How to Correctly Determine Dust Scrubber Air Quantity

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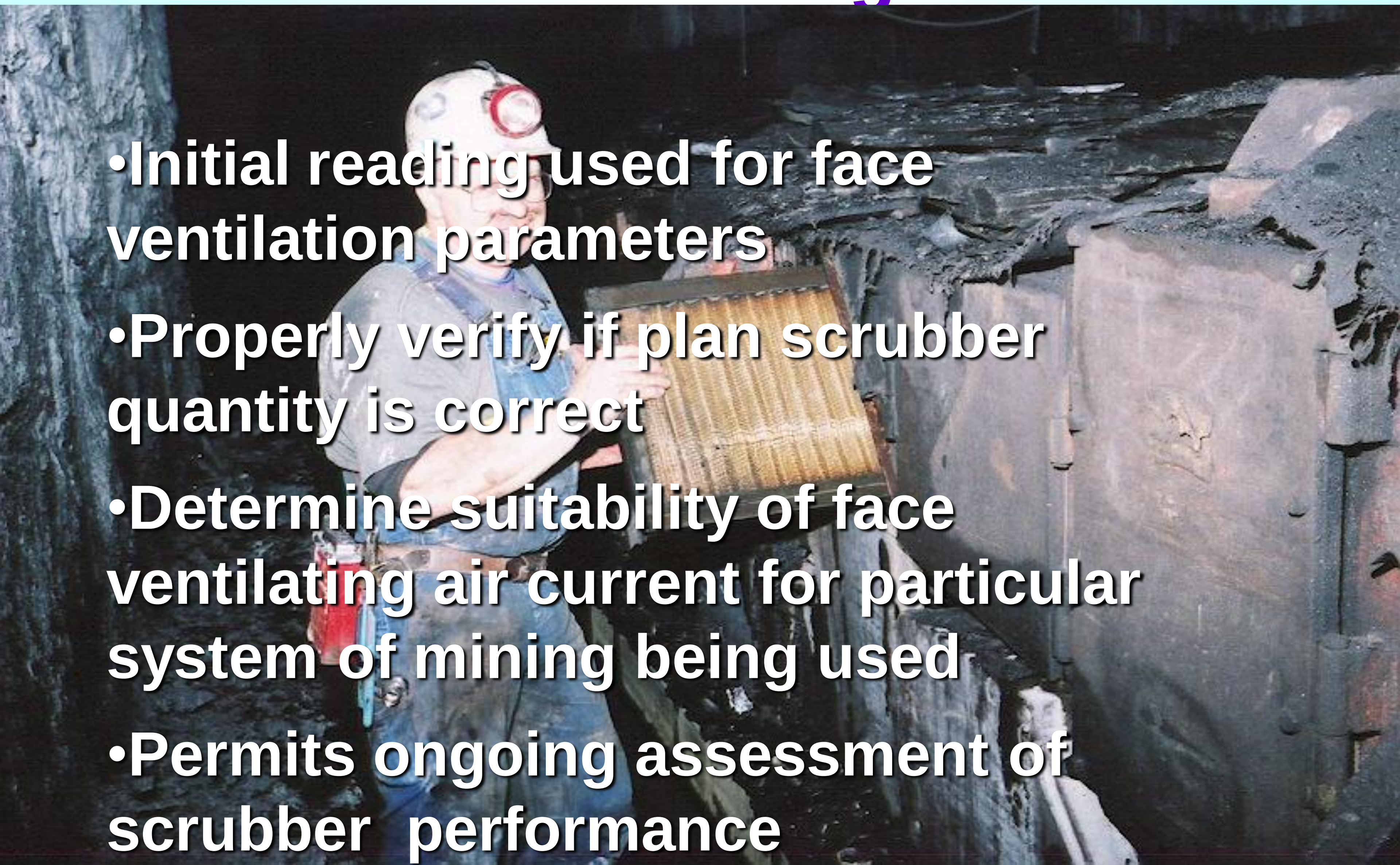
Purpose

Establish uniformity in performing pitot tube traverse measurements to correctly determine the scrubber flow rate.

Importance of Accurate Scrubber Air Readings



- Initial reading used for face ventilation parameters
- Properly verify if plan scrubber quantity is correct
- Determine suitability of face ventilating air current for particular system of mining being used
- Permits ongoing assessment of scrubber performance

Equipment Requirements

- Pitot Tube of Proper Length
  - Good Condition
    - All ports open
    - Tip of nose free from nicks and burrs
- Magnehelic Gauge w/ Hoses
  - Calibrated
  - Oriented in proper position
- Tape Measure
  - Preferably in feet

Pitot Tube

- Rugged
- Does not need to be calibrated
- Very accurate for velocities above 800 fpm

You Won’t Measure This (176,000 fpm)
(2,000 mph)

Air Velocity Measurements Using the Pitot Tube

Pitot Tube used to measure air velocities in high velocity areas. (>2000 fpm)

1. Vane anemometers can be damaged in high velocities
2. Pitot Tube is more accurate at higher velocities

Velocity, fpm	% Error (±)
4000	0.25
3000	0.3
2000	1.0
1000	4.0
800	6.0
600	15.0

Pitot Tubes Used in Coal Mines

1. Main Mine Fans
2. Auxilary Fans
3. Ventilation Tubing
4. Scrubbers

Pitot Tube

- Device measures
  - Static Pressure
  - Total Pressure
- Difference between Static and Total Pressure is called **Velocity Pressure**
- **Velocity Pressure** is used to determine **Air Velocity**

