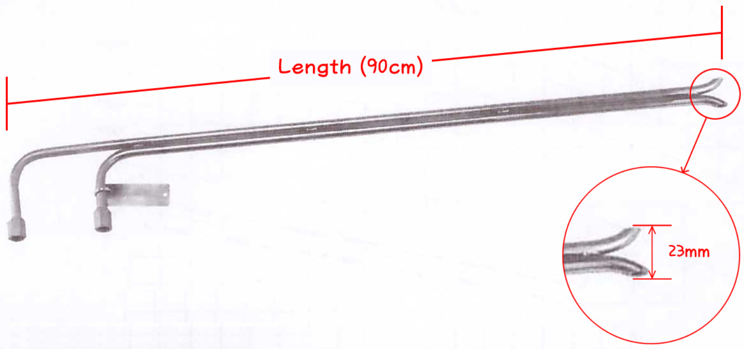
Probe for Velocity Type Pitot Tubes

Operating Instructions



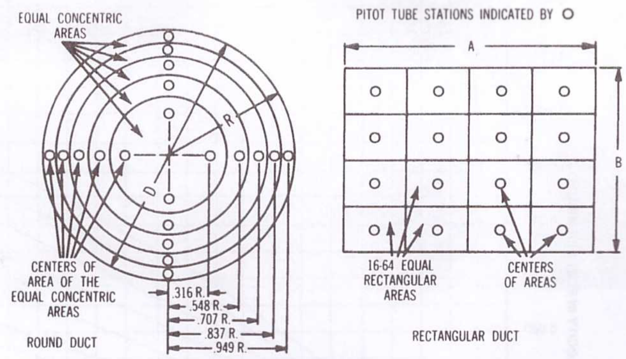


FIG. 4 – TRAVERSE ON ROUND AND SQUARE DUCT AREAS

Probe for Velocity are designed to meet the need of the environmental testing field for an inexpensive, yet accurate and reliable way to measure the flow of particulate-laden air or gas streams. These pitot tubes use large 5/16″ diameter stainless steel tubing for both total and static pressures to avoid plugging. Versatile 1/8″ female NPT connections enable use with any type of piping or tubing. Two barbed tubing adapters are included for use with 3/16″ I.D. rubber or vinyl tubing.

This instrument was built to allow measurement of flows by the procedures detailed in U.S. Environmental Protection Agency publication 40 CFR Change 1, Application A, Method 2. For complete information, refer to that publication and the procedures contained within.

INTRODUCTION

The **total pressure** of a flowing air stream in a duct or pipe is the sum of the **static** or bursting pressure exerted on the sidewalls and the **velocity** or impact pressure of the moving air. The difference between **total** and **static** pressure is called **velocity pressure**, which can be used to determine the linear rate of air movement expressed in FPM (feet per minute). A pitot tube has two tubes arranged to sense both pressures simultaneously. By connecting these two tubes differentially to a manometer, **velocity pressure** is indicated directly and the corresponding air velocity can be calculated after applying the appropriate correction factor. For maximum accuracy of ±2%, as in laboratory applications, care is required and the following recommendations should be followed.

1. Duct diameter should be 4″ or larger.
2. Point **total pressure** opening upstream facing flow and **static pressure** opening downstream pointing in the direction of the flow. The faces of both openings must be perpendicular to the airflow.
3. Make an accurate traverse per drawings; calculate the the velocities at each point and average them.
4. Take readings in a smooth, straight duct section a minimum of 8½ duct diameters in length upstream and 1½ diameters downstream from the pitot tube.
5. Provide an egg-crate type straightener upstream from the pitot tube.

TAKING AIR VELOCITY READINGS

To measure air velocity with a Probe for Pitot Tube, make a 13/16″ (20 mm) opening in side of duct. Permanent-mount models require a 1″ female NPT opening. Note: permanent mounting is not recommended with insertion lengths over 24″ (61 cm) due to risk of excessive deflection. Connect tubing from total pressure port to high pressure side of manometer and from static pressure port to the low pressure side. If reading is negative, reverse connections.

Make a series of readings traversing the duct in horizontal and vertical planes. Using velocity pressures recorded at each location, calculate velocities and average them for final velocity value. If circumstances do not permit or require an accurate traverse, center the pitot tube in the duct, determine the pressure differential (velocity pressure), calculate actual center velocity, and multiply this value by 0.9. Tests run in this manner should be accurate within ±5%.

