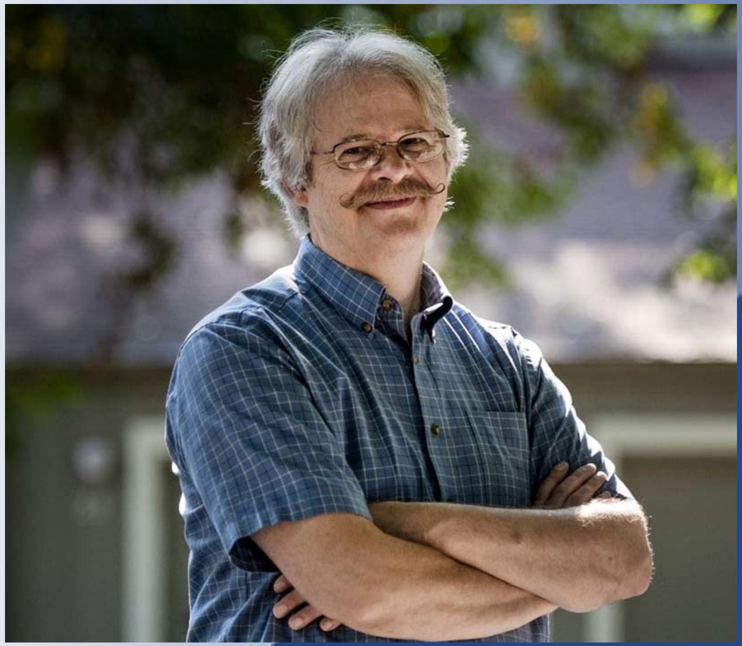
Better Plants
U.S. DEPARTMENT OF ENERGY

Industrial Fan Systems
Virtual INPLT Training & Assessment

Session 4

U.S. DEPARTMENT OF ENERGY

Fan Virtual INPLT Facilitator



Ron Wroblewski, PE,
Productive Energy Solutions, LLC
Madison, Wisconsin

ron@productiveenergy.com
(608) 232-1861

U.S. DEPARTMENT OF ENERGY

Acknowledgments

- William (Bill) Hunter, PE, Airclean Systems, Seattle WA
- Eddie Radd, CFW Fans, Cape Town, SA
- William (Bill) W.T. Corey, Corey Consultancy, Surrey England
- US Department of Energy , Advanced Manufacturing Office
- Oak Ridge National Laboratory
- United Nations Industrial Development Organization
- Air Movement and Control Association, AMCA International
- Many industrial clients – both in the US and internationally

Agenda – Session 4

- Welcome and Introductions
- Safety and Housekeeping
- Agenda for Fan System Virtual INPLT (8 weeks)
- Today's Content:
  - Creating a fan performance measurement plan
  - Selecting measurement planes
- Kahoot Quiz Game
- Q&A

Better Buildings is an initiative of the U.S. Department of Energy

Safety and Housekeeping

- Safety Moment
  - When testing fans in hot systems beware that the pitot tube will get very hot
  - Be cautious of heat exhaustion and heat stroke when testing hot fans
- You are welcome to ask questions at any time during the webinar
- When you are not asking a question, please <u>MUTE</u> your mic and this will provide the best sound quality for all participants
- We will be recording all these webinars and by staying on-line and attending the meeting you are giving your consent to be recorded
  - A link to the recorded webinars will be provided, afterwards

Fan system Virtual INPLT Agenda

- Week 1 – Industrial Fan Systems Fundamentals and Introduction to MEASUR
- Week 2 – Fan and system curves, Fan types
- Week 3 – Fan affinity laws, Fan system controls
- **Week 4 – Creating a fan performance measurement plan & selecting measurement planes**
- Week 5 – Pressure considerations, Sizing ducts and estimating losses, Optimization techniques
- Week 6 – Psychrometrics and air density for fan systems, System effect in fan systems
- Week 7 – Fan system optimization strategies, Fan system evaluation with MEASUR
- Week 8 – Industrial Fan System VINPLT Wrap-up Presentations

Learning objectives session 4

Class participants will:

1. Understand the use of manometers, pitot tubes, and other instruments as measurement tools in a fan performance test.
2. Develop a measurement plan as part of a performance test.
3. Use MEASUR to analyze fan performance test data

Creating a fan performance measurement plan

U.S. DEPARTMENT OF ENERGY

Fan System Performance Measurement Tools

Fan performance is measured with the goal of definitively establishing what the fan is doing. This goal includes completely defining the performance of the fan as it relates to flow, pressure and power.

Instrumentation includes:

- Manometers
- Barometers
- Tachometers
- Thermocouple
- Power meter

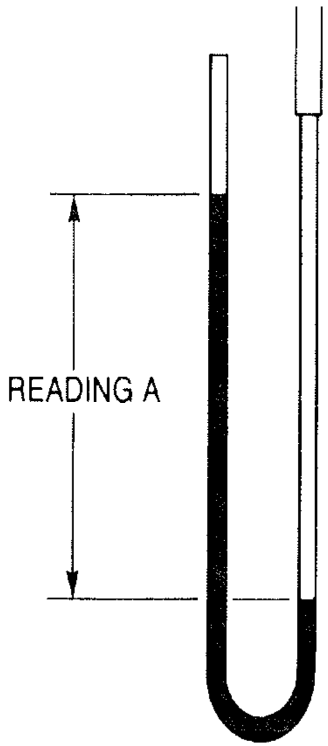
Manometers

Manometers measure pressure in Pascals or in inches or water

U-Tube Manometer

Disadvantage:

Fluid in an open tube

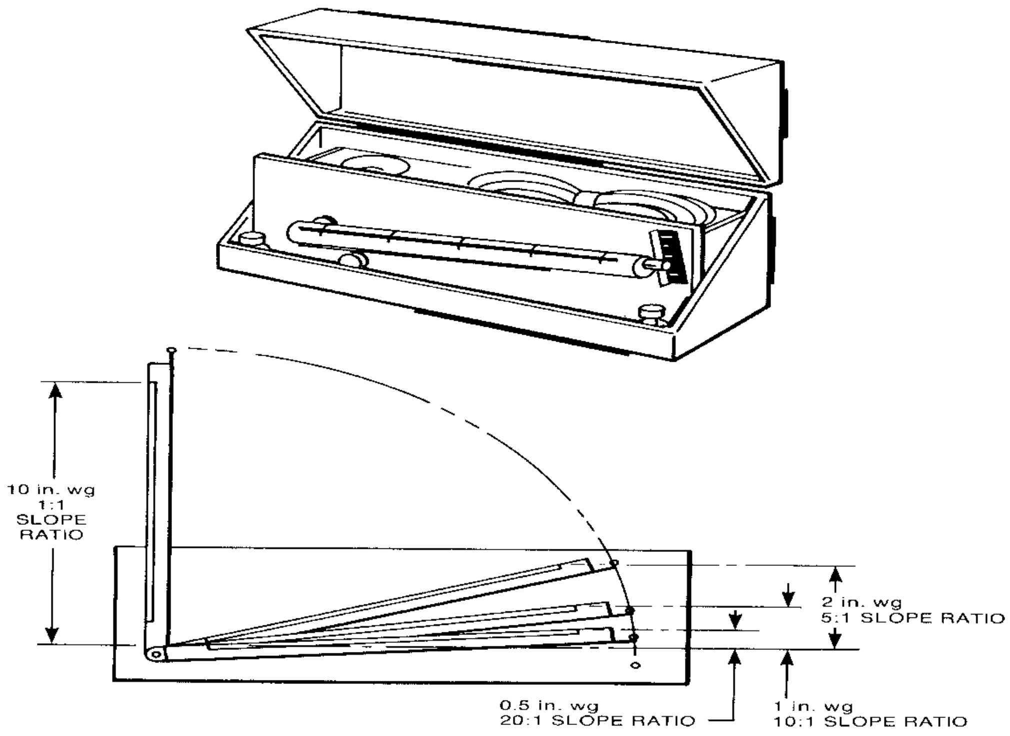


Inclined Tube Manometer

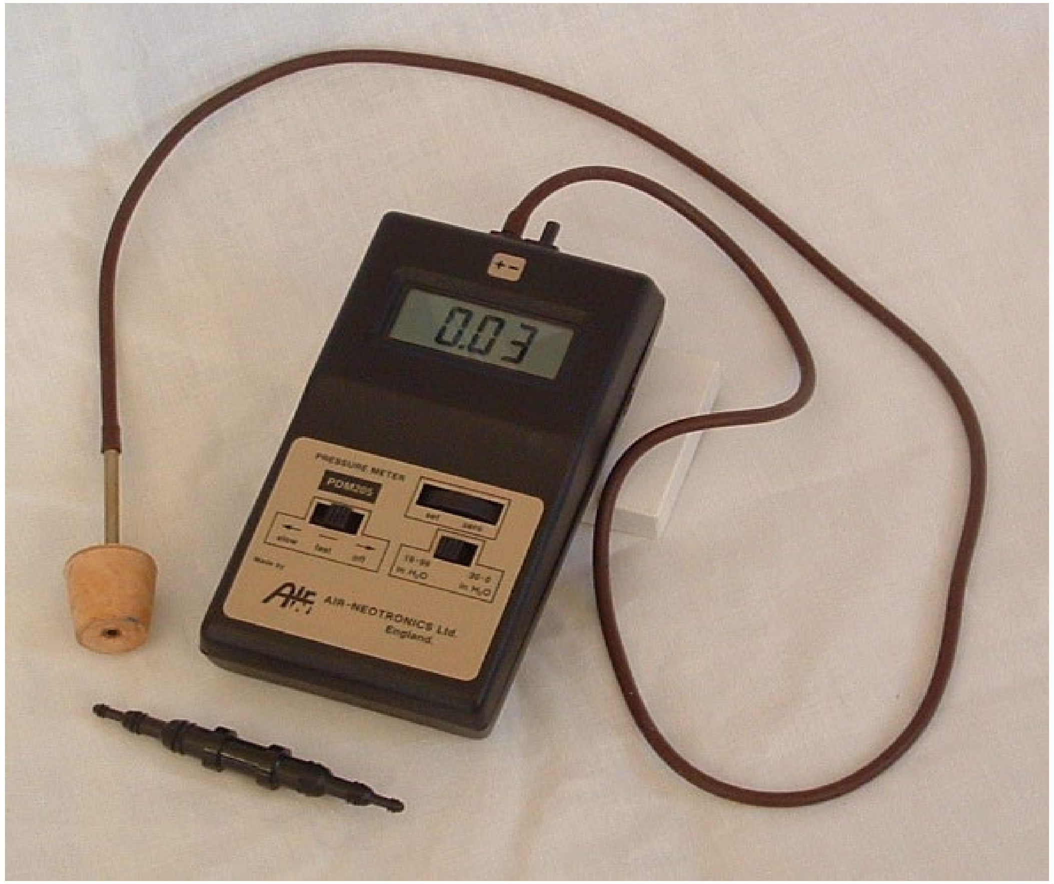
Offers greater precision

Disadvantage:

Fluid in an open tube

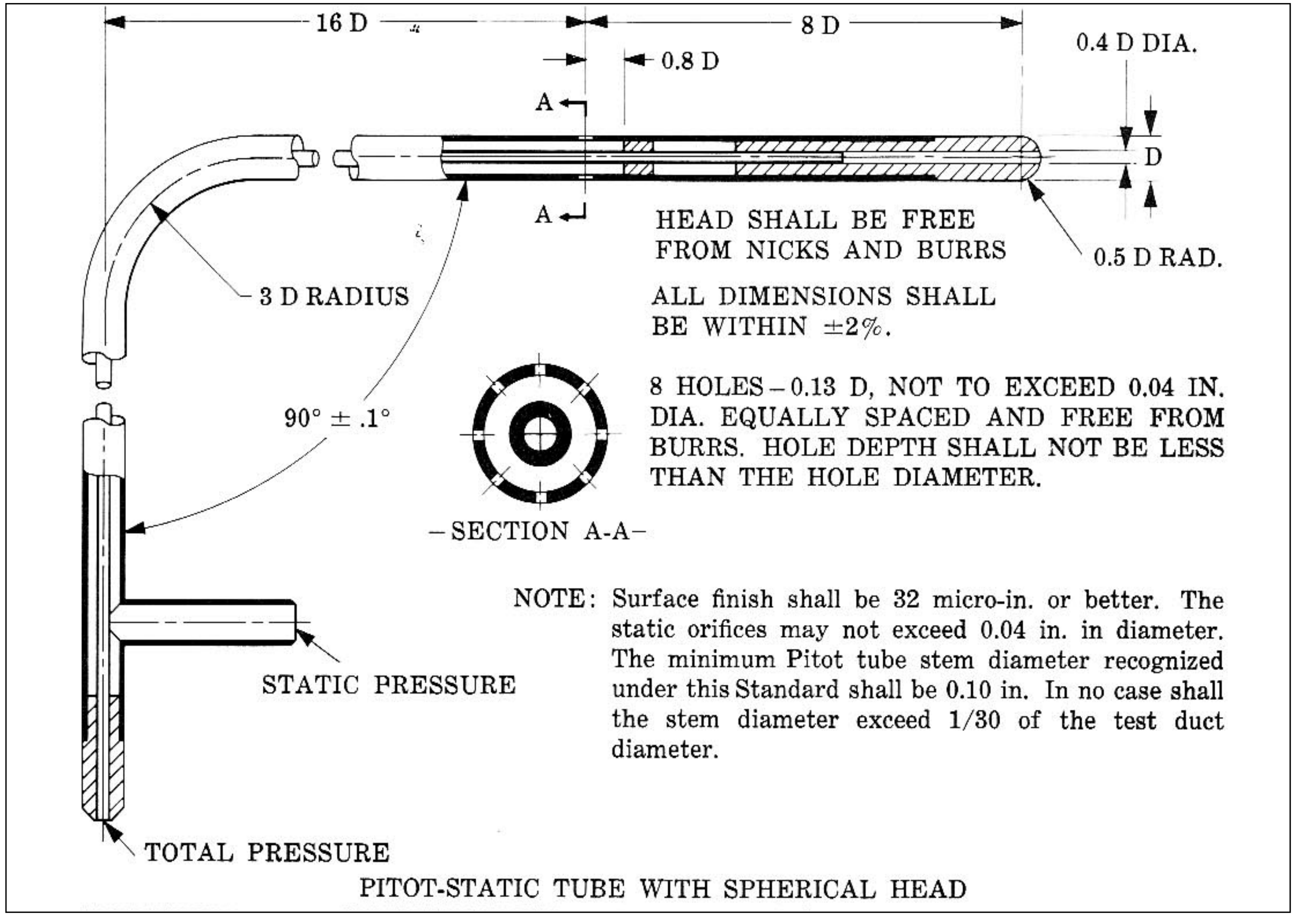


Digital Manometer



Pitôt Static Tube with Spherical or Ellipsoidal Head

Prone to becoming clogged if there is moisture or particles in the airstream

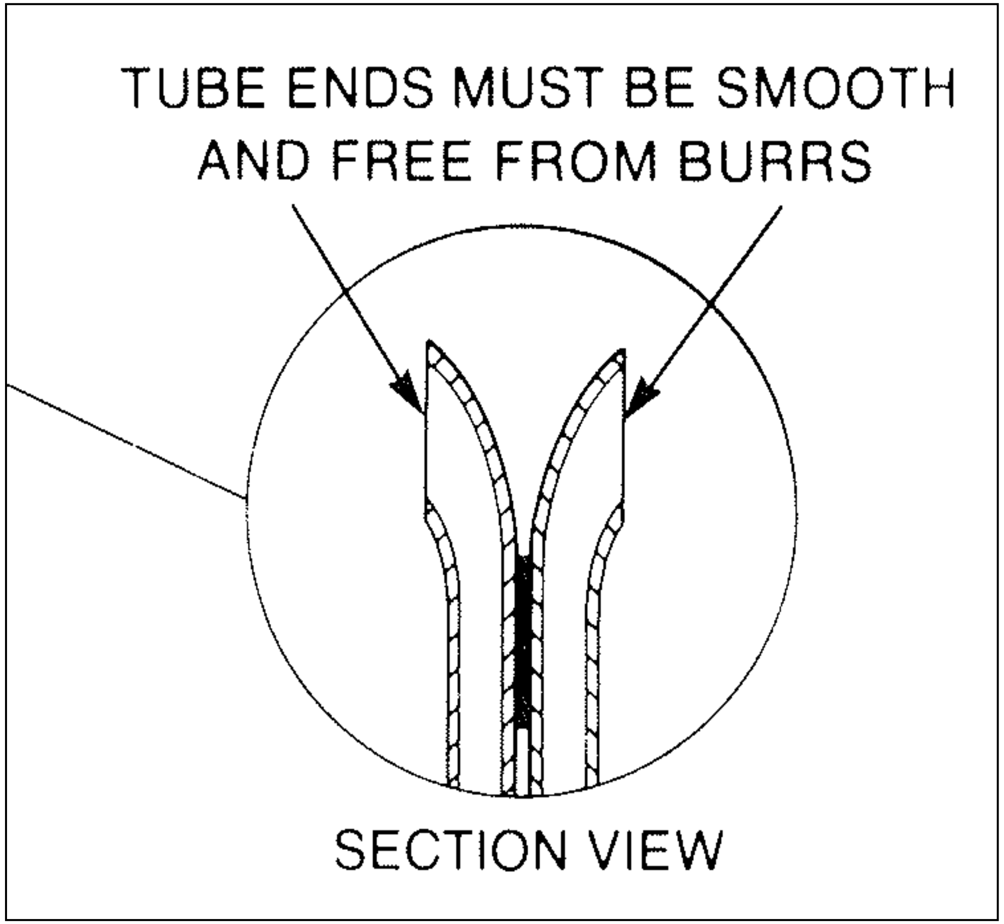


Double Reverse Tube (S-type)

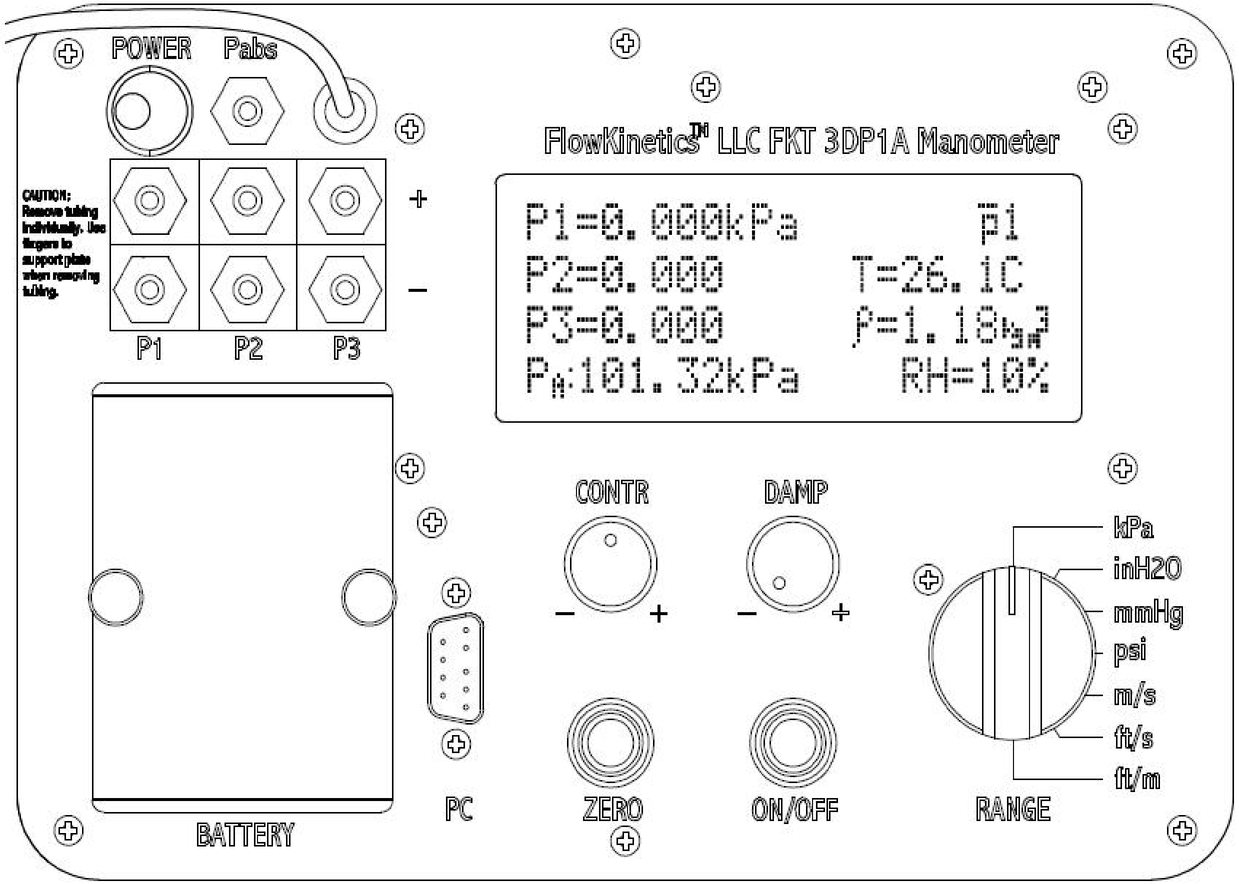
A better choice when dealing with particles or moisture