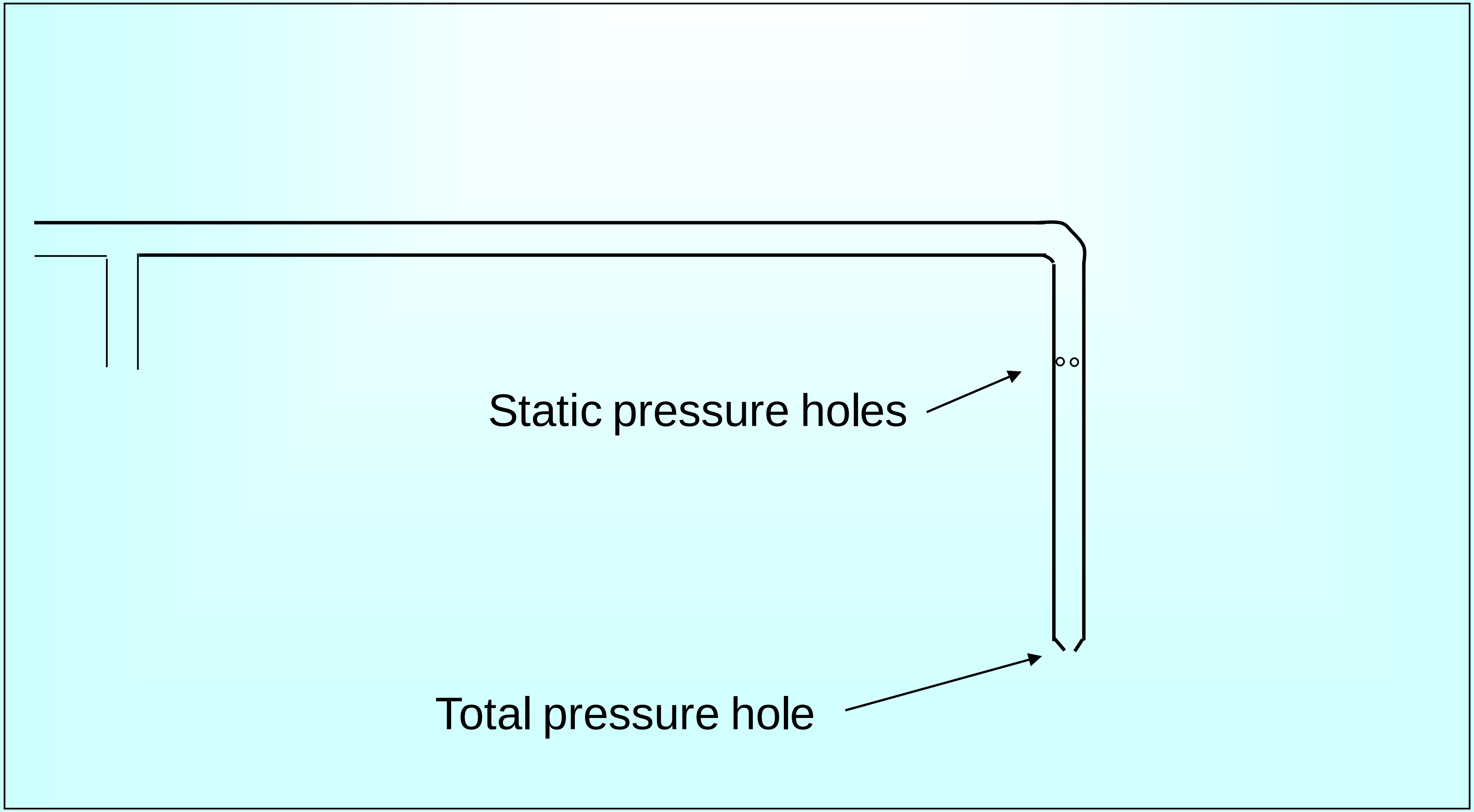
What Does a Pitot Tube Measure?

- **Static Pressure (S_p)** – The pressure in the system that tends to burst (positive pressure) or collapse (negative pressure) the walls of a system. It is the potential energy of the system.
- **Velocity Pressure (V_p)** – The pressure required to accelerate air from zero to the velocity of the system at a particular point. It is the kinetic energy in the system.
- **Total Pressure (T_p)** – The sum of the Static Pressure and the Velocity Pressure. Air will always travel from an area of higher Total Pressure to a region of lower Total Pressure.

- $T_p = S_p + V_p$

$$V_p = T_p - S_p$$

Velocity Pressure = Total Pressure – Static Pressure



Converting Velocity Pressures to Velocities (fpm)

