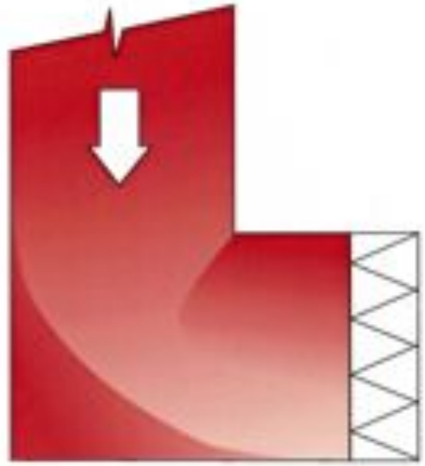
Basics of Air



An Introduction to the Principles of Moving Air Quietly & Efficiently

1st Edition, October 2008

teca

thermal environmental comfort association

Vancouver Test Hut

Satisfy Marc?
Technical 'Guard Dog'


AccuWeld inc.
AccuWeld inc.
TIRE RACK
SUNOCO
RACE FUELS
TIRE
SCCA

Harmony House

3500 sq. ft. Net Zero 30,000 BTU design loss

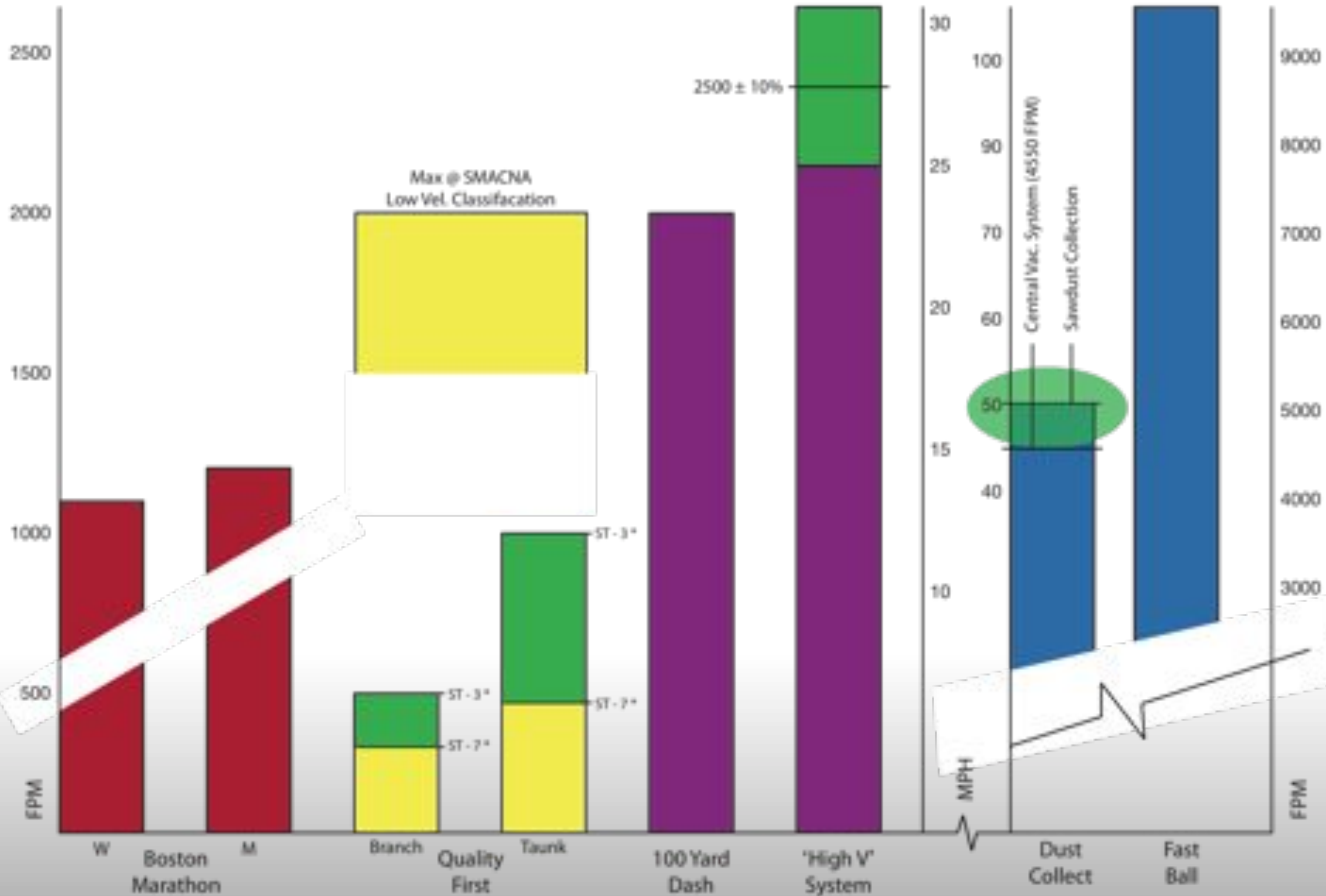
PITFALLS (if you don't know)

- Lack of Comfort
  - Poor heat/cool to distant rooms
  - Loss of heat/cool capacity
  - Excessive air noise
- Equipment failure
  - Compressor failures
  - Very short filter life
- High utility bill
  - Electricity, fighting duct losses
  - Gas, not scrubbing off heat

1 cubic foot weighs 1/10 lb.

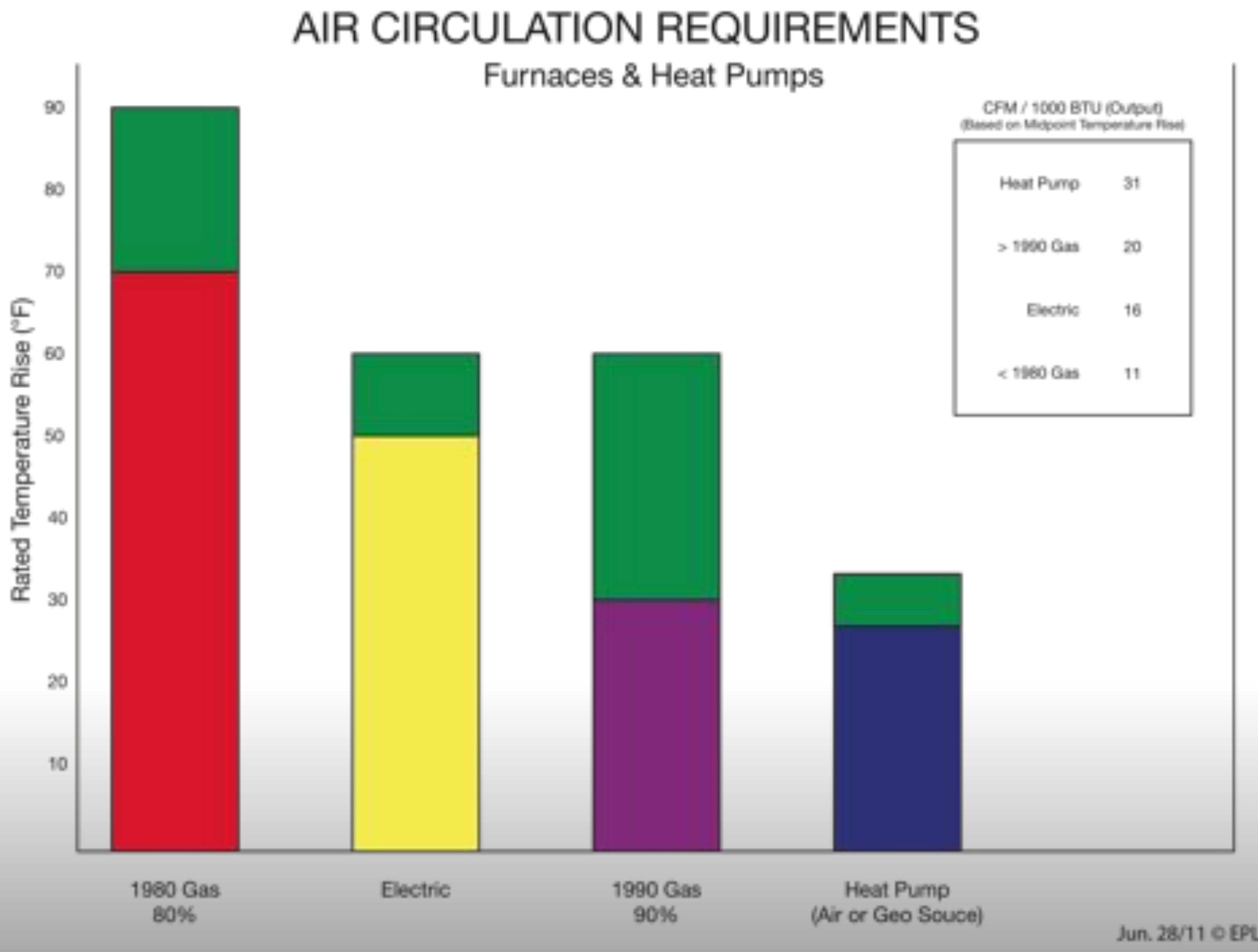
(almost)

COMMON VELOCITIES

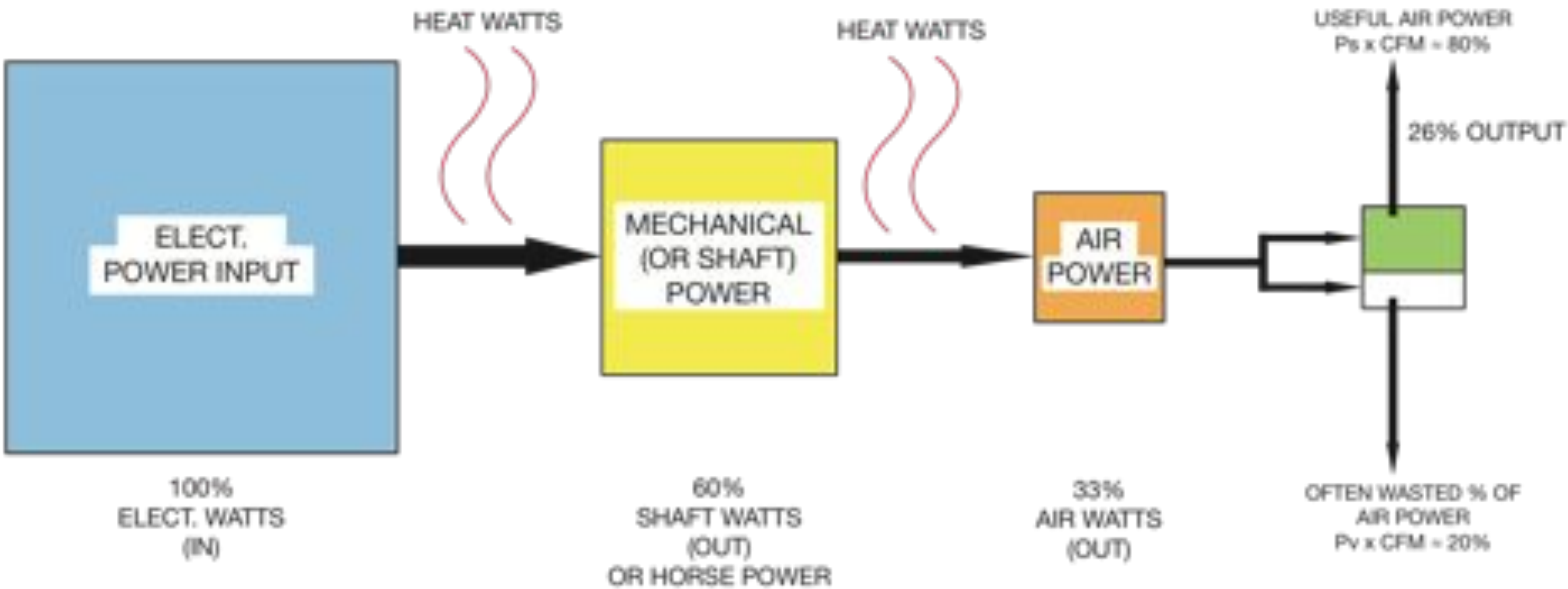


* Number of 90° direction changes between air handler and supply air grille of longest run

Jun. 28/11 © EPL


AIR CIRCULATION REQUIREMENTS
Furnaces & Heat Pumps
Rated Temperature Rise (°F)
90
80
70
60
50
40
30
20
10
CFM / 1000 BTU (Output)
(Based on Midpoint Temperature Rise)
Heat Pump 31
> 1990 Gas 20
Electric 16
< 1980 Gas 11
1980 Gas 80%
Electric
1990 Gas 90%
Heat Pump (Air or Geo Souce)
Jun. 28/11 © EPL

FAN POWER



W = VOLTS x AMPS

W = HORSE POWER x 746
EFFICIENCY FROM ELECT.
INPUT 50%-80%
(ASSUME 60% UNLESS
ECM AT 80%)

W = 117 x CFM x Pt
EFFICIENCY FROM
SHAFT INPUT
(ASSUME 55%)

AT RESIDENTIAL
PRESSURES AND
VELOCITIES
Ps = 80%
OF TOTAL
AIR WATTS

W = Watts, which is the same as horse power. Except 1 horse power is 746 times loger than 1 watt.
Air Watts: Used by leading central air vac manufacturers to rate suction power.