Double Reverse Tube (S-type) - Closeup of Tip

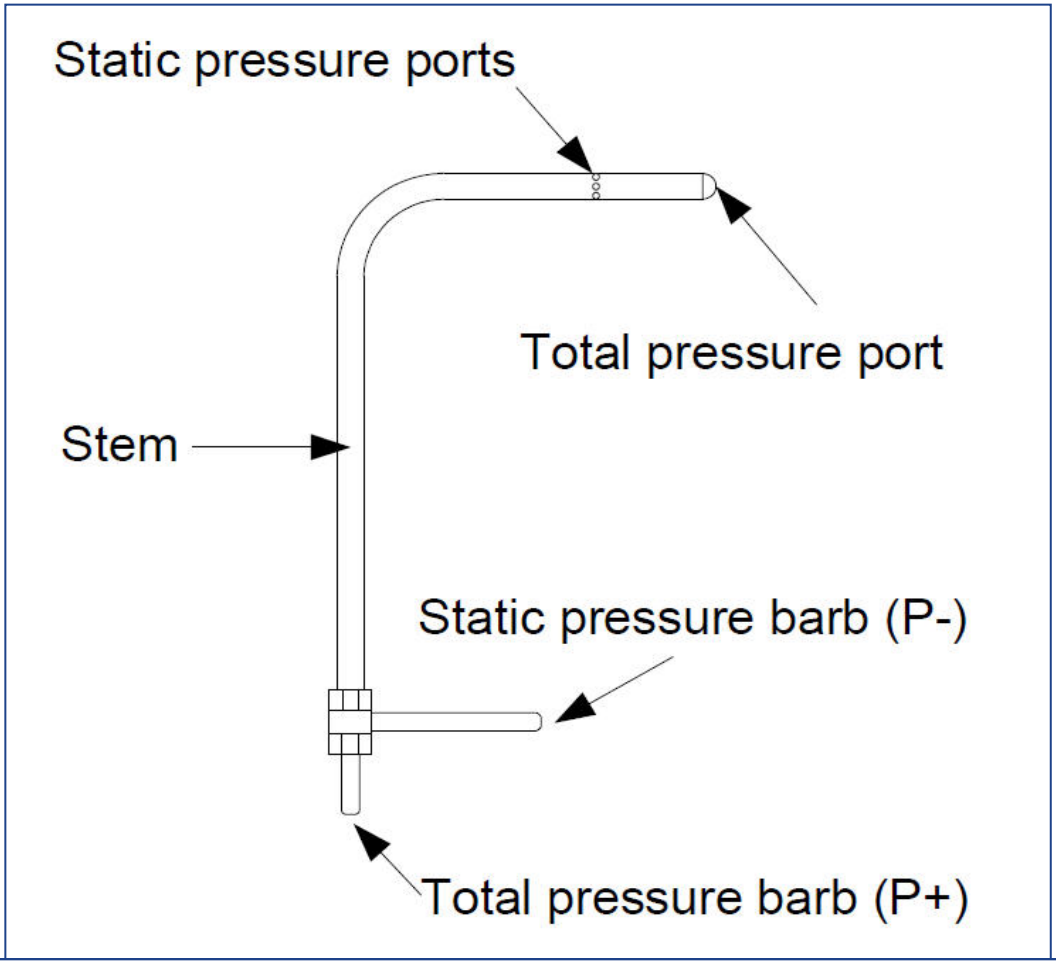
- Tip is fragile – avoid damaging it
- Relatively wide open area resists clogging
- Must correctly apply correction factor when analyzing data
- Requires double correction when measuring static pressure –
  - Standard Pitot better for measuring static pressure



FKT Manometer Face



Pitôt Static for Connection to Manometer



How to Ensure Accurate Data

IMPORTANT: Write down the **pressure** data

CAUTION: To determine if the pressure in the duct is (+) or (-), **ALWAYS** connect pressure source to (+) port of the manometer.

CAUTION: Always connect tubing and probe to manometer **FIRST** before inserting the probe into the flow.

Three Measurements

Depending on how you connect the Pitot tube to the manometer, you can measure:

1. Velocity pressure P_v
2. Static pressure P_s
2. Total pressure P_t

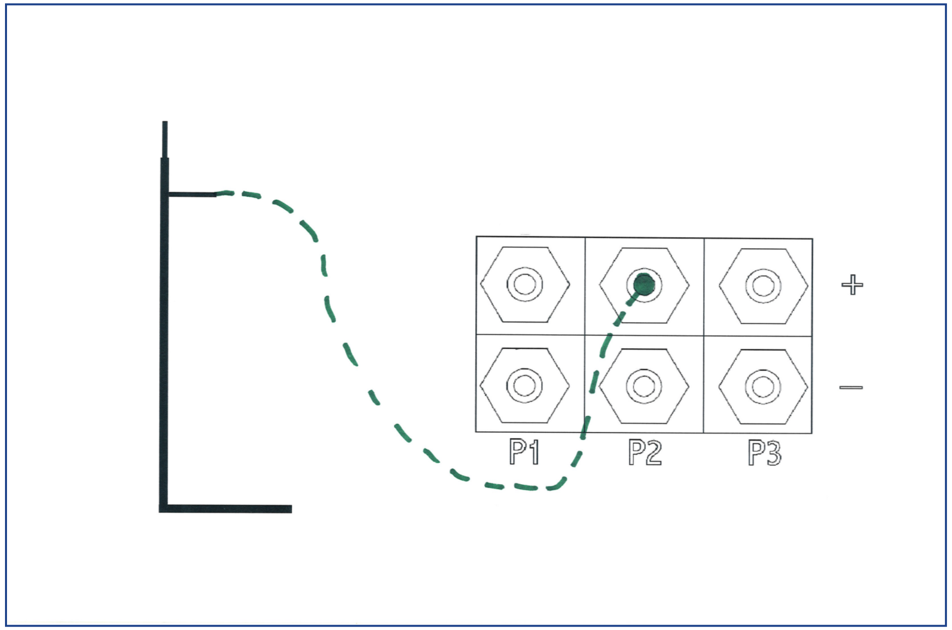
Using a manometer with three differential pressure transducers means you could simultaneously measure all three

Manometer-Pitôt Tube Connection for Static Pressure

Let's say we have a manometer with three pressure transducers:

1. Low pressure range (+/- 2 in w.g.)
2. Medium pressure range (+/- 10 in w.g.)
3. Higher pressure range (+/- 30 in. w.g.)

- Connect the plus (+) port of the manometer to the static port of the Pitôt

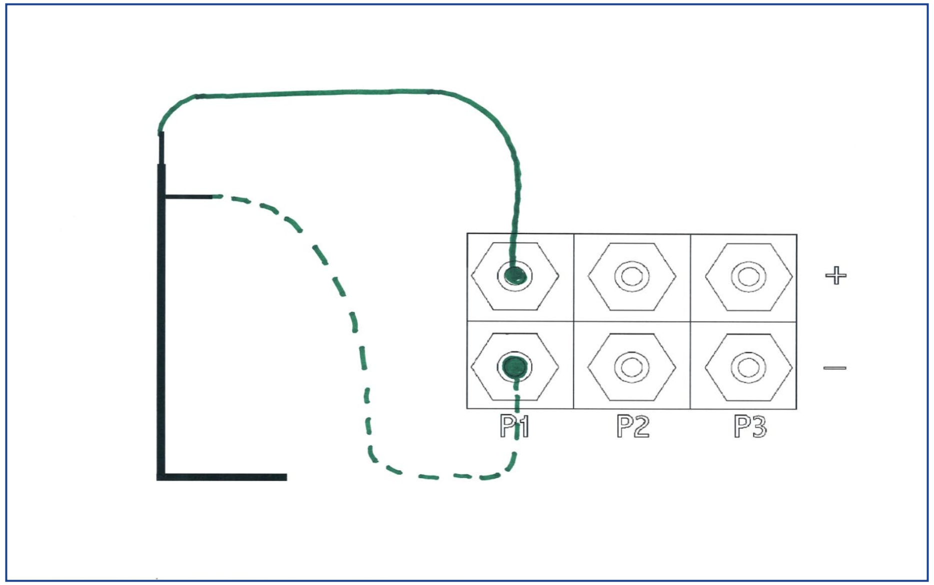


Manometer / Pitôt Tube Connection for Velocity Pressure

Remember that the velocity pressure is the total pressure *minus* the static pressure

Connect the plus port of the manometer to the total pressure port of the Pitôt

Connect the minus port of the manometer to the static port of the Pitôt



Barometers

A barometer measures the local atmospheric pressure relative to a vacuum, in units of kPa or inches of Mercury (in Hg)

Wet bulb / dry bulb temperature Psychrometer for measuring humidity

- Old-school version pictured on the right
- More modern versions are digital electronic instruments to measure temperature and humidity
- Thermocouple for dry-bulb temperature
- Wetted cloth over thermocouple probe can measure wet bulb temperature

Tachometers

Tachometers measure rotational speed in revolutions per minute of the fan and motor.

Strobe Tachometer:

Non-contact

Uses flashes of light to freeze the action of the spinning shaft.

Disadvantage: Possible to get an incorrect reading if the operator accidentally observes a harmonic frequency.

Also, direct contact and strobe type

Creating a Fan Performance Measurement Plan - Pressure

	Pressure

Where	▪ At the fan inlet, and fan outlet
	▪ Also, upstream and downstream of any elements suspected of reducing efficiency, including:
	  ▪ Dampers
	  ▪ Filters
	  ▪ Flow measuring stations
	  ▪ Poor ductwork arrangements
	▪ At every measurement plane

Creating a Fan Performance Measurement Plan - Pressure

	Pressure
How	▪ When measuring static pressure at a plane, a manometer can be connected to points on the perimeter of the duct wall. ▪ Or, use a manometer connected to the static ports of a pitot tube.