$$\text{Velocity} = 4005\sqrt{V_p}$$

Velocity Pressure Conversion Table

Velocity Pressure Conversion

VP	V	VP	V	VP	V	VP	V	VP	V	VP	V
0.01	401	0.51	2860	1.01	4025	1.51	4921	2.01	5678	2.60	6458
0.02	566	0.52	2888	1.02	4045	1.52	4938	2.02	5692	2.70	6581
0.03	694	0.53	2916	1.03	4065	1.53	4954	2.03	5706	2.80	6702
0.04	801	0.54	2943	1.04	4084	1.54	4970	2.04	5720	2.90	6820
0.05	896	0.55	2970	1.05	4104	1.55	4986	2.05	5734	3.00	6937
0.06	981	0.56	2997	1.06	4123	1.56	5002	2.06	5748	3.10	7052
0.07	1060	0.57	3024	1.07	4143	1.57	5018	2.07	5762	3.20	7164
0.08	1133	0.58	3050	1.08	4162	1.58	5034	2.08	5776	3.30	7275
0.09	1202	0.59	3076	1.09	4181	1.59	5050	2.09	5790	3.40	7385
0.10	**1266**	**0.60**	**3102**	**1.10**	**4200**	**1.60**	**5066**	**2.10**	**5804**	**3.50**	**7493**
0.11	1328	0.61	3128	1.11	4220	1.61	5082	2.11	5818	3.60	7599
0.12	1387	0.62	3154	1.12	4238	1.62	5098	2.12	5831	3.70	7704
0.13	1444	0.63	3179	1.13	4257	1.63	5113	2.13	5845	3.80	7807
0.14	1499	0.64	3204	1.14	4276	1.64	5129	2.14	5859	3.90	7909
0.15	1551	0.65	3229	1.15	4295	1.65	5145	2.15	5872	4.00	8010
0.16	1602	0.66	3254	1.16	4314	1.66	5160	2.16	5886	4.10	8110
0.17	1651	0.67	3278	1.17	4332	1.67	5176	2.17	5900	4.20	8208
0.18	1699	0.68	3303	1.18	4351	1.68	5191	2.18	5913	4.30	8305
0.19	1746	0.69	3327	1.19	4369	1.69	5207	2.19	5927	4.40	8401
0.20	**1791**	**0.70**	**3351**	**1.20**	**4387**	**1.70**	**5222**	**2.20**	**5940**	**4.50**	**8496**
0.21	1835	0.71	3375	1.21	4406	1.71	5237	2.21	5954	4.60	8590
0.22	1879	0.72	3398	1.22	4424	1.72	5253	2.22	5967	4.70	8683
0.23	1921	0.73	3422	1.23	4442	1.73	5268	2.23	5981	4.80	8775
0.24	1962	0.74	3445	1.24	4460	1.74	5283	2.24	5994	4.90	8865
0.25	2003	0.75	3468	1.25	4478	1.75	5298	2.25	6007	5.00	8955
0.26	2042	0.76	3491	1.26	4496	1.76	5313	2.26	6021	5.50	9393
0.27	2081	0.77	3514	1.27	4513	1.77	5328	2.27	6034	6.00	9810
0.28	2119	0.78	3537	1.28	4531	1.78	5343	2.28	6047	6.50	10211
0.29	2157	0.79	3560	1.29	4549	1.79	5358	2.29	6061	7.00	10596
0.30	**2194**	**0.80**	**3582**	**1.30**	**4566**	**1.80**	**5373**	**2.30**	**6074**	**7.50**	**10968**
0.31	2230	0.81	3605	1.31	4584	1.81	5388	2.31	6087	8.00	11328
0.32	2266	0.82	3627	1.32	4601	1.82	5403	2.32	6100	8.50	11676
0.33	2301	0.83	3649	1.33	4619	1.83	5418	2.33	6113	9.00	12015
0.34	2335	0.84	3671	1.34	4636	1.84	5433	2.34	6126	9.50	12344
0.35	2369	0.85	3692	1.35	4653	1.85	5447	2.35	6140	10.00	12665
0.36	2403	0.86	3714	1.36	4671	1.86	5462	2.36	6153	10.50	12978
0.37	2436	0.87	3736	1.37	4688	1.87	5477	2.37	6166	11.00	13283
0.38	2469	0.88	3757	1.38	4705	1.88	5491	2.38	6179	11.50	13582
0.39	2501	0.89	3778	1.39	4722	1.89	5506	2.39	6192	12.00	13874
0.40	**2533**	**0.90**	**3799**	**1.40**	**4739**	**1.90**	**5521**	**2.40**	**6205**	**12.50**	**14160**
0.41	2564	0.91	3821	1.41	4756	1.91	5535	2.41	6217	13.00	14440
0.42	2596	0.92	3841	1.42	4773	1.92	5549	2.42	6230	13.50	14715
0.43	2626	0.93	3862	1.43	4789	1.93	5564	2.43	6243	14.00	14985
0.44	2657	0.94	3883	1.44	4806	1.94	5578	2.44	6256	14.50	15251
0.45	2687	0.95	3904	1.45	4823	1.95	5593	2.45	6269	15.00	15511
0.46	2716	0.96	3924	1.46	4839	1.96	5607	2.46	6282	15.50	15768
0.47	2746	0.97	3944	1.47	4856	1.97	5621	2.47	6294	16.00	16020
0.48	2775	0.98	3965	1.48	4872	1.98	5636	2.48	6307	16.50	16268
0.49	2804	0.99	3985	1.49	4889	1.99	5650	2.49	6320	17.00	16513
0.50	**2832**	**1.00**	**4005**	**1.50**	**4905**	**2.00**	**5664**	**2.50**	**6332**	**17.50**	**16754**

