Measuring Air

July 31, 2015

IAOM Central/Wheat State/Texoma Districts
Summer Meeting

Presented by:
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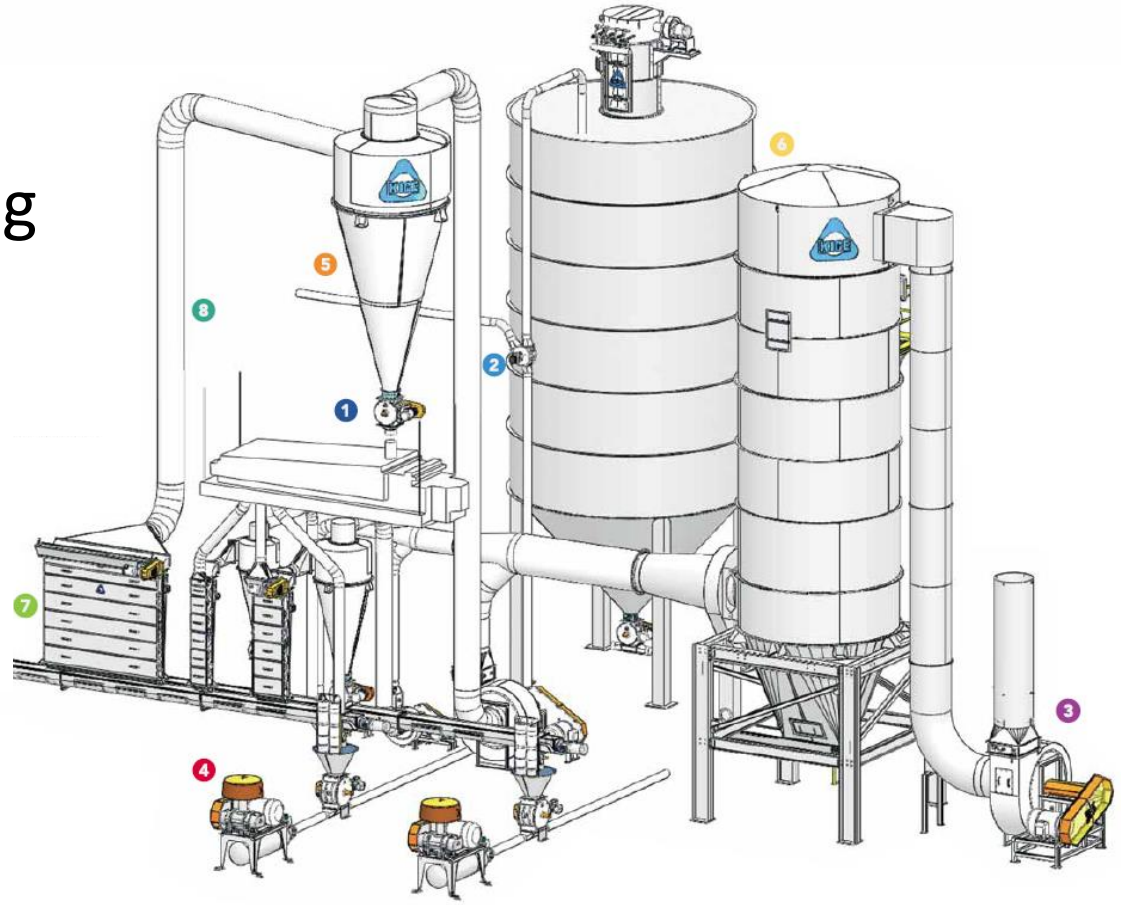
www.kice.com

Applications for “Air”

- Air Activated Processing
  - Grinders
  - Granulators
  - Hammermills
  - Rollmills
  - Aspirators
- Pneumatic Conveying
  - Positive Pressure
  - Vacuum
    (limited to non-fluctuating load)
- Dust Control
- Drying/Cooling



Reasons to know how to measure air volumes

- **To know if your equipment is operating efficiently**
  - Best operation for least amount of power
- **Sizing new equipment**
  - Dust Collection
  - Aspiration
  - Conveying
- **Important to know when you replace equipment**
  - Blowers
  - Cyclones
  - Filters
  - Fans
- **Record-keeping**
  - Plant operations
  - Government agencies

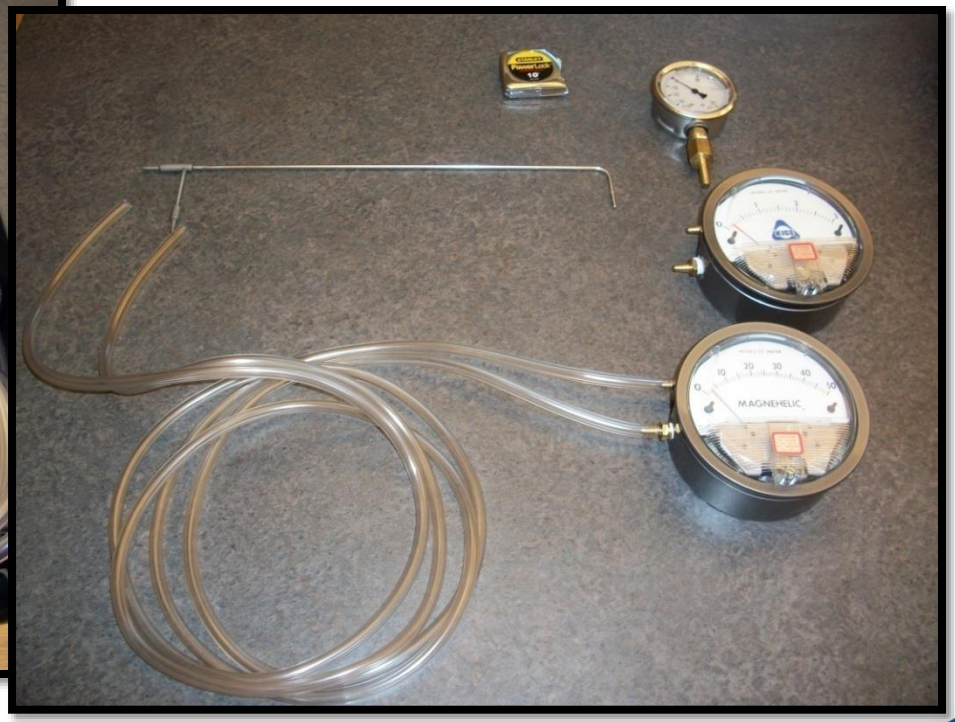
When to measure an air system

- **When a system is first installed**
  - Baseline measurement of system performance
  - Compare “real-life” performance with design parameters
- **When replacing equipment**
  - Ensure replacement equipment doesn’t affect system performance
  - Bring system back into balance
- **When adding or removing equipment**
  - More or less equipment on a system will affect how it behaves
- **When modifying ductwork**
  - Adding or subtracting duct length and elbows
  - Adding or subtracting “pick-up” points