CALCULATING VELOCITY

Air Velocity = $1096.2\,(C_p)\sqrt{\dfrac{P_V}{D}}$

where:

P_V = Sensed pressure difference (velocity pressure) in inches of water column

D = Air density in lbs./ft.³ (dry air = .075)

C_p = Pitot tube coefficient: 0.84

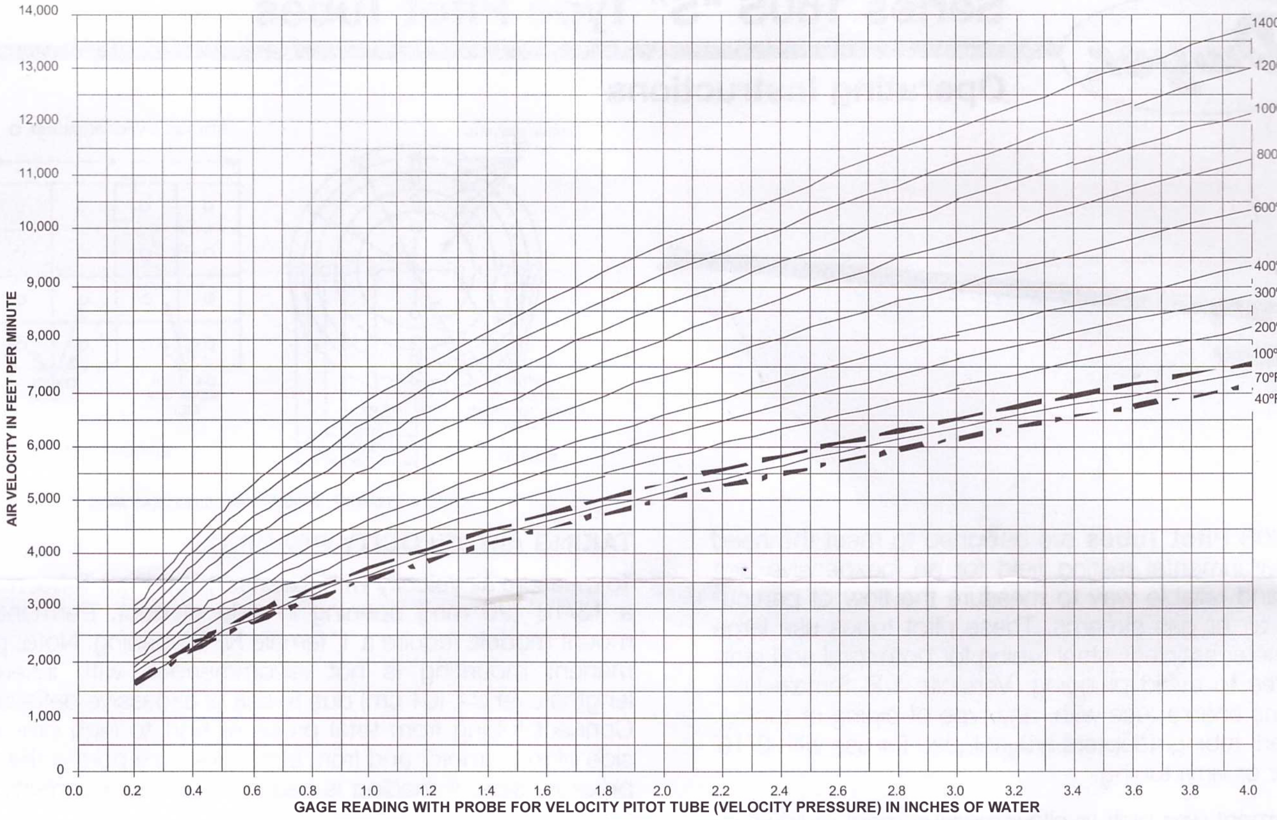
Air Density = $1.325 \times \dfrac{P_B}{T}$