$V = 4005 \times \sqrt{VP}$ V = Velocity in fpm   VP = Velocity Pressure "WG

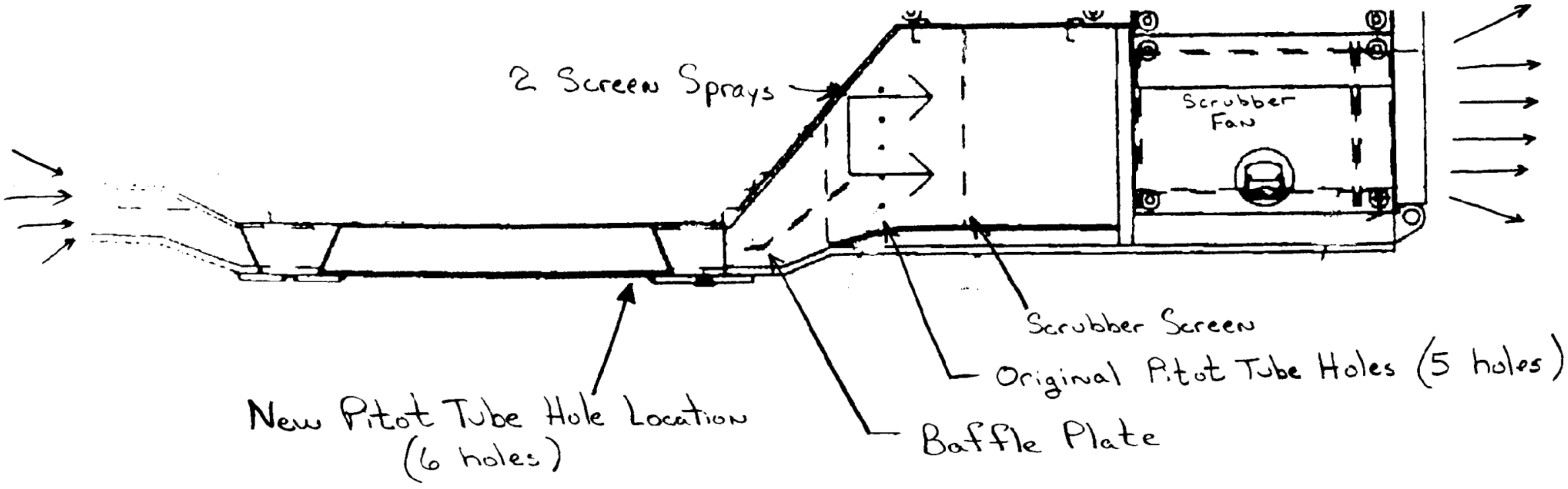
Why Not Use a Vane Anemometer?

- According to the ACGIH Industrial Ventilation Recommended Practice
  - This instrument is accurate to determine air flow through large supply and exhaust openings
  - The cross-sectional area of the instrument should not exceed 5% of the measured area.
  - Standard 4” anemometer is unsuited for measurements in ducts below 20” diameter
  - Generally, useful range is below 3,000 fpm
  - Pitot tube has less error at higher velocities!

Taking Velocity Readings

- Get CM in Good Location
  - Scrubber test ports must be accessible for pitot tube insertion (away from ribs and glory hole in low coal)
  - Inlets and exhaust of scrubber unobstructed
    - Raise cutterhead
- Clean screen and duct work
- Locate scrubber test ports
  - Locate test ports at the best possible location
    - Look for longest unobstructed straight airflow area
    - May not be where OEM installed ports
  - Loosen bolts

Example of Poor Sample Location



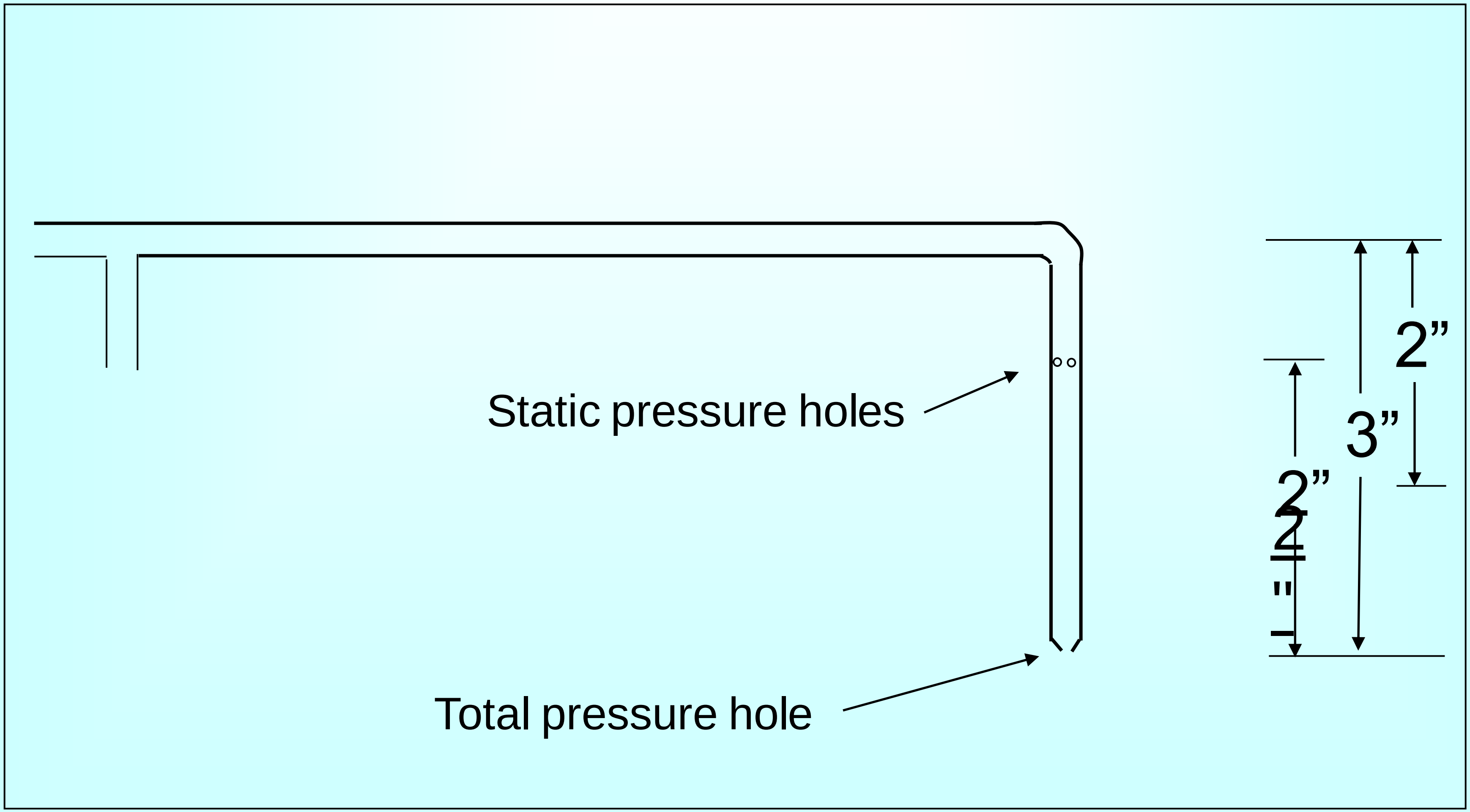
Original Sample Location				
#1 Port	**#2 Port**	**#3 Port**	**#4 Port**	**#5 Port**
0.55	0.05	0	0	0
1.05	0.05	0.20	0.10	0.10
1.25	0.80	1.35	0.10	0.05

