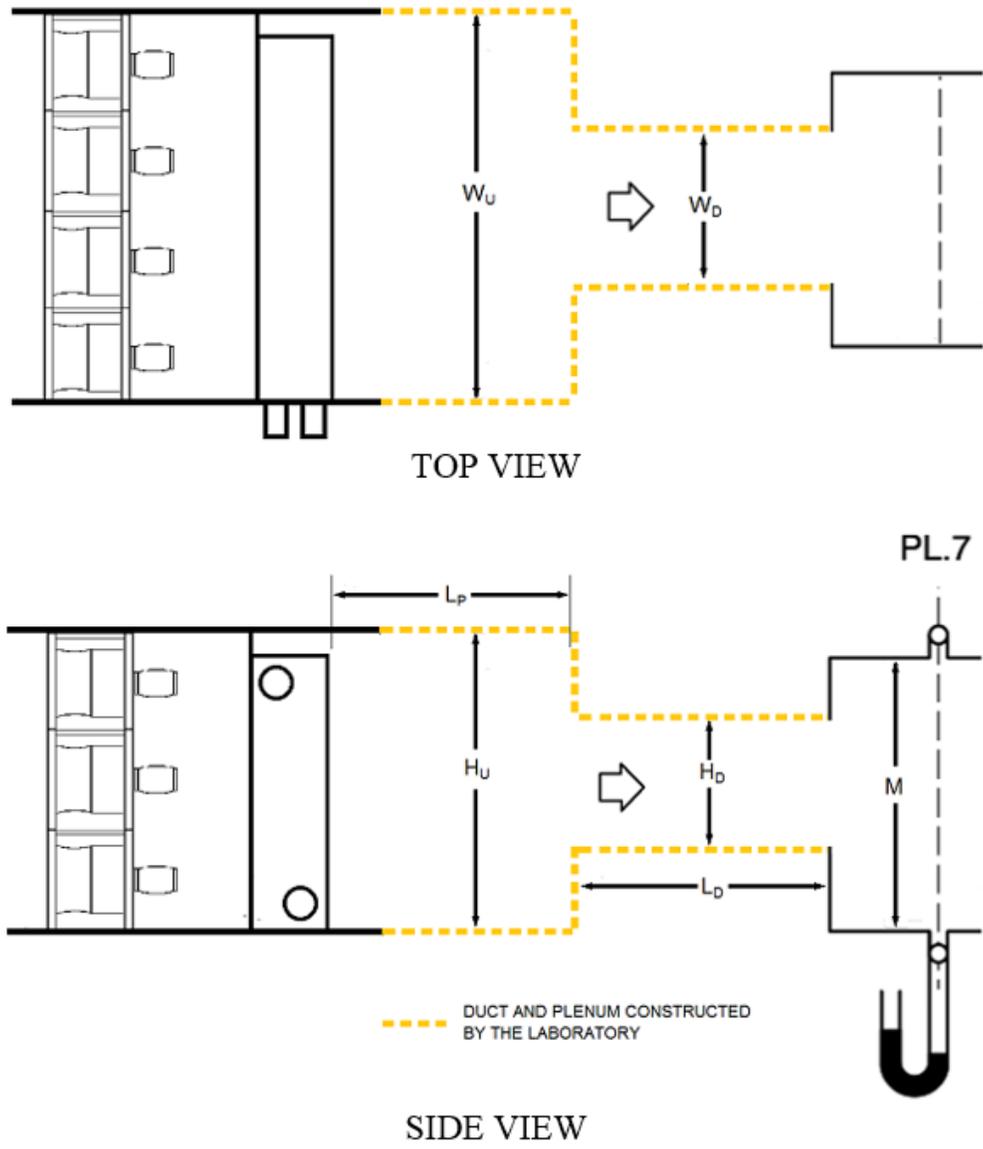


Figure E2. Unit Tested Per Figure 12 of AMCA 210 with Discharge Plenum Constructed By the Laboratory