Useful Terms in finding Air Volume

- Pitot Tube
- Magnehelic Gauge
  Manometer, Spring Gage
  Digital and Electronic Gauges
- Air Measuring Kit
- FPM (Feet per Minute)
  Speed or velocity of air
- CFM (Cubic Feet per Minute)
  Volume/amount of air being moved
- Area
  As measured on the inside of the duct and measured in square feet
- Static Pressure
  Pressure used to overcome the resistance to flow
- Velocity Pressure
  Pressure required to accelerate the flowing mass from rest to its' existing velocity or…..
  Air traveling at a given velocity
- Total Pressure
  Sum total of static and velocity pressures

Typical Air Measuring Kit



Follow a few basic principles

- Obtain the Velocity of the air in the duct
- Obtain the Area of the duct/pipe at the point of measurement
- Multiply Velocity x Area to determine Volume

Basic Formula

$$Q = VA$$

Q = ACFM (Volume of Air)

V = Velocity (in feet per minute)

A = Tube internal cross-section area (in square feet)

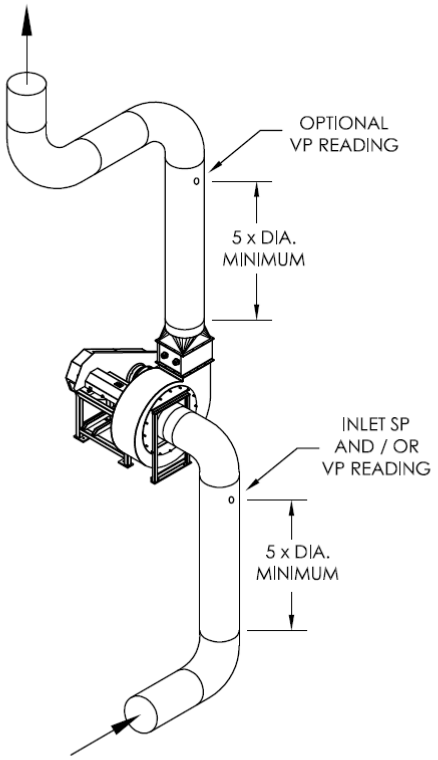
“By the Book” Method of Measuring Air for accurate air flow measurements

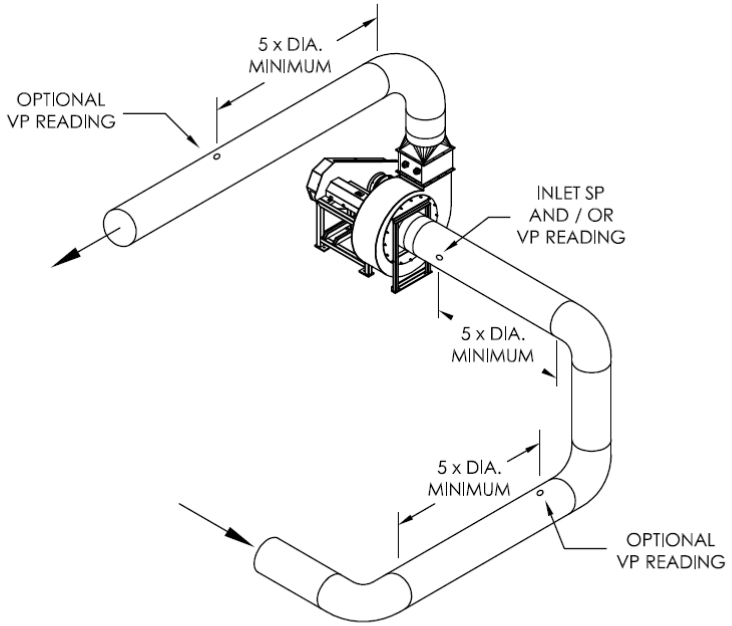
- Safety First
- Select location 10 pipe diameters, if possible, away from dampers, branches, elbows, etc…
- Drill 2 holes (90 degrees apart) to allow insertion of Pitot tube
- Connect Pitot tube static and/or total pressure connections to gauge
- Traverse the tube, recording readings at published insertion depths
- Take readings horizontally and vertically
- Average the velocities to determine Average Velocity Pressure (V_{avg})
- Convert Velocity Pressure (V_p) readings to Velocity (V)
  - Refer to chart for Velocity
  - Use math calculation
    - Determine Tube Area in Square Feet
      - In Feet: Area of circle = 3.14 x R^2 or .7854 x $Diameter^2$
      - In Inches: Area of circle = 3.14 x R^2/144 or .7854 x $Diameter^2$/144
        (144 square inches = 1 square foot)
    - Multiply Velocity by the Tube Area to get CFM