Creating a Fan Performance Measurement Plan - Pressure

	Pressure (Flow same)
When	▪ Coordinate the timing of the measurements to the process. ▪ The process must be held stable for the duration of the test (an hour), or the test should be performed at a time when the process is known to be stable. ▪ If process conditions vary, it may be necessary to take measurements for each condition. ▪ Record the state of the process when measurements are taken (e.g., damper open). ▪ Set dampers as they normally would be for the process.

Creating a Fan Performance Measurement Plan - Pressure

	Pressure
Who	▪ Determine responsibilities within the staff. ▪ An engineer should determine the measurement planes and where to drill into the ducts. ▪ Other staff should be assigned the drilling and mounting of measurement ports. ▪ All necessary safety precautions should be taken.

Creating a Fan Performance Measurement Plan - Pressure

	Pressure
Why	▪ To measure the loss across system elements. ▪ To measure the pressure rise across the fan.
So What	▪ To establish/understand process requirements and fan performance.

Creating a Fan Performance Measurement Plan - Flow

	Flow
Where	▪ In a portion of the duct that handles the full flow of the fan, and where a smooth velocity profile exists, ▪ e.g., a long run of straight duct such as on the fan inlet. ▪ Other planes where it is useful to establish a flow profile. *(more on this later)*

Creating a Fan Performance Measurement Plan - Flow

	Flow
How	▪ A measurement grid is established to measure velocity pressure using a micro-manometer and pitot tube. ▪ If the gas contains dust, an S-type pitot tube is better. ▪ The manometer needs to be sensitive enough to measure delicate velocity pressures. ▪ Flow rate is calculated from the velocity pressure measurements. *See below for more information on measurement grids.*

Creating a Fan Performance Measurement Plan - Flow

	Flow *(already covered –same as pressure)*
When	▪ Coordinate the timing of the measurements to the process. ▪ The process must be held stable for the duration of the test (an hour), or the test should be performed at a time when the process is known to be stable. ▪ If process conditions vary, it may be necessary to take measurements for each condition. ▪ Record the state of the process when measurements are taken (e.g., damper open). ▪ Set dampers as they normally would be for the process.

Creating a Fan Performance Measurement Plan - Flow

	Flow *(already covered –same as pressure)*
Who	▪ Determine responsibilities within the staff. ▪ An engineer should determine the measurement planes and where to drill into the ducts. ▪ Other staff should be assigned the drilling and mounting of measurement ports. ▪ All necessary safety precautions should be taken.

Creating a Fan Performance Measurement Plan - Flow

	Pressure
Why	▪ To establish the flow rate and quantify the air distribution within the duct.
So What	▪ To establish/understand process requirements and fan performance.

Creating a Fan Performance Measurement Plan - Power

	Power
Where	▪ Electrical Panel
How	▪ Measure motor power with a power meter, OR, ▪ Measure voltage and amperage with a voltmeter. ▪ NOTE: For voltages higher than 500V, use the ammeter mounted on the panel face.

Creating a Fan Performance Measurement Plan - Power

	Power
When	▪ A recording power meter should be used throughout the test. ▪ Otherwise, take voltmeter and ammeter readings before and after the pressure and flow measurements to verify that nothing has changed.
Who	▪ Power measurements should be performed only by a trained electrical technician with proper safety equipment. ▪ Follow established lockout/tagout procedures.

Creating a Fan Performance Measurement Plan - Power

	Power
Why	▪ To establish power input.
So What	▪ Necessary to determine operating costs.

Creating a Fan Performance Measurement Plan - Environment

	Environment • *Barometric pressure* • *Dry bulb and wet bulb temperatures* • *Fan speed*
Where	▪ *Barometric pressure* – Anywhere in the plant. ▪ *Dry bulb and wet bulb temperatures* – Usually need to be recorded within the duct a well as ambient plant conditions. ▪ *Fan and motor speed* – At the fan shaft and motor shaft.

Creating a Fan Performance Measurement Plan - Environment

	Environment • *Barometric pressure* • *Dry bulb and wet bulb temperatures* • *Fan speed*
When	▪ Read barometric pressure from a barometer or call the local airport. ▪ Use a psychrometer to obtain wet bulb and dry bulb temperatures or fashion a wet bulb thermometer from a thermocouple probe wrapped in a wetted cloth. ▪ Sometimes density in the duct can be inferred from ambient conditions. ▪ Use a tachometer to determine rotational speed of the fan & motor.

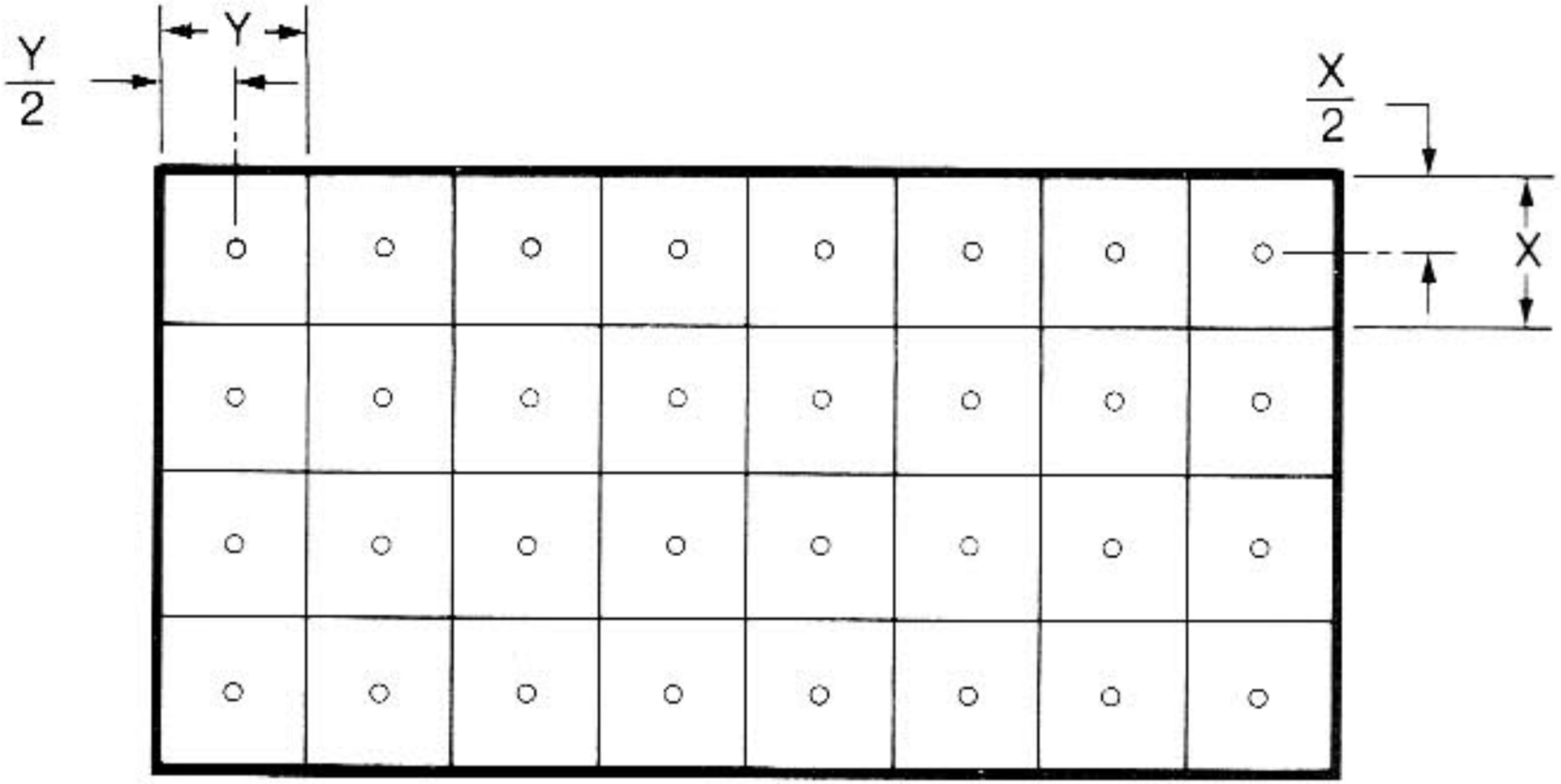
Creating a Fan Performance Measurement Plan - Environment

	Environment • *Barometric pressure* • *Dry bulb and wet bulb temperatures* • *Fan speed*
When	▪ Barometric pressure – Before and after fan measurements are made. ▪ Temperatures – Can be measured at any time. ▪ Fan speed – Can be measured at any time.