Electrolux Serenity QS* generates 640 air watts from 1500 watts electrical input. This is high, 43% overall efficiency.
*Central vac type unit

Credit side of the Air Moving ledger = 'Air Power'

Source of the power to move air through the system

Air Power (hp) = .000157 x cfm x Pt

Air Power (watts) = .117 x cfm x Pt

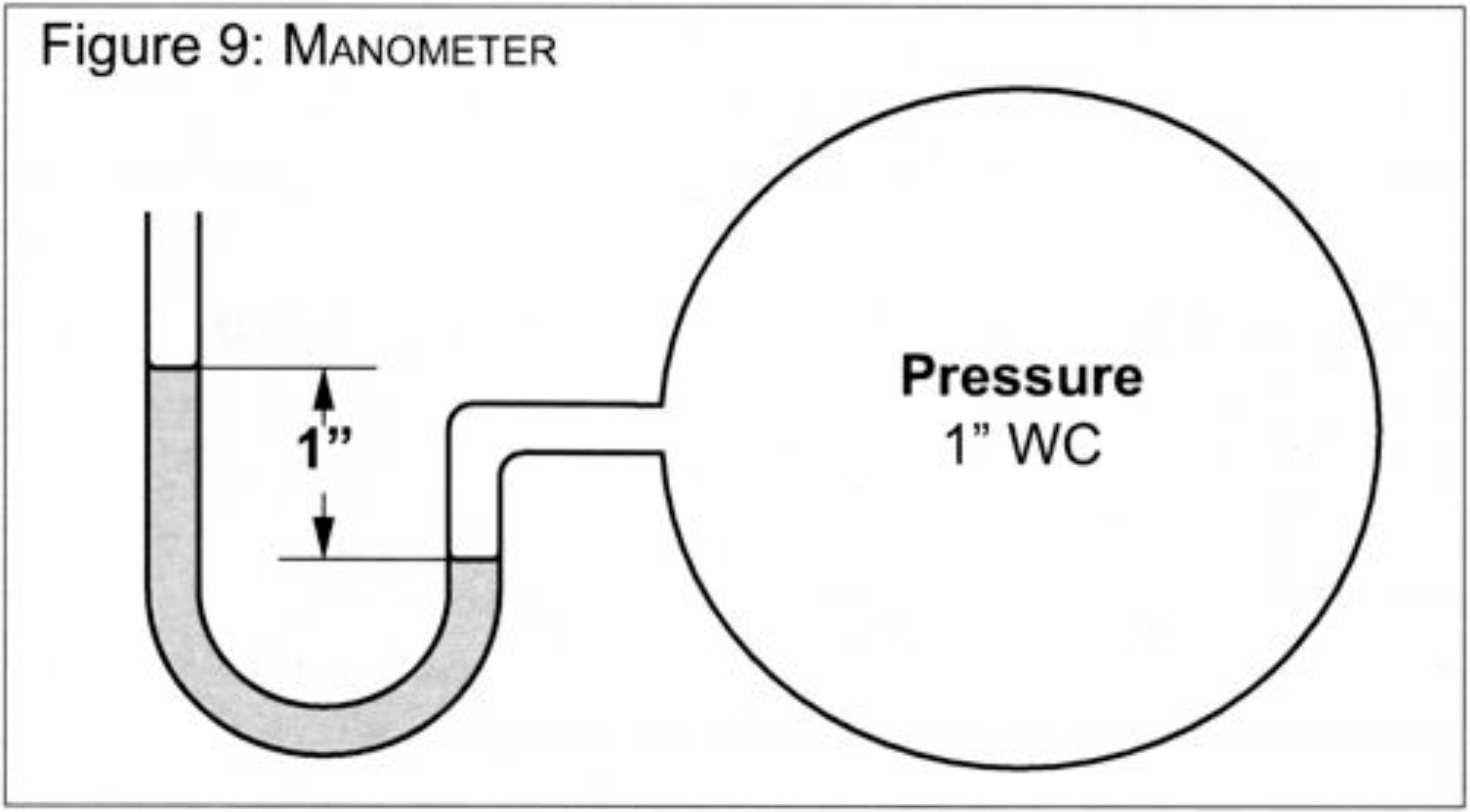
(Pt in inches WC)

Total pressure = Velocity pressure + Static Pressure

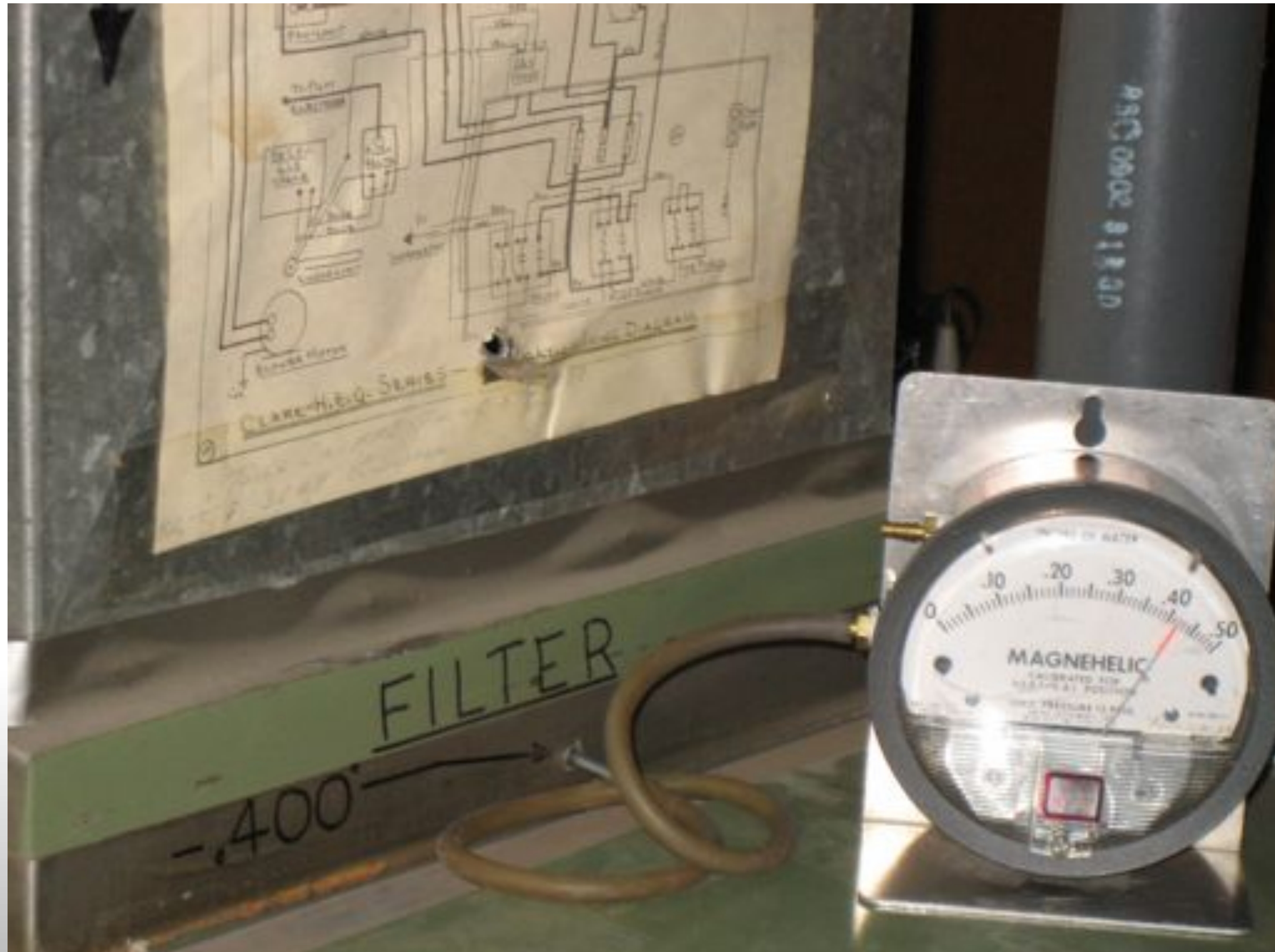
$$Pt = Pv + Ps$$


SPLIT
PHASE
EC PM
SHADED POLE
(SHORTED POLE)
(WORK HORSE)
PSC
'94 2 6

Duct pressure (Ps + as shown or -)

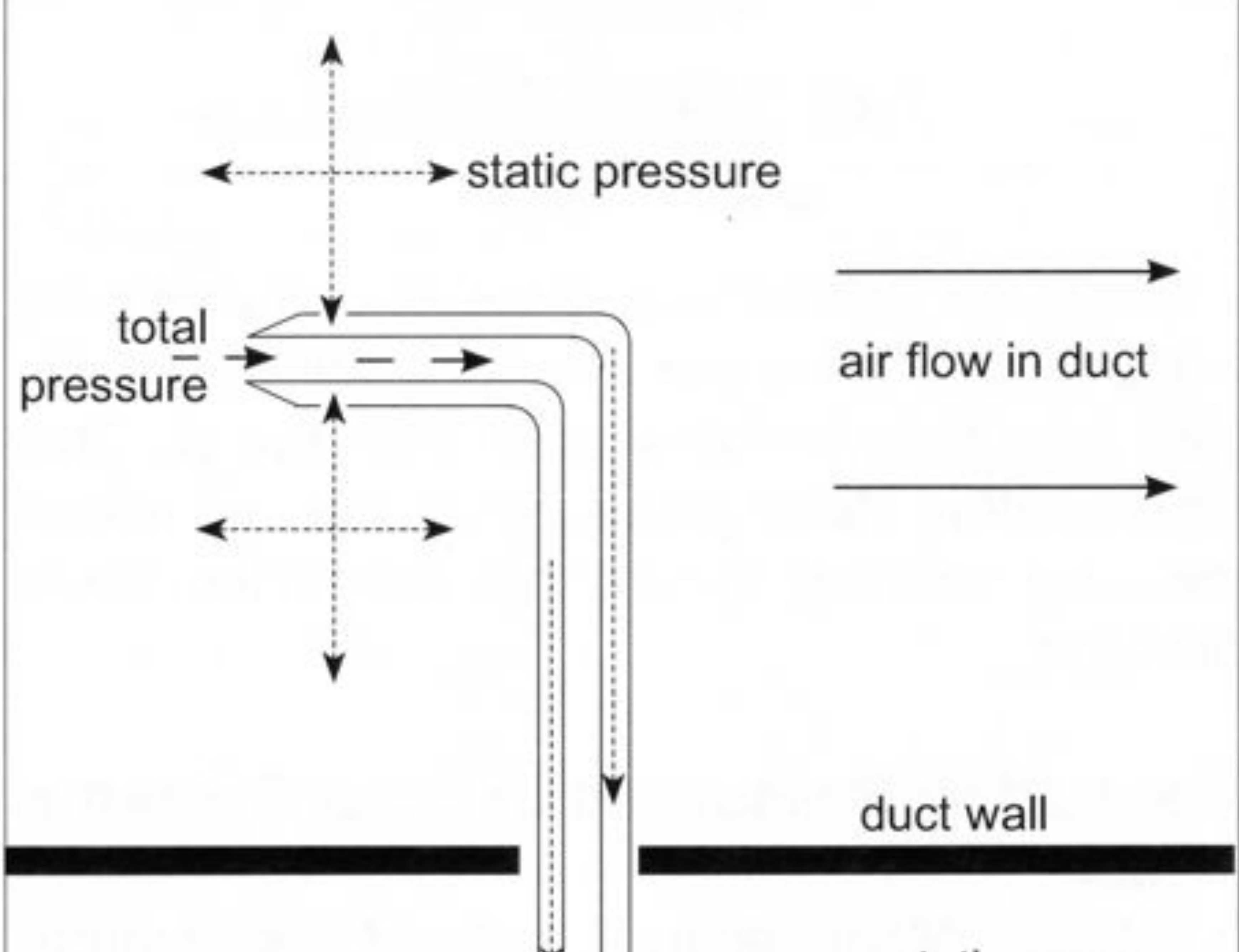


R/A Static Pressure (Ps)




STAR ALLIANCE

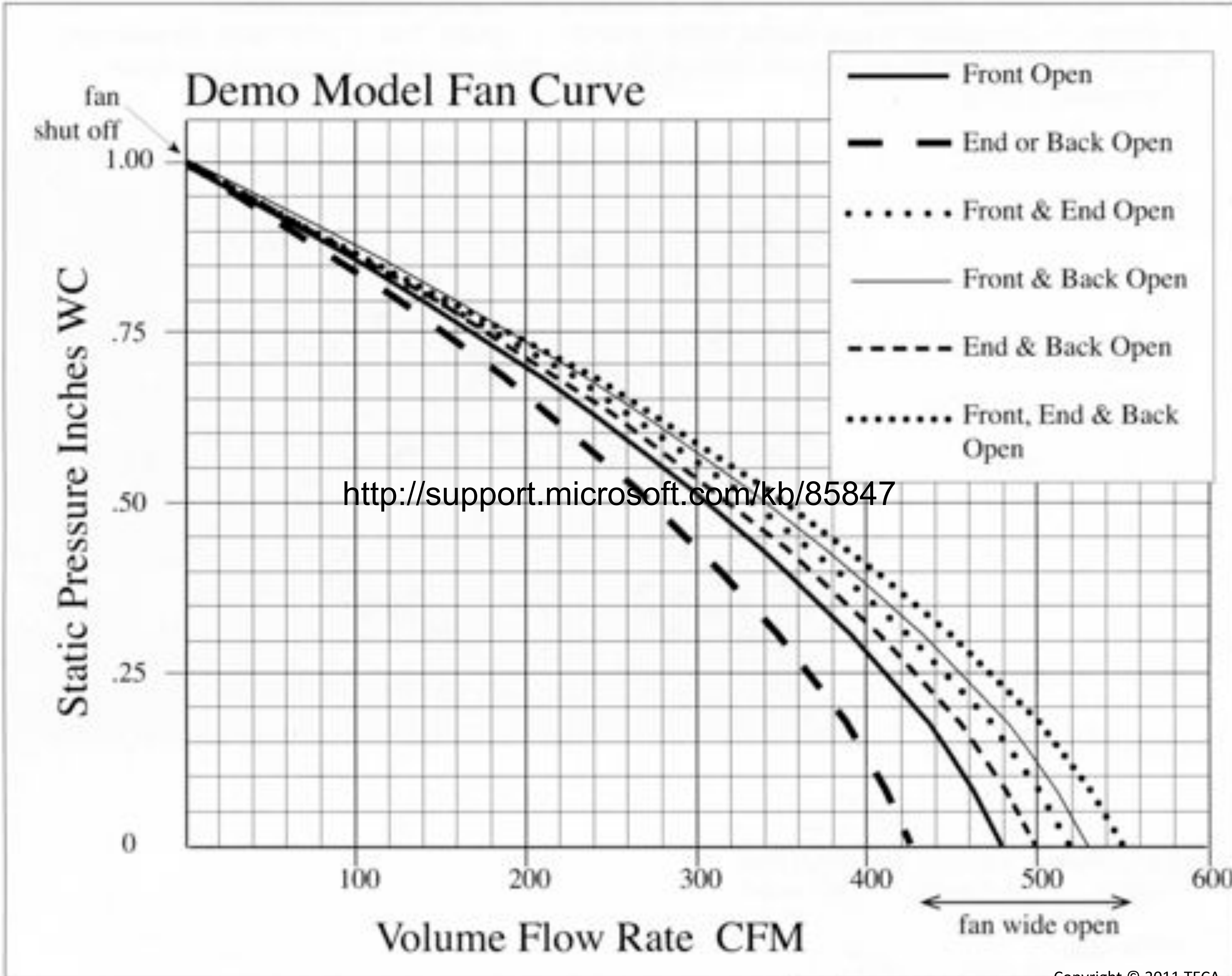
Figure 11: Pitot Tube Measurement of Velocity Pressure



Velocity Pressure

Correction to Pg. 26A   From Formula Pv (in ir

Pv "WC	V fpm	V mph
.01*	400	4.5
.02	566	6.4
.03	694	7.9
.04	801	9.1
.05	896	10.2
.06	981	11.1
.07	1060	12.0
.08	1133	12.9
.09	1201	13.6