P_B = Barometric pressure in inches of mercury

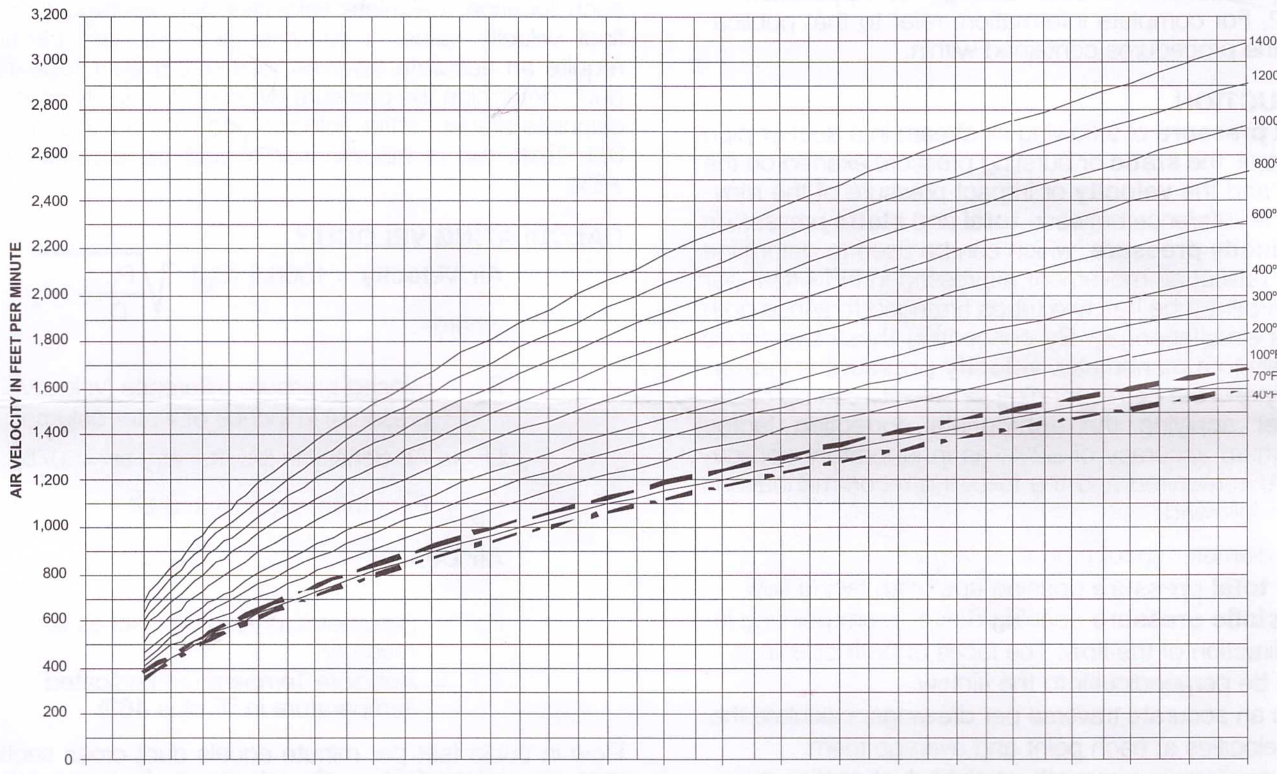
T = Absolute Temperature (Indicated Temperature in °F plus 460)

Flow in cubic feet per minute equals duct cross sectional area in square feet x air velocity in feet per minute.

With dry air at 29.9 inches of mercury, air velocity can be read directly from temperature correction charts on reverse.



AIR VELOCITY IN FEET PER MINUTE
GAGE READING WITH PROBE FOR VELOCITY PITOT TUBE (VELOCITY PRESSURE) IN INCHES OF WATER
14,000
13,000
12,000
11,000
10,000
9,000
8,000
7,000
6,000
5,000
4,000
3,000
2,000
1,000
0
0.0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
1.6
1.8
2.0
2.2
2.4
2.6
2.8
3.0
3.2
3.4
3.6
3.8
4.0
1400ºF
1200ºF
1000ºF
800ºF
600ºF
400ºF
300ºF
200ºF
100ºF
70ºF
40ºF



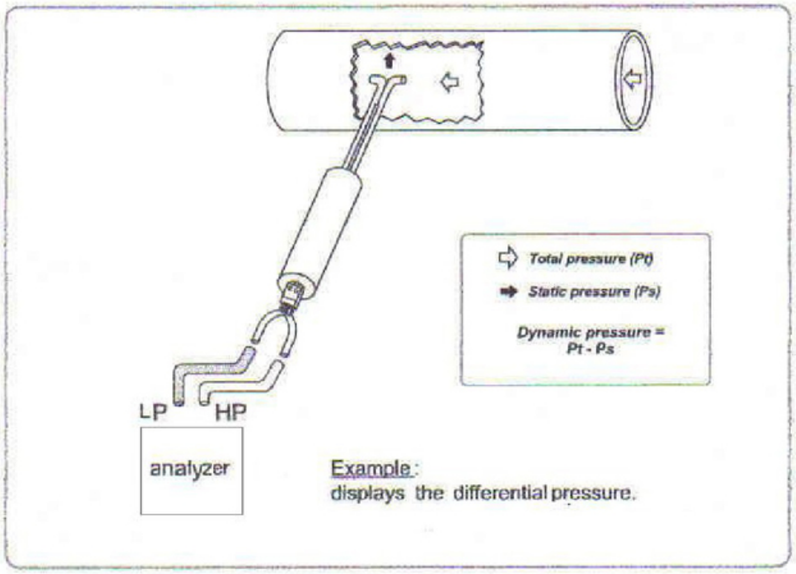
AIR VELOCITY IN FEET PER MINUTE
GAGE READING WITH PROBE FOR VELOCITY PITOT TUBE (VELOCITY PRESSURE) IN INCHES OF WATER
3,200
3,000
2,800
2,600
2,400
2,200
2,000
1,800
1,600
1,400
1,200
1,000
800
600
400
200
0
0.00
0.01
0.02
0.03
0.04
0.05
0.06
0.07
0.08
0.09
0.10
0.11
0.12
0.13
0.14
0.15
0.16
0.17
0.18
0.19
0.20
1400ºF
1200ºF
1000ºF
800ºF
600ºF
400ºF
300ºF
200ºF
100ºF
70ºF
40ºF