"Reality" Method of Measuring Air for taking ESTIMATED air flow measurements

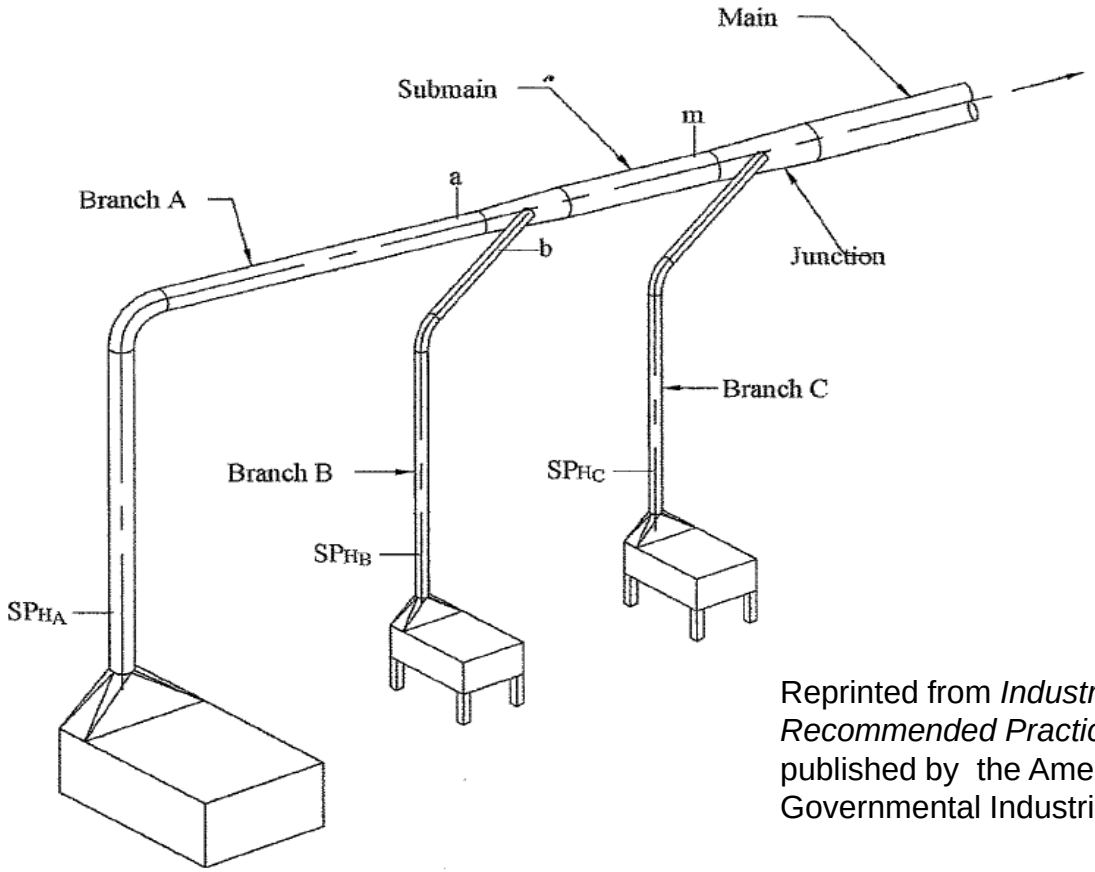
- Safety First
- Select location *5+ pipe diameters*, if possible, away any downstream flow disrubtions (dampers, branches, elbows, etc…)
- *Drill hole* to allow insertion of Pitot tube
  - 3/16" for 24" and less, 3/8" for 24" OD and larger
- Connect Pitot tube static and/or total pressure connections to gauge
- Traverse the tube, *recording the "center air" reading*
- *Multiply the reading by .9 for 6" OD and smaller and by .95 for ducts 8" OD and larger to determine Average Velocity Pressure (V_{avg})*
- Convert Velocity Pressure (V_p) readings to Velocity (V)
  - Refer to chart for Velocity
  - Use math calculation
    - Determine Tube Area in Square Feet
      - In Feet: Area of circle = 3.14 x R^2 or .7854 x $Diameter^2$
      - In Inches: Area of circle = 3.14 x R^2/144 or .7854 x $Diameter^2$/144 (144 square inches = 1 square foot)
    - Multiply Velocity by the Tube Area to get CFM

Typical Air Measurement Reading Points





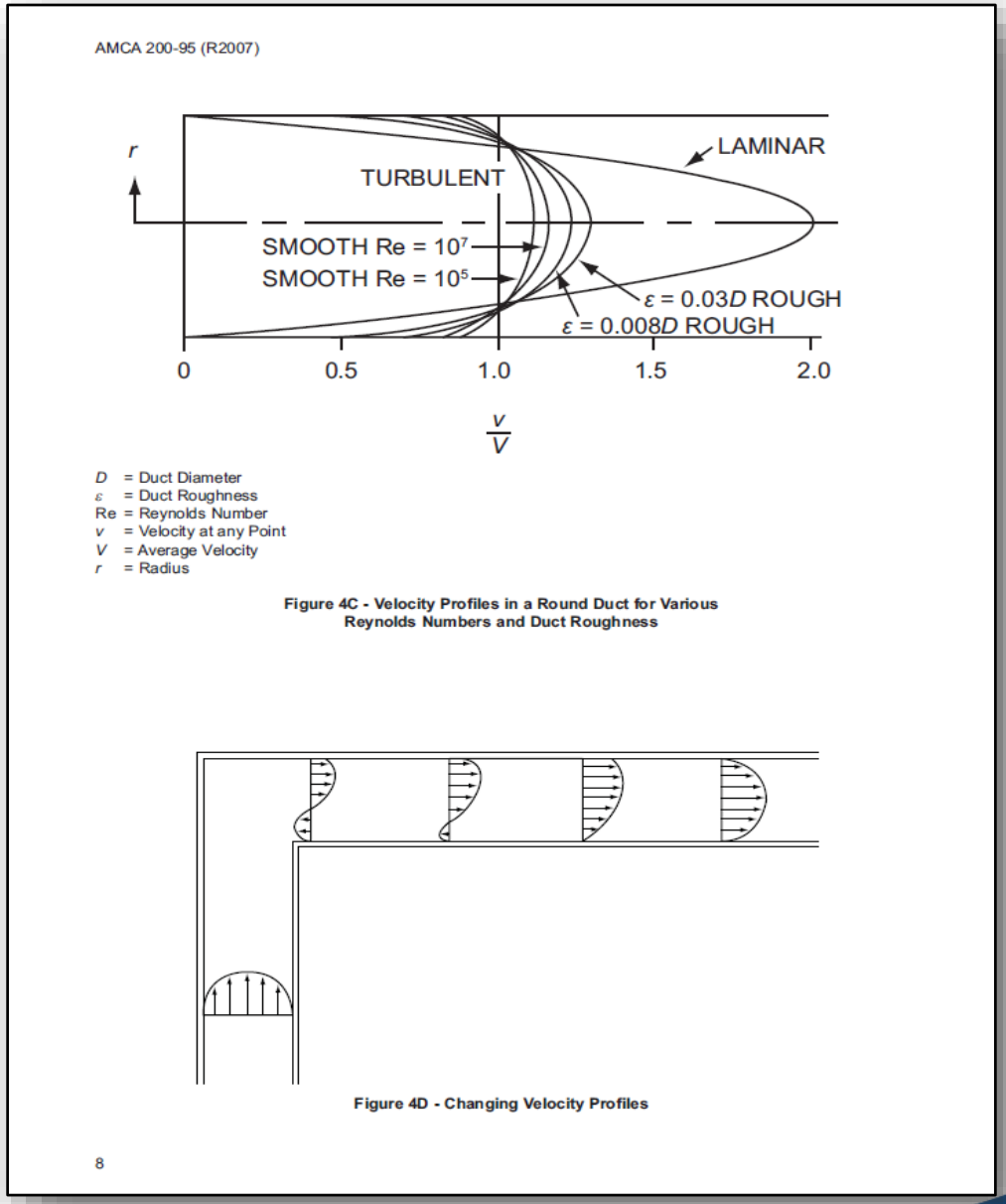
Useful Locations to Perform Airflow and Static Pressure Measurements



Reprinted from *Industrial Ventilation: A Manual of Recommended Practice for Design*, 27th Edition, published by the American Conference of Governmental Industrial Hygienists

Why “downstream” of fitting?