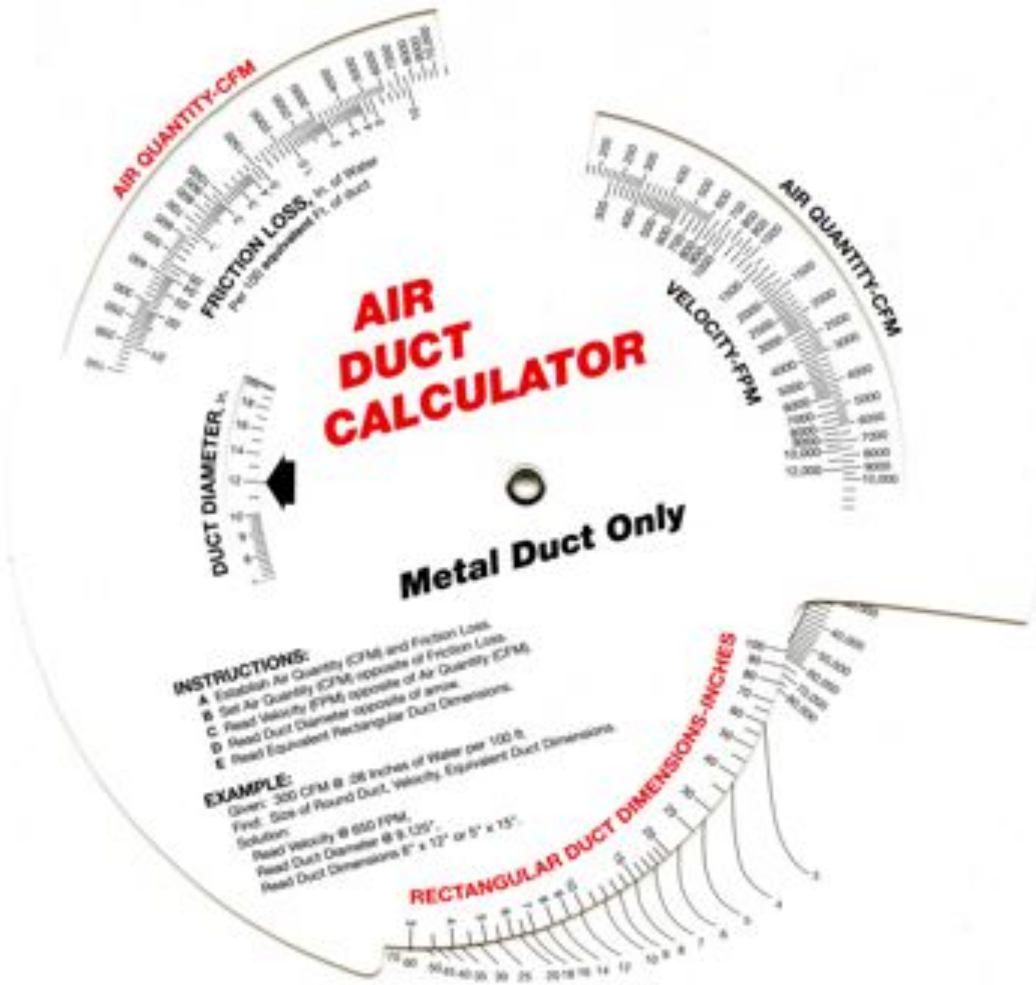

Demo Model Fan Curve
fan shut off
1.00
.75
.50
.25
0
100
200
300
400
500
600
Static Pressure Inches WC
Volume Flow Rate CFM
fan wide open
Front Open
End or Back Open
Front & End Open
Front & Back Open
End & Back Open
Front, End & Back Open
http://support.microsoft.com/kb/85847

Debt Side of the Air Moving ledger = parasites and ‘OK Things’

- Friction
  - Drag on duct walls
- Fittings
  - Change of direction
- System Effects
  - Cramping inlet or discharge of fan
- OK things, ie: Coils & Filters

American Standard

HEATING & AIR CONDITIONING



Residential Systems
Tyler, Texas

Duct calculator designed for smooth galvanized metal duct with a 0.0003 roughness Factor. Not intended for use with flexible duct.

Based on 1993 ASHRAE Fundamentals

Pub. No. 12-3012-03

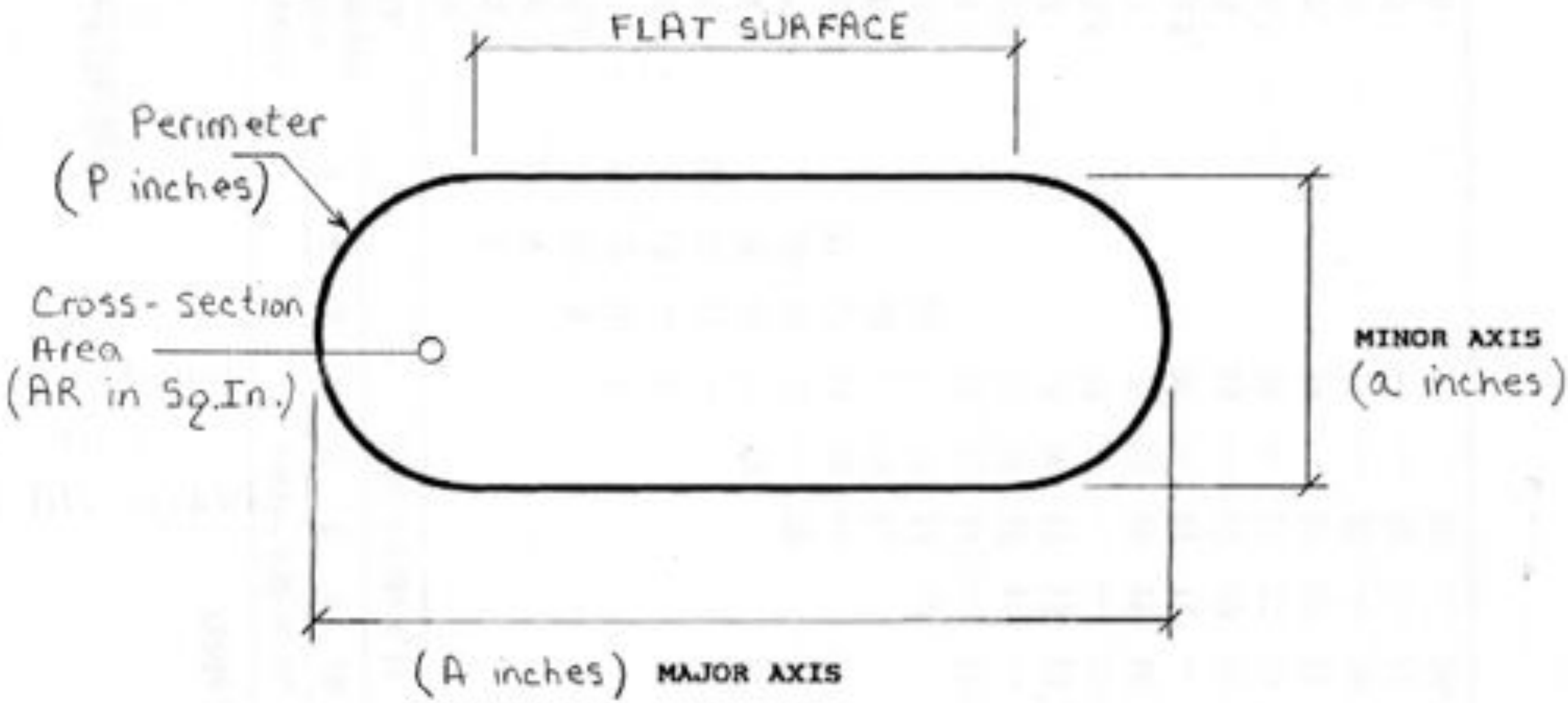
Equivalent Lengths (Le) for Flex Ducts

For Non-Metalic Flex Duct

Velocity @ 500 ft/min						
Flex Dia in. Ø	Fully Extended		90% Extended		70% Extended	
	Le	De	**Le**	De	**Le**	De
5	1.9	4.2	3.8	3.5	14.2	2.9
8	1.9	7.0	3.8	5.6	13.8	4.5
12	1.7	10.8	3.6	8.8	12.8	7.1
16	1.7	14.2	3.7	11.5	12.4	9.5
18	1.9	16.1	3.6	13.0	12.6	11.0

Velocity @ 1000 ft/min						
Flex Dia in. Ø	Fully Extended		90% Extended		70% Extended	
	Le	De	**Le**	De	**Le**	De
5	2.2	4.2	3.9	3.5	16.0	2.8
8	2.1	7.0	3.9	5.7	15.2	4.8
12	2.0	10.6 ~~11.6~~	3.7	8.5	14.5	7.2
16	1.9	14.7	3.8	11.5	14.2	9.4
18	1.9	16.0	3.5	12.8	14.0	10.5

5.21 Equations for Flat Oval Ductwork



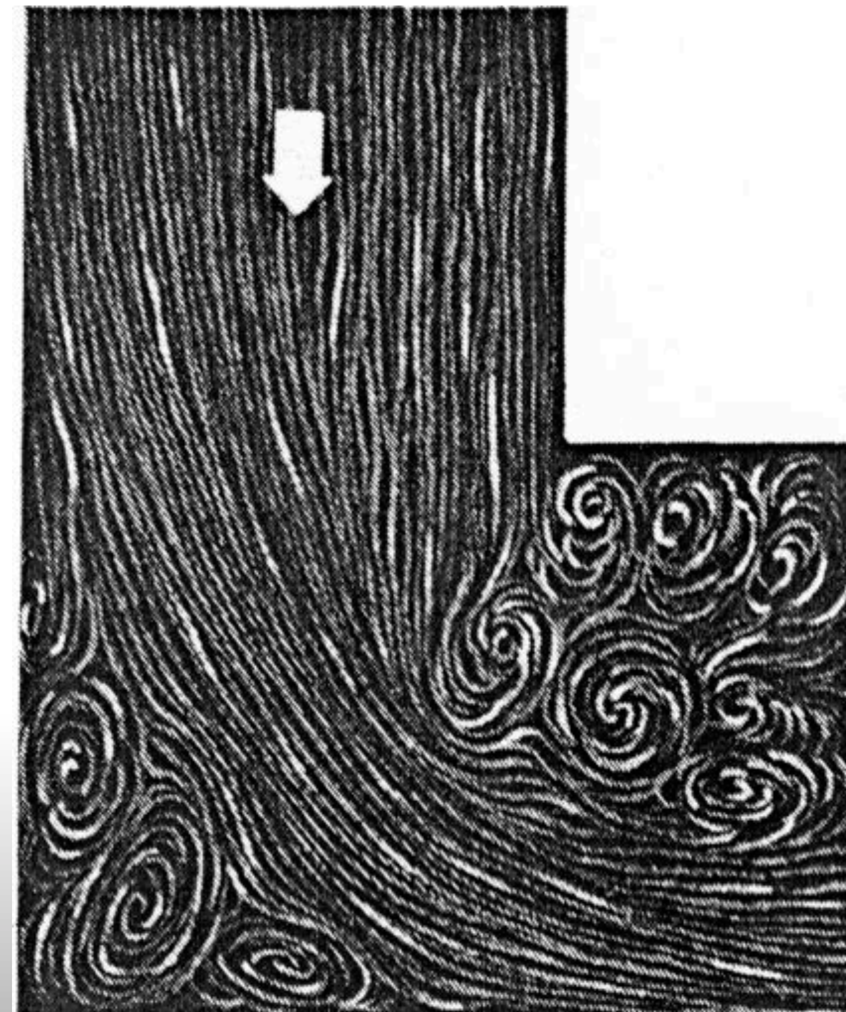
ASHRAE Fundamentals 2009

Example: 3" x 8" (nominal) flat oval all info in inches and sq. in. Apr. 3, '10

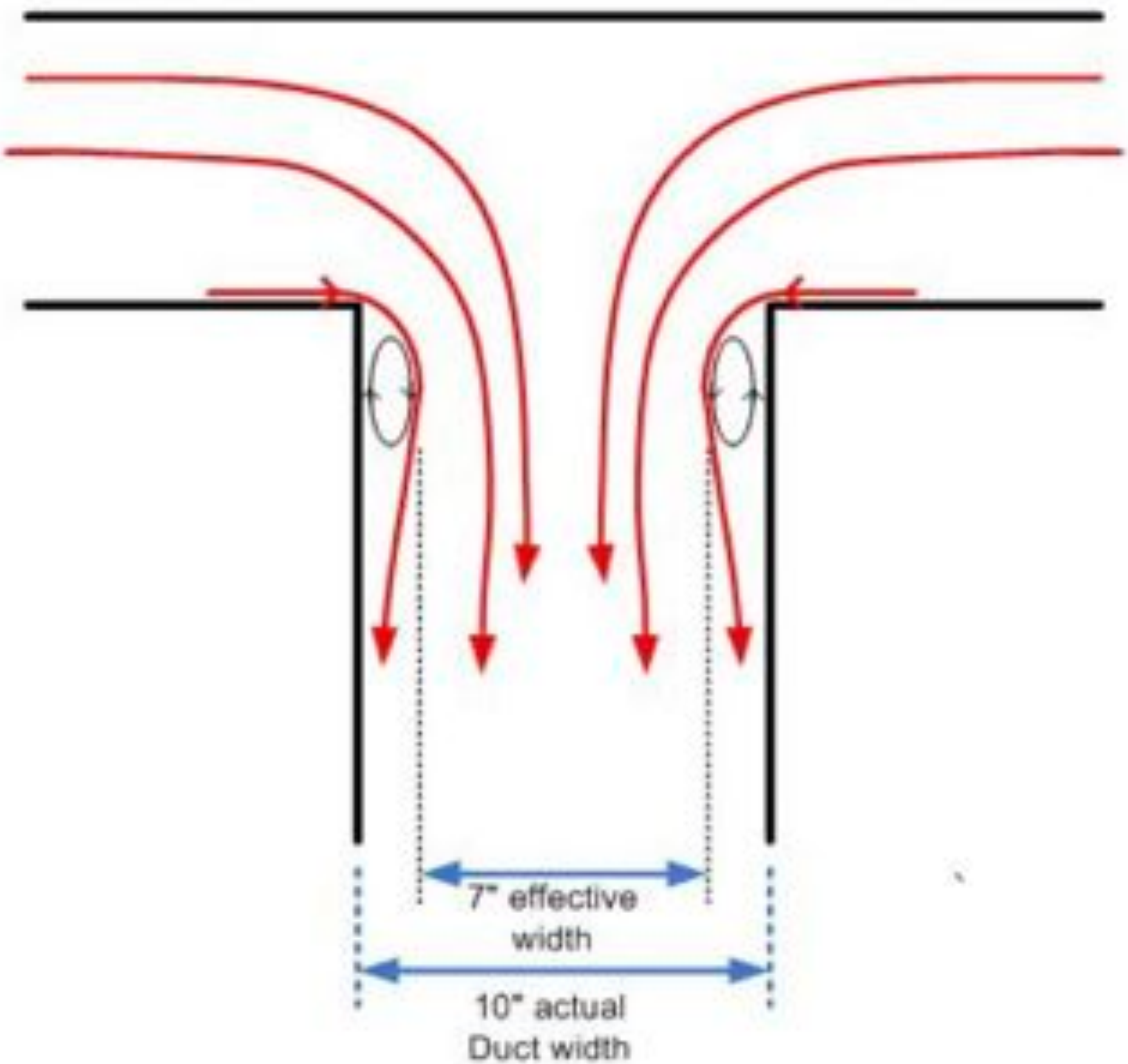
Shape (nominal size, in.)	Actual Size inch	Perimeter inch	Actual area in sq. in.	Diameter based on 'actual' area	De inch
Round 6"	6"ø	18.84	28.26	6"	6.00
Flat oval 3 x 8	3 x 7.71	18.84	21.20	5.20	5.02
Flat oval 3 x 8	3.25 x 7.57	18.84	22.33	5.33	5.18

De = Diameter, equivalent (if equivalent friction round duct were substituted)