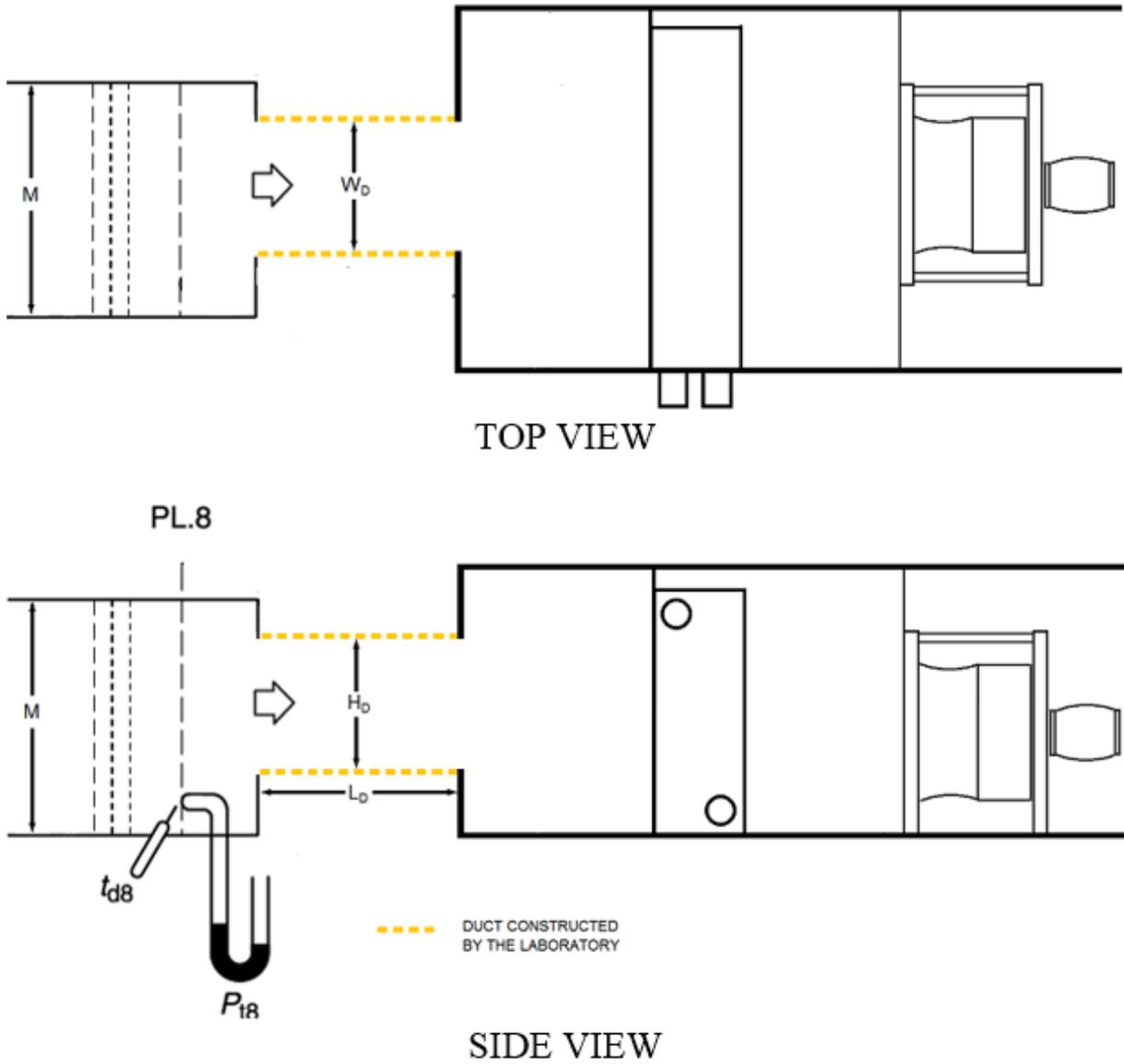


Figure E3. Unit Tested Per Figure 15 of AMCA 210 with Inlet Plenum Provided By the Manufacturer