- Air after an elbow, fitting, damper, etc... becomes turbulent.
- Allows air to become “laminar” and more even inside the tubing/ducting/pipe
- Makes measurements more accurate



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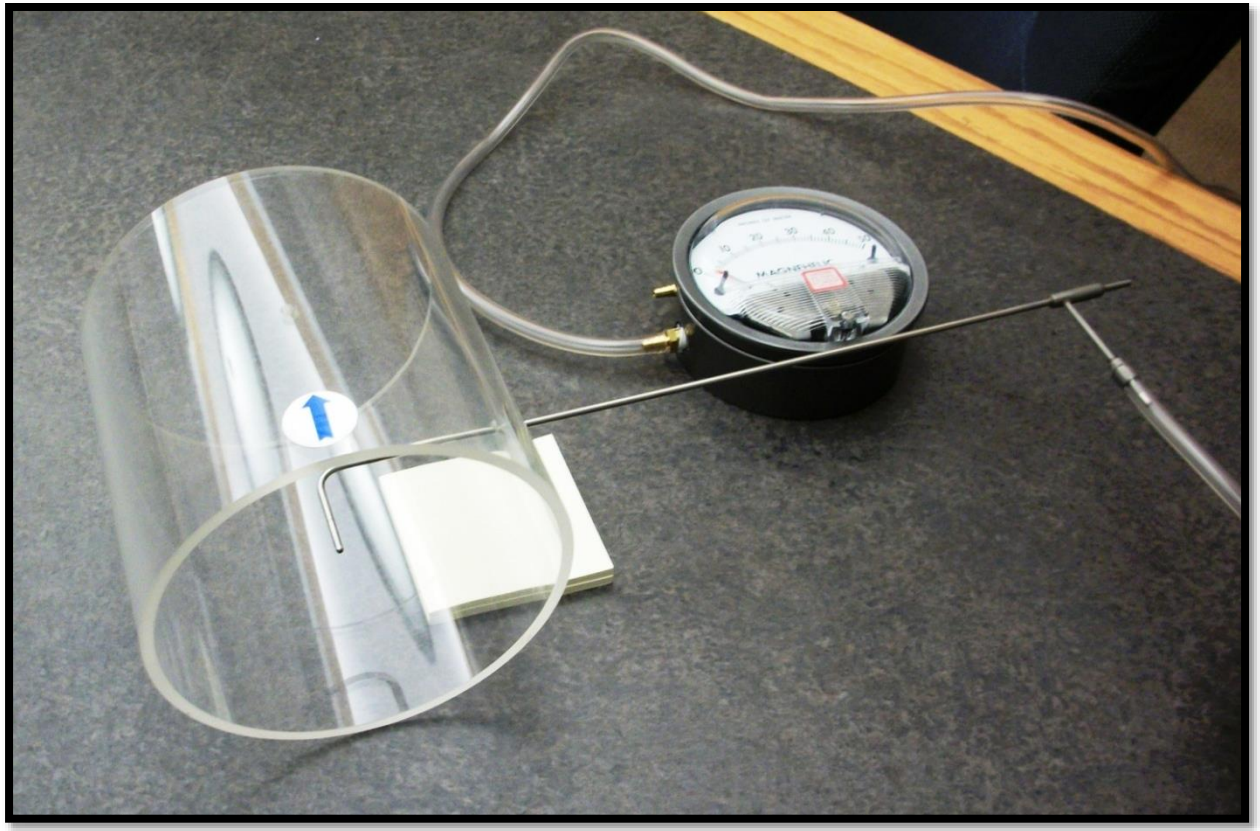
Measuring Static Pressure

"By the Book":

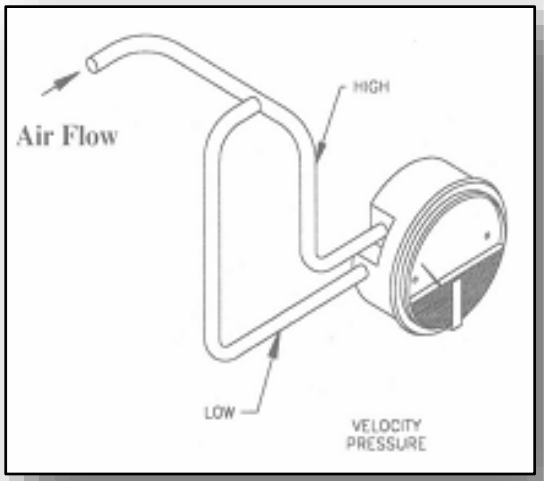
- Low pressure connections are hooked up
- Usually the higher reading gauge
- Traverse readings across tube
- Measure in 2 planes
- Pitot Tube is into flow

"Reality":

- Low pressure connections are hooked up
- Usually the higher reading gauge
- Center reading & average
- Pitot Tube is into flow



Velocity Pressure

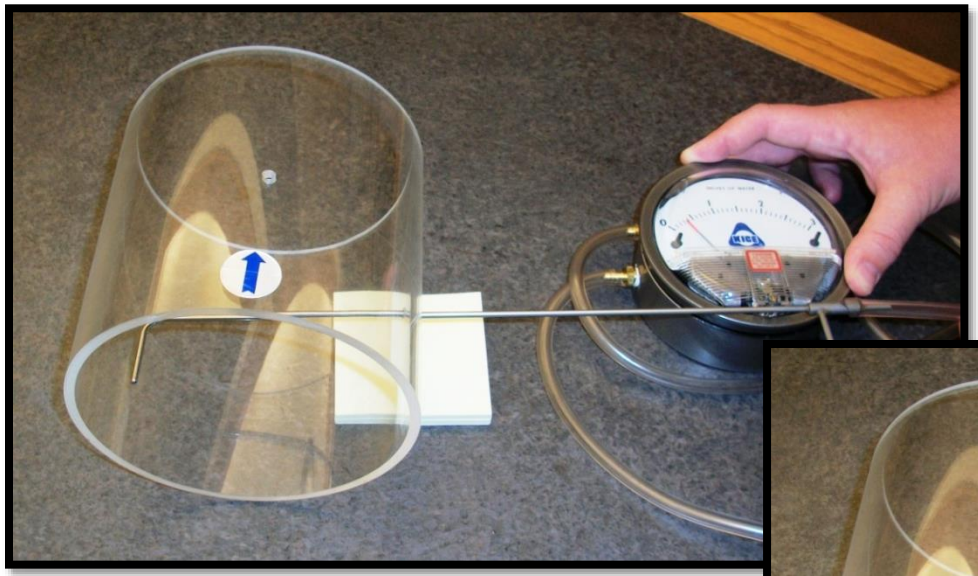


TP (Total Pressure) – SP (Static Pressure) = VP (Velocity Pressure)

Velocity = 4005 x √VP

Reprinted from "Industrial Ventilation, A Manual of Recommended Practice, 22nd Edition", published by the American Conference of Governmental Industrial Hygienists