Heel/Drop Elbow/Bottom of Drop



Typical return air duct transition



Equivalent Pressures					
Unit	**psi**	**Inches water**	**Inches mercury**	**Atmosphere**	**Pa**
psi	1	27.693	2.036	0.06804	6895
Inches of water @ 4°C	0.0361	1	0.0735	0.00224	248.843
Inches of mercury @ 32°F	0.49116	13.595	1	0.03342	3374
Atmosphere @ 68°F	14.696	406.8	29.921	1	101.325×10^3

1 psi = 27.693 inches of water
= 2.036 inches of mercury
= 0.6804 atmospheres

Double Inlet, Forward Inclined

1000 cfm @ .75” Ps, e = 49 +/- 7%

Previous in Cabinet

1000 cfm @ .75” Ps, e = 40 +/- 4%

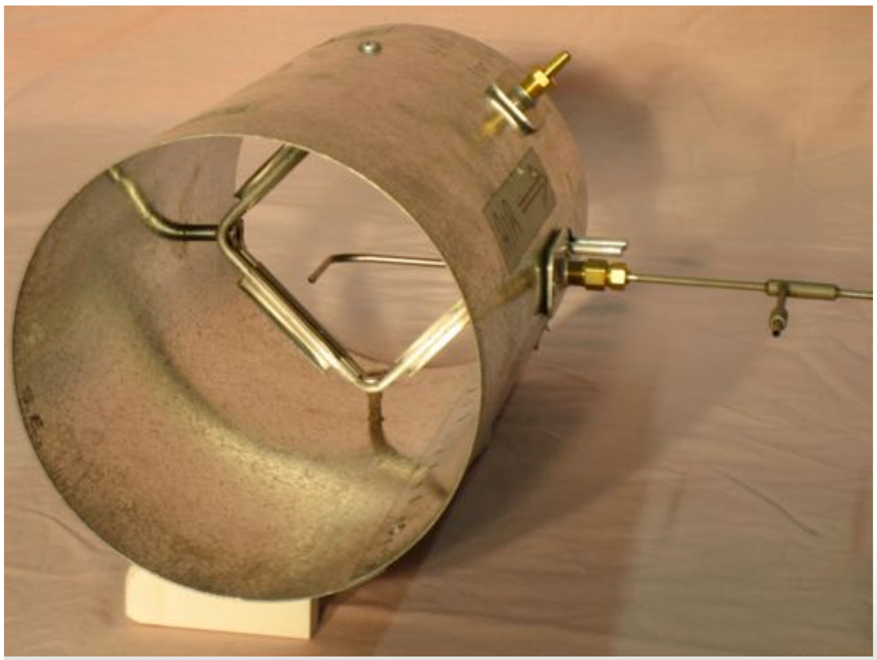
MODEL (key parts)

- Fan/Blower & Straight Section
- Pressure Gauges
- Measuring Section & Watts
- R/A fittings
- S/A fittings
- Venturi
- Evase


AIR


MAGNEHELIC
MAGNEHELIC
MAGNEHELIC
MAGNEHELIC
MAX
CONTIN

Measuring Section & Watts



Elbow, sharp throat, sharp heel

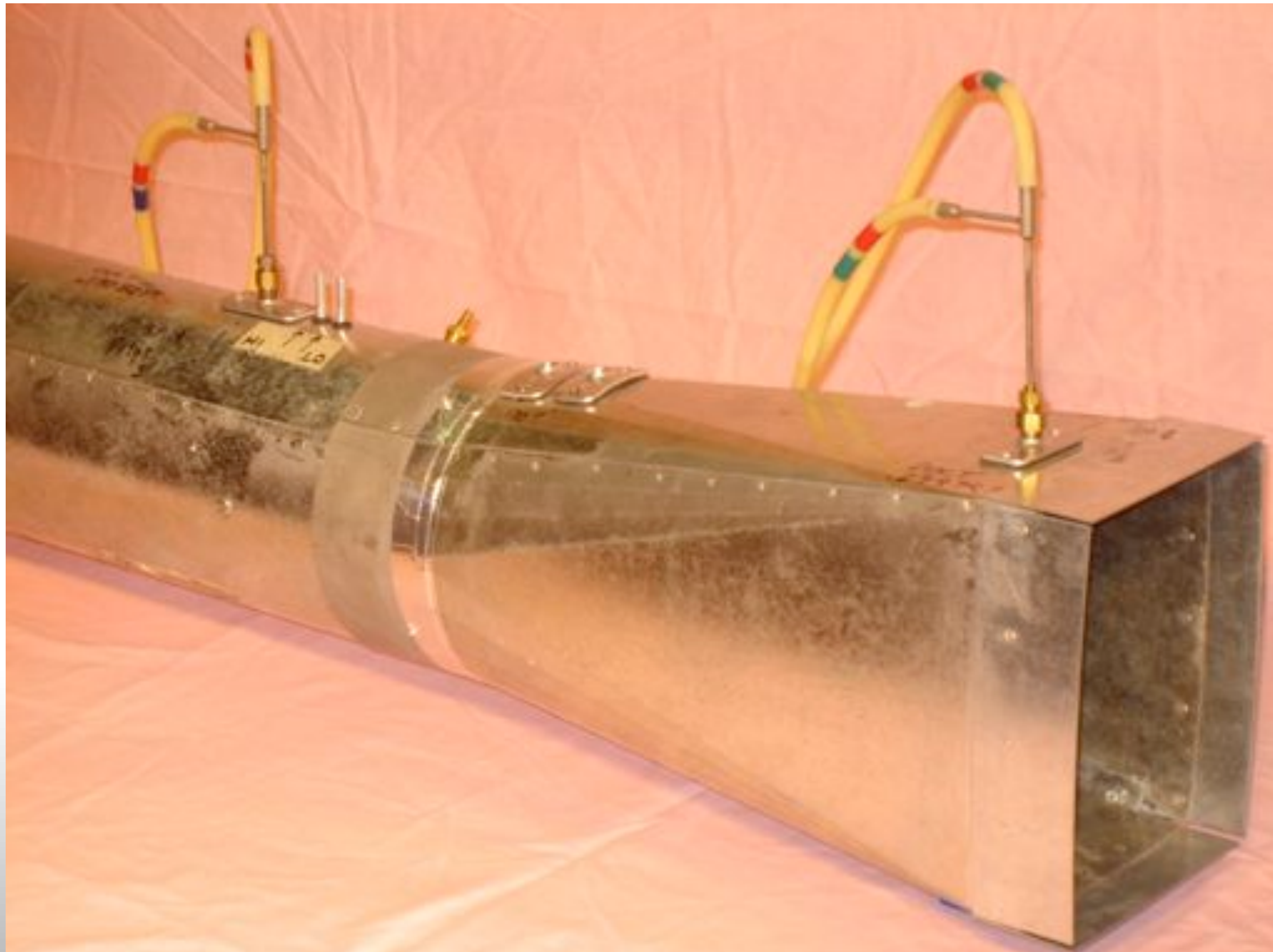
Elbow, radiused throat, radiused heel, e/w turning vanes

Plenum Take-off/PTO (Poor)

Plenum Take-off/PTO (near) standard

Plenum Take-off/PTO
'Pair of Pants'

SMOOTH TRANSITION/EVASE



Model, show & tell

Conversion Chart: Pitot Tube A VP to CFM

Centre		90% Centre	Meas. Sec.
VP in WC	FPM	FPM	CFM
.01	400	360	68
.02	566	509	97
.03	694	624	119
.04	801	721	137
.05	896	806	153
.06	981	882	168
.07	1060	954	181
.08	1133	1020	193
.09	1201	1081	205
.10	1266	1139	216
.11	1328	1195	227
.12	1387	1248	237
.13	1444	1300	247
.14	1498	1348	256
.15	1551	1396	265
.16	1602	1442	274
.17	1651	1486	282
.18	1699	1529	290
.19	1746	1571	299
.20	1791	1612	306
.21	1835	1651	314

Centre		90% Centre	Meas. Sec.
VP in WC	FPM	FPM	CFM
.22	1879	1691	321
.23	1921	1729	328
.24	1962	1766	336
.25	2003	1802	342
.26	2042	1838	349
.28	2119	1907	362
.30	2193	1973	375
.32	2260	2034	386
.34	2335	2101	399
.36	2403	2163	411
.38	2469	2221	421
.40	2533	2280	433
.42	2595	2336	444
.44	2656	2390	454
.46	2716	2444	464
.48	2775	2498	475
.50	2832	2549	484
.55	2970	2673	508
.60	3102	2792	530
.65	3229	2906	552
.70	3351	3016	573

MODEL DEMO

- Vary flow using R/A damper
  - S/A with R/A fully open
- Shut off Condition
- R/A variable set Pv = .14”
  - S/A sharp PTO
  - S/A pair of pants PTO
- S/A variable set Pv = .14”with S/A damper in place
  - Sharp heal
  - Best heal
- Evase, static regain (e/w pair of pants)

Lets fix it

- Forget (almost) friction
- Count Fittings
- Select smooth fittings, bad fittings suffocate flow; especially those which
  - handle 100% flow or
  - are used in longest runs
- System effects, don't abuse fans
- Fan Laws
- Other neat stuff!

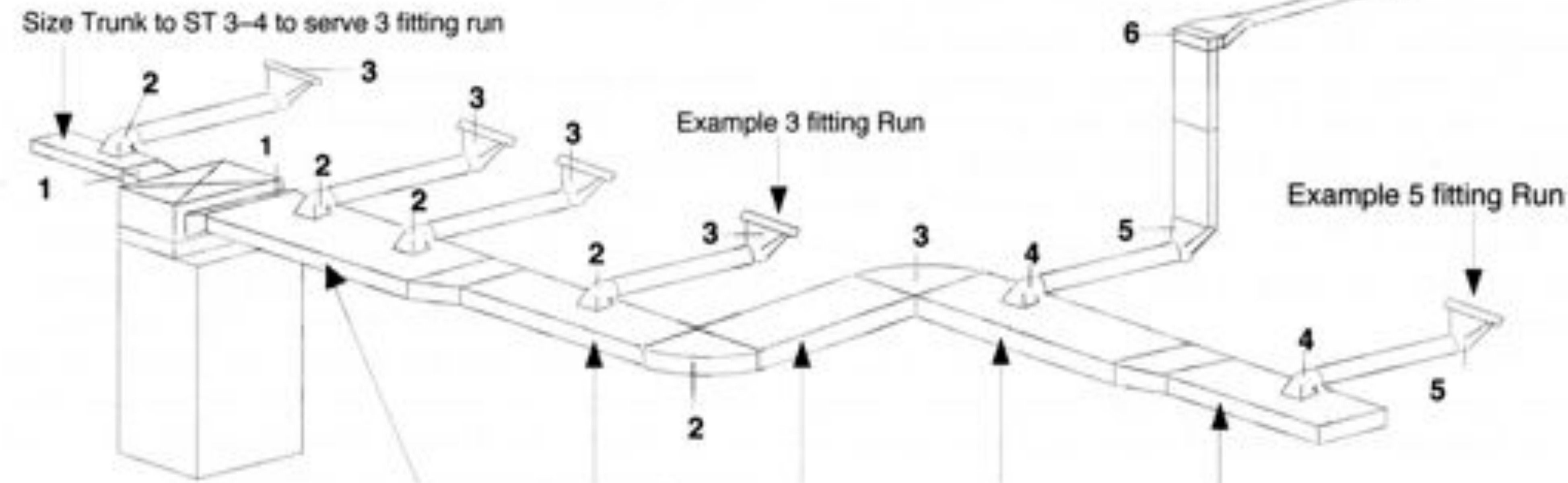
Forced Air Guidelines

Heat Loss & Heat Gain · Appliance Selection
Duct System Layout & Sizing

5th Edition, January 2008

teca
thermal environmental comfort association

Supply Air Trunk Duct Sizing
Conventional: 0.3 in wc ESP



Use **TABLE ST 3–4** when trunk duct serves only runs to first floor or basement with a **maximum of 4 fittings.**

Use **TABLE ST 5–6** when trunk duct serves second floor runs or any runs with a **maximum of 6 fittings.**

Use **TABLE ST 7** when the trunk duct serves runs with **7 or more fittings**.

Table ST 3–4 @.3"WC

Supply Air CFM	Trunk Duct Size
142 - 179	7 x 6 (7"Ø)
180 - 220	8 x 6 (8"Ø)
221 - 268	8 x 7 (8"Ø)
269 - 355	10 x 7 (9"Ø)
356 - 440	12 x 7 (10"Ø)
441 - 535	14 x 7 (11"Ø)
269 - 320	8 x 8 (9"Ø)
321 - 420	10 x 8 (10"Ø)
421 - 530	12 x 8 (11"Ø)
531 - 650	14 x 8 (12"Ø)
651 - 760	16 x 8 (13"Ø)
761 - 860	18 x 8 (13"Ø)
861 - 980	20 x 8 (14"Ø)
981 - 1125	22 x 8 (14"Ø)
1126 - 1225	24 x 8 (15"Ø)
1226 - 1270	25 x 8 (15"Ø)
1271 - 1340	26 x 8 (15"Ø)
1341 - 1480	28 x 8 (16"Ø)
1481 - 1560	30 x 8 (16"Ø)
1200 - 1360	20 x 10 (16"Ø)
1361 - 1510	22 x 10 (16"Ø)
1511 - 1710	24 x 10 (17"Ø)
1711 -1850	26 x 10 (17"Ø)
1851 -2050	28 x 10 (18"Ø)
2051 -2210	30 x 10 (18"Ø)
2211 -2400	32 x 10 (19"Ø)
2401 - 2475	34 x 10 (19"Ø)

Table ST 5–6 @.3"WC

Supply Air CFM	Trunk Duct Size
120–159	7 x 6 (7"Ø)
160–188	8 x 6 (8"Ø)
189–230	8 x 7 (8"Ø)
231–310	10 x 7 (9"Ø)
311–380	12 x 7 (10"Ø)
381–455	14 x 7 (11"Ø)
230–275	8 x 8 (9"Ø)
276–365	10 x 8 (10"Ø)
366–460	12 x 8 (11"Ø)
461–570	14 x 8 (12"Ø)
571–650	16 x 8 (13"Ø)
651–750	18 x 8 (13"Ø)
751–850	20 x 8 (14"Ø)
851–950	22 x 8 (14"Ø)
951–1050	24 x 8 (15"Ø)
1051–1100	25 x 8 (15"Ø)
1101–1160	26 x 8 (15"Ø)
1161–1280	28 x 8 (16"Ø)
1281–1340	30 x 8 (16"Ø)
1050–1180	20 x 10 (16"Ø)
1181–1310	22 x 10 (16"Ø)
1311–1500	24 x 10 (17"Ø)
1501–1600	26 x 10 (17"Ø)
1601–1780	28 x 10 (18"Ø)
1781–1920	30 x 10 (18"Ø)
1921–2080	32 x 10 (19"Ø)
2081–2130	34 x 10 (19"Ø)