Creating a Fan Performance Measurement Plan - Environment

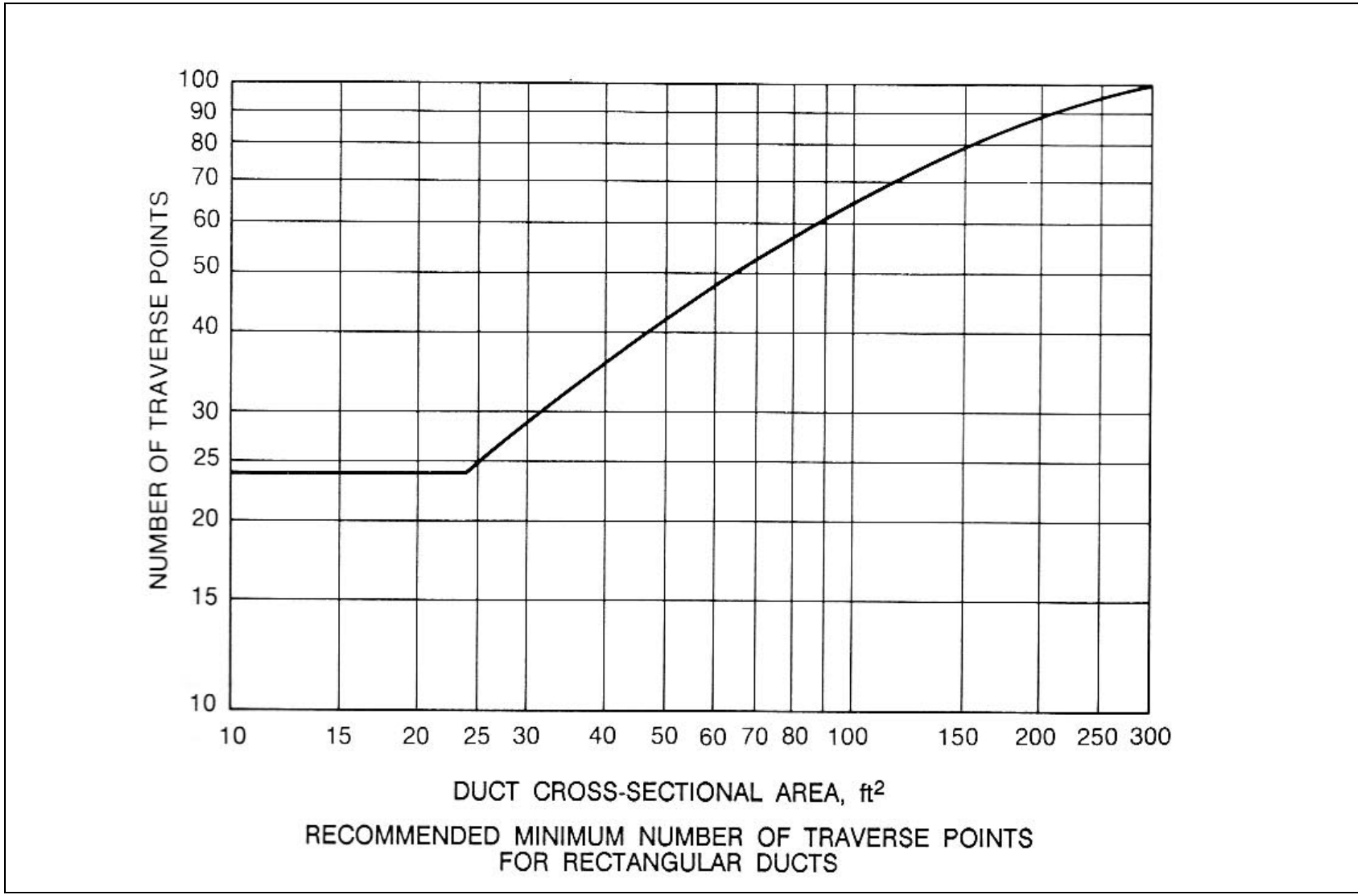
	Environment • *Barometric pressure* • *Dry bulb and wet bulb temperatures* • *Fan speed*
Who	▪ Determine responsibilities within the staff. Only staff with proper training in the use of psychrometers and tachometers should perform all measurements. All necessary safety precautions should be taken.
Why	▪ To establish gas density and fan speed.
So What	▪ Necessary inputs for fan affinity laws.

Measurement Grids – AMCA 203

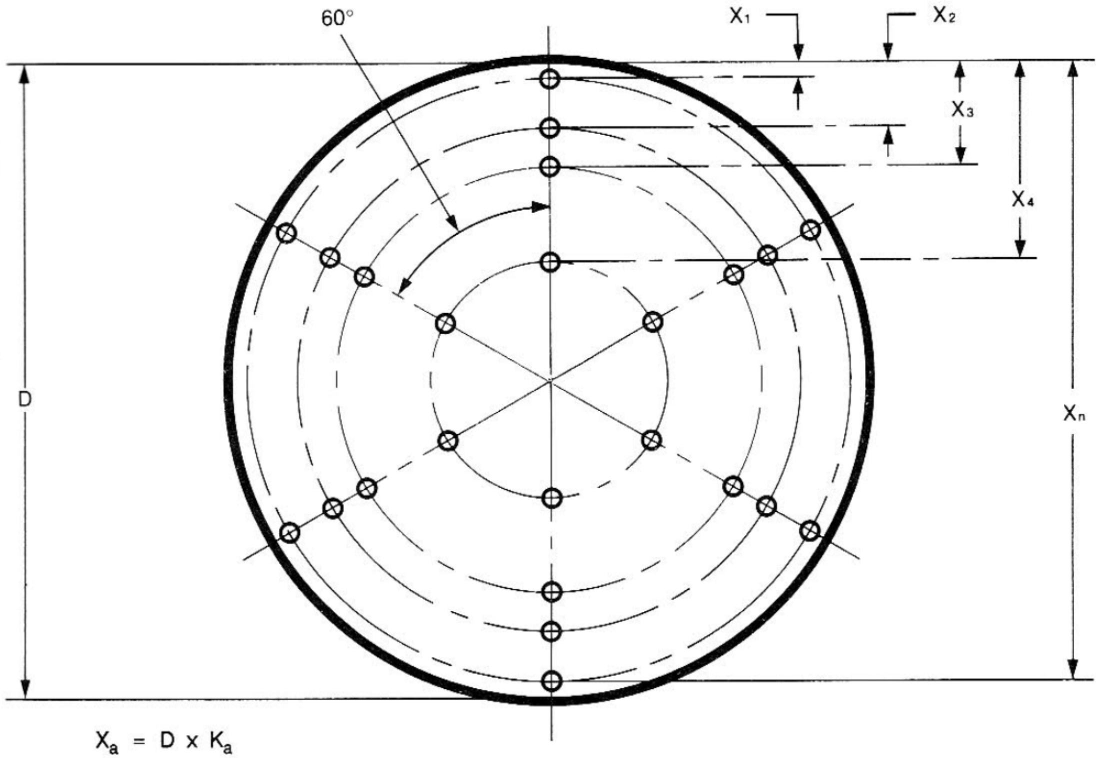


DISTRIBUTION OF TRAVERSE POINTS FOR RECTANGULAR DUCT

Measurement Grids – AMCA 203



Measurement Grids – AMCA 203



$X_a = D \times K_a$

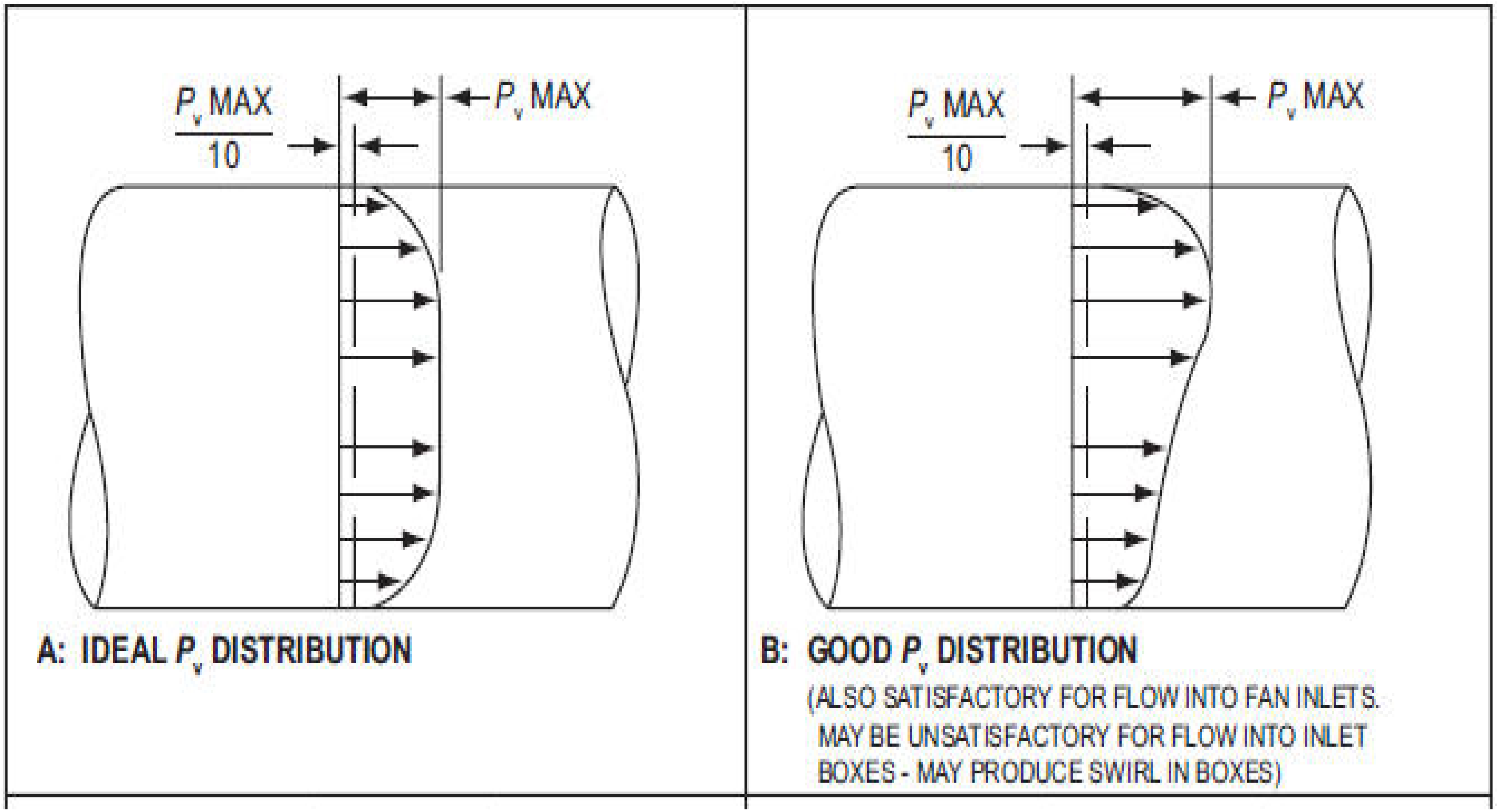
where D is the inside diameter of the duct and K_a is the factor corresponding to the duct size and the traverse point location as indicated in the table below.