Measuring Velocity Pressure

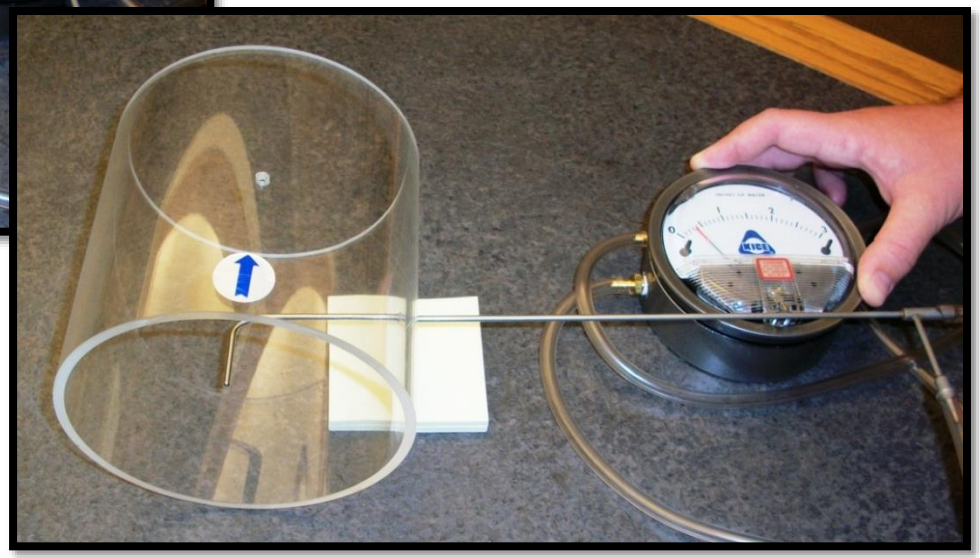


"By the Book":

- Both connections hooked up
- Usually the lower reading gauge
- Traverse readings across tube
- Measure in 2 planes
- Pitot Tube is into flow

"Reality":

- Both connections hooked up
- Usually the lower reading gauge
- Center reading & average
- Pitot Tube is into flow



Finding Velocity

Example 1:

- VP reading = 1.0
- Velocity = 4005 FPM

Example 2:

- VP reading = 1.75
- Velocity = 5298 FPM

Example 3:

- VP reading = 3.60
- Velocity = 7599 FPM

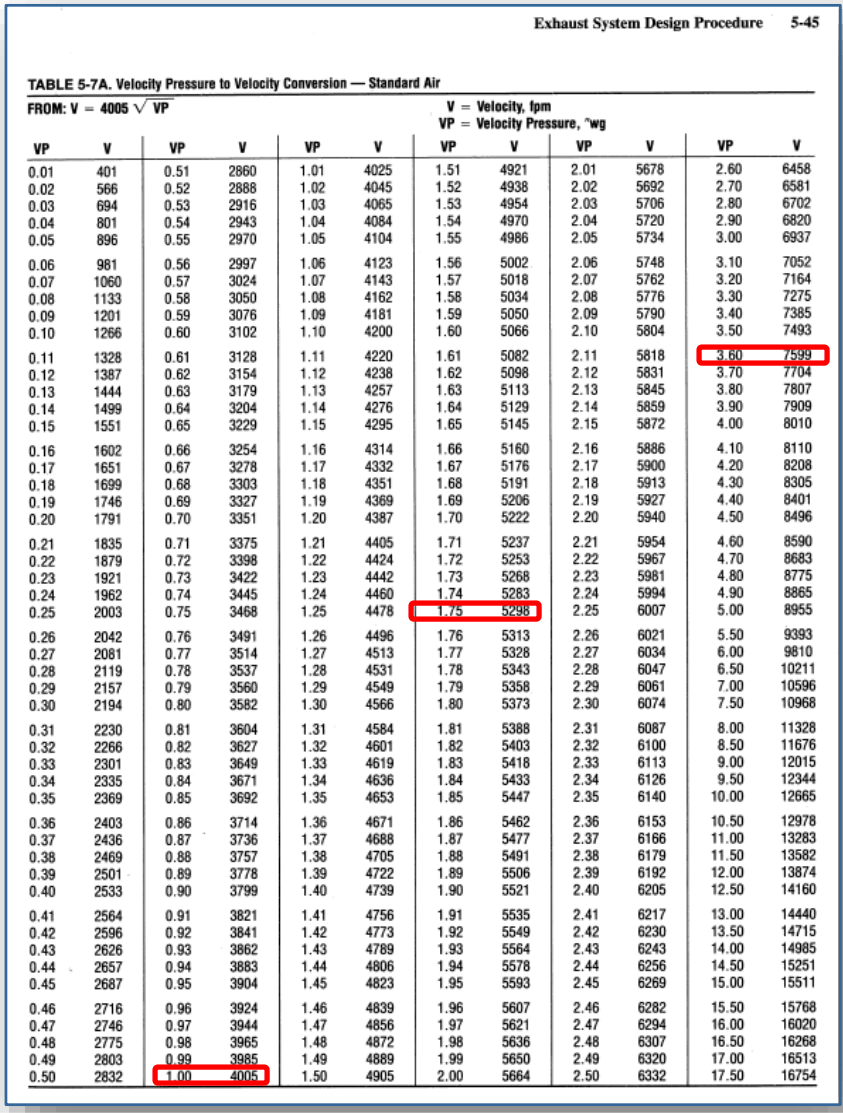


TABLE 5-7A. Velocity Pressure to Velocity Conversion — Standard Air

FROM: $V = 4005\sqrt{VP}$

V = Velocity, fpm
VP = Velocity Pressure, "wg

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	1201	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	5206	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	4405	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	3604	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	2803	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

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Finding Volume (Q = V x A)

Example 1:

- Velocity = 4005 FPM
- Tube = 12” OD (.7854 sq ft)
- Volume = 3145 CFM

Example 2:

- Velocity = 5298 FPM
- Tube = 12” OD (.7854 sq ft)
- Volume = 4161 CFM

Example 3:

- Velocity = 7599 FPM
- Tube = 12” OD (.7854 sq ft)
- Volume = 5968 CFM

TABLE 5-8. Area and Circumference of Circles

Diam. in Inches	AREA Square Inches	AREA Square Feet	CIRCUMFERENCE Inches	CIRCUMFERENCE Feet	Diam. in Inches	AREA Square Inches	AREA Square Feet	CIRCUMFERENCE Inches	CIRCUMFERENCE Feet
1	0.79	0.0055	3.14	0.2618	30	706.9	4.909	94.2	7.854
1.5	1.77	0.0123	4.71	0.3927	31	754.8	5.241	97.4	8.116
2	3.14	0.0218	6.28	0.5236	32	804.2	5.585	100.5	8.378
2.5	4.91	0.0341	7.85	0.6545	33	855.3	5.940	103.7	8.639
3	7.07	0.0491	9.42	0.7854	34	907.9	6.305	106.8	8.901
3.5	9.62	0.0668	11.00	0.9163	35	962.1	6.681	110.0	9.163
4	12.57	0.0873	12.57	1.0472	36	1017.9	7.069	113.1	9.425
4.5	15.90	0.1104	14.14	1.1781	37	1075.2	7.467	116.2	9.687
5	19.63	0.1364	15.71	1.3090	38	1134.1	7.876	119.4	9.948
5.5	23.76	0.1650	17.28	1.4399	39	1194.6	8.296	122.5	10.210
6	28.27	0.1963	18.85	1.5708	40	1256.6	8.727	125.7	10.472
6.5	33.18	0.2304	20.42	1.7017	41	1320.3	9.168	128.8	10.734
7	38.48	0.2673	21.99	1.8326	42	1385.4	9.621	131.9	10.996
7.5	44.18	0.3068	23.56	1.9635	43	1452.2	10.085	135.1	11.257
8	50.27	0.3491	25.13	2.0944	44	1520.5	10.559	138.2	11.519
8.5	56.75	0.3941	26.70	2.2253	45	1590.4	11.045	141.4	11.781
9	63.62	0.4418	28.27	2.3562	46	1661.9	11.541	144.5	12.043
9.5	70.88	0.4922	29.85	2.4871	47	1734.9	12.048	147.7	12.305
10	78.54	0.5454	31.42	2.6180	48	1809.6	12.566	150.8	12.566
10.5	86.59	0.6013	32.99	2.7489	49	1885.7	13.095	153.9	12.828
11	95.03	0.6600	34.56	2.8798	50	1963.5	13.635	157.1	13.090
11.5	103.87	0.7213	36.13	3.0107	52	2123.7	14.748	163.4	13.614
12	113.10	0.7854	37.70	3.1416	54	2290.2	15.904	169.6	14.137
13	132.73	0.9218	40.84	3.4034	56	2463.0	17.104	175.9	14.661
14	153.94	1.0690	43.98	3.6652	58	2642.1	18.348	182.2	15.184
15	176.71	1.2272	47.12	3.9270	60	2827.4	19.635	188.5	15.708
16	201.06	1.3963	50.27	4.1888	62	3019.1	20.966	194.8	16.232
17	226.98	1.5763	53.41	4.4506	64	3217.0	22.340	201.1	16.755
18	254.47	1.7671	56.55	4.7124	66	3421.2	23.758	207.3	17.279
19	283.53	1.9689	59.69	4.9742	68	3631.7	25.220	213.6	17.802
20	314.16	2.1817	62.83	5.2360	70	3848.5	26.725	219.9	18.326
21	346.36	2.4053	65.97	5.4978	72	4071.5	28.274	226.2	18.850
22	380.13	2.6398	69.12	5.7596	74	4300.8	29.867	232.5	19.373
23	415.48	2.8852	72.26	6.0214	76	4536.5	31.503	238.8	19.897
24	452.39	3.1416	75.40	6.2832	78	4778.4	33.183	245.0	20.420
25	490.87	3.4088	78.54	6.5450	80	5026.5	34.907	251.3	20.944
26	530.93	3.6870	81.68	6.8068	82	5281.0	36.674	257.6	21.468
27	572.56	3.9761	84.82	7.0686	84	5541.8	38.485	263.9	21.991
28	615.75	4.2761	87.96	7.3304	86	5808.8	40.339	270.2	22.515
29	660.52	4.5869	91.11	7.5922	88	6082.1	42.237	276.5	23.038

The usual sheet metal fabricator will have patterns for ducts in 0.5-inch steps through 5.5-inch diameter; 1 inch steps 6 inches through 20 inches and 2-inch steps 22 inches and larger diameters.

Reprinted from “Industrial Ventilation, A Manual of Recommended Practice, 22nd Edition”, published by the American Conference of Governmental Industrial Hygienists

Why is this information important in a Dust Collection System?

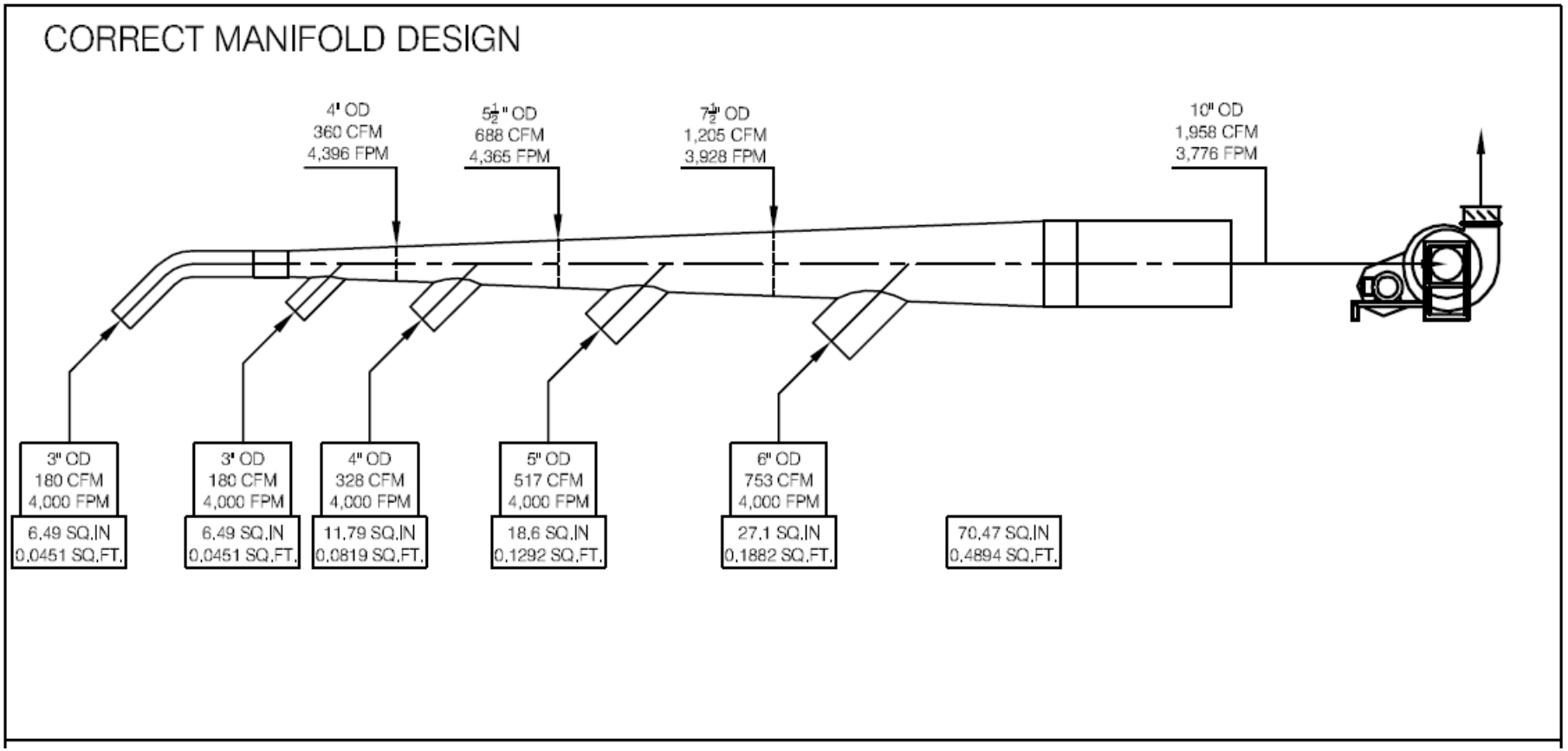
• *Take proof-of-performance airflow and static pressure measurements:* These will show whether you have adequate conveying velocity in all system branches at startup and provide a reference point to which you can return.