New Sample Location					
#1 Port	**#2 Port**	**#3 Port**	**#4 Port**	**#5 Port**	**#6 Port**
0.75	0.70	0.70	0.75	0.86	0.86
0.55	0.65	0.70	0.75	0.88	0.90
0.50	0.65	0.65	0.75	0.86	0.90

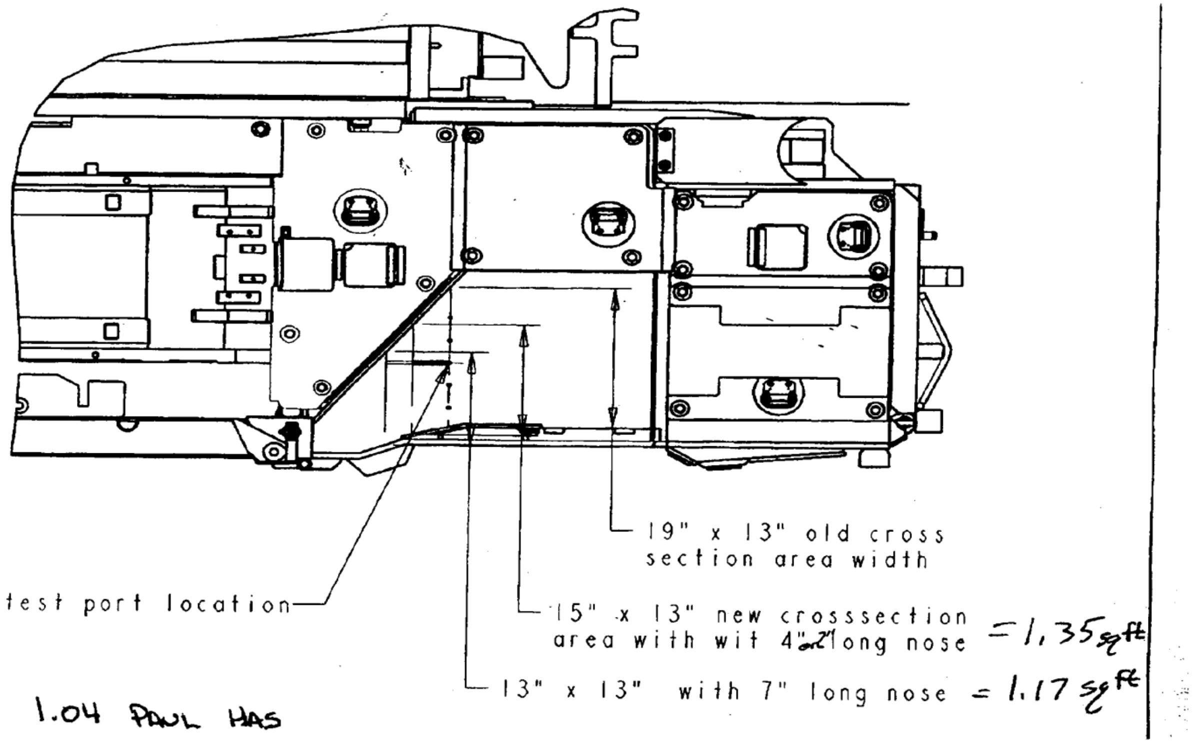
Determine Area at Sampled Location

- Obtain the duct cross-sectional area at location where pitot tube takes measurements:
  - Measured location is inby test port location
  - Short nose pitot tube has 3” from sample holes to tip
    - Measured Area is at location between total pressure port and static pressure port.
      - Short nose pitot tube has 2 inches between total and static ports. Therefore measured area is 2 inches inby sample port locations on the CM
  - Measure depth and width Area = depth X width

Short Nose Pitot Tube Measurements



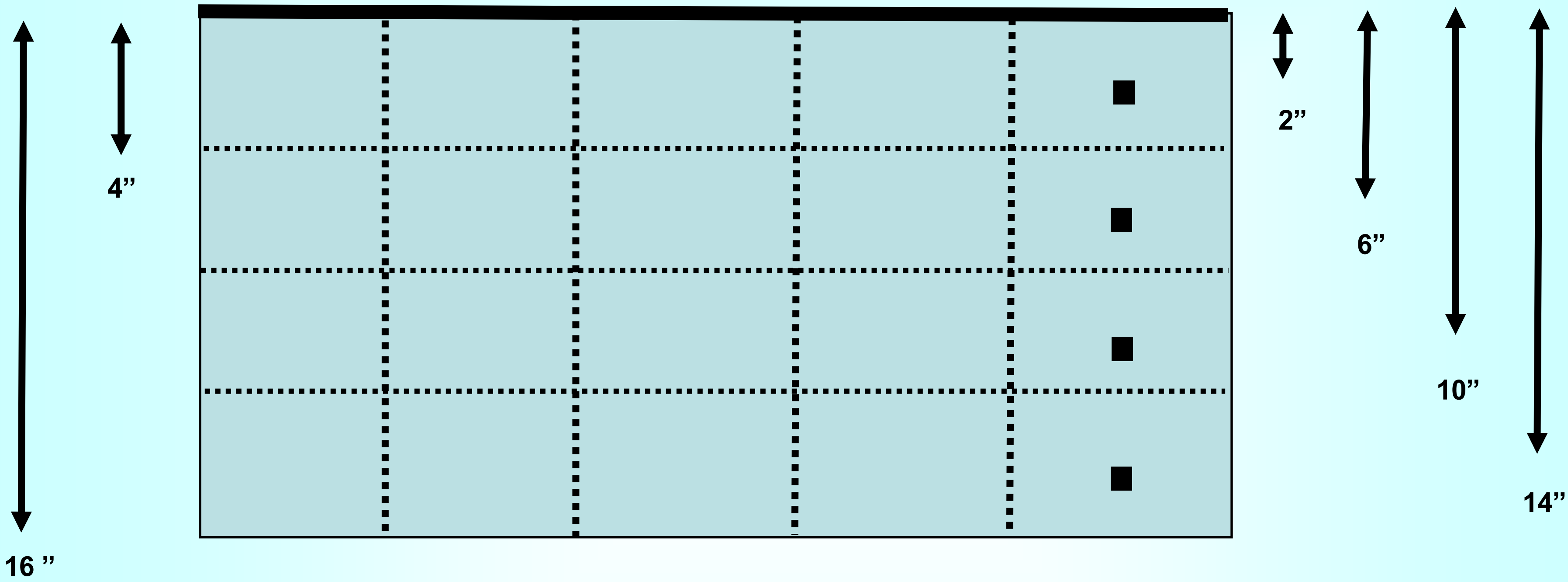
Example of Different Areas for Different Pitot Tubes Used