Table ST 7@.3"WC

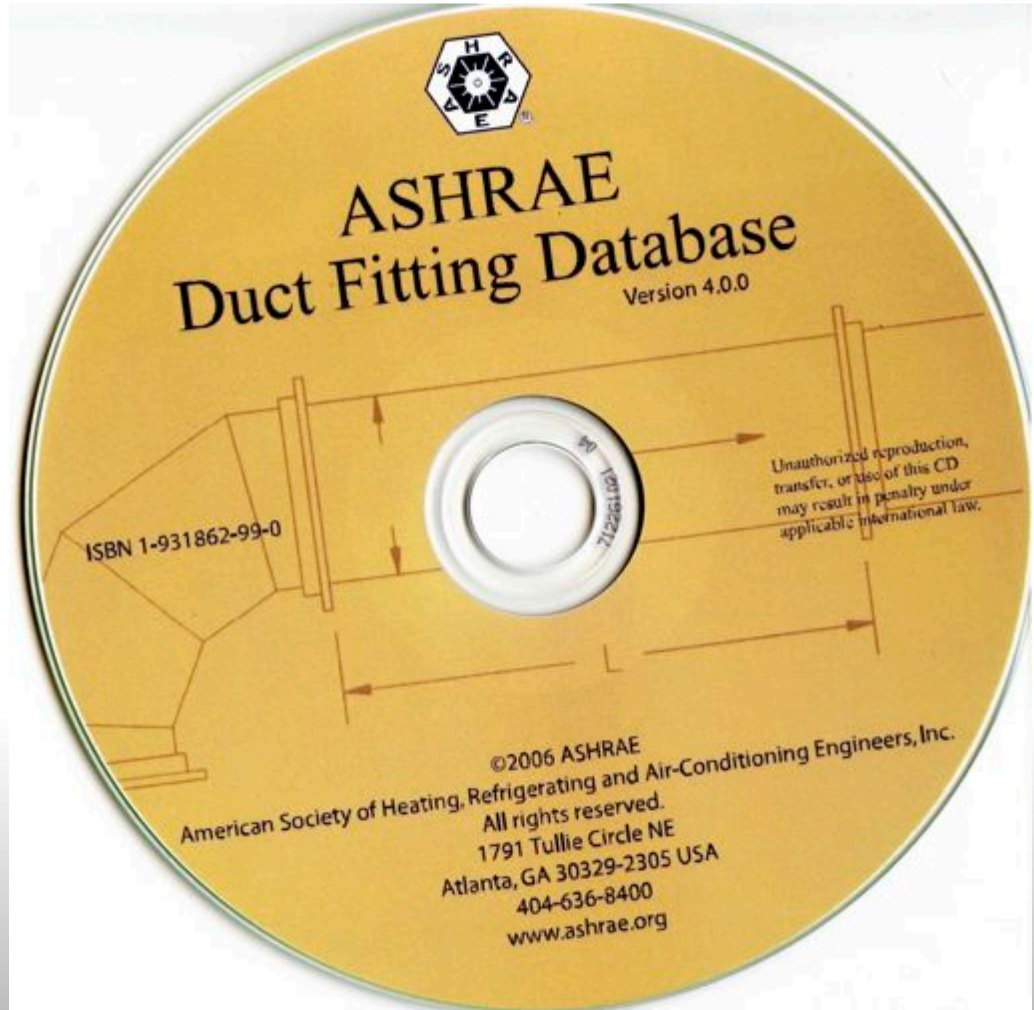
Supply Air CFM	Trunk Duct Size
97–124	7 x 6 (7"Ø)
125–150	8 x 6 (8"Ø)
151–188	8 x 7 (8"Ø)
189–245	10 x 7 (9"Ø)
246–305	12 x 7 (10"Ø)
306–370	14 x 7 (11"Ø)
189–225	8 x 8 (9"Ø)
226–290	10 x 8 (10"Ø)
291–370	12 x 8 (11"Ø)
371–455	14 x 8 (12"Ø)
456–520	16 x 8 (13"Ø)
521–600	18 x 8 (13"Ø)
601–685	20 x 8 (14"Ø)
686–765	22 x 8 (14"Ø)
766–860	24 x 8 (15"Ø)
861–880	25 x 8 (15"Ø)
881–940	26 x 8 (15"Ø)
941–1020	28 x 8 (16"Ø)
1021–1080	30 x 8 (16"Ø)
860–950	20 x 10 (16"Ø)
951–1050	22 x 10 (16"Ø)
1051–1200	24 x 10 (17"Ø)
1201–1290	26 x 10 (17"Ø)
1291–1425	28 x 10 (18"Ø)
1426–1550	30 x 10 (18"Ø)
1551–1680	32 x 10 (19"Ø)
1681–1720	34 x 10 (19"Ø)

SA Branch Run Sizing .3 In. wc ESP

Maximum CFM per Branch Run

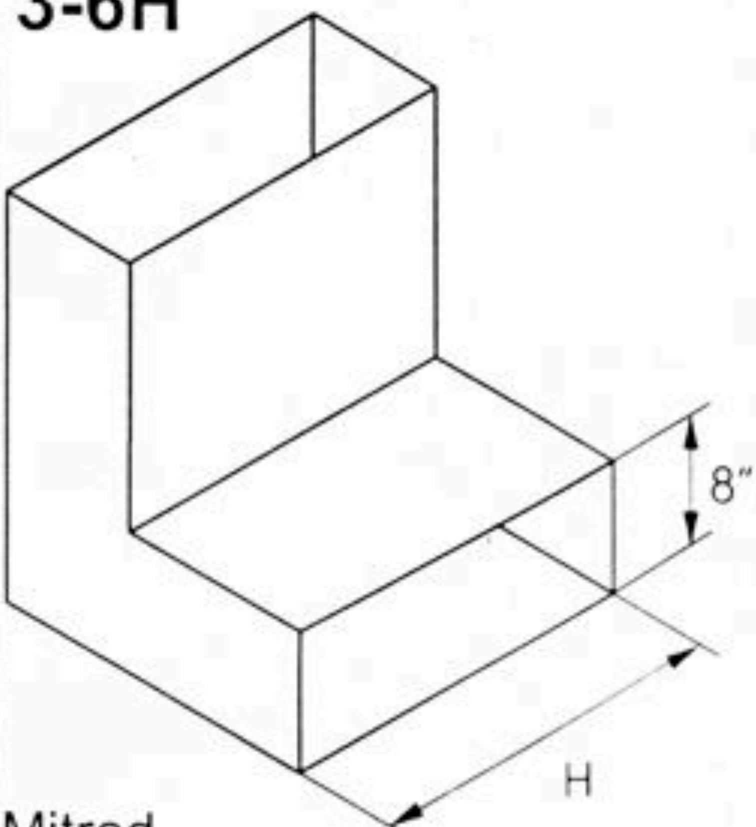
Branch Duct Size	Max. No. of fittings per branch		
	4 ftg	6 ftg	7 ftg
4"Ø	35	30	25
5"Ø	65	55	45
6"Ø	100	90	75
7"Ø	160	135	110

Eli Howard SMACNA/ASHRAE chair tech committee

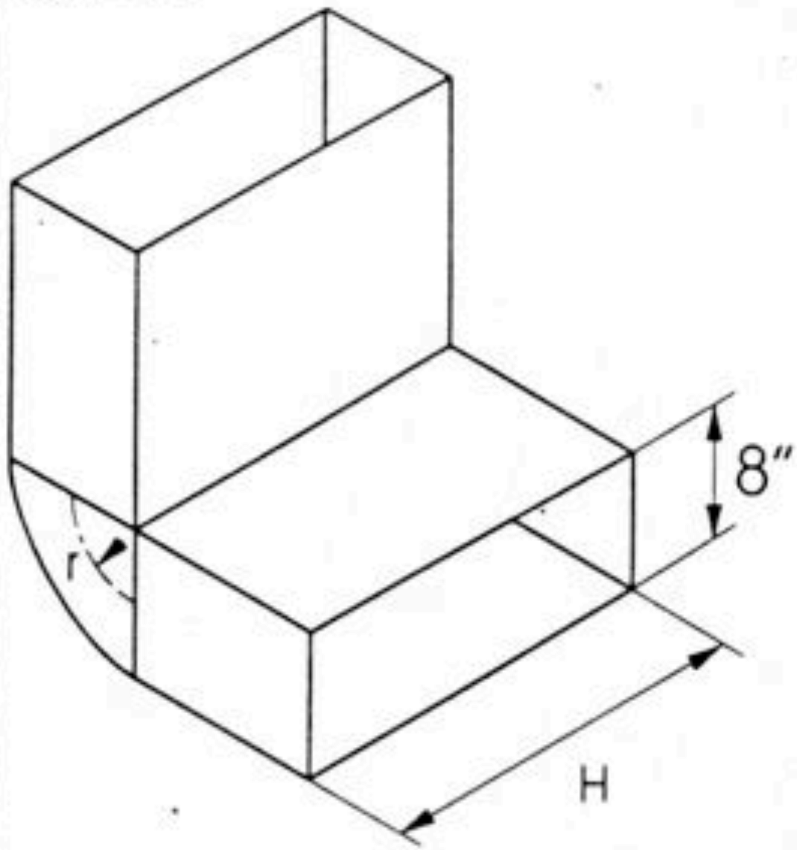


tangular 90° Fittings — Short Way (H)

Elbow Fitting R_t Throat Radius r Centreline Radius r/W Radius Ratio	WxH in	Velocity (fpm) 500		1000	
		Le ft	CFM	Le ft	CFM
3-6H	8x8	31	222	36	444
	8x12	37	333	43	667
	8x14	39	387	45	778
	8x20	42	556	49	1111
	8x24	43	667	49	1333
Mitred Sharp Heel & Throat No Vanes	8x32	43	889	50	1778



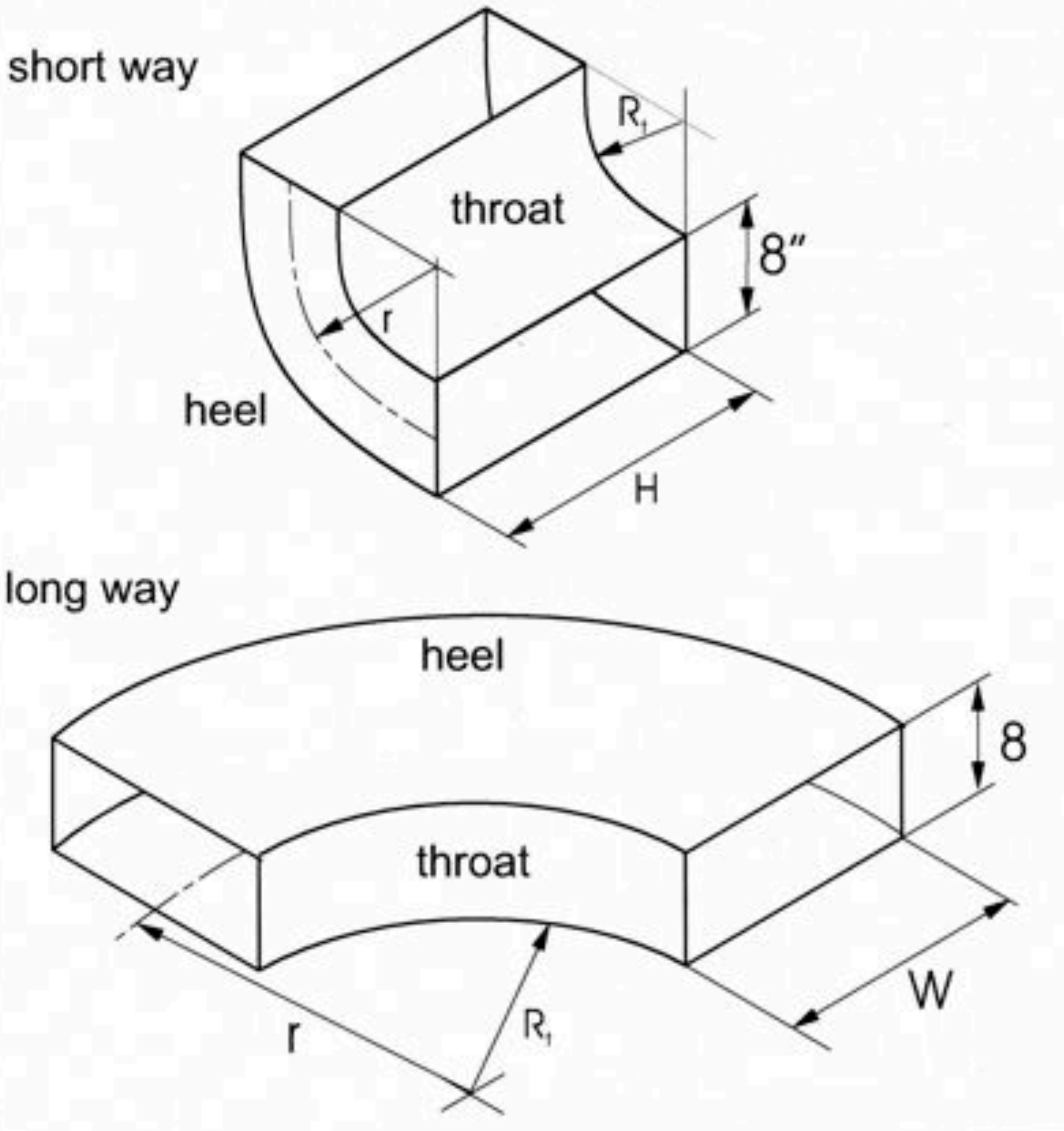
Elbow Fitting R_t Throat Radius r Centreline Radius r/W Radius Ratio	WxH in	Velocity (fpm) 500		Velocity (fpm) 1000	
		Le ft	CFM	Le ft	CFM
3-2H	8x8	31	222	36	444
	8x12	35	333	40	667
	8x14	36	387	42	778
	8x20	41	556	47	1111
	8x24	43	667	50	1333
	8x32	50	889	57	1778



Smooth Heel, Sharp Throat
No Vanes

Fittings & Turning Vanes

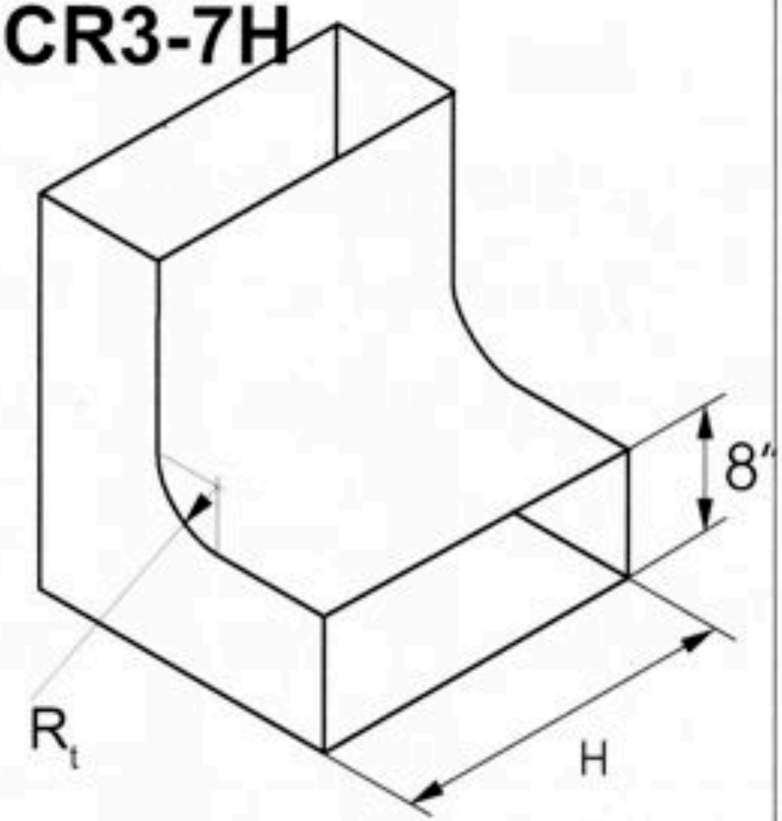
Figure 36: 90° Fittings — Short Way & Long Way, Smooth Throat & Heel