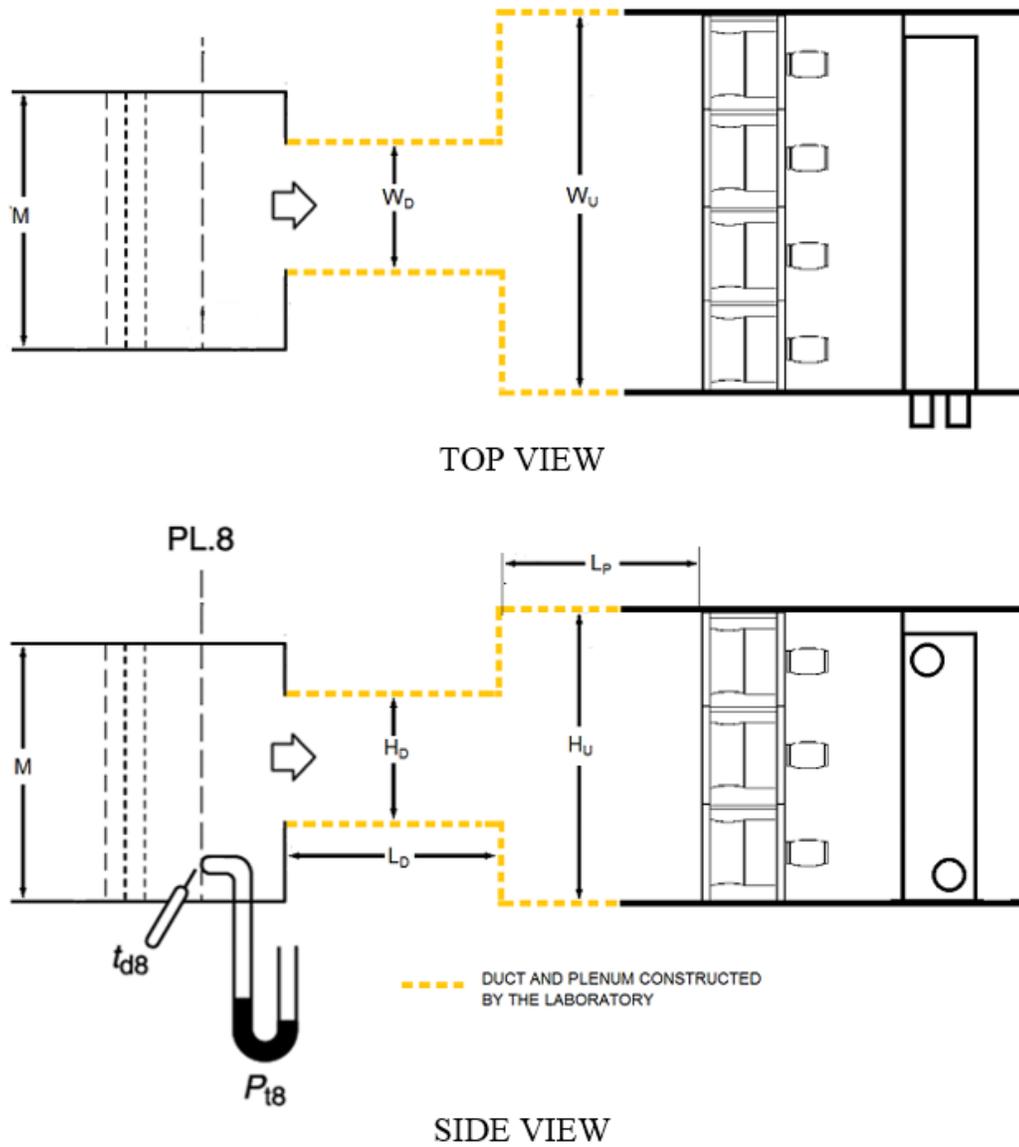


Figure E4. Unit Tested Per Figure 15 Of AMCA 210 With Inlet Plenum Constructed By The Laboratory.