INSIDE DIAMETER OF DUCT	NUMBER OF TRAVERSE POINTS IN EACH OF 3 DIAMETERS	K_1	K_2	K_3	K_4	K_5	K_6	K_7	K_8	K_9	K_{10}	K_{11}	K_{12}	K_{13}	K_{14}	K_{15}	K_{16}
LESS THAN 8 ft	8	.021	.117	.184	.345	.655	.816	.883	.979	—	—	—	—	—	—	—	—
8 ft THRU 12 ft	12	.014	.075	.114	.183	.241	.374	.626	.759	.817	.886	.925	.986	—	—	—	—
GREATER THAN 12 ft	16	.010	.055	.082	.128	.166	.225	.276	.391	.609	.724	.775	.834	.872	.918	.945	.990

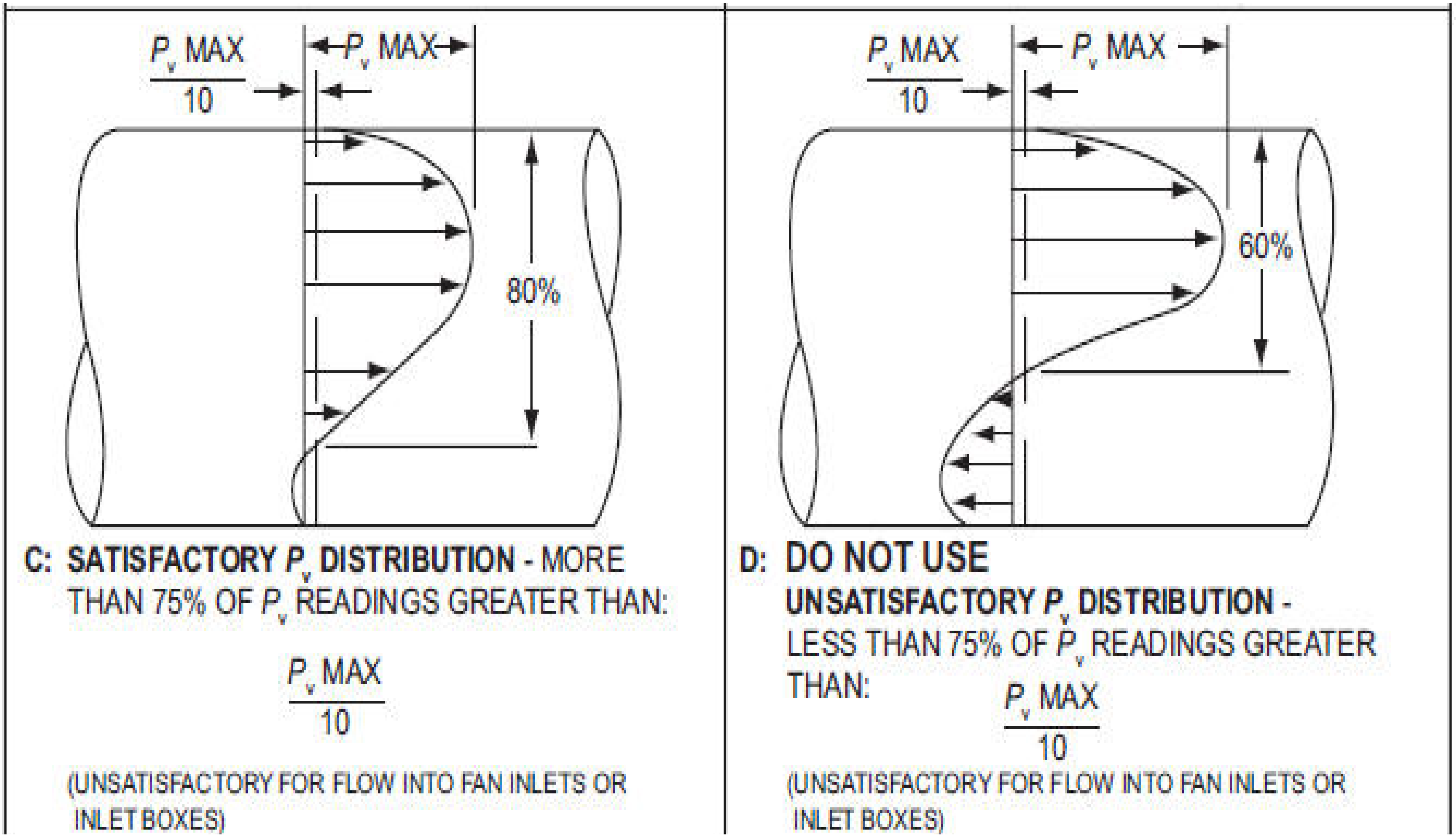
Flow Traverse Plane Criteria

1. Uniform velocity distribution
2. Flow stream at right angles to plane
3. Regular duct cross section (i.e. rectangle or circle)
4. Uniform cross section at plane (not diverging or converging)
5. If in a converging or diverging section, the plane is at the tip of the pitot tube.
6. In a section of duct unaffected by leakage
7. If at the fan discharge, then a 100% effective duct length is needed
8. If at inlet, ½ duct diameter upstream of inlet
9. If in inlet box, then 12” downstream of inlet damper trailing edge

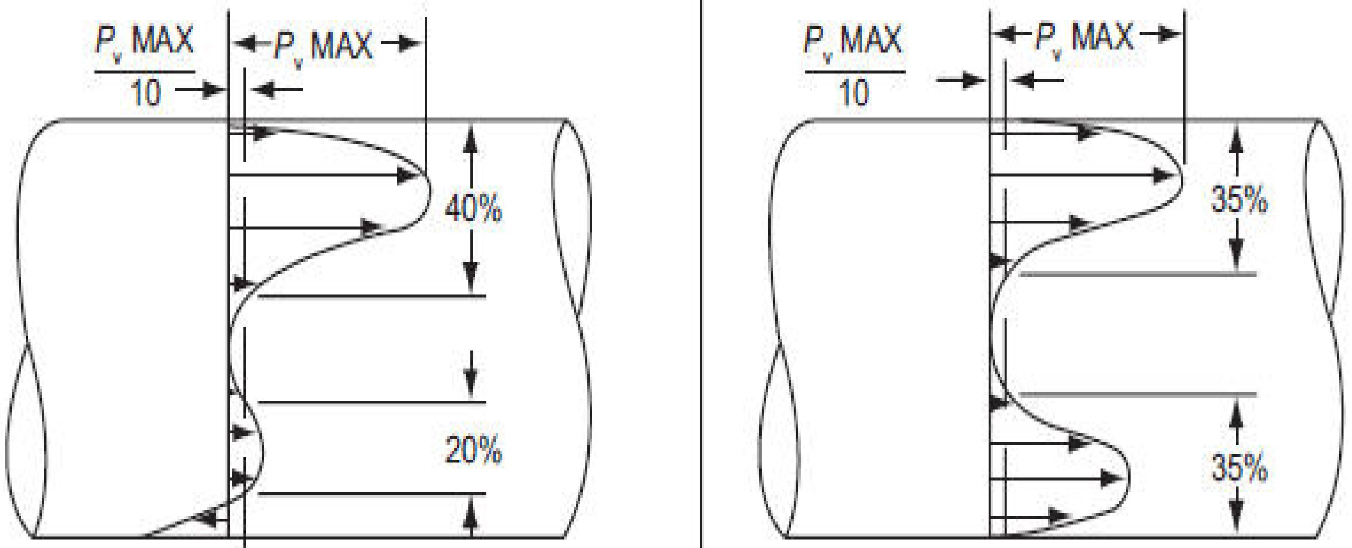
Satisfactory Velocity Pressure Distribution in Traverse Plane



Satisfactory Velocity Pressure Distribution in Traverse Plane (cont.)



Satisfactory Velocity Pressure Distribution in Traverse Plane (cont.)



E: DO NOT USE

UNSATISFACTORY P_v DISTRIBUTION

LESS THAN 75% OF P_v READINGS GREATER THAN: $\frac{P_v \text{ MAX}}{10}$

(UNSATISFACTORY FOR FLOW INTO FAN INLETS OR INLET BOXES)