Elbow Fitting

R_t Throat Radius
r Centreline Radius
r/W Radius Ratio

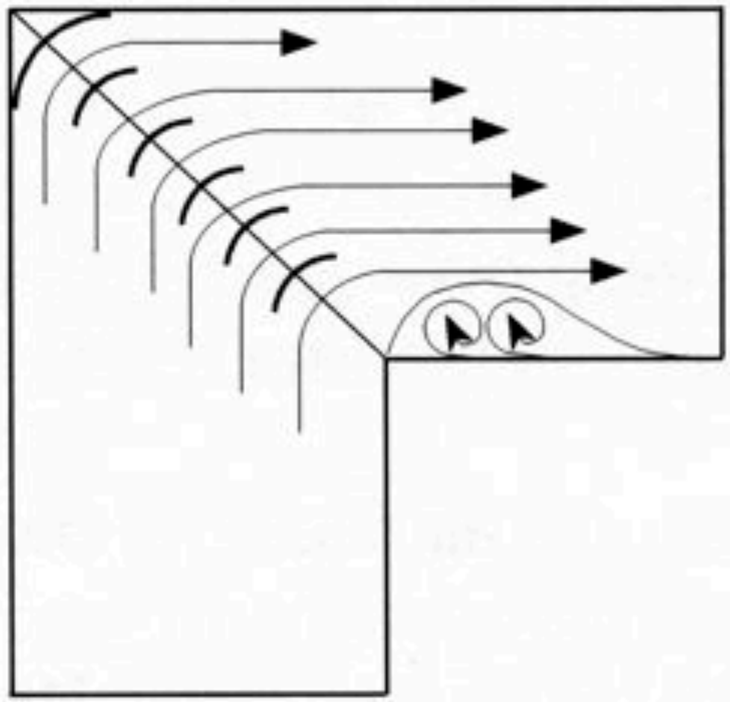
CR3-7H



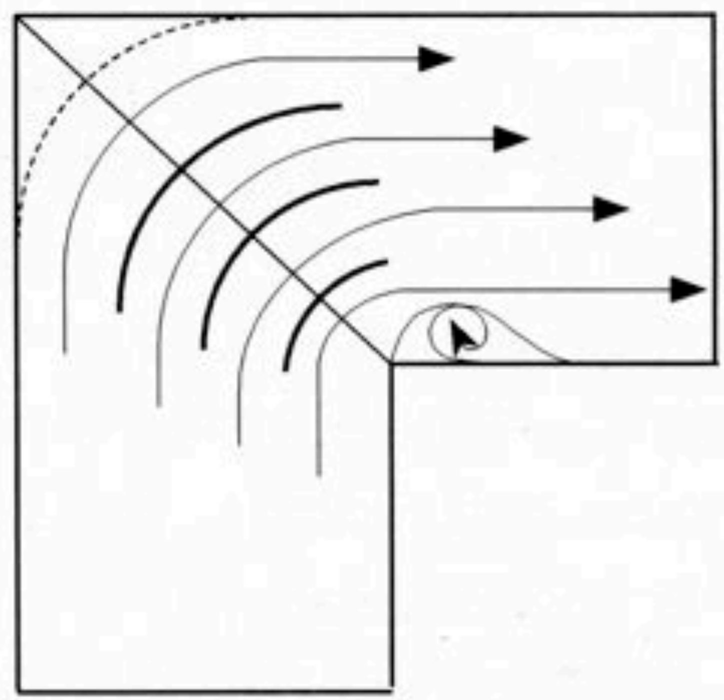
Sharp Heel, Smooth Throat, No Vanes
R_t = 6"

WxH in	Velocity (fpm) 500 Le ft	500 CFM	1000 Le ft	1000 CFM
8x8	11	222	13	444
8x12	12	333	14	667
8x14	13	387	16	778
8x20	15	556	18	1111
8x24	16	667	19	1333
8x32	18	889	21	1778

Figure 37: Turning Vanes Installed in Mitred 90° Fitting

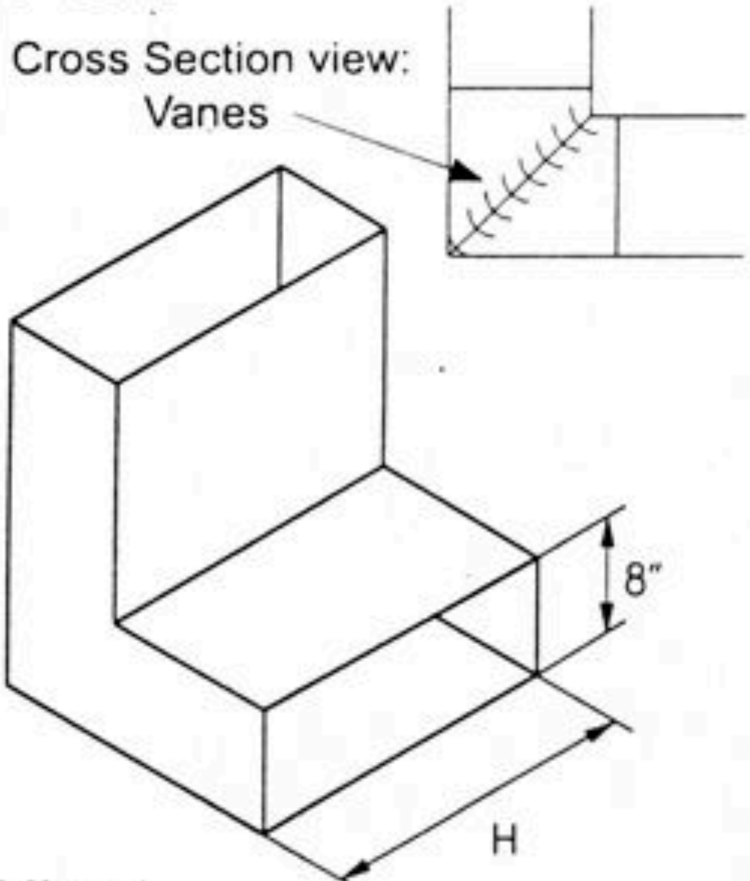


constant radius vanes
- less turbulence with vanes installed



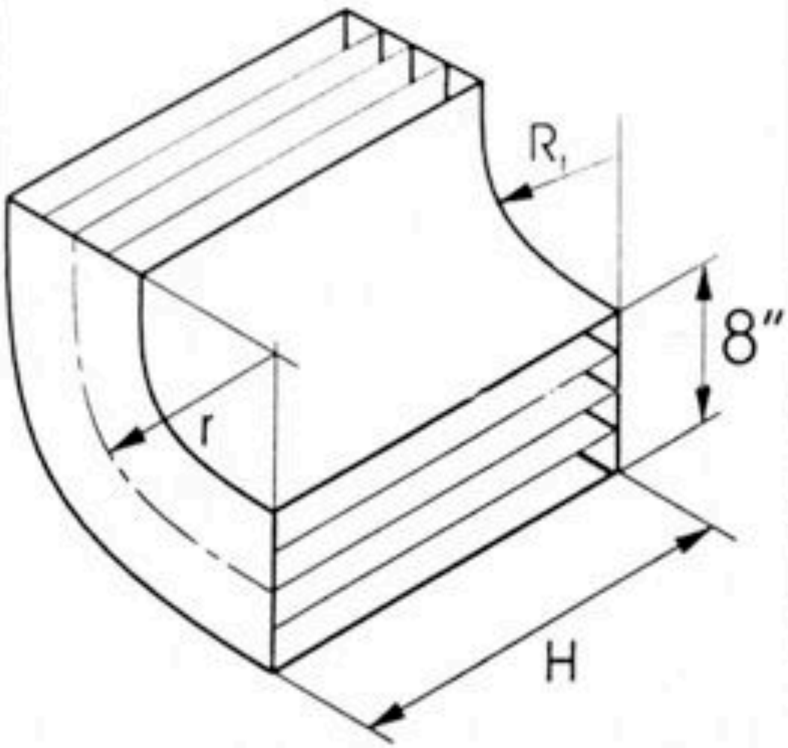
full radius vanes
- turbulence reduced more
- harder to install— accurate postioning required

Elbow Fitting R_t Throat Radius r Centreline Radius r/W Radius Ratio	WxH in	Velocity (fpm)			
		500		1000	
		Le ft	CFM	Le ft	CFM
3-9H	8x8	3	222	3	444
	8x12	4	333	4	667
	8x14	4	387	4	778
	8x20	5	556	5	1111
	8x24	5	667	6	1333
	8x32	5	889	6	1778



Mitred
Single Thickness Vane
1 1/2" Spacing

Elbow Fitting	WxH	Velocity (fpm)			
R_t Throat Radius r Centreline Radius r/W Radius Ratio	in	500		1000	
		Le ft	CFM	Le ft	CFM
3-5H	8x8	1	222	1	444
	8x12	1	333	1	667
	8x14	1	387	1	778
	8x20	1	556	1	1111
	8x24	1	667	1	1333
	8x32	1	889	1	1778



Smooth Heel & Throat
3 Splitter Vanes
R_t = 6" Radius Ratio= .75

System Effects

- Fancy word for aerodynamic screw-up right next to the fan!
- Unfortunately you screw-up successfully on BOTH the inlet (intake) and the outlet (discharge) of the fan

Double Inlet, Forward Inclined

1000 cfm @ .75” Ps, e = 49 +/- 7%

Previous in Cabinet

1000 cfm @ .75” Ps, e = 40 +/- 4%

Figure 28: Air Flow Stabalization at Fan Outlet

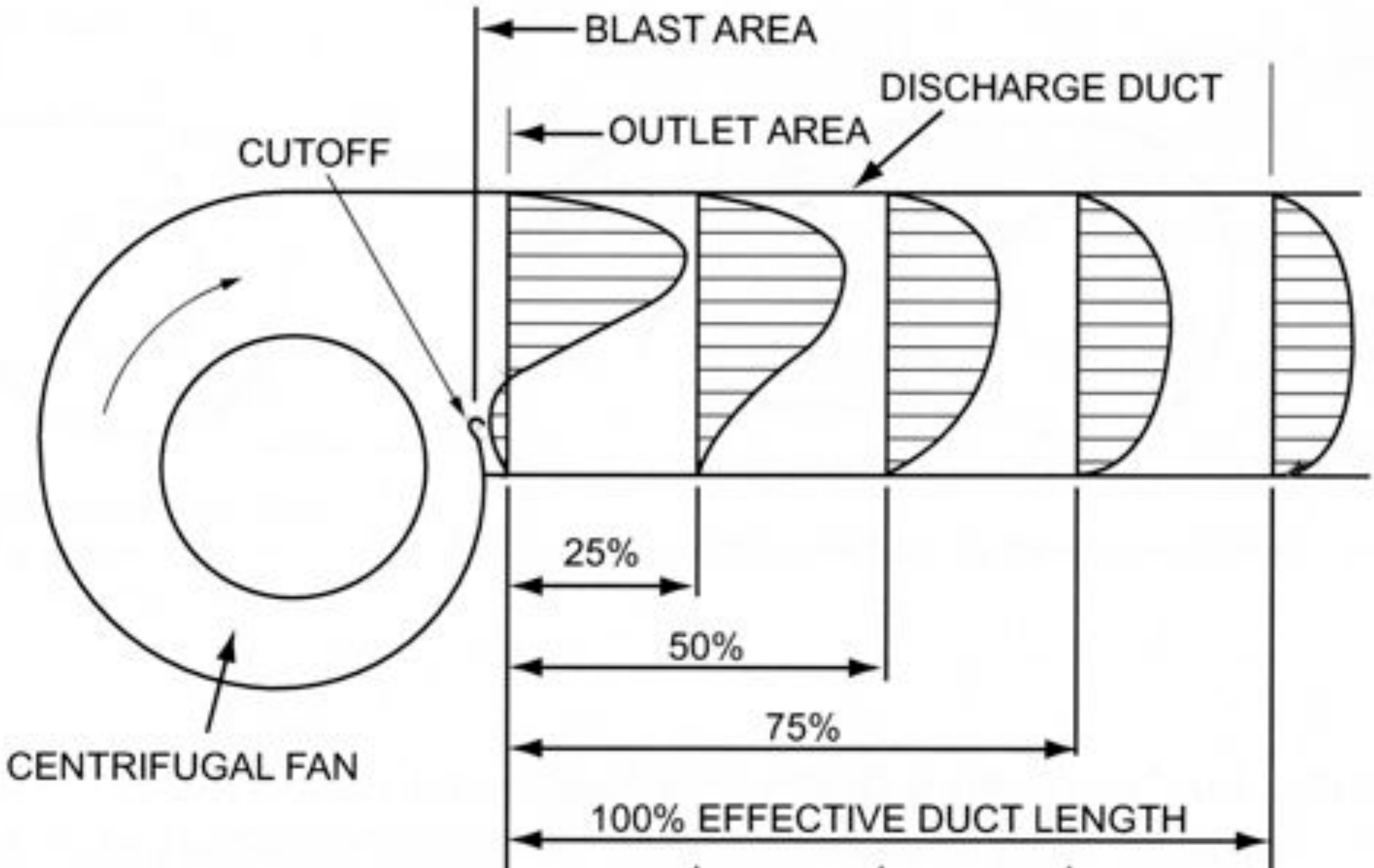
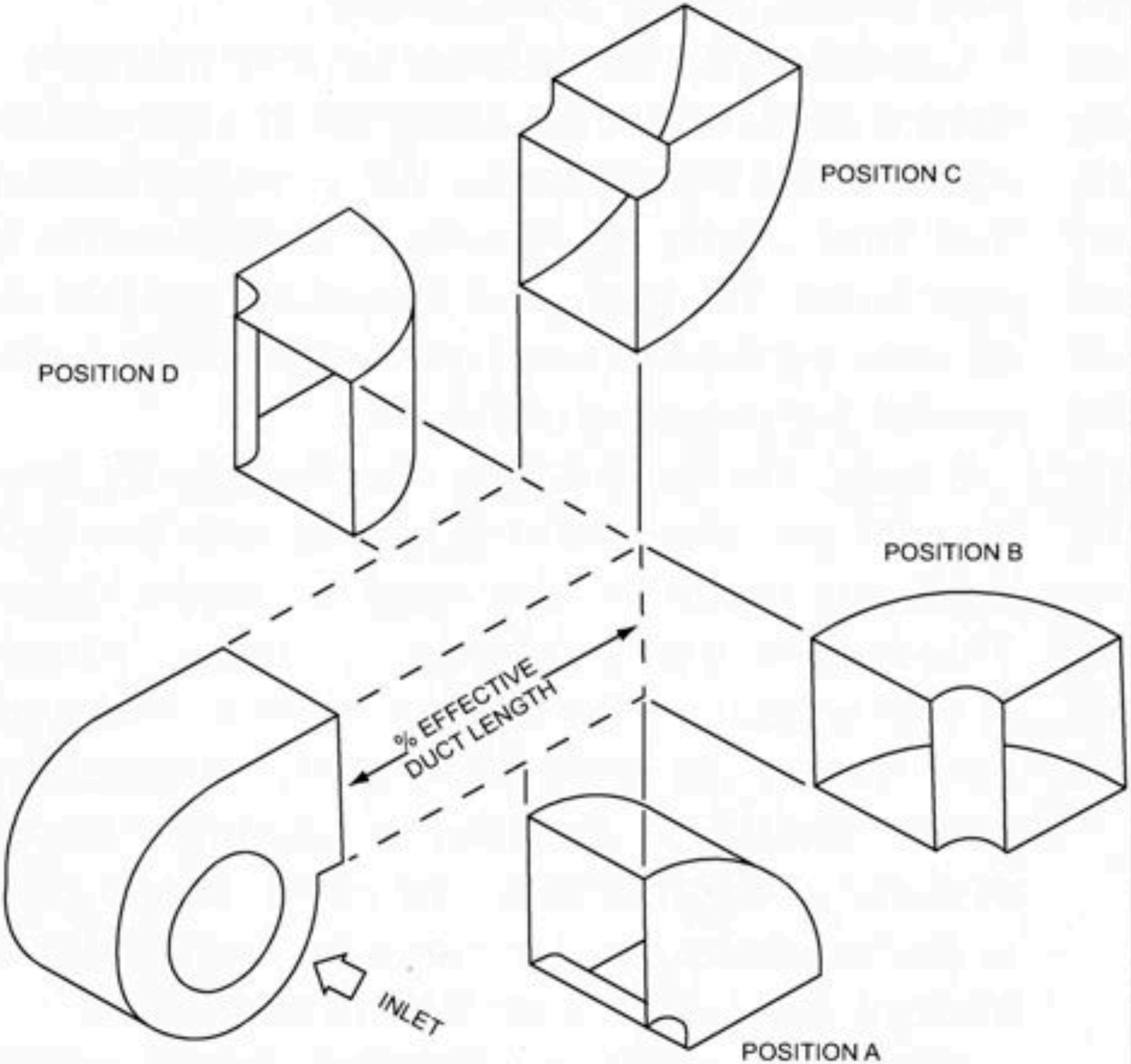