Depths of Traverse Readings

- Decide how many readings to take per test port
  - **Minimum of 14 readings** are needed for a proper full pitot tube traverse
  - Determine how many quadrants will be sampled
- Determine the depth of each quadrant
    - Depth / Number of readings
      - Depth is 16 inches, 4 readings per port
      - 16/4 = 4 inches depth per quadrant
- Determine first traverse depth
  - First depth is ½ of a quadrant depth
    - 4 inches / 2 = 2 inches
    - First Reading is at 2 inches
  - Keep adding quadrant depth to previous reading for additional readings
    - 2 inches + 4 inches = 6 inches 2nd reading depth
    - 6 inches + 4 inches = 10 inches 3rd reading depth
    - 10 inches + 4 inches = 14 inches 4th reading depth

Depth of Traverse Readings



If measuring from top, add top plate thickness (usually 3/8 inch)

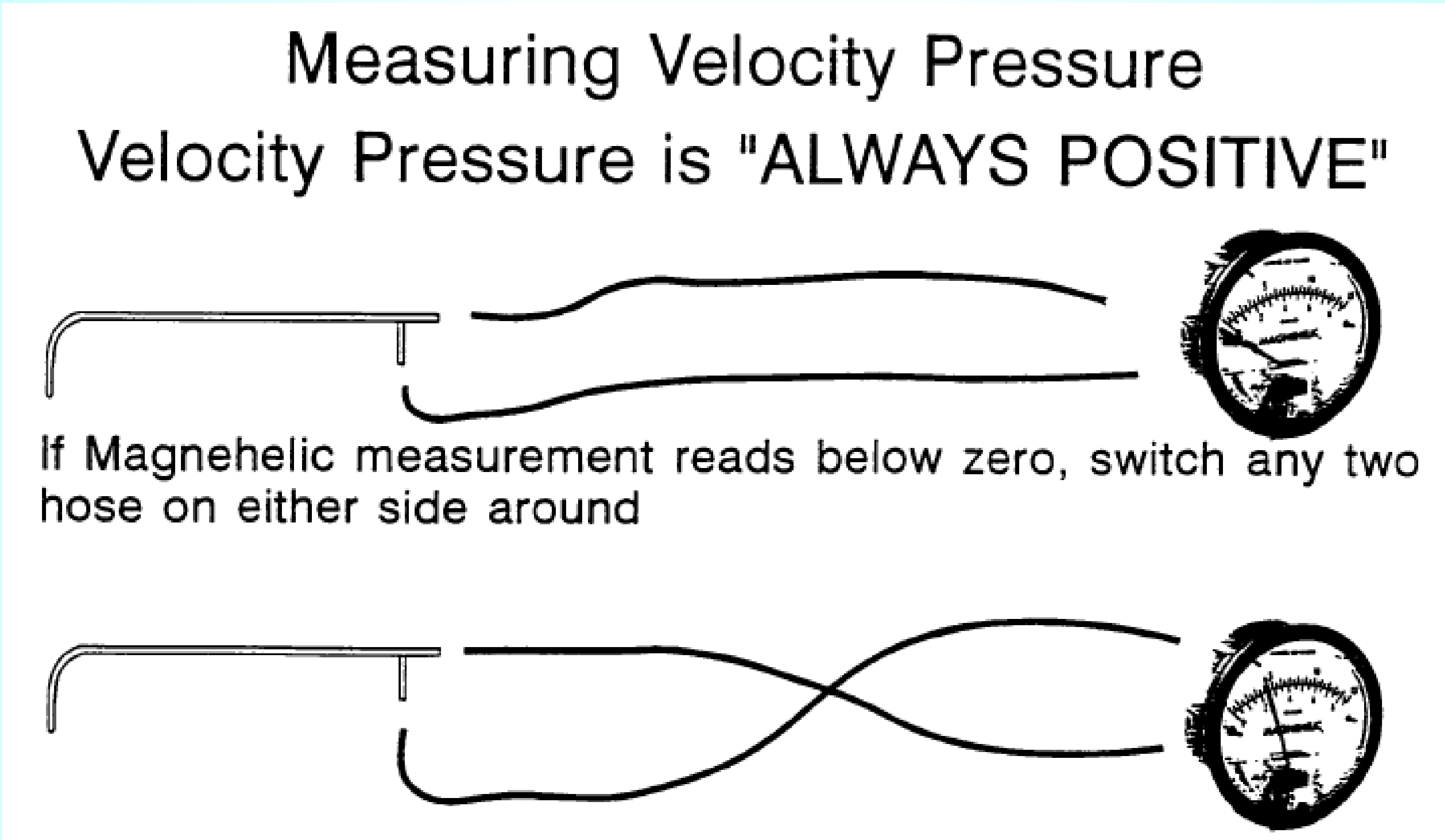
Total Depth 10 3/8 Inch

Mark the insertion depths on your Pitot tube or use the scale on the side of the Pitot tube