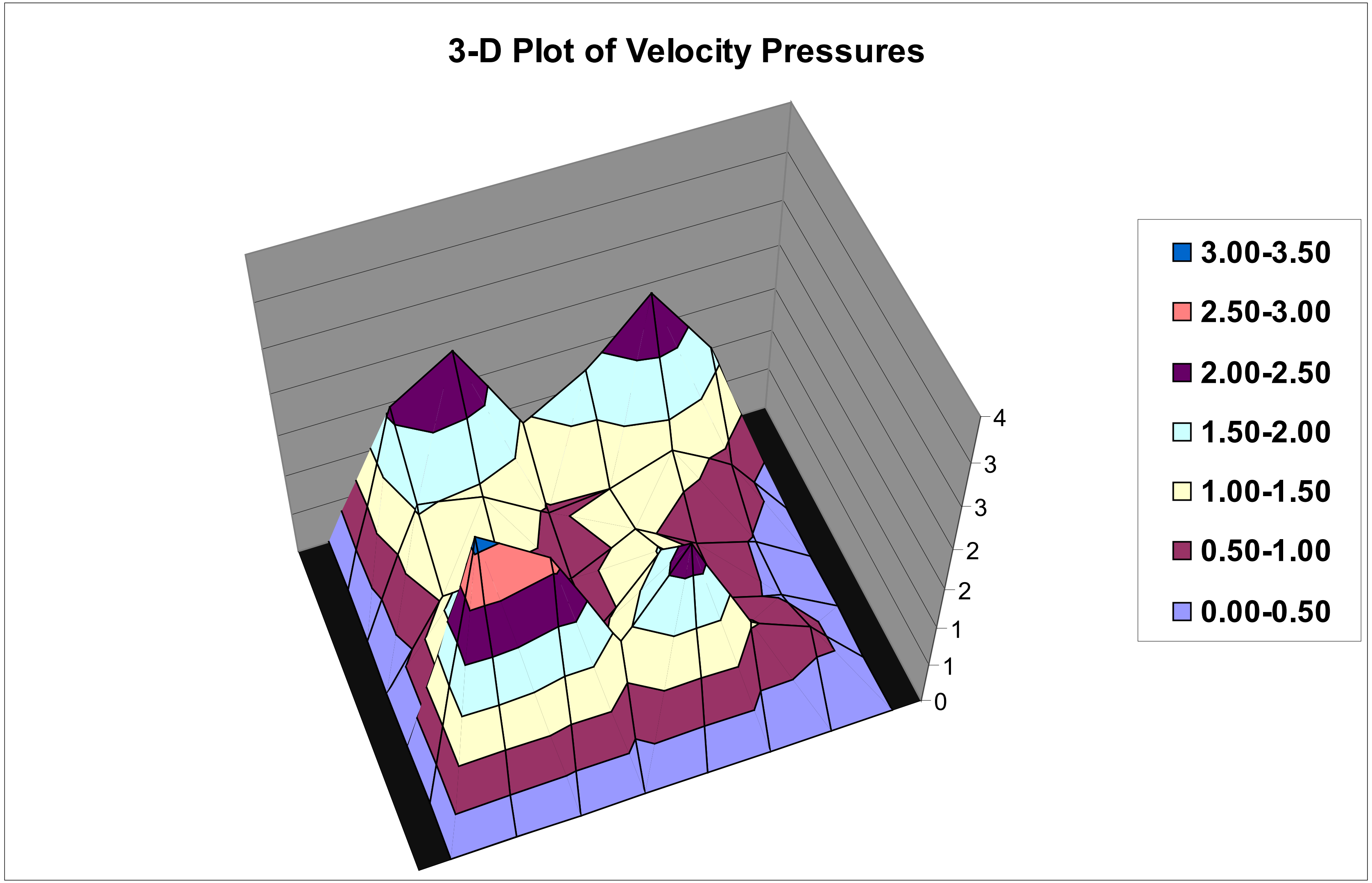
F: DO NOT USE

UNSATISFACTORY P_v DISTRIBUTION

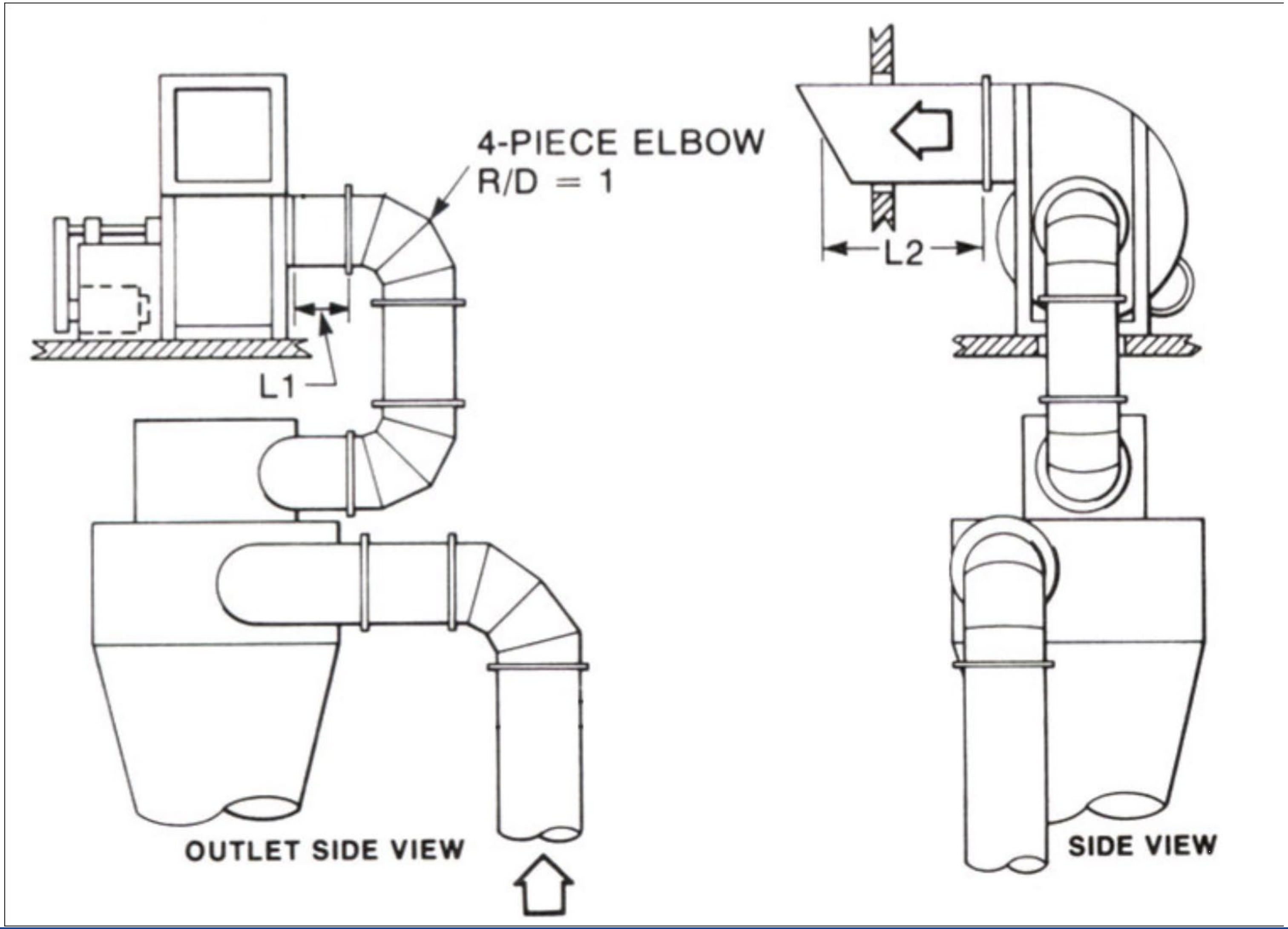
LESS THAN 75% OF P_v READINGS GREATER THAN: $\frac{P_v \text{ MAX}}{10}$

(UNSATISFACTORY FOR FLOW INTO FAN INLETS OR INLET BOXES)

Cement Plant Velocity Profile



Measurement Plan Example – Sawdust Collection System

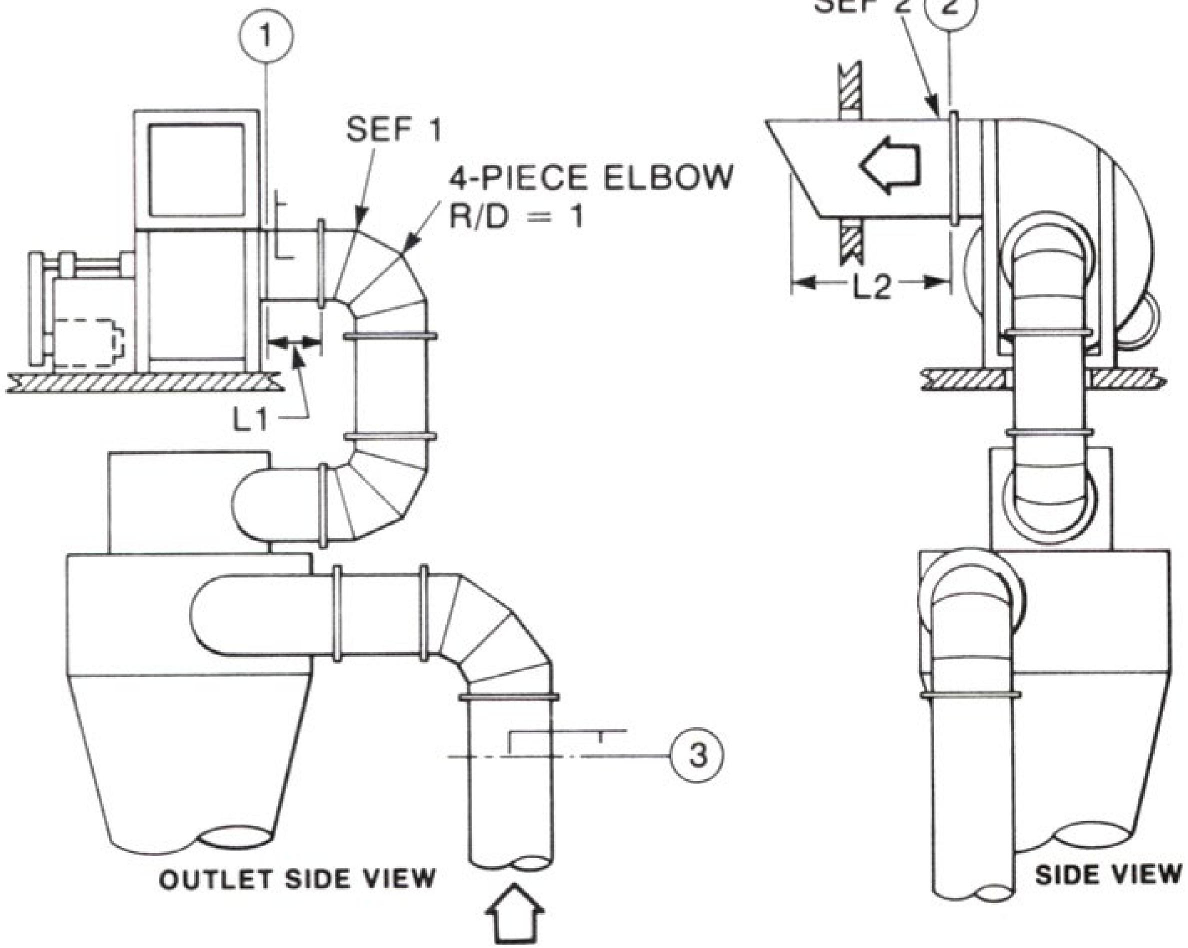


Measurement Plan Example – Sawdust Collection System

- Locate the following measurement planes on the system shown in Fig. 3-1:
  - Inlet
  - Outlet
  - Traverse
- Locate measurement planes to measure the pressure drop across the cyclone.
- Estimate the system effect at the inlet and the outlet.
  - D: 12”
  - L1: 12”
  - L2: 18”
  - Q: 3,000 cfm
  - Blast A: 0.8 ft2
  - Outlet A: 1.2 ft2