Figure 29: Fitting Position at Fan Outlet



Fan Laws

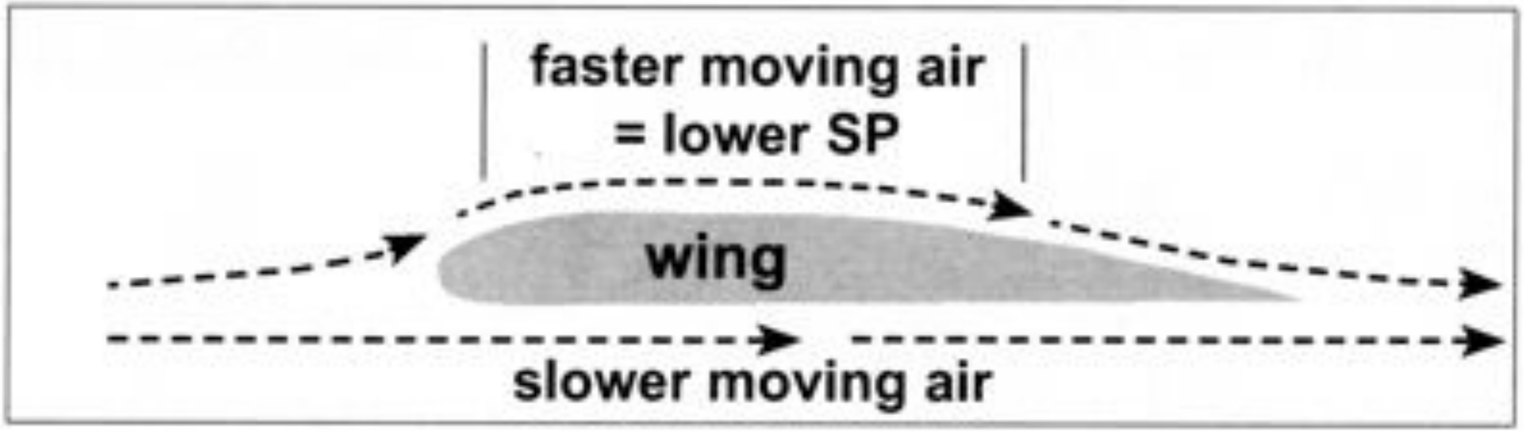
- 1) CFM varies directly with RPM
- 2) doubling cfm requires 4 x Ps (static pressure)
- 3) doubling cfm requires 8 x air power (and hence motor power)
- Conclusion: The moment the duct is installed the (air flow/cfm capacity of the system is 'baked in the cake'

Other Neat Stuff

- Evase (with moving air there is only 1 free lunch!)
- Motors
- Filters & Coils
- Trunk duct sizing
- Suggestions, from HVAC trade)

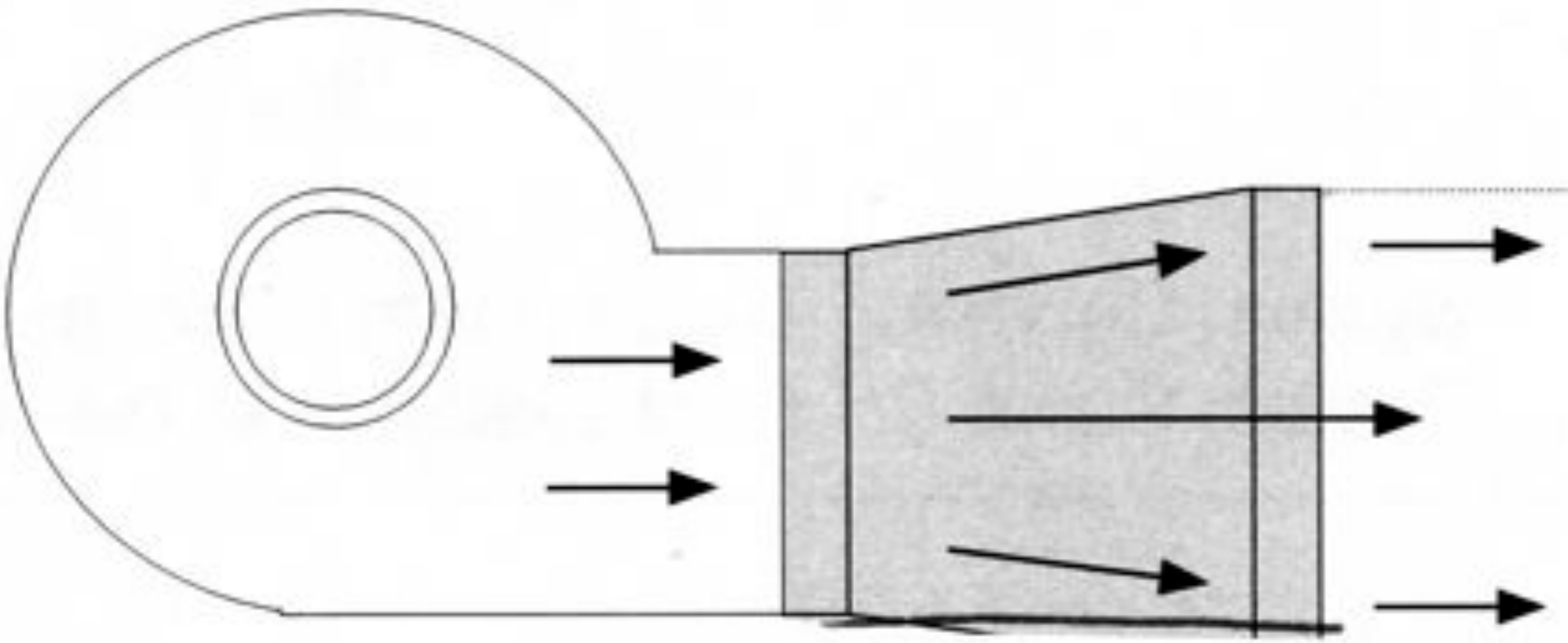
Bernoulli's Law

Daniel Bernoulli concluded in the 1700's that increasing air velocity reduces its static pressure. This is the principal that explains how an airplane can fly.



Due to the airfoil shape of the wing, the velocity of the air that flows over the wing will be greater than the speed of the wing through the air. This reduces the static pressure of the air above the wing creating the lift that keeps the plane airborne.

Figure 27: 7° Evase Fitting on Fan Outlet



Total pressure = Velocity pressure + Static Pressure

Pt = Pv + Ps

Velocity Pressure

Correction to Pg. 26A From Formula Pv (in inches WC

Pv "WC	V fpm	V mph
.01"	400	4.5
.02	566	6.4
.03	694	7.9
.04	801	9.1
.05	896	10.2
.06	981	11.1
.07	1060	12.0
.08	1133	12.9
.09	1201	13.6
.10	1266	14.4
.11	1328	15.1
.12	1387	15.8
.13	1444	16.4
.14	1498	17.0
.15	1551	17.6
.16	1602	18.2
.17	1651	18.8
.18	1699	19.3
.19	1746	19.8
.20	1791	20.4
.21	1835	20.9
.22	1879	21.4
.23	1921	21.8
.24	1962	22.3
.25	2003	22.8

Motor Current

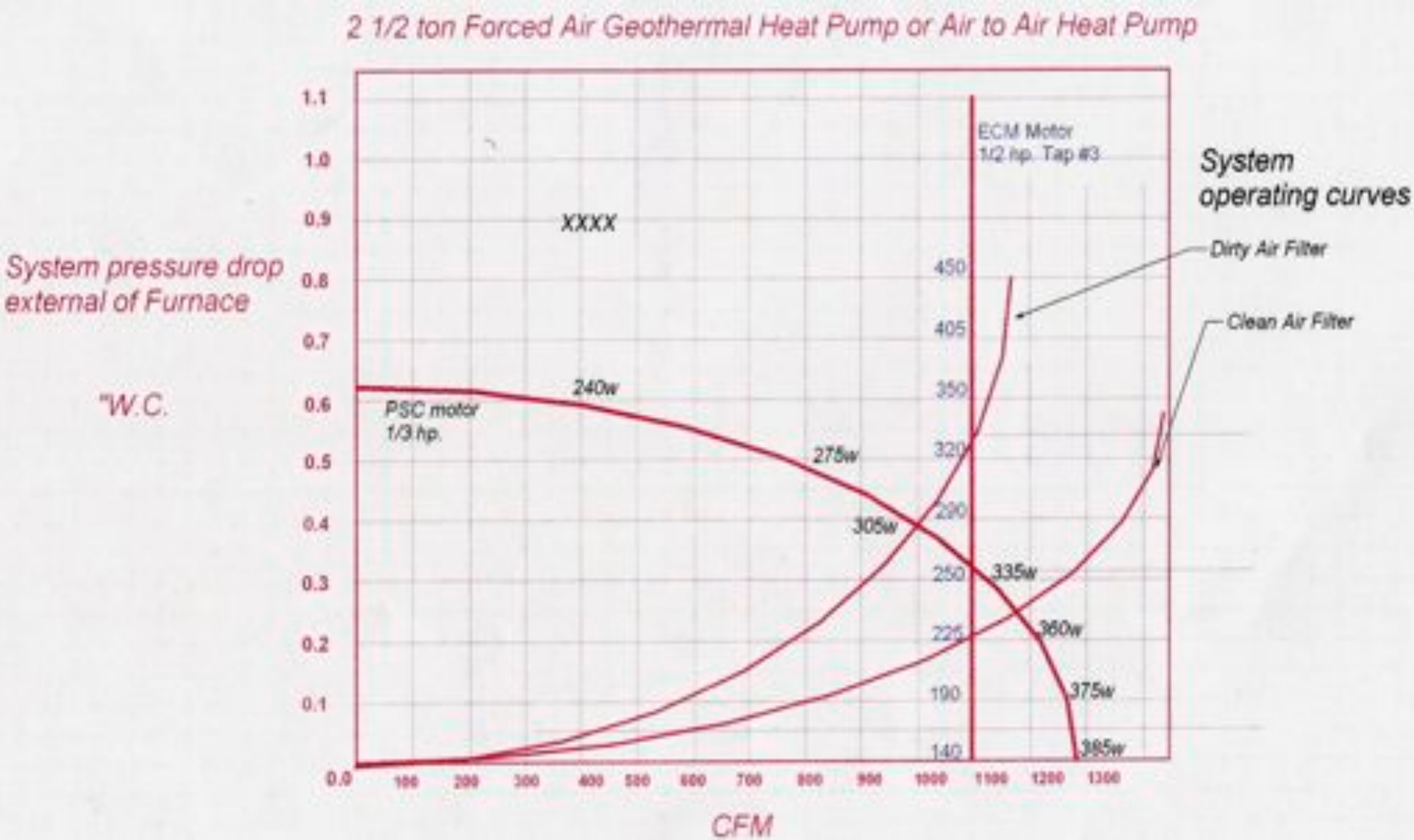
No Filter


AC 05.0 A
CLAMPET SK-7610
kaise
DATA HOLD
ON
OFF
~A
~V
LO
HI
~500V MAX.
~300A MAX.
NOSTIC CODES

Equipment Protection (5% efficiency) Filter

Respiratory protection pleat filter

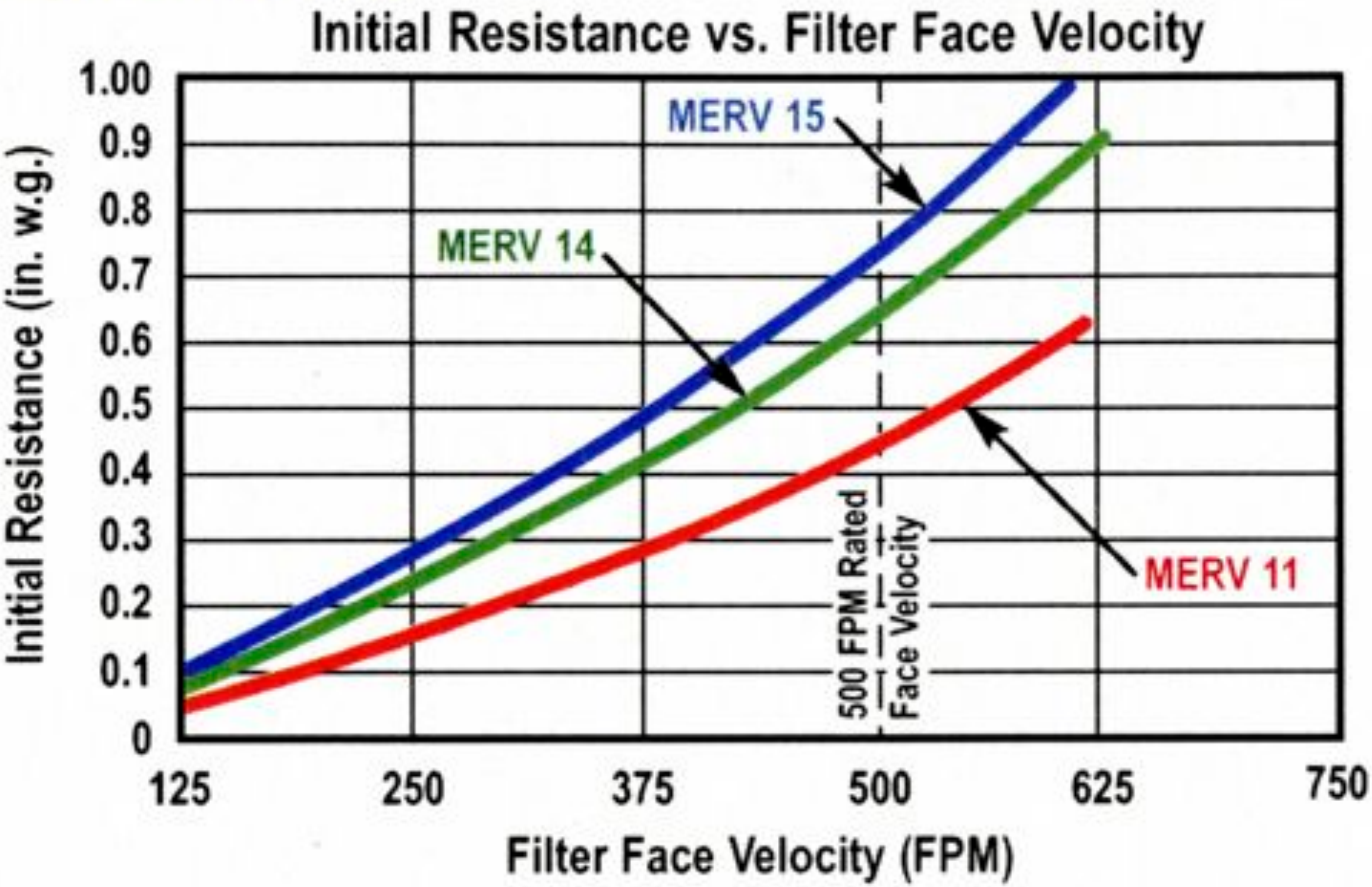
(45% efficiency)