OPERATING

The Pitot tube must be introduced perpendicularly into the duct, in several points pre-determined.
The holes must be made in proper alignment to the line of the air or gas flow.
Compared to the Pitot tube L, the Pitot tube S is much more sensitive to wrong alignments.

Taking into account that the Pitot tube is symetrical, it is no use to identify the 2 legs. However, it is important to connect the instrument as follows :

- the leg facing the air flow must be connected to the + sign of the micromanometer
- the leg opposite to the air flow must be connected to the - sign of the micromanometer.



With the dynamic pressure in mm H_2O or in Pa, we can calculate the air velocity in m/s, with the simplified BERNOULLI formula :

$$\mathbf{V} \text{ in m/s at 20 °C : } \mathbf{K} \times \sqrt{\frac{\mathbf{2}}{\delta} \times \Delta \mathbf{P} \text{ in Pa}}$$

Formula to get the velocity, with temperature balancing of the airflow :

$$\mathbf{V} \text{ in m/s } = \mathbf{K} \times \sqrt{\frac{\mathbf{574{,}2\,\theta + 156842{,}77}}{\mathbf{\mathit{Po}}}} \times \sqrt{\Delta \mathbf{P} \text{ in Pa}}$$

With :

Po = barometric pressure in Pa
θ = temperature in °C
δ = volumic mass
K = coefficient of the Pitot tube

Velocity Calculation

The basic formula is as follows:

$$V = K \times C \times \sqrt{\Delta P} \times \frac{\sqrt{Tstack + 273}}{\sqrt{M \times P}}$$

where

- V = stack gas velocity (m/s)
- K = pitot tube velocity constant (34.97)
- C = velocity pressure coefficient (for S-type pitot=0.84) (dimensionless)
- $\sqrt{\Delta P}$ = square root of differential pressure of stack gas (mmH_20)
- Tstack = stack temperature (°C)
- M = molecular weight of stack gas, wet basis (g/g mole)
- P = absolute stack gas pressure (mm.Hg)

K

K is the velocity constant for pitot tubes and is set to 34.97.

C

C is the velocity pressure coefficient and for S type pitot tubes is around 0.84. This parameter should be adjusted for the individual pitot tubes used in the specific application.

Molecular Weight

M is the molecular weight of the stack gas on a wet basis in g/g mole. To calculate this value the component of the stack gas must be known. In general the main components are CO_2, O_2 and N_2 plus water. The dry weight is calculated by:

$$Mdry = 44\frac{\%CO_2}{100} + 32\frac{\%O_2}{100} + 28\frac{\%CO}{100} + 28\frac{\%N_2}{100}$$

When

- Mdry = dry molecular weight of stack gas (g/g mole)
- $\%CO_2$ = percentage CO_2 in gas stream
- $\%O_2$ = percentage O2 in gas stream
- %CO = percentage CO in gas stream
- $\%N_2$ = percentage N_2 in gas stream
- 44 = molecular weight of carbon dioxide (g/g mole)
- 32 = molecular weight of oxygen (g/g mole)
- 28 = molecular weight of carbon monoxide and nitrogen (g/g mole)

This can then be converted to a wet basis by:

$$Mwet = Mdry(1 - B_{wo}) + 18(B_{wo})$$

When

- Mwet = wet molecular weight of stack gas (g/g mole)
- Mdry = dry molecular weight of stack gas (g/g mole)
- B_{wo} = proportional of water vapor in the gas stream by volume
- 18 = molecular weight of water in (g/g mole)