Measurement Plan Example – Sawdust Collection System - Key

Note Measurement Planes



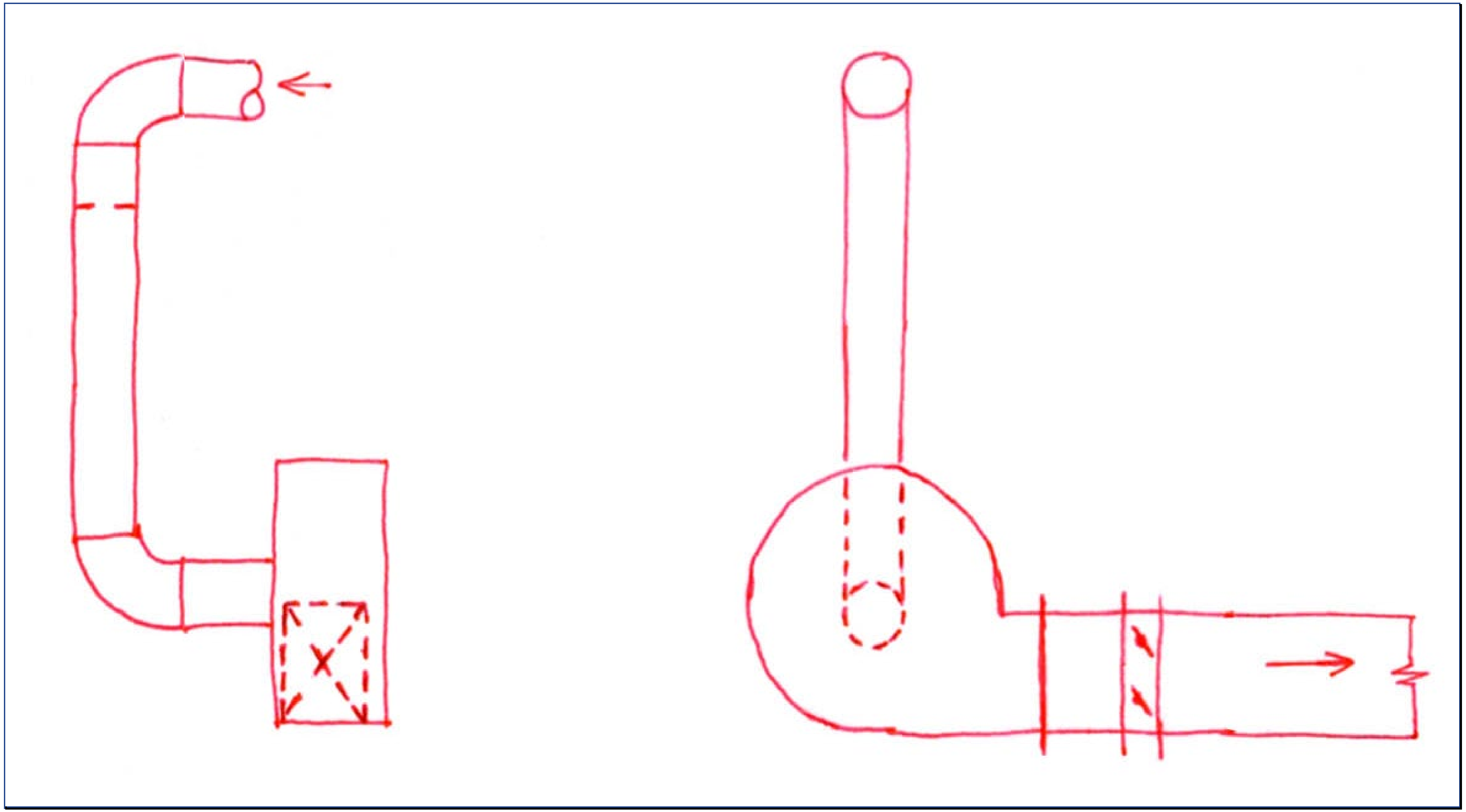
Selecting Measurement Planes Worksheet

Potential Measurement Planes:

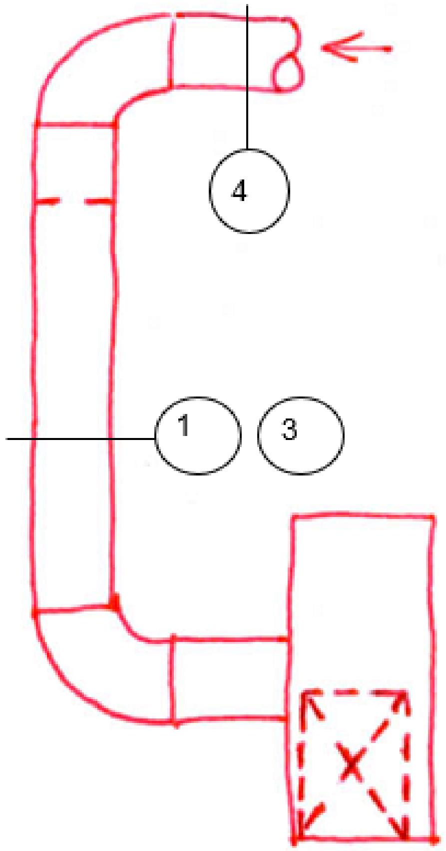
- Inlet
- Upstream of inlet damper
- Upstream of filter
- Upstream of orifice plate
- Traverse plane for flow measurement
- Number of traverse points for traverse plane for flow measurement
- Outlet
- Downstream of outlet damper
- Downstream of filter
- Downstream of orifice plate

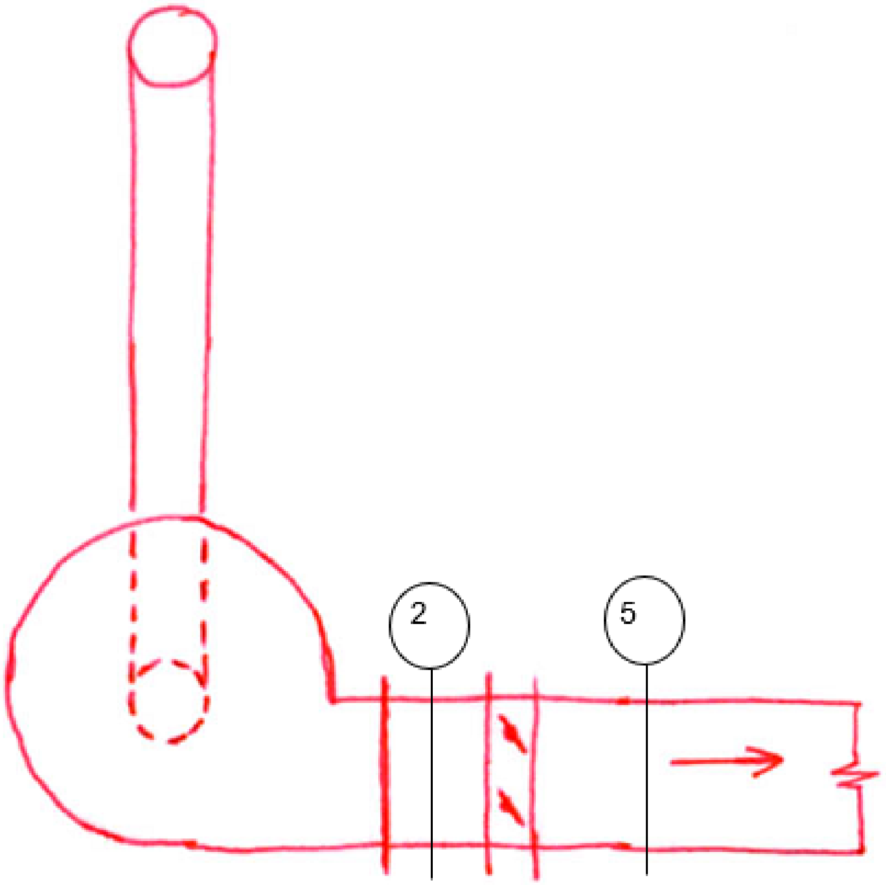
Selecting Measurement Planes Worksheet

Directions: Identify the measurement planes in Fig. 3-6:



Measurement plan for combustion air blower





Data Analysis of Combustion Air Blower

Fan System Field Data Collection Sheet	initial RW	test # 1	1 of 3
	File 1215		

FAN SYSTEM: SURFACE COMBUSTION AIR BLOWER		
Customer: OSB		
Tester: RW/FP	Test Start Time: 9:00 2/19/96	Test End Time: 10:10

PROCESS CONDITIONS

Steady 59% Dryer load - Typical

Hours operation 8,000

MOTOR NAME PLATE DATA

Manufacturer	Model/Frame
SIEMENS	HI/EFF /445T

HP	rpm	Volts	FLA	PF	EFF
125	1785	460	145	89	95.4

Data Analysis of Combustion Air Blower

FAN NAME PLATE DATA	
Manufacturer CHAMPION FAN	Model 385 HPR
Impeller Flat radial	serial 266 V92-1
rpm 2473	Impeller diameter
Notes (age and general condition) Approx 15 years old. good condition	

SYSTEM EFFECT FACTORS Estimate as per Fans and Systems, AMCA Publication 201.
SEF1 N/A
SEF2

AMBIENT CONDITIONS		DB	WB	$P_{Barometric}$
Does $P_{Barometric}$ require altitude correction? NO	pre test	65 °F	50 °F	29.45 in. Hg
Altitude —	post test	67 °F	50 °F	29.45 in. Hg

Data Analysis of Combustion Air Blower

Fan System Field Data Collection Sheet initial RW test # 1 2 of 3
file 1215

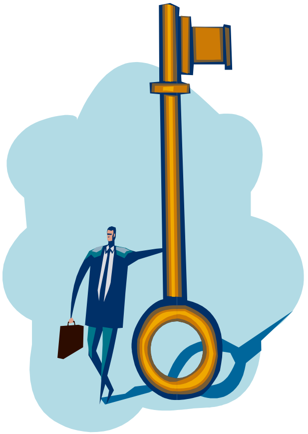
FAN AND MOTOR			A	B	C
Motor rpm	1787	Volts	460	458	462
Fan rpm	2473	Amps	104	104.4	104.2
Drive type	BELT	or kW			

TEST PLANES (show on sketch)	DB	WB	Area	P (local)
Plane #1 Fan Inlet BELOW ORIFICE SAME AS #3	°F 127.5	°F 71.7	ft² or 2.761	in. H_2O -6.850
Plane #2 Fan Outlet	°F 155	°F	ft² or l x w 1.611	in. H_2O 35.60
Plane #3 Traverse SAME AS #1	°F 127.5	°F 71.7	ft² or l x w 2.761	in. H_2O -6.850
Plane #4 Upstream	°F 127.5	°F 71.7	ft² or l x w 2.761	in. H_2O -2.95
Plane #5 Downstream	°F 155	°F	ft² or l x w 2.297	in. H_2O 10.00
Plane #6	°F	°F	ft² or l x w	in. H_2O
	°F	°F	ft² or l x w	in. H_2O

Data Analysis of Combustion Air Blower

TRAVERSE DATA velocity pressure in. w.g.										
	Points									
Ports	1	2	3	4	5	6	7	8	9	10
1	0.20	1.20	2.50	0.90	0.20	-0.05	-0.04	0.35		
2	0.30	1.50	1.90	0.40	0.10	-0.01	0.03	0.65		
3	0.10	1.90	2.20	0.40	0.20	0.20	0.50	0.70		
4										
5										
6										
7										
8										
9										
10										

Key Points / Action Items



1. *Proper selection of measurement planes is critical when setting up an in-situ fan performance test*
2. *Ideally, the traverse plane should be located in a section of duct that is at least a few diameters downstream of elbows or other flow impediments, and relatively near the fan inlet if possible.*
3. *Avoid putting the flow traverse plane on the outlet of the fan, if possible*
4. *For dusty airstreams use an S-type pitot tube and make sure you apply the correction factor*
5. *Work with a mentor to gain experience in conducting a fan test – somethings are not possible to learn from a book or a webinar – they require hands-on training.*

Homework #4

- Identify measurement planes for the system or systems that you think are best candidates for an optimization project. Take pictures, markup drawings, or make a sketch to locate:
  - the traverse plane
  - Inlet plane
  - Outlet plane
- Consider other measurement planes to measure pressure loss across elements of interest in your fan system, such as dampers, filters, orifice plates, etc.

Thank You all for attending today's webinar.

See you all on next week –

If you have specific questions, please stay online and we will try and answer them.

Alternately, you can email questions to me at ron@productiveenergy.com