Check Equipment

- Pitot tube
  - Proper length
  - Tip free of nicks and burrs
  - All airways free
    - Blow air through each port section
- Magnehelic Gauge
  - Proper range (Usually a 2” or 4” mag.)
  - Zeroed properly in position of use
  - Orientated properly (vertical or horizontal)

Properly Connect Pitot Tube to Magnehelic Gauge



Velocity Pressure Readings

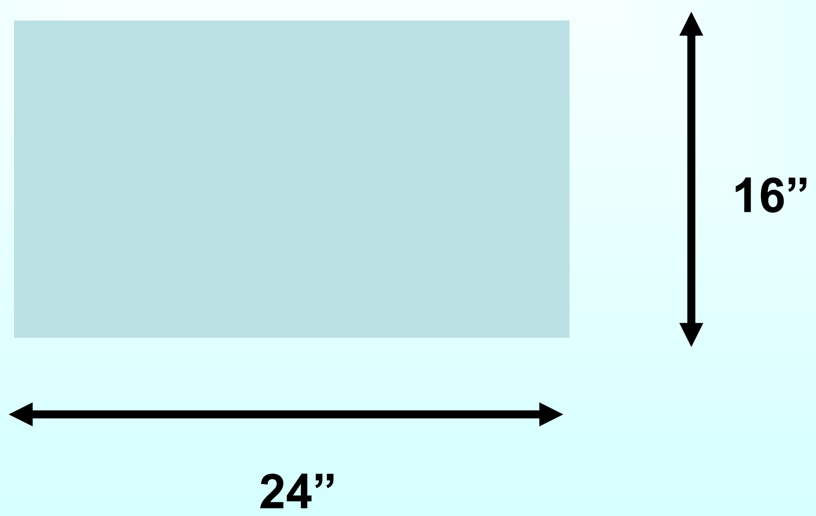
- Energize the scrubber and machine water sprays
- Take velocity pressure readings
  - Take readings in the center of each quadrant
  - Best to have one person taking readings while someone else records observed velocity pressures
  - Hold Pitot tube perpendicular to air flow
    - Tip of tube should point directly into direction of airflow
  - Slightly rotate the Pitot tube to obtain highest reading
  - Keep checking to assure all ports remain open
    - Water, dirt and dust can clog the openings
    - If readings vary substantially from previous readings, do not change or become abnormally calm, check the ports
- Take a centerline reading if you wish to use it to establish a Centerline Correlation Factor (CF).

Calculate Scrubber Duct Area

Area of a rectangle duct is length x width

A = L x W

- Inside of scrubber measurement: 24 in. x 16 in.



Area = 24/12ft. x 16/12ft. = 2ft x 1.33ft = 2.67 ft^2

or

Area = 24in. X 16in /144 = 2.67 ft^2

Example of Air Velocity Readings

Duct Cross Sectional Area = 24 in (W) x 16 in (H) = 384 in^2
384 in^2 / 144 in^2/ft^2 = 2.67 **ft^2**

Measurements of VP (inches w.g.)

Ports:

#1	**#2**	**#3**	**#4**	**#5**	Depth (in.)
0.9	0.8	1.0	1.0	0.4	2
0.6	1.1	1.1	0.9	0.4	6
0.7	1.1	1.5	0.7	0.6	10
1.0	1.5	1.0	0.5	0.0	14

Centerline Reading (VP) = **1.2" w.g.** (Measured in #3 Port at a depth of 8 inches)

Velocity Pressures Converted to Velocities

Velocities (V) (*fpm*)

#1	#2	#3	#4	#5	Sum
3799	3582	4005	4005	2533	17924
3102	4200	4200	3799	2533	17834
3351	4200	4905	3351	3102	18909
4005	4905	4005	2832	0	15747
		Total Sum of Velocities:			70,414

Avg. V (70,414   20) = ***3520 fpm***

Centerline V (1.2w.g) = ***4390 fpm***

NOTE: You cannot just average velocity pressures!

Calculate Air Quantity

- Quantity = Area X Avg. Velocity
- Q= A X V
- Q = 2.67 ft^2 x 3,520 ft/min = 9,398 ft^3/min

Corrections for Elevation or Temperature

- Calculations have been made assuming standard air
  - Standard Air is at
    - Sea Level
    - 70^{o} F
- Corrections are needed if:
  - Elevation varies over 1000 ft.
  - Temperature varies more than 30^{o} F
    - Elevation and temperature affect the density of the air