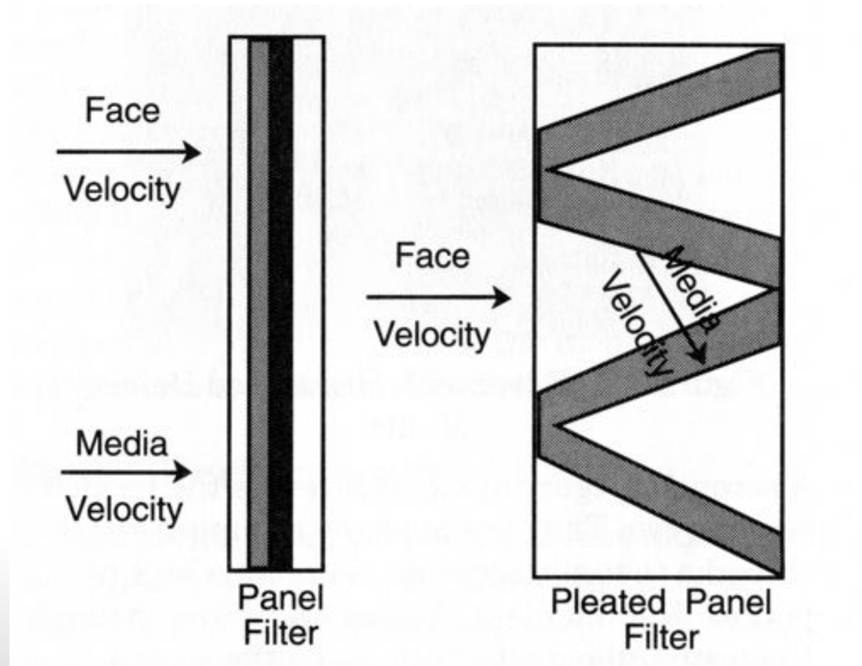
2 1/2 ton Forced Air Geothermal Heat Pump or Air to Air Heat Pump
System pressure drop external of Furnace
"W.C.
1.1
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
100
200
300
400
500
600
700
800
900
1000
1100
1200
1300
CFM
XXXX
PSC motor 1/3 hp.
240w
275w
305w
335w
360w
375w
385w
ECM Motor 1/2 hp. Tap #3
450
405
350
320
290
250
225
190
140
System operating curves
Dirty Air Filter
Clean Air Filter

Filter, horrible (std.) location

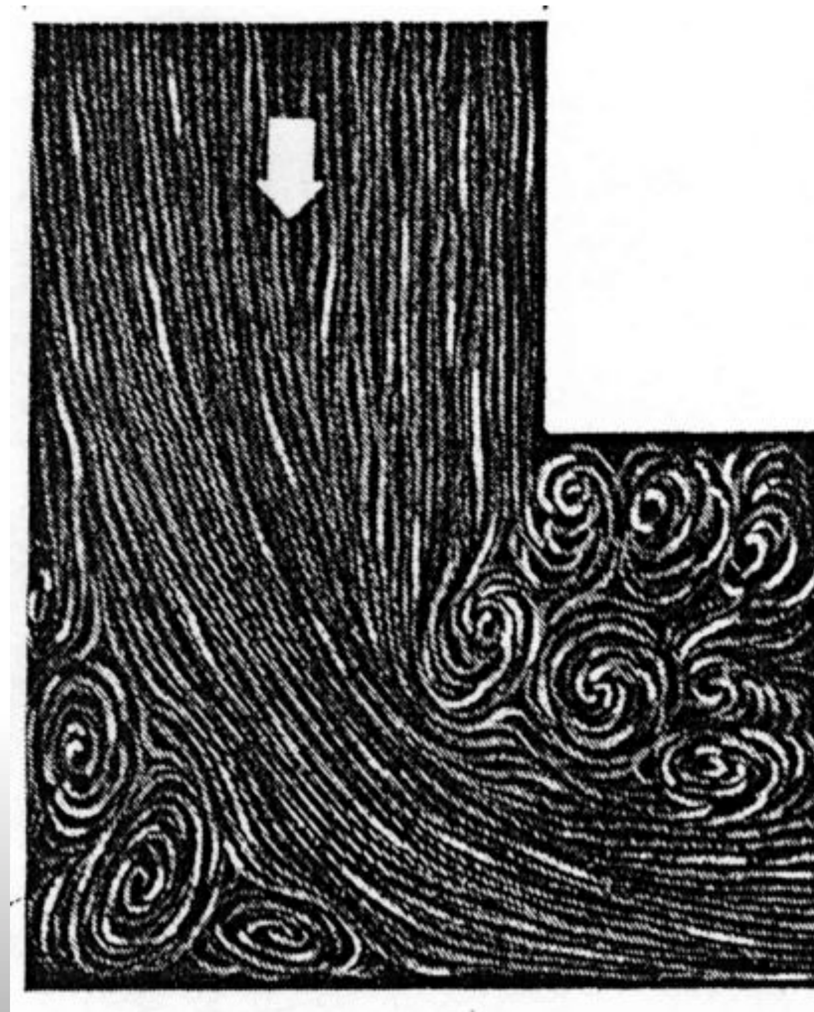
Operating Data

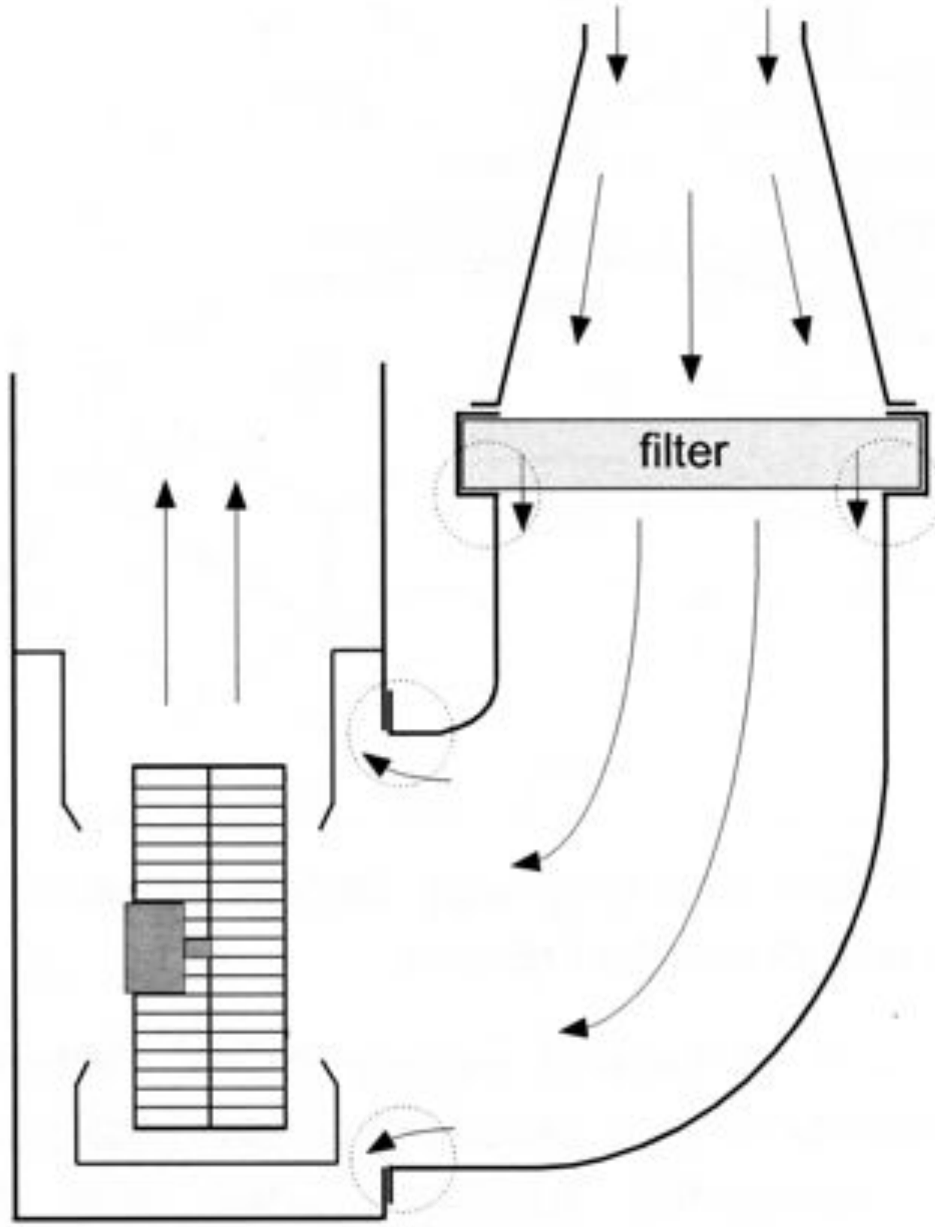


Air must approach filters 'square on'



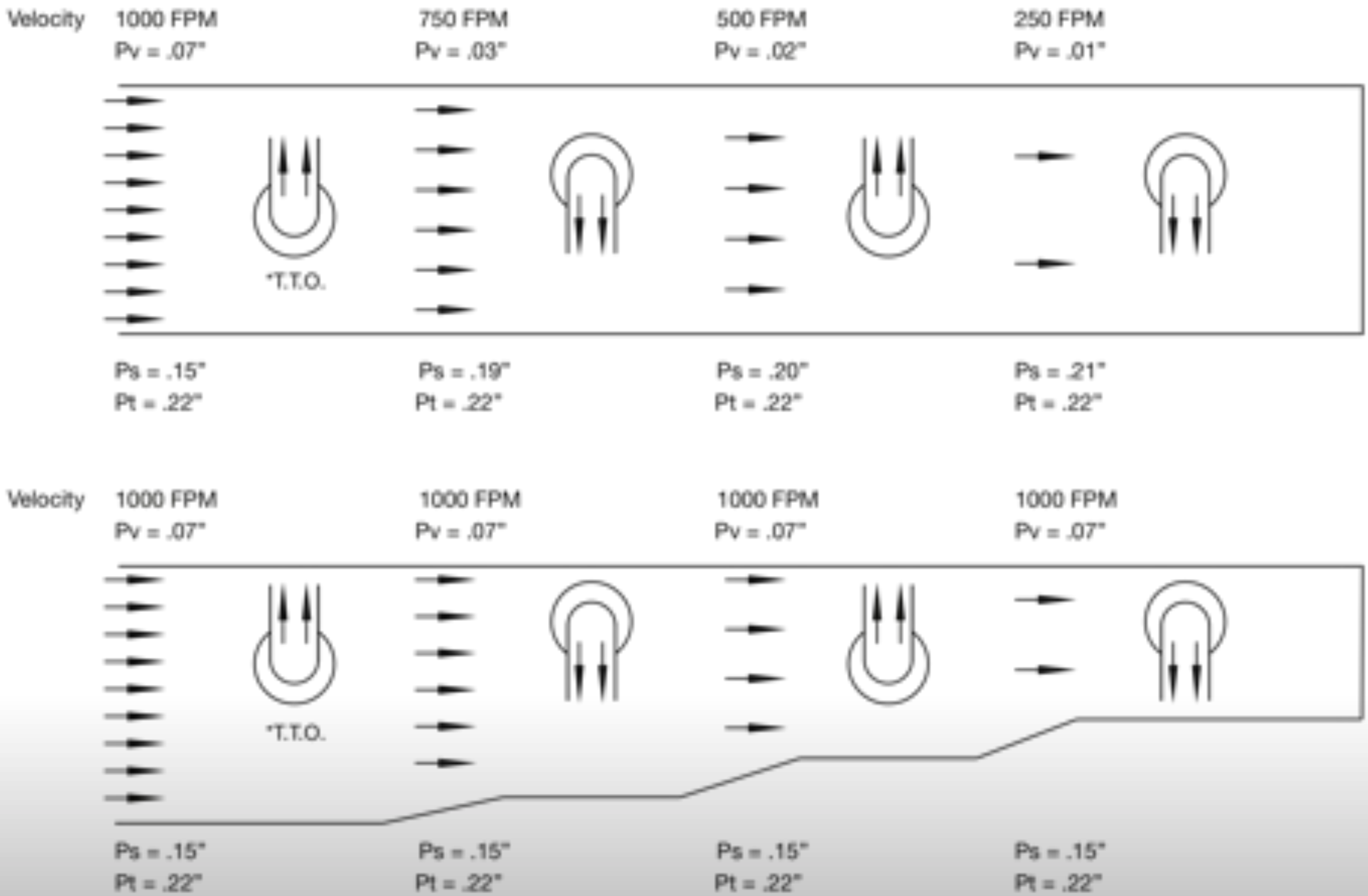
Heel, Drop elbow, Bottom of Drop





Results: more air moved per watt of electricity
quieter operation
longer filter life
better quality filter can be used

TRUNK DUCT (without & with reducing X section area)



Note: In both cases the Pt remains constant along the length of the duct because duct is short fat & straight.
*T.T.O. - Top Take Off

Jun. 28/11 © EPL

Conclusion: (requests/notes from HVAC Trade)

- Leave adequate space for duct, or, Ms. Smith will pay
- Today, appliances **are** smaller, but duct <u>must be</u> larger
- Equipment Safety!, check temperature rise!!!!