• *Keep records of recent routine system measurements with timely follow-up for out-of-limit problems:* You need the data history to know which parts of the system typically fail first (for example, plugged elbows, blinded filter media, or other component) for timely corrective action.

• *Assign trained personnel responsibility for the system:* Your personnel need the skills and time to take the data and complete necessary follow-up actions.

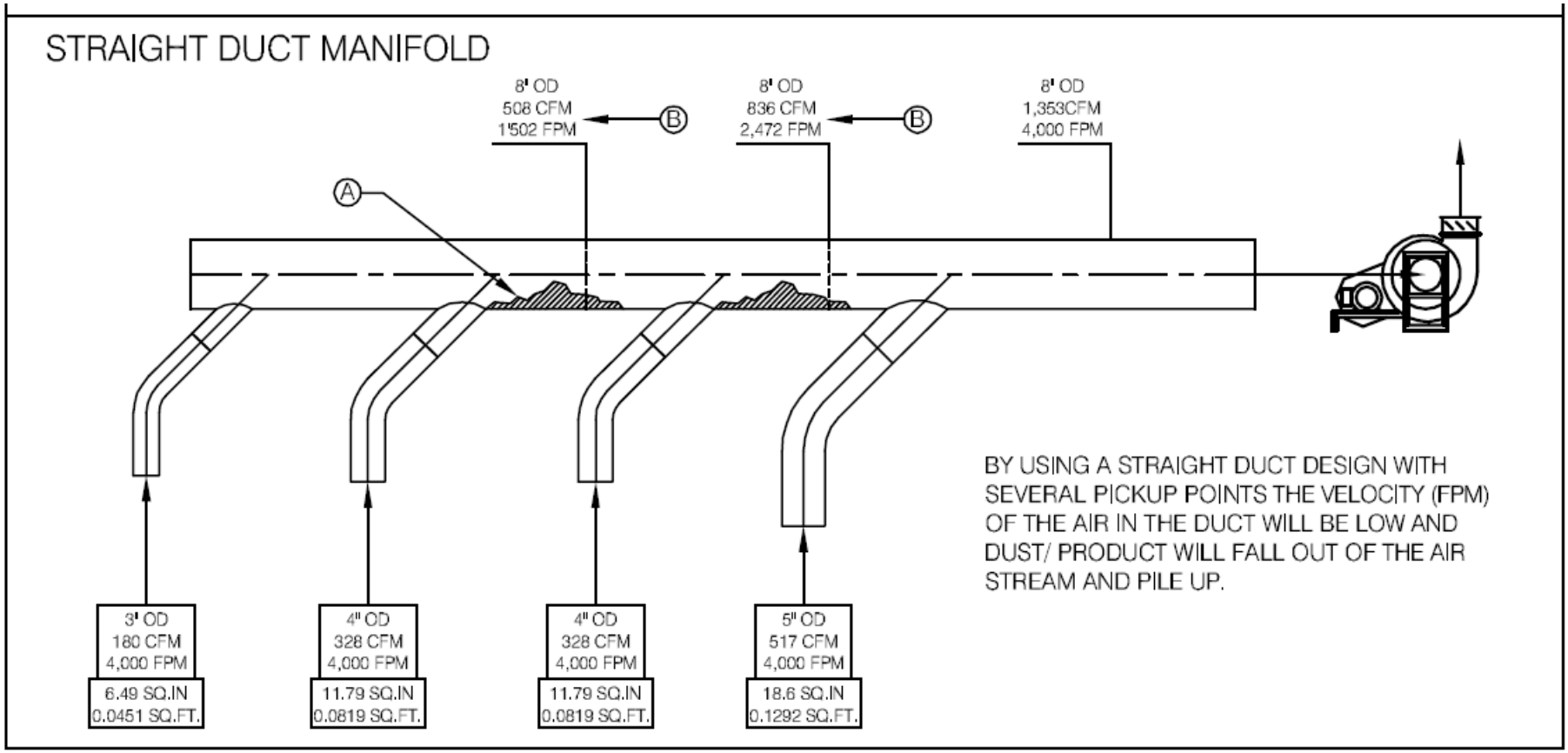
• *Make system changes for adequate conveying velocity as required in NFPA standards with system redesign:* For example, for effective explosion protection, the downstream duct area must roughly equal the sum of the area of the upstream ducts. A system tour can reveal duct junctions where this isn't the case.