Corrections for Elevation or Temperature

$$d = \frac{(17.327)(B)}{460 + T}$$

$B = barometric\ pressure, inches\ of\ mercury$

$T = dry\ bulb\ temperature\ of\ air\ ^\circ F$

Correction Chart

	ALTITUDE RELATIVE TO SEA LEVEL, ft															
	−5000	−4000	−3000	−2000	−1000	0	1000	2000	3000	4000	5000	6000	7000	8000	9000	10000
	Barometric Pressure															
″Hg	35.74	34.51	33.31	32.15	31.02	29.92	28.86	27.82	26.82	25.84	24.89	23.98	23.09	22.22	21.39	20.57
″w	486.74	469.97	453.67	437.84	422.45	407.50	392.98	378.89	365.21	351.93	339.04	326.54	314.42	302.66	291.26	280.21
Temp., F	Density Factor, df															
−40	1.51	1.46	1.40	1.36	1.31	1.26	1.22	1.17	1.13	1.09	1.05	1.01	0.97	0.94	0.90	0.87
0	1.38	1.33	1.28	1.24	1.19	1.15	1.11	1.07	1.03	1.00	0.96	0.92	0.89	0.86	0.82	0.79
40	1.27	1.22	1.18	1.14	1.10	1.06	1.02	0.99	0.95	0.92	0.88	0.85	0.82	0.79	0.76	0.73
70	1.19	1.15	1.11	1.07	1.04	1.00	0.96	0.93	0.90	0.86	0.83	0.80	0.77	0.74	0.71	0.69
100	1.13	1.09	1.05	1.02	0.98	0.95	0.91	0.88	0.85	0.82	0.79	0.76	0.73	0.70	0.68	0.65
150	1.04	1.00	0.97	0.93	0.90	0.87	0.84	0.81	0.78	0.75	0.72	0.70	0.67	0.65	0.62	0.60
200	0.96	0.93	0.89	0.86	0.83	0.80	0.77	0.75	0.72	0.69	0.67	0.64	0.62	0.60	0.57	0.55
250	0.89	0.86	0.83	0.80	0.77	0.75	0.72	0.69	0.67	0.64	0.62	0.60	0.58	0.55	0.53	0.51
300	0.83	0.80	0.78	0.75	0.72	0.70	0.67	0.65	0.62	0.60	0.58	0.56	0.54	0.52	0.50	0.48
350	0.78	0.75	0.73	0.70	0.68	0.65	0.63	0.61	0.59	0.57	0.54	0.52	0.50	0.49	0.47	0.45
400	0.74	0.71	0.69	0.66	0.64	0.62	0.59	0.57	0.55	0.53	0.51	0.49	0.48	0.46	0.44	0.42
450	0.70	0.67	0.65	0.63	0.60	0.58	0.56	0.54	0.52	0.50	0.48	0.47	0.45	0.43	0.42	0.40
500	0.66	0.64	0.61	0.59	0.57	0.55	0.53	0.51	0.49	0.48	0.46	0.44	0.43	0.41	0.39	0.38
550	0.63	0.61	0.58	0.56	0.54	0.52	0.51	0.49	0.47	0.45	0.44	0.42	0.40	0.39	0.38	0.36
600	0.60	0.58	0.56	0.54	0.52	0.50	0.48	0.46	0.45	0.43	0.42	0.40	0.39	0.37	0.36	0.34
700	0.55	0.53	0.51	0.49	0.47	0.46	0.44	0.42	0.41	0.39	0.38	0.37	0.35	0.34	0.33	0.31
800	0.50	0.49	0.47	0.45	0.44	0.42	0.41	0.39	0.38	0.36	0.35	0.34	0.32	0.31	0.30	0.29
900	0.47	0.45	0.43	0.42	0.40	0.39	0.38	0.36	0.35	0.34	0.32	0.31	0.30	0.29	0.28	0.27
1000	0.43	0.42	0.40	0.39	0.38	0.36	0.35	0.34	0.33	0.31	0.30	0.29	0.28	0.27	0.26	0.25

How to Correct for Density

Divide the measured air quantity by the square root of the density

$$\frac{\textbf{Measured Quantity}}{\sqrt{\textbf{density}}}$$

Example using

Q = 9,000cfm

D = .81

$$\frac{\textbf{9,000 cfm}}{\sqrt{\textbf{.81}}}$$

Actual Air Quantity = 10,000 cfm

Correlation Factor

- Correlation Factor is used to correlate a centerline reading to a scrubber quantity.
- Enables the mine operator to take only a centerline air velocity reading instead of a full Pitot tube traverse
- Full Pitot tube traverse required to determine the **Average Air Velocity** – normally once per week

Correlation Factor

From Previous Example:

Average Velocity from samples was 3520 fpm

Velocity from centerline reading was 4390 fpm

$$\frac{\text{Average Velocity}}{\text{Centerline Velocity}} \qquad \frac{3520 \text{ fpm}}{4390 \text{ fpm}} = .80$$

Correlation Factor (CF) = .80

Scrubber Flow Rate

After establishing the Correlation Factor (CF), you can determine the scrubber flow rate using only the centerline air reading, as illustrated in the following example:

Example

Suppose an inspector took a centerline reading as part of the 2nd plan parameter check and recorded the observed velocity pressure as 1.0” w.g.

1. Convert the centerline reading of 1.0” w.g. to a velocity (V), which is 4005 fpm.

2. Multiply the centerline V by the CF to obtain the approximate Avg. V

   4005 fpm X .80 = 3200 fpm

3. Multiply the approximate Avg. V by the cross sectional area to obtain the scrubber volume

   3200 fpm X 2.67 ft^2 = 8544 cfm

Example (continued)

- Now, compare the quantity of 8544 cfm obtained using a centerline air reading to 9398 cfm, the quantity based on full Pitot traverse readings:

$$\frac{8544 \text{ cfm}}{9398 \text{ cfm}} = .91 = 91\ \%$$

This scrubber is producing 91 percent of it’s full traverse air quantity!

What if the scrubber has an even number of test ports?

- A centerline reading must be taken in the middle 2 ports
- These 2 readings are then converted into velocity readings
- The two readings are averaged
- This average reading is related to the average air velocity based on full Pitot traverse readings to obtain the Correlation Factor (CF)
- Two centerline readings used to establish the CF must be obtained when the full Pitot traverse readings are taken

Questions?

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