Good Velocity, Good Volume, Good Design



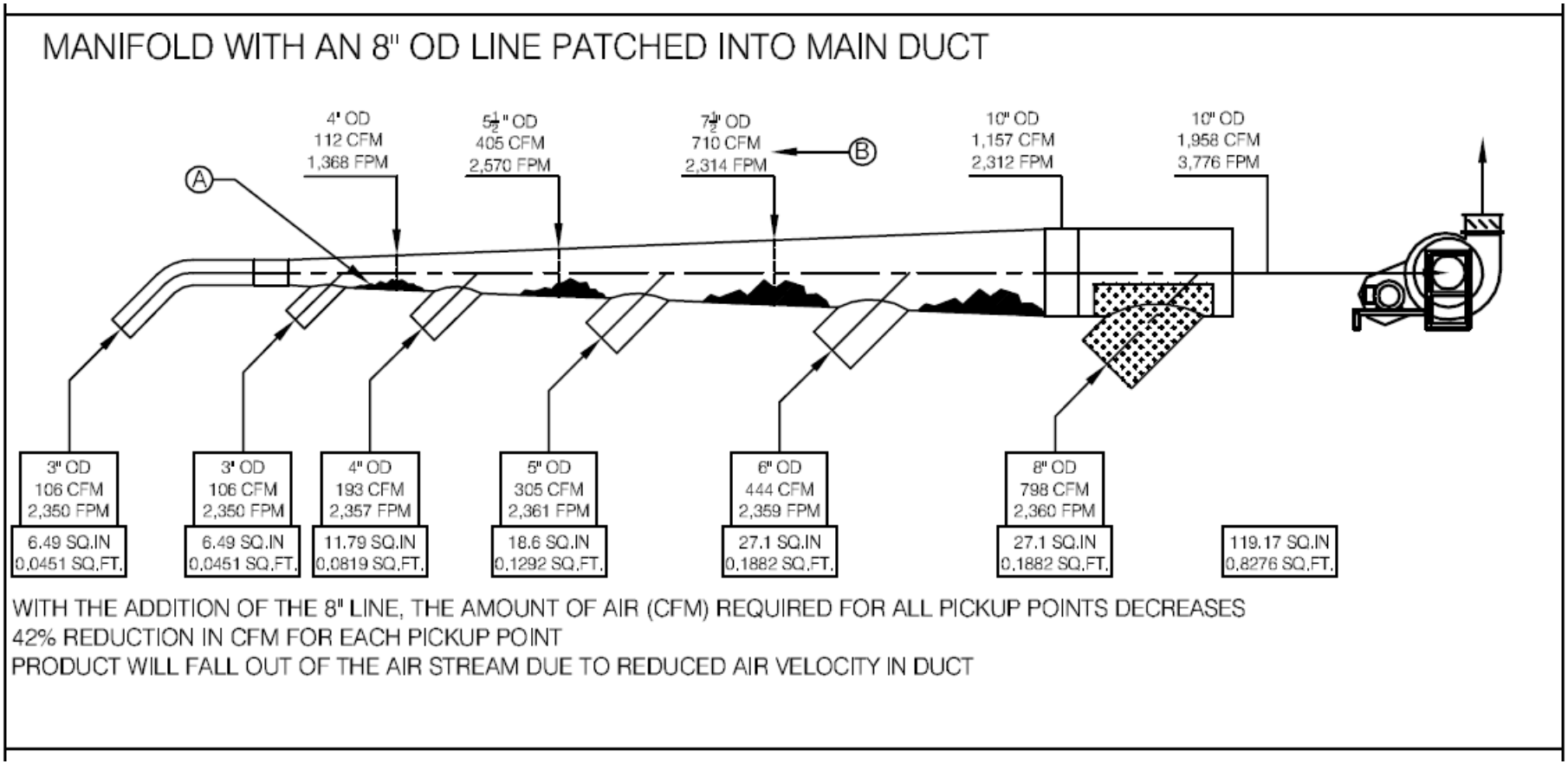
Dust is in suspension; System is balanced.

Bad Velocity, Good Volume, Bad Design



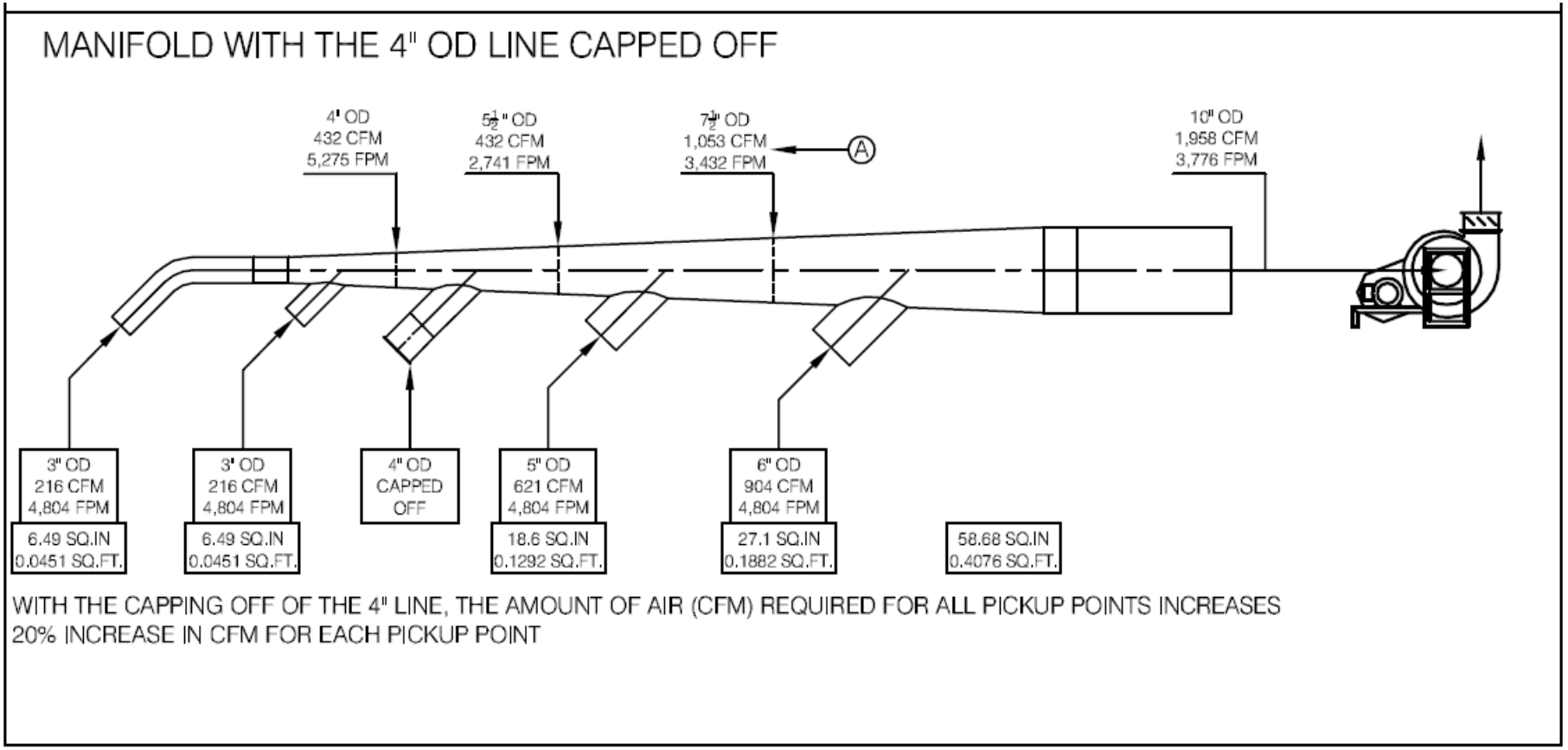
Dust is dropping out (in locations); System is balanced (at end of system).

Additions without Rebalancing



Dust is NOT in suspension; System is NOT balanced. Air taking path of least resistance.

Deductions without Rebalancing



Dust is in suspension (but at higher velocity); System is not balanced.

Conclusion

- It is not difficult to take air measurement reading with the correct tools.
- The information the air readings provide can:

Benefit product quality

Benefit in product recovery

Extend equipment life

Save energy

Reduce emissions

Reduce housekeeping

Keep the plant running and out of trouble


Thank you for the opportunity to speak with you today
KICE INDUSTRIES INC
EST. 1946